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STD.ASME A13.1-ENGL 1996 ■ 0759670 0579255 T03 ■

ASME A13.1-1996
(Revision of ASME A13.1-1981)

SCHEME FOR THE IDENTIFICATION OF PIPING SYSTEMS

AN AMERICAN NATIONAL STANDARD

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Erratum
to
ASME A13.1-1996
Scheme for the Identification of Piping Systems

On page 3, in Table 3, under the third column, Size of Letters B, (in.), penultimate entry revised. The complete table appears below.

TABLE 3
SIZE OF LEGEND LETTERS

Outside Diameter of Pipe or Covering		Length of Color Field A		Size of Letters B	
in.	mm	in.	mm	in.	mm
3/4 to 1 1/4	19 to 32	8	200	1/2	13
1 1/2 to 2	38 to 51	8	200	3/4	19
2 1/2 to 6	64 to 150	12	300	1 1/4	32
8 to 10	200 to 250	24	600	2 1/2	64
over 10	over 250	32	800	3 1/2	89

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SCHEME FOR THE IDENTIFICATION OF PIPING SYSTEMS

ASME A13.1-1996

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Date of Issuance: January 31, 1997

This Standard will be revised when the Society approves the issuance of a new edition. There will be no addenda issued to ASME A13.1-1996.

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ASME A13.1-1996

Following approval by the ASME A13 Committee and ASME, after public review, this ASME A13.1-1996 was approved by the American National Standards Institute on August 13, 1996.

SUMMARY OF CHANGES

ASME A13.1-1996 consists of A13.1-1981, as well as the following additional changes. The changes given below are identified on the page by a margin note **(96)**, placed on the affected area. The pages not listed do not contain changes.

Page	*Location*	*Change*
iii	Foreword	(1) First paragraph revised (2) Fifth paragraph revised (3) Sixth paragraph deleted (4) Eighth paragraph revised
v	Committee Roster	Updated
vii	Table of Contents	Added
1	2 2.5	Title revised Added
3	Table 2, Note (1)	Reference updated

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FOREWORD

(This Foreword is not a part of ASME A13.1-1996.)

This is a revision of the Scheme for the Identification of Piping Systems, originally affirmed in 1928, reaffirmed in 1945, revised in 1956, revised in 1975, revised in 1981, reaffirmed in 1985 and 1993, and revised in 1996. (96)

Shortly after the turn of the century, with the resultant industrial expansion, it became apparent that some scheme should be devised to identify piping. In 1908, an article on "Identification of Power House Piping by Colors" was read at a meeting of The American Society of Mechanical Engineers. In 1909, an article called "Standard Colors for Power Station Piping" was read at the meeting of the Association of Edison Illuminating Companies.

In 1920, the National Safety News pointed out the need for a color scheme for pipe lines, and the following year several papers were published and reports made to various committees, notably the Prime Movers Committee of the National Electric Light Association, The American Society of Mechanical Engineers, and the U. S. Navy Department which actually wrote its specifications.

In the meantime, many large companies compiled their own scheme with no thought to standardization of pipe colors, even in their own plants. When personnel were shifted, accidents could and did happen.

The organization of the Sectional Committee on the Identification of Piping Systems, under the procedure of the American Standards Association (now called the American National Standards Institute, Inc.), took place on June 14, 1922. (96)

On August 23, 1950, the committee was reorganized to investigate the possibility of a revision to the standard. It was felt that a revision was necessary because of the tremendous number of different materials being carried in pipes. After many meetings and much discussion, this revision of American Standard, Scheme for Identification of Piping Systems, was approved by the sectional committee and sponsors. It was then presented to the American Standards Association (now called the American National Standards Institute, Inc.) for approval and designation as an American Standard. This was granted on January 27, 1956.

In the late 1960's the committee began discussions on the possibility of revising the 1956 Standard. These discussions continued for a number of years, eventually resulting in approval by the American National Standards Institute, Inc. and the secretariat. Approval by the American National Standards Institute, Inc. and designation as an American National Standard was obtained on November 16, 1981.

This latest edition of A13.1 was approved by the American National Standards Institute on August 13, 1996. (96)

Suggestions for improvement of this revision will be welcomed. They should be sent to The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N.Y., 10017.

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COMMITTEE ON THE SCHEME FOR THE IDENTIFICATION OF PIPING SYSTEMS

(96)

(The following is a roster of the Committee at the time of approval of this Standard.)

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INTRODUCTION

Purposes of Standardization

Schemes for identification of the contents of piping systems have been developed in the past by a large number of industrial plants and organizations of various kinds. Generally speaking, the standards arrived at in individual cases may have given satisfaction to those using them but they also may have suffered from a lack of uniformity. Numerous injuries to personnel and damage to property have occurred because of mistakes made in turning valves on, or disconnecting pipes at the wrong time or place, particularly when outside agencies, such as municipal fire departments, were called in to assist. Furthermore, there has been considerable confusion in the minds of those who change employment from one plant to another.

In order to promote greater safety, lessen the changes of error, confusion, or inaction, especially in times of emergency, a uniform system for the identification of piping contents has been established to warn personnel when the piping contents are inherently hazardous. Therefore, while this Standard has been prepared to specify the identification of the contents of piping systems on the basis of legends, it also suggests the use of color as a supplementary means of identifying the type of hazard of the material contained in the system.

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SCHEME FOR THE IDENTIFICATION OF PIPING SYSTEMS

1 OBJECT AND SCOPE

1.1 This Standard is intended to establish a common system to assist in identification of hazardous materials conveyed in piping systems and their hazards when released in the environment.

1.2 This scheme concerns identification of contents of piping systems in industrial and power plants. It is also recommended for the identification of piping systems used in commercial and institutional installations, and in buildings used for public assembly. It does not apply to pipes buried in the ground nor to electrical conduits.

1.3 Existing schemes for identification shall be considered acceptable if such schemes are described in writing and implemented so that the using facility can demonstrate that the basic concerns outlined in this Standard are being met. For example, petroleum refineries and primary chemical manufacturing plants, in which hazardous work permit systems and emergency procedure manuals are utilized, wherein effective methods for the identification of pipe contents have been established, and wherein employees are trained as to the operation and hazards of the piping systems, shall be considered as meeting the requirements of this Standard.

(96) 2 DEFINITIONS AND REFERENCES

2.1 Piping Systems

For the purpose of this Standard, piping systems shall include pipes of any kind and, in addition, fittings, valves, and pipe coverings. Supports, brackets, or other accessories are specifically excluded from applications of this Standard. Pipes are defined as conduits for the transport of gases, liquids, semiliquids, or fine particulate dust.

2.2 Materials Inherently Hazardous

2.2.1 Flammable or Explosive. This classification includes materials which are easily ignited. It includes materials known as fire producers or those creating an explosive atmosphere.

2.2.2 Chemically Active or Toxic. This classification includes materials which are corrosive, or are in themselves toxic or productive of poisonous gases.

2.2.3 At Temperatures or Pressures. This classification includes materials which when released from the piping would have a potential for inflicting injury or property damage by burns, impingement, or flashing to vapor state.

2.2.4 Radioactive. This classification includes those materials which emit ionizing radiation.

2.3 Materials of Inherently Low Hazard

This classification includes all materials which are not hazardous by nature, and are near enough to ambient pressure and temperature that people working on systems carrying these materials run little risk through the release of these materials.

2.4 Fire Quenching Materials

This classification includes sprinkler systems and other piped fire fighting or fire protection equipment. This includes water (for fire fighting), foam, CO_2, Halon, etc.

2.5 References (96)

This Standard is supplemented by the following standard. Since revisions in and additions to this Standard do occur, the edition bearing the latest date of issue shall be used. It is expected that best current practice will prevail.

The following standard shall, to the extent specified herein, form a part of this Standard.

ANSI Z535.1 Safety Color Code

Publisher: American National Standards Institute, Inc.
11 West 42nd Street
New York, NY 10036

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TABLE 1 EXAMPLES OF LEGEND

"HOT WATER"	"HYDRAULIC OIL"
"SLURRY"	"FOAM"
"AIR 100 PSIG"	"CARBON TETRACHLORIDE"
"ARGON 500 PSIG"	"CAUSTIC"
"PROPANE"	"SULFURIC ACID"
"H. P. RETURN"	"STEAM 100 PSIG"

3 METHOD OF IDENTIFICATION

3.1 Legend

This Standard considers legend to be primary and explicit for identification of contents. Positive identification of the contents of a piping system shall be by lettered legend giving the name of the contents in full or abbreviated form (see Table 1). Arrows shall be used to indicate direction of flow. Contents shall be identified by legend with sufficient additional details such as temperature, pressure, etc., as are necessary to identify the hazard.

Legend shall be brief, informative, pointed, and simple for greatest effectiveness. Legends shall be applied close to valves or flanges and adjacent to changes in direction, branches, and where pipes pass through walls or floors; and at intervals on straight pipe runs sufficient for identification. Identification may be accomplished by stenciling, the use of tape, or markers. In any situation, the number and location of identification markers shall be based on the particular piping system. (See Fig. 1.)

3.2 Color

Color should be used to identify the characteristic hazards of the contents (see Table 2). Color should be displayed on, or contiguous to, the piping by any physical means, but its use shall be in combination with legend. Color may be used in continuous, total length coverage or in intermittent displays.

3.3 Visibility

Attention shall be given to visibility with reference to pipe markings. Where pipe lines are located above or below the normal line of vision, the lettering shall be placed below or above the horizontal centerline of the pipe.

3.4 Type and Size of Letters

Contrast shall be provided between color field and legend for readability. Table 2 gives recommendations for color of legend on various color fields covered in this Standard. Use of letters of standard style,[1] in sizes 1/2 in. (13 mm) and larger, is recommended. Refer to Table 3 for specific size recommendations. For identification of materials in pipes of less than 3/4 in. (19 mm) in diameter, and for valve and fitting identification, the use of a permanently legible tag is recommended.

[1] Sans serif gothic bold lettering provides high readability.

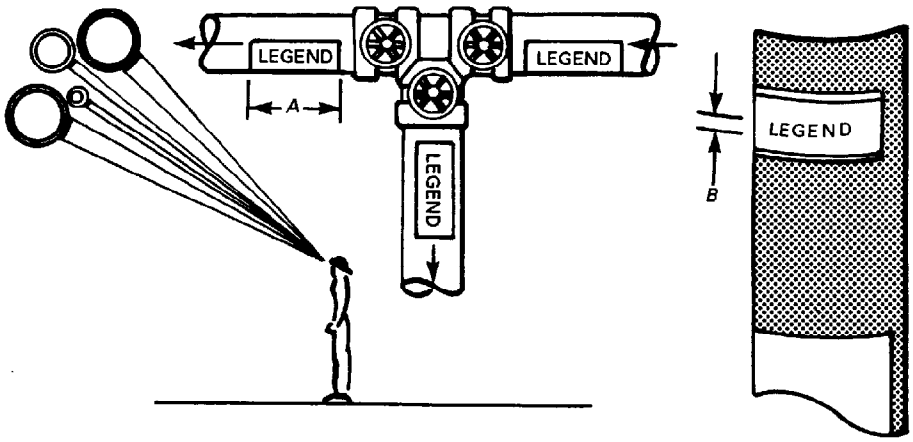

FIG. 1

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TABLE 2
CLASSIFICATION OF HAZARDS OF MATERIALS AND DESIGNATION OF COLORS[1]

Classification	Color Field	Color of Letters for Legend
Materials Inherently Hazardous		
Flammable or Explosive	Yellow	Black
Chemically Active or Toxic	Yellow	Black
Extreme Temperatures or Pressures	Yellow	Black
Radioactive[2]	Yellow	Black
Materials of Inherently Low Hazard		
Liquid or Liquid Admixture[3]	Green	White
Gas or Gaseous Admixture	Blue	White
Fire Quenching Materials		
Water, Foam, CO_2, Halon, etc.	Red	White

(96) NOTES:

(1) When the color scheme above is used, the colors should be as recommended in ANSI Z535.1 latest revision, Safety Color Code.

(2) Previously specified radioactive markers using yellow and purple are acceptable if already installed and/or until existing supplies are depleted, subject to pertinent Federal Regulations.

(3) Markers with black letters on a green color field are acceptable if already installed and/or until existing supplies are depleted.

TABLE 3 SIZE OF LEGEND LETTERS

Outside Diameter of Pipe or Covering		Length of Color Field A		Size of Letters B	
in.	mm	in.	mm	in.	mm
¾ to 1¼	19 to 32	8	200	½	13
1½ to 2	38 to 51	8	200	¾	19
2½ to 6	64 to 150	12	300	1¼	32
8 to 10	200 to 250	24	600	1½	64
over 10	over 250	32	800	3½	89

3.5 Unusual or Extreme Situations

When the piping layout creates or occurs in a limited area of inaccessibility or of extreme complexity, such segments of layouts may require substitute techniques to achieve positive identification. Use of substitute techniques shall be limited to such segments and shall not deviate from the concept of identification described in 3.1, "Legend," 3.2, "Color," and Table 2, "Classification of Hazards of Materials and Designation of Colors."

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STD.ASME B36.10M-ENGL 2000 ■ 0759670 0621931 T76 ■

ASME B36.10M-2000
(Revision of ASME B36.10M-1996)

WELDED AND SEAMLESS WROUGHT STEEL PIPE

AN AMERICAN NATIONAL STANDARD

The American Society of
Mechanical Engineers

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STD.ASME B36.10M-ENGL 2000 ■ 0759670 0621932 902 ■

The American Society of Mechanical Engineers

AN AMERICAN NATIONAL STANDARD

WELDED AND SEAMLESS WROUGHT STEEL PIPE

ASME B36.10M-2000

(Revision of ASME B36.10M-1996)

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Date of Issuance: March 15, 2001

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FOREWORD

In March 1927, the American Standards Association authorized the organization of a Sectional Committee on Standardization of Dimensions and Material of Wrought Steel and Wrought Iron Pipe and Tubing for the purpose of unifying the standards of these commodities in force in this country. The American Society for Testing and Materials and The American Society of Mechanical Engineers were designated as sponsors, and the first meeting of the Sectional Committee was held in Pittsburgh, Pennsylvania, on May 18, 1928.

The dimensions of commercial pipe in general use in the United States at the time conformed rather generally to those recommended by the ASME Committee on Standard Pipe and Pipe Threads published in 1886 (ASME Transactions, Vol. VIII, p. 29). On these standards an enormous industry has been built and the satisfactory use of this product proves the soundness of the original design and specification.

Increasingly severe service demands at the time of the Committee's organization had been met by using the nearest available pipe or tubing for heavier sections such as casing, mechanical tubing, etc., with resulting uneconomical multiplicity of wall thicknesses.

Subsequently, the Committee, with the cooperation of the industry, made a survey of existing practice as the logical starting point for the development of an American Standard. From this survey, a table was designed to provide a selection of wall thicknesses of pipe to cover the power piping requirements of industry where strength to resist internal pressure governs selection and was later expanded to include pipe diameters and thicknesses used in other industries.

The original intent of the Committee was to establish a system of Schedule Numbers for pipe size/wall thickness combinations which would have an approximately uniform relationship equal to 1000 times the *P/S* expression contained in the modified Barlow formula for pipe wall thickness as defined in the Appendix to this standard. The resulting Numbers departed so far from existing wall thicknesses in common use that the original intent could not be accomplished. The Schedule Numbers were then adopted strictly as a convenient designation system for use in ordering.

In all cases, the designer must base his selection on the rules and allowable stresses set by the code which governs his particular construction. The table is dimensionally complete for all sizes and wall thicknesses within its scope, but some of the larger, heavier wall sections are beyond the capability of seamless mill production and must be obtained from forged and bored billets or other sources.

The first issue of this standard was given with the designation American Standard "tentative" by the American Standards Association in November 1935. Subsequent slight revisions to Table 1 and the footnotes of the dimensional tables were approved and the ASA changed the designation to American Standard; the date of ASA approval was April 28, 1939.

Further revisions were made by the Sectional Committee. The list of specifications in Table 1 was revised where necessary and slight revisions in wall thicknesses of some of the large sizes of the heavy schedules were made where *P/S* values were out of line.

It was the hope in 1939 that the designation of pipe used commercially by all industry as Standard weight, Extra-Strong, and Double Extra-Strong would gradually be replaced by Schedule Number designation. However, owing to customs of over 50 years' standing,

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demand and production of pipe to these traditional dimensions is undiminished. Consequently, in response to a demand from users, accepted practice for dimensions and weights of commercial wrought steel and welded wrought iron pipe were added. These changes were designated an American Standard on February 23, 1950.

Subcommittee No. 1 was reorganized in 1957. In addition to necessary editorial changes, a simplified format was selected for the tables of weights and dimensions so as to include and identify the sizes and weights of API Standards 5L and 5LX. These changes to the standard were approved and it was designated an American Standard on December 21, 1959.

The standard was revised in 1969. A uniform method to calculate the plain end weight of steel pipe was included, and minor adjustments were made in the tabulated weights of steel pipe in Table 2 to conform to this new method. Additional sizes and thicknesses of steel pipe that had come into common use were also added to Table 2. Inasmuch as API Standard 5L no longer included wrought iron pipe, reference to this API Standard was deleted from Table 3. These changes to the standard were approved and it was designated an American National Standard on February 3, 1970.

Further revisions were made to the standard in 1975. Additional sizes and thicknesses of steel pipe that had been added to API specifications were added to Table 2. Table 3, Dimensions and Weights of Welded Wrought Iron Pipe, was deleted in its entirety, since wrought iron pipe is no longer produced. These changes in the standard were approved and it was designated an American National Standard on June 5, 1975.

The standard was revised in 1978 to include SI metric dimensions. The outside diameter and wall thicknesses were converted to millimeters by multiplying the inch dimensions by 25.4. Outside diameters larger than 16 in. were rounded to the nearest millimeter, and outside diameters 16 in. and smaller were rounded to the nearest 0.1 mm. Wall thicknesses were rounded to the nearest 0.01 mm. These converted and rounded SI metric dimensions were added to Table 2. A formula to calculate the SI metric plain end mass, in kilograms per meter, using SI metric diameters and thicknesses was added to section 5. The SI metric plain end mass was calculated and was added to Table 2. These changes in the standard were approved and it was designated an American National Standard on July 18, 1979.

Further revisions were made in 1984. The ANSI designations, which are no longer in use, were deleted from Table 1, and the list of specifications was revised to agree with current ASTM and API specifications. Additional sizes and thicknesses which had been added to API specifications were added to Table 2. That edition was approved as an American National Standard on August 19, 1985.

The next edition included additional wall thicknesses and was approved by the American National Standards Institute on August 24, 1995.

The 1996 edition contained revisions to Table 2, adding pipe sizes, changing some plain end weights and masses, identifying metric pipe by the dimensionless designator DN, and eliminating the API Specification column. The 1996 edition was approved as an American National Standard on September 23, 1996.

The current edition contains revisions to Table 2 to include the revised density for steel incorporated into Section 5 previously. Table 1 was deleted and other editorial changes to Sections 1, 2, 3, 5, 8, and 9 were made. This edition was approved as an American National Standard on December 1, 2000.

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ASME STANDARDS COMMITTEE B32
Metal and Metal Alloy
Wrought Mill Product Nominal Sizes

(The following is the roster of the Committee at the time of approval of this Standard.)

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Table
1 Dimensions and Weights of Welded and Seamless Wrought Steel Pipe 3

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WELDED AND SEAMLESS WROUGHT STEEL PIPE

1 SCOPE

This Standard covers the standardization of dimensions of welded and seamless wrought steel pipe for high or low temperatures and pressures.

The word *pipe* is used as distinguished from *tube* to apply to tubular products of dimensions commonly used for pipeline and piping systems. Pipe NPS 12 (DN 300) and smaller have outside diameters numerically larger than their corresponding sizes. In contrast, the outside diameters of tubes are numerically identical to the size number for all sizes.

2 SIZE

The size of all pipe is identified by the nominal pipe size.

The manufacture of pipe NPS $\frac{1}{8}$ (DN 6) to NPS 12 (DN 300) inclusive is based on a standardized outside diameter (OD). This OD was originally selected so that pipe with a standard OD and having a wall thickness that was typical of the period would have an inside diameter (ID) approximately equal to the nominal size. Although there is no such relation between the existing standard thickness — OD and nominal size — these nominal sizes and standard ODs continue in use as "standard."

The manufacture of pipe NPS 14 (DN 350) and larger proceeds on the basis of an OD corresponding to the nominal size.

3 MATERIALS

The dimensional standards for pipe described here are for products covered in ASTM specifications.

4 WALL THICKNESS

The nominal wall thicknesses are given in Table 1.

5 WEIGHTS

The nominal weights of steel pipe are calculated values and are tabulated in Table 1.

The nominal plain end weight, in pounds per foot, is calculated using the following formula:

$$W_{pe} = 10.69(D - t)t$$

where

W_{pe} = nominal plain end weight rounded to the nearest 0.01 lb/ft
D = outside diameter to the nearest 0.001 in. (the symbol D is to be used for OD only in mathematical equations or formulas)
t = specified wall thickness rounded to the nearest 0.001 in.

The nominal plain end mass, in kilograms per meter, is calculated using the following formula:

$$W_{pe} = 0.0246615(D - t)t$$

where

W_{pe} = nominal plain end weight rounded to the nearest 0.01 kg/m
D = outside diameter to the nearest 0.1 mm for outside diameters that are 16 in. (406.4 mm) and smaller and to the nearest 1.0 mm for outside diameters larger than 16 in. (406.4 mm) (the symbol D is to be used for OD only in mathematical equations or formulas)
t = specified wall thickness rounded to the nearest 0.01 mm

6 PERMISSIBLE VARIATIONS

Variations in dimensions differ depending upon the method of manufacture employed in making the pipe to the various specifications available. Permissible variations for dimensions are indicated in each specification.

7 PIPE THREADS

Unless otherwise specified, the threads of threaded pipe shall conform to ANSI/ASME B1.20.1, Pipe Threads, General Purpose (Inch).

Schedules 5 and 10 wall thicknesses do not permit threading in accordance with ANSI/ASME B1.20.1.

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8 WALL THICKNESS DESIGNATIONS

The wall thickness designations Standard, Extra-Strong, and Double Extra-Strong have been commercially used designations for many years. As explained in the Foreword, the Schedule Numbers were subsequently added as a convenient designation for use in ordering pipe. Standard and Schedule 40 are identical for up to NPS 10 (DN 250) inclusive. All larger sizes of Standard have $\frac{3}{8}$ in. (9.53 mm) wall thicknesses. Extra-Strong and Schedule 80 are identical for up to NPS 8 (DN 200) inclusive. All larger sizes of Extra-Strong have $\frac{1}{2}$ in. (12.70 mm) wall thicknesses.

Pipe of sizes and wall thicknesses other than those of Standard, Extra-Strong, and Double Extra-Strong, and Schedule Number were adopted from API Specification 5L. It was not considered practical to establish Schedule Numbers or new designations for them.

9 WALL THICKNESS SELECTION

When the selection of wall thickness depends primarily upon capacity to resist internal pressure under given conditions, the designer shall compute the exact value of wall thickness suitable for conditions for which the pipe is required, as prescribed in detail in the ASME Boiler and Pressure Vessel Code, ASME B31 Code for Pressure Piping, or other similar codes, whichever governs the construction. A thickness shall be selected from Table 1 to suit the value computed to fulfill the conditions for which the pipe is desired.

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE

	Customary Units						SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
1/8	0.405	0.049	0.19	...	10	...	10.3	1.24	0.28
1/8	0.405	0.057	0.21	...	30	...	10.3	1.45	0.32
1/8	0.405	0.068	0.24	STD	40	...	10.3	1.73	0.37
1/8	0.405	0.095	0.31	XS	80	...	10.3	2.41	0.47
1/4	0.540	0.065	0.33	...	10	...	13.7	1.65	0.49
1/4	0.540	0.073	0.36	...	30	...	13.7	1.85	0.54
1/4	0.540	0.088	0.43	STD	40	...	13.7	2.24	0.63
1/4	0.540	0.119	0.54	XS	80	...	13.7	3.02	0.80
3/8	0.675	0.065	0.42	...	10	10	17.1	1.65	0.63
3/8	0.675	0.073	0.47	...	30	10	17.1	1.85	0.70
3/8	0.675	0.091	0.57	STD	40	10	17.1	2.31	0.84
3/8	0.675	0.126	0.74	XS	80	10	17.1	3.20	1.10
1/2	0.840	0.065	0.54	...	5	15	21.3	1.65	0.80
1/2	0.840	0.083	0.67	...	10	15	21.3	2.11	1.00
1/2	0.840	0.095	0.76	...	30	15	21.3	2.41	1.12
1/2	0.840	0.109	0.85	STD	40	15	21.3	2.77	1.27
1/2	0.840	0.147	1.09	XS	80	15	21.3	3.73	1.62
1/2	0.840	0.188	1.31	...	160	15	21.3	4.78	1.95
1/2	0.840	0.294	1.72	XXS	...	15	21.3	7.47	2.55
3/4	1.050	0.065	0.69	...	5	20	26.7	1.65	1.03
3/4	1.050	0.083	0.86	...	10	20	26.7	2.11	1.28
3/4	1.050	0.095	0.97	...	30	20	26.7	2.41	1.44
3/4	1.050	0.113	1.13	STD	40	20	26.7	2.87	1.69
3/4	1.050	0.154	1.48	XS	80	20	26.7	3.91	2.20
3/4	1.050	0.219	1.95	...	160	20	26.7	5.56	2.90
3/4	1.050	0.308	2.44	XXS	...	20	26.7	7.82	3.64
1	1.315	0.065	0.87	...	5	25	33.4	1.65	1.29
1	1.315	0.109	1.41	...	10	25	33.4	2.77	2.09
1	1.315	0.114	1.46	...	30	25	33.4	2.90	2.18
1	1.315	0.133	1.68	STD	40	25	33.4	3.38	2.50
1	1.315	0.179	2.17	XS	80	25	33.4	4.55	3.24
1	1.315	0.250	2.85	...	160	25	33.4	6.35	4.24
1	1.315	0.358	3.66	XXS	...	25	33.4	9.09	5.45
1 1/4	1.660	0.065	1.11	...	5	32	42.2	1.65	1.65
1 1/4	1.660	0.109	1.81	...	10	32	42.2	2.77	2.69
1 1/4	1.660	0.117	1.93	...	30	32	42.2	2.97	2.87
1 1/4	1.660	0.140	2.27	STD	40	32	42.2	3.56	3.39
1 1/4	1.660	0.191	3.00	XS	80	32	42.2	4.85	4.47
1 1/4	1.660	0.250	3.77	...	160	32	42.2	6.35	5.61
1 1/4	1.660	0.382	5.22	XXS	...	32	42.2	9.70	7.77

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

	Customary Units						SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
1½	1.900	0.065	1.28	...	5	40	48.3	1.65	1.90
1½	1.900	0.109	2.09	...	10	40	48.3	2.77	3.11
1½	1.900	0.125	2.37	...	30	40	48.3	3.18	3.53
1½	1.900	0.145	2.72	STD	40	40	48.3	3.68	4.05
1½	1.900	0.200	3.63	XS	80	40	48.3	5.08	5.41
1½	1.900	0.281	4.86	...	160	40	48.3	7.14	7.25
1½	1.900	0.400	6.41	XXS	...	40	48.3	10.15	9.55
2	2.375	0.065	1.61	...	5	50	60.3	1.65	2.39
2	2.375	0.083	2.03	...	...	50	60.3	2.11	3.03
2	2.375	0.109	2.64	...	10	50	60.3	2.77	3.93
2	2.375	0.125	3.01	...	30	50	60.3	3.18	4.48
2	2.375	0.141	3.37	...	...	50	60.3	3.58	5.01
2	2.375	0.154	3.66	STD	40	50	60.3	3.91	5.44
2	2.375	0.172	4.05	...	...	50	60.3	4.37	6.03
2	2.375	0.188	4.40	...	...	50	60.3	4.78	6.54
2	2.375	0.218	5.03	XS	80	50	60.3	5.54	7.48
2	2.375	0.250	5.68	...	...	50	60.3	6.35	8.45
2	2.375	0.281	6.29	...	...	50	60.3	7.14	9.36
2	2.375	0.344	7.47	...	160	50	60.3	8.74	11.11
2	2.375	0.436	9.04	XXS	...	50	60.3	11.07	13.44
2½	2.875	0.083	2.48	...	5	65	73.0	2.11	3.69
2½	2.875	0.109	3.22	...	...	65	73.0	2.77	4.80
2½	2.875	0.120	3.53	...	10	65	73.0	3.05	5.26
2½	2.875	0.125	3.67	...	...	65	73.0	3.18	5.48
2½	2.875	0.141	4.12	...	...	65	73.0	3.58	6.13
2½	2.875	0.156	4.53	...	...	65	73.0	3.96	6.74
2½	2.875	0.172	4.97	...	...	65	73.0	4.37	7.40
2½	2.875	0.188	5.40	...	30	65	73.0	4.78	8.04
2½	2.875	0.203	5.80	STD	40	65	73.0	5.16	8.63
2½	2.875	0.216	6.14	...	...	65	73.0	5.49	9.14
2½	2.875	0.250	7.02	...	...	65	73.0	6.35	10.44
2½	2.875	0.276	7.67	XS	80	65	73.0	7.01	11.41
2½	2.875	0.375	10.02	...	160	65	73.0	9.53	14.92
2½	2.875	0.552	13.71	XXS	...	65	73.0	14.02	20.39
3	3.500	0.083	3.03	...	5	80	88.9	2.11	4.52
3	3.500	0.109	3.95	...	...	80	88.9	2.77	5.88
3	3.500	0.120	4.34	...	10	80	88.9	3.05	6.46
3	3.500	0.125	4.51	...	...	80	88.9	3.18	6.72
3	3.500	0.141	5.06	...	...	80	88.9	3.58	7.53
3	3.500	0.156	5.58	...	...	80	88.9	3.96	8.30
3	3.500	0.172	6.12	...	...	80	88.9	4.37	9.11
3	3.500	0.188	6.66	...	30	80	88.9	4.78	9.92
3	3.500	0.216	7.58	STD	40	80	88.9	5.49	11.29

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

	Customary Units			Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]			SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft		Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
3	3.500	0.250	8.69	...	...	80	88.9	6.35	12.93
3	3.500	0.281	9.67	...	...	80	88.9	7.14	14.40
3	3.500	0.300	10.26	XS	80	80	88.9	7.62	15.27
3	3.500	0.438	14.34	...	160	80	88.9	11.13	21.35
3	3.500	0.600	18.60	XXS	...	80	88.9	15.24	27.68
3½	4.000	0.083	3.48	...	5	90	101.6	2.11	5.18
3½	4.000	0.109	4.53	...	...	90	101.6	2.77	6.75
3½	4.000	0.120	4.98	...	10	90	101.6	3.05	7.41
3½	4.000	0.125	5.18	...	...	90	101.6	3.18	7.72
3½	4.000	0.141	5.82	...	...	90	101.6	3.58	8.65
3½	4.000	0.156	6.41	...	...	90	101.6	3.96	9.54
3½	4.000	0.172	7.04	...	...	90	101.6	4.37	10.48
3½	4.000	0.188	7.66	...	30	90	101.6	4.78	11.41
3½	4.000	0.226	9.12	STD	40	90	101.6	5.74	13.57
3½	4.000	0.250	10.02	...	...	90	101.6	6.35	14.92
3½	4.000	0.281	11.17	...	...	90	101.6	7.14	16.63
3½	4.000	0.318	12.52	XS	80	90	101.6	8.08	18.64
4	4.500	0.083	3.92	...	5	100	114.3	2.11	5.84
4	4.500	0.109	5.12	...	...	100	114.3	2.77	7.62
4	4.500	0.120	5.62	...	10	100	114.3	3.05	8.37
4	4.500	0.125	5.85	...	...	100	114.3	3.18	8.71
4	4.500	0.141	6.57	...	...	100	114.3	3.58	9.78
4	4.500	0.156	7.24	...	...	100	114.3	3.96	10.78
4	4.500	0.172	7.96	...	...	100	114.3	4.37	11.85
4	4.500	0.188	8.67	...	30	100	114.3	4.78	12.91
4	4.500	0.203	9.32	...	...	100	114.3	5.16	13.89
4	4.500	0.219	10.02	...	...	100	114.3	5.56	14.91
4	4.500	0.237	10.80	STD	40	100	114.3	6.02	16.08
4	4.500	0.250	11.36	...	...	100	114.3	6.35	16.91
4	4.500	0.281	12.67	...	...	100	114.3	7.14	18.87
4	4.500	0.312	13.97	...	...	100	114.3	7.92	20.78
4	4.500	0.337	15.00	XS	80	100	114.3	8.56	22.32
4	4.500	0.438	19.02	...	120	100	114.3	11.13	28.32
4	4.500	0.531	22.53	...	160	100	114.3	13.49	33.54
4	4.500	0.674	27.57	XXS	...	100	114.3	17.12	41.03
5	5.563	0.083	4.86	...	...	125	141.3	2.11	7.24
5	5.563	0.109	6.36	...	5	125	141.3	2.77	9.46
5	5.563	0.125	7.27	...	...	125	141.3	3.18	10.83
5	5.563	0.134	7.78	...	10	125	141.3	3.40	11.56
5	5.563	0.156	9.02	...	...	125	141.3	3.96	13.41
5	5.563	0.188	10.80	...	...	125	141.3	4.78	16.09
5	5.563	0.219	12.51	...	...	125	141.3	5.56	18.61
5	5.563	0.258	14.63	STD	40	125	141.3	6.55	21.77

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

	Customary Units			Identification			SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	[Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
5	5.563	0.281	15.87	...	...	125	141.3	7.14	23.62
5	5.563	0.312	17.51	...	...	125	141.3	7.92	26.05
5	5.563	0.344	19.19	...	...	125	141.3	8.74	28.57
5	5.563	0.375	20.80	XS	80	125	141.3	9.53	30.97
5	5.563	0.500	27.06	...	120	125	141.3	12.70	40.28
5	5.563	0.625	32.99	...	160	125	141.3	15.88	49.12
5	5.563	0.750	38.59	XXS	...	125	141.3	19.05	57.43
6	6.625	0.083	5.80	...	...	150	168.3	2.11	8.65
6	6.625	0.109	7.59	...	5	150	168.3	2.77	11.31
6	6.625	0.125	8.69	...	...	150	168.3	3.18	12.95
6	6.625	0.134	9.30	...	10	150	168.3	3.40	13.83
6	6.625	0.141	9.77	...	...	150	168.3	3.58	14.54
6	6.625	0.156	10.79	...	...	150	168.3	3.96	16.05
6	6.625	0.172	11.87	...	...	150	168.3	4.37	17.67
6	6.625	0.188	12.94	...	...	150	168.3	4.78	19.28
6	6.625	0.203	13.94	...	...	150	168.3	5.16	20.76
6	6.625	0.219	15.00	...	...	150	168.3	5.56	22.31
6	6.625	0.250	17.04	...	...	150	168.3	6.35	25.36
6	6.625	0.280	18.99	STD	40	150	168.3	7.11	28.26
6	6.625	0.312	21.06	...	...	150	168.3	7.92	31.33
6	6.625	0.344	23.10	...	...	150	168.3	8.74	34.39
6	6.625	0.375	25.05	...	...	150	168.3	9.53	37.31
6	6.625	0.432	28.60	XS	80	150	168.3	10.97	42.56
6	6.625	0.500	32.74	...	...	150	168.3	12.70	48.73
6	6.625	0.562	36.43	...	120	150	168.3	14.27	54.21
6	6.625	0.625	40.09	...	...	150	168.3	15.88	59.69
6	6.625	0.719	45.39	...	160	150	168.3	18.26	67.57
6	6.625	0.750	47.10	...	...	150	168.3	19.05	70.12
6	6.625	0.864	53.21	XXS	...	150	168.3	21.95	79.22
6	6.625	0.875	53.78	...	...	150	168.3	22.23	80.08
8	8.625	0.109	9.92	...	5	200	219.1	2.77	14.78
8	8.625	0.125	11.36	...	...	200	219.1	3.18	16.93
8	8.625	0.148	13.41	...	10	200	219.1	3.76	19.97
8	8.625	0.156	14.12	...	...	200	219.1	3.96	21.01
8	8.625	0.188	16.96	...	...	200	219.1	4.78	25.26
8	8.625	0.203	18.28	...	...	200	219.1	5.16	27.22
8	8.625	0.219	19.68	...	...	200	219.1	5.56	29.28
8	8.625	0.250	22.38	...	20	200	219.1	6.35	33.32
8	8.625	0.277	24.72	...	30	200	219.1	7.04	36.82
8	8.625	0.312	27.73	...	...	200	219.1	7.92	41.25
8	8.625	0.322	28.58	STD	40	200	219.1	8.18	42.55
8	8.625	0.344	30.45	...	...	200	219.1	8.74	45.34

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

Customary Units						SI Units			
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
8	8.625	0.375	33.07	...	...	200	219.1	9.53	49.25
8	8.625	0.406	35.67	...	60	200	219.1	10.31	53.09
8	8.625	0.438	38.33	...	...	200	219.1	11.13	57.08
8	8.625	0.500	43.43	XS	80	200	219.1	12.70	64.64
8	8.625	0.562	48.44	...	...	200	219.1	14.27	72.08
8	8.625	0.594	51.00	...	100	200	219.1	15.09	75.92
8	8.625	0.625	53.45	...	...	200	219.1	15.88	79.59
8	8.625	0.719	60.77	...	120	200	219.1	18.26	90.44
8	8.625	0.750	63.14	...	...	200	219.1	19.05	93.98
8	8.625	0.812	67.82	...	140	200	219.1	20.62	100.93
8	8.625	0.875	72.49	XXS	...	200	219.1	22.23	107.93
8	8.625	0.906	74.76	...	160	200	219.1	23.01	111.27
8	8.625	1.000	81.51	...	...	200	219.1	25.40	121.33
10	10.750	0.134	15.21	...	5	250	273.0	3.40	22.61
10	10.750	0.156	17.67	...	...	250	273.0	3.96	26.27
10	10.750	0.165	18.67	...	10	250	273.0	4.19	27.78
10	10.750	0.188	21.23	...	...	250	273.0	4.78	31.62
10	10.750	0.203	22.89	...	...	250	273.0	5.16	34.08
10	10.750	0.219	24.65	...	...	250	273.0	5.56	36.67
10	10.750	0.250	28.06	...	20	250	273.0	6.35	41.76
10	10.750	0.279	31.23	...	...	250	273.0	7.09	46.49
10	10.750	0.307	34.27	...	30	250	273.0	7.80	51.01
10	10.750	0.344	38.27	...	...	250	273.0	8.74	56.96
10	10.750	0.365	40.52	STD	40	250	273.0	9.27	60.29
10	10.750	0.438	48.28	...	...	250	273.0	11.13	71.88
10	10.750	0.500	54.79	XS	60	250	273.0	12.70	81.53
10	10.750	0.562	61.21	...	...	250	273.0	14.27	91.05
10	10.750	0.594	64.49	...	80	250	273.0	15.09	95.98
10	10.750	0.625	67.65	...	...	250	273.0	15.88	100.69
10	10.750	0.719	77.10	...	100	250	273.0	18.26	114.71
10	10.750	0.812	86.26	...	...	250	273.0	20.62	128.34
10	10.750	0.844	89.38	...	120	250	273.0	21.44	133.01
10	10.750	0.875	92.37	...	...	250	273.0	22.23	137.48
10	10.750	0.938	98.39	...	...	250	273.0	23.83	146.43
10	10.750	1.000	104.23	XXS	140	250	273.0	25.40	155.10
10	10.750	1.125	115.75	...	160	250	273.0	28.58	172.27
10	10.750	1.250	126.94	...	...	250	273.0	31.75	188.90
12	12.750	0.156	21.00	...	5	300	323.8	3.96	31.24
12	12.750	0.172	23.13	...	...	300	323.8	4.37	34.43
12	12.750	0.180	24.19	...	10	300	323.8	4.57	35.98
12	12.750	0.188	25.25	...	...	300	323.8	4.78	37.61

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

	Customary Units			Identification			SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	[Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
12	12.750	0.203	27.23	...	...	300	323.8	5.16	40.55
12	12.750	0.219	29.34	...	...	300	323.8	5.56	43.64
12	12.750	0.250	33.41	...	20	300	323.8	6.35	49.71
12	12.750	0.281	37.46	...	...	300	323.8	7.14	55.76
12	12.750	0.312	41.48	...	...	300	323.8	7.92	61.70
12	12.750	0.330	43.81	...	30	300	323.8	8.38	65.19
12	12.750	0.344	45.62	...	...	300	323.8	8.74	67.91
12	12.750	0.375	49.61	STD	...	300	323.8	9.53	73.86
12	12.750	0.406	53.57	...	40	300	323.8	10.31	79.71
12	12.750	0.438	57.65	...	...	300	323.8	11.13	85.82
12	12.750	0.500	65.48	XS	...	300	323.8	12.70	97.44
12	12.750	0.562	73.22	...	60	300	323.8	14.27	108.93
12	12.750	0.625	81.01	...	...	300	323.8	15.88	120.59
12	12.750	0.688	88.71	...	80	300	323.8	17.48	132.05
12	12.750	0.750	96.21	...	...	300	323.8	19.05	143.17
12	12.750	0.812	103.63	...	...	300	323.8	20.62	154.17
12	12.750	0.844	107.42	...	100	300	323.8	21.44	159.87
12	12.750	0.875	111.08	...	...	300	323.8	22.23	165.33
12	12.750	0.938	118.44	...	...	300	323.8	23.83	176.29
12	12.750	1.000	125.61	XXS	120	300	323.8	25.40	186.92
12	12.750	1.062	132.69	...	...	300	323.8	26.97	197.43
12	12.750	1.125	139.81	...	140	300	323.8	28.58	208.08
12	12.750	1.250	153.67	...	...	300	323.8	31.75	228.68
12	12.750	1.312	160.42	...	160	300	323.8	33.32	238.69
14	14.000	0.156	23.09	...	5	350	355.6	3.96	34.34
14	14.000	0.188	27.76	...	...	350	355.6	4.78	41.36
14	14.000	0.203	29.94	...	...	350	355.6	5.16	44.59
14	14.000	0.210	30.96	...	...	350	355.6	5.33	46.04
14	14.000	0.219	32.26	...	...	350	355.6	5.56	48.00
14	14.000	0.250	36.75	...	10	350	355.6	6.35	54.69
14	14.000	0.281	41.21	...	...	350	355.6	7.14	61.36
14	14.000	0.312	45.65	...	20	350	355.6	7.92	67.91
14	14.000	0.344	50.22	...	...	350	355.6	8.74	74.76
14	14.000	0.375	54.62	STD	30	350	355.6	9.53	81.33
14	14.000	0.406	59.00	...	...	350	355.6	10.31	87.79
14	14.000	0.438	63.50	...	40	350	355.6	11.13	94.55
14	14.000	0.469	67.84	...	...	350	355.6	11.91	100.95
14	14.000	0.500	72.16	XS	...	350	355.6	12.70	107.40
14	14.000	0.562	80.73	...	...	350	355.6	14.27	120.12
14	14.000	0.594	85.13	...	60	350	355.6	15.09	126.72
14	14.000	0.625	89.36	...	...	350	355.6	15.88	133.04
14	14.000	0.688	97.91	...	...	350	355.6	17.48	145.76
14	14.000	0.750	106.23	...	80	350	355.6	19.05	158.11
14	14.000	0.812	114.48	...	...	350	355.6	20.62	170.34

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

Customary Units						SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
14	14.000	0.875	122.77	...	...	350	355.6	22.23	182.76
14	14.000	0.938	130.98	...	100	350	355.6	23.83	194.98
14	14.000	1.000	138.97	...	...	350	355.6	25.40	206.84
14	14.000	1.062	146.88	...	...	350	355.6	26.97	218.58
14	14.000	1.094	150.93	...	120	350	355.6	27.79	224.66
14	14.000	1.125	154.84	...	...	350	355.6	28.58	230.49
14	14.000	1.250	170.37	...	140	350	355.6	31.75	253.58
14	14.000	1.406	189.29	...	160	350	355.6	35.71	281.72
14	14.000	2.000	256.56	...	...	350	355.6	50.80	381.85
14	14.000	2.125	269.76	...	...	350	355.6	53.98	401.52
14	14.000	2.200	277.51	...	...	350	355.6	55.88	413.04
14	14.000	2.500	307.34	...	...	350	355.6	63.50	457.43
16	16.000	0.165	27.93	...	5	400	406.4	4.19	41.56
16	16.000	0.188	31.78	...	...	400	406.4	4.78	47.34
16	16.000	0.203	34.28	...	...	400	406.4	5.16	51.06
16	16.000	0.219	36.95	...	...	400	406.4	5.56	54.96
16	16.000	0.250	42.09	...	10	400	406.4	6.35	62.65
16	16.000	0.281	47.22	...	...	400	406.4	7.14	70.30
16	16.000	0.312	52.32	...	20	400	406.4	7.92	77.83
16	16.000	0.344	57.57	...	...	400	406.4	8.74	85.71
16	16.000	0.375	62.64	STD	30	400	406.4	9.53	93.27
16	16.000	0.406	67.68	...	...	400	406.4	10.31	100.71
16	16.000	0.438	72.86	...	...	400	406.4	11.13	108.49
16	16.000	0.469	77.87	...	...	400	406.4	11.91	115.87
16	16.000	0.500	82.85	XS	40	400	406.4	12.70	123.31
16	16.000	0.562	92.75	...	...	400	406.4	14.27	138.00
16	16.000	0.625	102.72	...	...	400	406.4	15.88	152.94
16	16.000	0.656	107.60	...	60	400	406.4	16.66	160.13
16	16.000	0.688	112.62	...	...	400	406.4	17.48	167.66
16	16.000	0.750	122.27	...	...	400	406.4	19.05	181.98
16	16.000	0.812	131.84	...	...	400	406.4	20.62	196.18
16	16.000	0.844	136.74	...	80	400	406.4	21.44	203.54
16	16.000	0.875	141.48	...	...	400	406.4	22.23	210.61
16	16.000	0.938	151.03	...	...	400	406.4	23.83	224.83
16	16.000	1.000	160.35	...	...	400	406.4	25.40	238.66
16	16.000	1.031	164.98	...	100	400	406.4	26.19	245.57
16	16.000	1.062	169.59	...	...	400	406.4	26.97	252.37
16	16.000	1.125	178.89	...	...	400	406.4	28.58	266.30
16	16.000	1.188	188.11	...	...	400	406.4	30.18	280.01
16	16.000	1.219	192.61	...	120	400	406.4	30.96	286.66
16	16.000	1.250	197.10	...	...	400	406.4	31.75	293.35
16	16.000	1.438	223.85	...	140	400	406.4	36.53	333.21
16	16.000	1.594	245.48	...	160	400	406.4	40.49	365.38

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

	Customary Units			Identification			SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	[Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
18	18.000	0.165	31.46	...	5	450	457	4.19	46.79
18	18.000	0.188	35.80	...	...	450	457	4.78	53.31
18	18.000	0.219	41.63	...	...	450	457	5.56	61.90
18	18.000	0.250	47.44	...	10	450	457	6.35	70.57
18	18.000	0.281	53.23	...	...	450	457	7.14	79.21
18	18.000	0.312	58.99	...	20	450	457	7.92	87.71
18	18.000	0.344	64.93	...	...	450	457	8.74	96.62
18	18.000	0.375	70.65	STD	...	450	457	9.53	105.17
18	18.000	0.406	76.36	...	...	450	457	10.31	113.58
18	18.000	0.438	82.23	...	30	450	457	11.13	122.38
18	18.000	0.469	87.89	...	...	450	457	11.91	130.73
18	18.000	0.500	93.54	XS	...	450	457	12.70	139.16
18	18.000	0.562	104.76	...	40	450	457	14.27	155.81
18	18.000	0.625	116.09	...	...	450	457	15.88	172.75
18	18.000	0.688	127.32	...	...	450	457	17.48	189.47
18	18.000	0.750	138.30	...	60	450	457	19.05	205.75
18	18.000	0.812	149.20	...	...	450	457	20.62	221.91
18	18.000	0.875	160.18	...	...	450	457	22.23	238.35
18	18.000	0.938	171.08	...	80	450	457	23.83	254.57
18	18.000	1.000	181.73	...	...	450	457	25.40	270.36
18	18.000	1.062	192.29	...	...	450	457	26.97	286.02
18	18.000	1.125	202.94	...	...	450	457	28.58	301.96
18	18.000	1.156	208.15	...	100	450	457	29.36	309.64
18	18.000	1.188	213.51	...	...	450	457	30.18	317.68
18	18.000	1.250	223.82	...	...	450	457	31.75	332.97
18	18.000	1.375	244.37	...	120	450	457	34.93	363.58
18	18.000	1.562	274.48	...	140	450	457	39.67	408.28
18	18.000	1.781	308.79	...	160	450	457	45.24	459.39
20	20.000	0.188	39.82	...	5	500	508	4.78	59.32
20	20.000	0.219	46.31	...	...	500	508	5.56	68.89
20	20.000	0.250	52.78	...	10	500	508	6.35	78.56
20	20.000	0.281	59.23	...	...	500	508	7.14	88.19
20	20.000	0.312	65.66	...	...	500	508	7.92	97.68
20	20.000	0.344	72.28	...	...	500	508	8.74	107.61
20	20.000	0.375	78.67	STD	20	500	508	9.53	117.15
20	20.000	0.406	85.04	...	...	500	508	10.31	126.54
20	20.000	0.438	91.59	...	...	500	508	11.13	136.38
20	20.000	0.469	97.92	...	...	500	508	11.91	145.71
20	20.000	0.500	104.23	XS	30	500	508	12.70	155.13
20	20.000	0.562	116.78	...	...	500	508	14.27	173.75
20	20.000	0.594	123.23	...	40	500	508	15.09	183.43
20	20.000	0.625	129.45	...	...	500	508	15.88	192.73
20	20.000	0.688	142.03	...	...	500	508	17.48	211.45
20	20.000	0.750	154.34	...	...	500	508	19.05	229.71

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

	Customary Units						SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
20	20.000	0.812	166.56	...	60	500	508	20.62	247.84
20	20.000	0.875	178.89	...	...	500	508	22.23	266.31
20	20.000	0.938	191.14	...	...	500	508	23.83	284.54
20	20.000	1.000	203.11	...	...	500	508	25.40	302.30
20	20.000	1.031	209.06	...	80	500	508	26.19	311.19
20	20.000	1.062	215.00	...	...	500	508	26.97	319.94
20	20.000	1.125	227.00	...	...	500	508	28.58	337.91
20	20.000	1.188	238.91	...	...	500	508	30.18	355.63
20	20.000	1.250	250.55	...	...	500	508	31.75	372.91
20	20.000	1.281	256.34	...	100	500	508	32.54	381.55
20	20.000	1.312	262.10	...	...	500	508	33.32	390.05
20	20.000	1.375	273.76	...	...	500	508	34.93	407.51
20	20.000	1.500	296.65	...	120	500	508	38.10	441.52
20	20.000	1.750	341.41	...	140	500	508	44.45	508.15
20	20.000	1.969	379.53	...	160	500	508	50.01	564.85
22	22.000	0.188	43.84	...	5	...	559	4.78	65.33
22	22.000	0.219	50.99	...	...	...	559	5.56	75.89
22	22.000	0.250	58.13	...	10	...	559	6.35	86.55
22	22.000	0.281	65.24	...	...	...	559	7.14	97.17
22	22.000	0.312	72.34	...	...	...	559	7.92	107.64
22	22.000	0.344	79.64	...	...	...	559	8.74	118.60
22	22.000	0.375	86.69	STD	20	...	559	9.53	129.14
22	22.000	0.406	93.72	...	...	...	559	10.31	139.51
22	22.000	0.438	100.96	...	...	...	559	11.13	150.38
22	22.000	0.469	107.95	...	...	...	559	11.91	160.69
22	22.000	0.500	114.92	XS	30	...	559	12.70	171.10
22	22.000	0.562	128.79	...	...	...	559	14.27	191.70
22	22.000	0.625	142.81	...	...	...	559	15.88	212.70
22	22.000	0.688	156.74	...	...	...	559	17.48	233.44
22	22.000	0.750	170.37	...	...	...	559	19.05	253.67
22	22.000	0.812	183.92	...	...	...	559	20.62	273.78
22	22.000	0.875	197.60	...	60	...	559	22.23	294.27
22	22.000	0.938	211.19	...	...	...	559	23.83	314.51
22	22.000	1.000	224.49	...	...	...	559	25.40	334.25
22	22.000	1.062	237.70	...	...	...	559	26.97	353.86
22	22.000	1.125	251.05	...	80	...	559	28.58	373.85
22	22.000	1.188	264.31	...	...	...	559	30.18	393.59
22	22.000	1.250	277.27	...	...	...	559	31.75	412.84
22	22.000	1.312	290.15	...	...	...	559	33.32	431.96
22	22.000	1.375	303.16	...	100	...	559	34.93	451.45
22	22.000	1.438	316.08	...	...	...	559	36.53	470.69

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

	Customary Units			Identification			SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	[Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
22	22.000	1.500	328.72	...	...	...	559	38.10	489.44
22	22.000	1.625	353.94	...	120	...	559	41.28	527.05
22	22.000	1.875	403.38	...	140	...	559	47.63	600.67
22	22.000	2.125	451.49	...	160	...	559	53.98	672.30
24	24.000	0.218	55.42	...	5	600	610	5.54	82.58
24	24.000	0.250	63.47	...	10	600	610	6.35	94.53
24	24.000	0.281	71.25	...	...	600	610	7.14	106.15
24	24.000	0.312	79.01	...	...	600	610	7.92	117.60
24	24.000	0.344	86.99	...	...	600	610	8.74	129.60
24	24.000	0.375	94.71	STD	20	600	610	9.53	141.12
24	24.000	0.406	102.40	...	...	600	610	10.31	152.48
24	24.000	0.438	110.32	...	...	600	610	11.13	164.38
24	24.000	0.469	117.98	...	...	600	610	11.91	175.67
24	24.000	0.500	125.61	XS	...	600	610	12.70	187.07
24	24.000	0.562	140.81	...	30	600	610	14.27	209.65
24	24.000	0.625	156.17	...	...	600	610	15.88	232.67
24	24.000	0.688	171.45	...	40	600	610	17.48	255.43
24	24.000	0.750	186.41	...	...	600	610	19.05	277.63
24	24.000	0.812	201.28	...	...	600	610	20.62	299.71
24	24.000	0.875	216.31	...	...	600	610	22.23	322.23
24	24.000	0.938	231.25	...	...	600	610	23.83	344.48
24	24.000	0.969	238.57	...	60	600	610	24.61	355.28
24	24.000	1.000	245.87	...	...	600	610	25.40	366.19
24	24.000	1.062	260.41	...	...	600	610	26.97	387.79
24	24.000	1.125	275.10	...	...	600	610	28.58	409.80
24	24.000	1.188	289.71	...	...	600	610	30.18	431.55
24	24.000	1.219	296.86	...	80	600	610	30.96	442.11
24	24.000	1.250	304.00	...	...	600	610	31.75	452.77
24	24.000	1.312	318.21	...	...	600	610	33.32	473.87
24	24.000	1.375	332.56	...	...	600	610	34.93	495.38
24	24.000	1.438	346.83	...	...	600	610	36.53	516.63
24	24.000	1.500	360.79	...	...	600	610	38.10	537.36
24	24.000	1.531	367.74	...	100	600	610	38.89	547.74
24	24.000	1.562	374.66	...	...	600	610	39.67	557.97
24	24.000	1.812	429.79	...	120	600	610	46.02	640.07
24	24.000	2.062	483.57	...	140	600	610	52.37	720.19
24	24.000	2.344	542.64	...	160	600	610	59.54	808.27
26	26.000	0.250	68.82	...	...	...	660	6.35	102.36
26	26.000	0.281	77.26	...	...	...	660	7.14	114.96
26	26.000	0.312	85.68	...	10	...	660	7.92	127.36
26	26.000	0.344	94.35	...	...	...	660	8.74	140.37

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

	Customary Units						SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
26	26.000	0.375	102.72	STD	...	...	660	9.53	152.88
26	26.000	0.406	111.08	...	...	...	660	10.31	165.19
26	26.000	0.438	119.69	...	...	...	660	11.13	178.10
26	26.000	0.469	128.00	...	...	...	660	11.91	190.36
26	26.000	0.500	136.30	XS	20	...	660	12.70	202.74
26	26.000	0.562	152.83	...	...	...	660	14.27	227.25
26	26.000	0.625	169.54	...	...	...	660	15.88	252.25
26	26.000	0.688	186.16	...	...	...	660	17.48	276.98
26	26.000	0.750	202.44	...	...	...	660	19.05	301.12
26	26.000	0.812	218.64	...	...	...	660	20.62	325.14
26	26.000	0.875	235.01	...	...	...	660	22.23	349.64
26	26.000	0.938	251.30	...	...	...	660	23.83	373.87
26	26.000	1.000	267.25	...	...	...	660	25.40	397.51
28	28.000	0.250	74.16	...	...	700	711	6.35	110.35
28	28.000	0.281	83.26	...	...	700	711	7.14	123.94
28	28.000	0.312	92.35	...	10	700	711	7.92	137.32
28	28.000	0.344	101.70	...	...	700	711	8.74	151.37
28	28.000	0.375	110.74	STD	...	700	711	9.53	164.86
28	28.000	0.406	119.76	...	...	700	711	10.31	178.16
28	28.000	0.438	129.05	...	...	700	711	11.13	192.10
28	28.000	0.469	138.03	...	...	700	711	11.91	205.34
28	28.000	0.500	146.99	XS	20	700	711	12.70	218.71
28	28.000	0.562	164.84	...	...	700	711	14.27	245.19
28	28.000	0.625	182.90	...	30	700	711	15.88	272.23
28	28.000	0.688	200.87	...	...	700	711	17.48	298.96
28	28.000	0.750	218.48	...	...	700	711	19.05	325.08
28	28.000	0.812	236.00	...	...	700	711	20.62	351.07
28	28.000	0.875	253.72	...	...	700	711	22.23	377.60
28	28.000	0.938	271.36	...	...	700	711	23.83	403.84
28	28.000	1.000	288.63	...	...	700	711	25.40	429.46
30	30.000	0.250	79.51	...	5	...	762	6.35	118.34
30	30.000	0.281	89.27	...	...	...	762	7.14	132.92
30	30.000	0.312	99.02	...	10	...	762	7.92	147.29
30	30.000	0.344	109.06	...	...	...	762	8.74	162.36
30	30.000	0.375	118.76	STD	...	...	762	9.53	176.85
30	30.000	0.406	128.44	...	...	...	762	10.31	191.12
30	30.000	0.438	138.42	...	...	...	762	11.13	206.10
30	30.000	0.469	148.06	...	...	...	762	11.91	220.32
30	30.000	0.500	157.68	XS	20	...	762	12.70	234.68
30	30.000	0.562	176.86	...	...	...	762	14.27	263.14
30	30.000	0.625	196.26	...	30	...	762	15.88	292.20
30	30.000	0.688	215.58	...	...	...	762	17.48	320.95

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

	Customary Units			Identification			SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	[Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
30	30.000	0.750	234.51	...	...	...	762	19.05	349.04
30	30.000	0.812	253.36	...	...	...	762	20.62	377.01
30	30.000	0.875	272.43	...	...	...	762	22.23	405.56
30	30.000	0.938	291.41	...	...	...	762	23.83	433.81
30	30.000	1.000	310.01	...	...	...	762	25.40	461.41
30	30.000	1.062	328.53	...	...	...	762	26.97	488.88
30	30.000	1.125	347.26	...	...	...	762	28.58	516.93
30	30.000	1.188	365.90	...	...	...	762	30.18	544.68
30	30.000	1.250	384.17	...	...	...	762	31.75	571.79
32	32.000	0.250	84.85	...	...	800	813	6.35	126.32
32	32.000	0.281	95.28	...	...	800	813	7.14	141.90
32	32.000	0.312	105.69	...	10	800	813	7.92	157.25
32	32.000	0.344	116.41	...	...	800	813	8.74	173.35
32	32.000	0.375	126.78	STD	...	800	813	9.53	188.83
32	32.000	0.406	137.12	...	...	800	813	10.31	204.09
32	32.000	0.438	147.78	...	...	800	813	11.13	220.10
32	32.000	0.469	158.08	...	...	800	813	11.91	235.29
32	32.000	0.500	168.37	XS	20	800	813	12.70	250.65
32	32.000	0.562	188.87	...	...	800	813	14.27	281.09
32	32.000	0.625	209.62	...	30	800	813	15.88	312.17
32	32.000	0.688	230.29	...	40	800	813	17.48	342.94
32	32.000	0.750	250.55	...	...	800	813	19.05	373.00
32	32.000	0.812	270.72	...	...	800	813	20.62	402.94
32	32.000	0.875	291.14	...	...	800	813	22.23	433.52
32	32.000	0.938	311.47	...	...	800	813	23.83	463.78
32	32.000	1.000	331.39	...	...	800	813	25.40	493.35
32	32.000	1.062	351.23	...	...	800	813	26.97	522.80
32	32.000	1.125	371.31	...	...	800	813	28.58	552.88
32	32.000	1.188	391.30	...	...	800	813	30.18	582.64
32	32.000	1.250	410.90	...	...	800	813	31.75	611.72
34	34.000	0.250	90.20	...	...	...	864	6.35	134.31
34	34.000	0.281	101.29	...	...	...	864	7.14	150.88
34	34.000	0.312	112.36	...	10	...	864	7.92	167.21
34	34.000	0.344	123.77	...	...	...	864	8.74	184.34
34	34.000	0.375	134.79	STD	...	...	864	9.53	200.82
34	34.000	0.406	145.80	...	...	...	864	10.31	217.06
34	34.000	0.438	157.14	...	...	...	864	11.13	234.10
34	34.000	0.469	168.11	...	...	...	864	11.91	250.27
34	34.000	0.500	179.06	XS	20	...	864	12.70	266.63
34	34.000	0.562	200.89	...	...	...	864	14.27	299.04
34	34.000	0.625	222.99	...	30	...	864	15.88	332.14
34	34.000	0.688	245.00	...	40	...	864	17.48	364.92

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

	Customary Units			Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]			SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft		Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
34	34.000	0.750	266.58	...	...	...	864	19.05	396.96
34	34.000	0.812	288.08	...	...	...	864	20.62	428.88
34	34.000	0.875	309.84	...	...	...	864	22.23	461.48
34	34.000	0.938	331.52	...	...	...	864	23.83	493.75
34	34.000	1.000	352.77	...	...	...	864	25.40	525.30
34	34.000	1.062	373.94	...	...	...	864	26.97	556.73
34	34.000	1.125	395.36	...	...	...	864	28.58	588.83
34	34.000	1.188	416.70	...	...	...	864	30.18	620.60
34	34.000	1.250	437.62	...	...	...	864	31.75	651.65
36	36.000	0.250	95.54	...	...	900	914	6.35	142.14
36	36.000	0.281	107.30	...	...	900	914	7.14	159.68
36	36.000	0.312	119.03	...	10	900	914	7.92	176.97
36	36.000	0.344	131.12	...	...	900	914	8.74	195.12
36	36.000	0.375	142.81	STD	...	900	914	9.53	212.57
36	36.000	0.406	154.48	...	...	900	914	10.31	229.77
36	36.000	0.438	166.51	...	...	900	914	11.13	247.82
36	36.000	0.469	178.14	...	...	900	914	11.91	264.96
36	36.000	0.500	189.75	XS	20	900	914	12.70	282.29
36	36.000	0.562	212.90	...	...	900	914	14.27	316.63
36	36.000	0.625	236.35	...	30	900	914	15.88	351.73
36	36.000	0.688	259.71	...	...	900	914	17.48	386.47
36	36.000	0.750	282.62	...	40	900	914	19.05	420.45
36	36.000	0.812	305.44	...	...	900	914	20.62	454.30
36	36.000	0.875	328.55	...	...	900	914	22.23	488.89
36	36.000	0.938	351.57	...	...	900	914	23.83	523.14
36	36.000	1.000	374.15	...	...	900	914	25.40	556.62
36	36.000	1.062	396.64	...	...	900	914	26.97	589.98
36	36.000	1.125	419.42	...	...	900	914	28.58	624.07
36	36.000	1.188	442.10	...	...	900	914	30.18	657.81
36	36.000	1.250	464.35	...	...	900	914	31.75	690.80
38	38.000	0.312	125.70	...	...	...	965	7.92	186.94
38	38.000	0.344	138.47	...	...	...	965	8.74	206.11
38	38.000	0.375	150.83	STD	...	...	965	9.53	224.56
38	38.000	0.406	163.16	...	...	...	965	10.31	242.74
38	38.000	0.438	175.87	...	...	...	965	11.13	261.82
38	38.000	0.469	188.17	...	...	...	965	11.91	279.94
38	38.000	0.500	200.44	XS	...	...	965	12.70	298.26
38	38.000	0.562	224.92	...	...	...	965	14.27	334.58
38	38.000	0.625	249.71	...	...	...	965	15.88	371.70
38	38.000	0.688	274.42	...	...	...	965	17.48	408.46
38	38.000	0.750	298.65	...	...	...	965	19.05	444.41
38	38.000	0.812	322.80	...	...	...	965	20.62	480.24

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

	Customary Units			Identification			SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	[Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
38	38.000	0.875	347.26	...	...	...	965	22.23	516.85
38	38.000	0.938	371.63	...	...	...	965	23.83	553.11
38	38.000	1.000	395.53	...	...	...	965	25.40	588.57
38	38.000	1.062	419.35	...	...	...	965	26.97	623.90
38	38.000	1.125	443.47	...	...	...	965	28.58	660.01
38	38.000	1.188	467.50	...	...	...	965	30.18	695.77
38	38.000	1.250	491.07	...	...	...	965	31.75	730.74
40	40.000	0.312	132.37	...	...	1 000	1 016	7.92	196.90
40	40.000	0.344	145.83	...	...	1 000	1 016	8.74	217.11
40	40.000	0.375	158.85	STD	...	1 000	1 016	9.53	236.54
40	40.000	0.406	171.84	...	...	1 000	1 016	10.31	255.71
40	40.000	0.438	185.24	...	...	1 000	1 016	11.13	275.82
40	40.000	0.469	198.19	...	...	1 000	1 016	11.91	294.92
40	40.000	0.500	211.13	XS	...	1 000	1 016	12.70	314.23
40	40.000	0.562	236.93	...	...	1 000	1 016	14.27	352.53
40	40.000	0.625	263.07	...	...	1 000	1 016	15.88	391.67
40	40.000	0.688	289.13	...	...	1 000	1 016	17.48	430.45
40	40.000	0.750	314.69	...	...	1 000	1 016	19.05	468.37
40	40.000	0.812	340.16	...	...	1 000	1 016	20.62	506.17
40	40.000	0.875	365.97	...	...	1 000	1 016	22.23	544.81
40	40.000	0.938	391.68	...	...	1 000	1 016	23.83	583.08
40	40.000	1.000	416.91	...	...	1 000	1 016	25.40	620.51
40	40.000	1.062	442.05	...	...	1 000	1 016	26.97	657.82
40	40.000	1.125	467.52	...	...	1 000	1 016	28.58	695.96
40	40.000	1.188	492.90	...	...	1 000	1 016	30.18	733.73
40	40.000	1.250	517.80	...	...	1 000	1 016	31.75	770.67
42	42.000	0.344	153.18	...	...	...	1 067	8.74	228.10
42	42.000	0.375	166.86	STD	...	...	1 067	9.53	248.53
42	42.000	0.406	180.52	...	...	...	1 067	10.31	268.67
42	42.000	0.438	194.60	...	...	...	1 067	11.13	289.82
42	42.000	0.469	208.22	...	...	...	1 067	11.91	309.90
42	42.000	0.500	221.82	XS	...	...	1 067	12.70	330.21
42	42.000	0.562	248.95	...	...	...	1 067	14.27	370.48
42	42.000	0.625	276.44	...	...	...	1 067	15.88	411.64
42	42.000	0.688	303.84	...	...	...	1 067	17.48	452.43
42	42.000	0.750	330.72	...	...	...	1 067	19.05	492.33
42	42.000	0.812	357.52	...	...	...	1 067	20.62	532.11
42	42.000	0.875	384.67	...	...	...	1 067	22.23	572.77
42	42.000	0.938	411.74	...	...	...	1 067	23.83	613.05
42	42.000	1.000	438.29	...	...	...	1 067	25.40	652.46
42	42.000	1.062	464.76	...	...	...	1 067	26.97	691.75
42	42.000	1.125	491.57	...	...	...	1 067	28.58	731.91

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

	Customary Units						SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
42	42.000	1.188	518.30	...	...	...	1 067	30.18	771.69
42	42.000	1.250	544.52	...	...	...	1067	31.75	810.60
44	44.000	0.344	160.54	...	...	1 100	1 118	8.74	239.09
44	44.000	0.375	174.88	STD	...	1 100	1 118	9.53	260.52
44	44.000	0.406	189.20	...	...	1 100	1 118	10.31	281.64
44	44.000	0.438	203.97	...	...	1 100	1 118	11.13	303.82
44	44.000	0.469	218.25	...	...	1 100	1 118	11.91	324.88
44	44.000	0.500	232.51	XS	...	1 100	1 118	12.70	346.18
44	44.000	0.562	260.97	...	...	1 100	1 118	14.27	388.42
44	44.000	0.625	289.80	...	...	1 100	1 118	15.88	431.62
44	44.000	0.688	318.55	...	...	1 100	1 118	17.48	474.42
44	44.000	0.750	346.76	...	...	1 100	1 118	19.05	516.29
44	44.000	0.812	374.88	...	...	1 100	1 118	20.62	558.04
44	44.000	0.875	403.38	...	...	1 100	1 118	22.23	600.73
44	44.000	0.938	431.79	...	...	1 100	1 118	23.83	643.03
44	44.000	1.000	459.67	...	...	1 100	1 118	25.40	684.41
44	44.000	1.062	487.47	...	...	1 100	1 118	26.97	725.67
44	44.000	1.125	515.63	...	...	1 100	1 118	28.58	767.85
44	44.000	1.188	543.70	...	...	1 100	1 118	30.18	809.65
44	44.000	1.250	571.25	...	...	1 100	1 118	31.75	850.54
46	46.000	0.344	167.89	...	...	...	1 168	8.74	249.87
46	46.000	0.375	182.90	STD	...	...	1 168	9.53	272.27
46	46.000	0.406	197.88	...	...	...	1 168	10.31	294.35
46	46.000	0.438	213.33	...	...	...	1 168	11.13	317.54
46	46.000	0.469	228.27	...	...	...	1 168	11.91	339.56
46	46.000	0.500	243.20	XS	...	...	1 168	12.70	361.84
46	46.000	0.562	272.98	...	...	...	1 168	14.27	406.02
46	46.000	0.625	303.16	...	...	...	1 168	15.88	451.20
46	46.000	0.688	333.26	...	...	...	1 168	17.48	495.97
46	46.000	0.750	362.79	...	...	...	1 168	19.05	539.78
46	46.000	0.812	392.24	...	...	...	1 168	20.62	583.47
46	46.000	0.875	422.09	...	...	...	1 168	22.23	628.14
46	46.000	0.938	451.85	...	...	...	1 168	23.83	672.41
46	46.000	1.000	481.05	...	...	...	1 168	25.40	715.73
46	46.000	1.062	510.17	...	...	...	1 168	26.97	758.92
46	46.000	1.125	539.68	...	...	...	1 168	28.58	803.09
46	46.000	1.188	569.10	...	...	...	1 168	30.18	846.86
46	46.000	1.250	597.97	...	...	...	1 168	31.75	889.69
48	48.000	0.344	175.25	...	...	1 200	1 219	8.74	260.86
48	48.000	0.375	190.92	STD	...	1 200	1 219	9.53	284.25
48	48.000	0.406	206.56	...	...	1 200	1 219	10.31	307.32
48	48.000	0.438	222.70	...	...	1 200	1 219	11.13	331.54

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

Customary Units						SI Units			
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
48	48.000	0.469	238.30	...	...	1 200	1 219	11.91	354.54
48	48.000	0.500	253.89	XS	...	1 200	1 219	12.70	377.81
48	48.000	0.562	285.00	...	...	1 200	1 219	14.27	423.97
48	48.000	0.625	316.52	...	...	1 200	1 219	15.88	471.17
48	48.000	0.688	347.97	...	...	1 200	1 219	17.48	517.95
48	48.000	0.750	378.83	...	...	1 200	1 219	19.05	563.74
48	48.000	0.812	409.61	...	...	1 200	1 219	20.62	609.40
48	48.000	0.875	440.80	...	...	1 200	1 219	22.23	656.10
48	48.000	0.938	471.90	...	...	1 200	1 219	23.83	702.38
48	48.000	1.000	502.43	...	...	1 200	1 219	25.40	747.67
48	48.000	1.062	532.88	...	...	1 200	1 219	26.97	792.84
48	48.000	1.125	563.73	...	...	1 200	1 219	28.58	839.04
48	48.000	1.188	594.50	...	...	1 200	1 219	30.18	884.82
48	48.000	1.250	624.70	...	...	1 200	1 219	31.75	929.62
52	52.000	0.375	206.95	...	...	...	1 321	9.53	308.23
52	52.000	0.406	223.93	...	...	...	1 321	10.31	333.26
52	52.000	0.438	241.42	...	...	...	1 321	11.13	359.54
52	52.000	0.469	258.36	...	...	...	1 321	11.91	384.50
52	52.000	0.500	275.27	...	...	...	1 321	12.70	409.76
52	52.000	0.562	309.03	...	...	...	1 321	14.27	459.86
52	52.000	0.625	343.25	...	...	...	1 321	15.88	511.12
52	52.000	0.688	377.39	...	...	...	1 321	17.48	561.93
52	52.000	0.750	410.90	...	...	...	1 321	19.05	611.66
52	52.000	0.812	444.33	...	...	...	1 321	20.62	661.27
52	52.000	0.875	478.21	...	...	...	1 321	22.23	712.02
52	52.000	0.938	512.01	...	...	...	1 321	23.83	762.33
52	52.000	1.000	545.19	...	...	...	1 321	25.40	811.57
52	52.000	1.062	578.29	...	...	...	1 321	26.97	860.69
52	52.000	1.125	611.84	...	...	...	1 321	28.58	910.93
52	52.000	1.188	645.30	...	...	...	1 321	30.18	960.74
52	52.000	1.250	678.15	...	...	...	1 321	31.75	1 009.49
56	56.000	0.375	222.99	...	...	1 400	1 422	9.53	331.96
56	56.000	0.406	241.29	...	...	1 400	1 422	10.31	358.94
56	56.000	0.438	260.15	...	...	1 400	1 422	11.13	387.26
56	56.000	0.469	278.41	...	...	1 400	1 422	11.91	414.17
56	56.000	0.500	296.65	...	...	1 400	1 422	12.70	441.39
56	56.000	0.562	333.06	...	...	1 400	1 422	14.27	495.41
56	56.000	0.625	369.97	...	...	1 400	1 422	15.88	550.67
56	56.000	0.688	406.80	...	...	1 400	1 422	17.48	605.46
56	56.000	0.750	442.97	...	...	1 400	1 422	19.05	659.11
56	56.000	0.812	479.05	...	...	1 400	1 422	20.62	712.63
56	56.000	0.875	515.63	...	...	1 400	1 422	22.23	767.39
56	56.000	0.938	552.12	...	...	1 400	1 422	23.83	821.68

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

Customary Units							SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
56	56.000	1.000	587.95	...	...	1 400	1 422	25.40	874.83
56	56.000	1.062	623.70	...	...	1 400	1 422	26.97	927.86
56	56.000	1.125	659.94	...	...	1 400	1 422	28.58	982.12
56	56.000	1.188	696.10	...	...	1 400	1 422	30.18	1 035.91
56	56.000	1.250	731.60	...	...	1 400	1 422	31.75	1 088.57
60	60.000	0.375	239.02	...	...	1 500	1 524	9.53	355.94
60	60.000	0.406	258.65	...	...	1 500	1 524	10.31	384.87
60	60.000	0.438	278.88	...	...	1 500	1 524	11.13	415.26
60	60.000	0.469	298.47	...	...	1 500	1 524	11.91	444.13
60	60.000	0.500	318.03	...	...	1 500	1 524	12.70	473.34
60	60.000	0.562	357.09	...	...	1 500	1 524	14.27	531.30
60	60.000	0.625	396.70	...	...	1 500	1 524	15.88	590.62
60	60.000	0.688	436.22	...	...	1 500	1 524	17.48	649.44
60	60.000	0.750	475.04	...	...	1 500	1 524	19.05	707.03
60	60.000	0.812	513.77	...	...	1 500	1 524	20.62	764.50
60	60.000	0.875	553.04	...	...	1 500	1 524	22.23	823.31
60	60.000	0.938	592.23	...	...	1 500	1 524	23.83	881.63
60	60.000	1.000	630.71	...	...	1 500	1 524	25.40	938.73
60	60.000	1.062	669.11	...	...	1 500	1 524	26.97	995.71
60	60.000	1.125	708.05	...	...	1 500	1 524	28.58	1 054.01
60	60.000	1.188	746.90	...	...	1 500	1 524	30.18	1 111.83
60	60.000	1.250	785.05	...	...	1 500	1 524	31.75	1 168.44
64	64.000	0.375	255.06	...	...	1 600	1 626	9.53	379.91
64	64.000	0.406	276.01	...	...	1 600	1 626	10.31	410.81
64	64.000	0.438	297.61	...	...	1 600	1 626	11.13	443.25
64	64.000	0.469	318.52	...	...	1 600	1 626	11.91	474.09
64	64.000	0.500	339.41	...	...	1 600	1 626	12.70	505.29
64	64.000	0.562	381.12	...	...	1 600	1 626	14.27	567.20
64	64.000	0.625	423.42	...	...	1 600	1 626	15.88	630.56
64	64.000	0.688	465.64	...	...	1 600	1 626	17.48	693.41
64	64.000	0.750	507.11	...	...	1 600	1 626	19.05	754.95
64	64.000	0.812	548.49	...	...	1 600	1 626	20.62	816.37
64	64.000	0.875	590.46	...	...	1 600	1 626	22.23	879.23
64	64.000	0.938	632.34	...	...	1 600	1 626	23.83	941.57
64	64.000	1.000	673.47	...	...	1 600	1 626	25.40	1 002.62
64	64.000	1.062	714.52	...	...	1 600	1 626	26.97	1 063.55
64	64.000	1.125	756.15	...	...	1 600	1 626	28.58	1 125.90
64	64.000	1.188	797.69	...	...	1 600	1 626	30.18	1 187.74
64	64.000	1.250	838.50	...	...	1 600	1 626	31.75	1 248.30
68	68.000	0.469	338.57	...	...	...	1 727	11.91	503.75
68	68.000	0.500	360.79	...	...	...	1 727	12.70	536.92
68	68.000	0.562	405.15	...	...	...	1 727	14.27	602.74
68	68.000	0.625	450.15	...	...	...	1 727	15.88	670.12

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

Customary Units						SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
68	68.000	0.688	495.06	...	...	...	1 727	17.48	736.95
68	68.000	0.750	539.18	...	...	...	1 727	19.05	802.40
68	68.000	0.812	583.21	...	...	...	1 727	20.62	867.73
68	68.000	0.875	627.87	...	...	...	1 727	22.23	934.60
68	68.000	0.938	672.45	...	...	...	1 727	23.83	1 000.92
68	68.000	1.000	716.23	...	...	...	1 727	25.40	1 065.89
68	68.000	1.062	759.93	...	...	...	1 727	26.97	1 130.73
68	68.000	1.125	804.26	...	...	...	1 727	28.58	1 197.09
68	68.000	1.188	848.49	...	...	...	1 727	30.18	1 262.92
68	68.000	1.250	891.95	...	...	...	1 727	31.75	1 327.39
72	72.000	0.500	382.17	...	...	1 800	1 829	12.70	568.87
72	72.000	0.562	429.18	...	...	1 800	1 829	14.27	638.64
72	72.000	0.625	476.87	...	...	1 800	1 829	15.88	710.06
72	72.000	0.688	524.48	...	...	1 800	1 829	17.48	780.92
72	72.000	0.750	571.25	...	...	1 800	1 829	19.05	850.32
72	72.000	0.812	617.93	...	...	1 800	1 829	20.62	919.60
72	72.000	0.875	665.29	...	...	1 800	1 829	22.23	990.52
72	72.000	0.938	712.55	...	...	1 800	1 829	23.83	1 060.87
72	72.000	1.000	758.99	...	...	1 800	1 829	25.40	1 129.78
72	72.000	1.062	805.34	...	...	1 800	1 829	26.97	1 198.57
72	72.000	1.125	852.36	...	...	1 800	1 829	28.58	1 268.98
72	72.000	1.188	899.29	...	...	1 800	1 829	30.18	1 338.83
72	72.000	1.250	945.40	...	...	1 800	1 829	31.75	1 407.25
76	76.000	0.500	403.55	...	...	...	1 930	12.70	600.50
76	76.000	0.562	453.21	...	...	...	1 930	14.27	674.18
76	76.000	0.625	503.60	...	...	...	1 930	15.88	749.62
76	76.000	0.688	553.90	...	...	...	1 930	17.48	824.45
76	76.000	0.750	603.32	...	...	...	1 930	19.05	897.77
76	76.000	0.812	652.65	...	...	...	1 930	20.62	970.96
76	76.000	0.875	702.70	...	...	...	1 930	22.23	1 045.89
76	76.000	0.938	752.66	...	...	...	1 930	23.83	1 120.22
76	76.000	1.000	801.75	...	...	...	1 930	25.40	1 193.05
76	76.000	1.062	850.75	...	...	...	1 930	26.97	1 265.74
76	76.000	1.125	900.47	...	...	...	1 930	28.58	1 340.17
76	76.000	1.188	950.09	...	...	...	1 930	30.18	1 414.01
76	76.000	1.250	998.85	...	...	...	1 930	31.75	1 486.33
80	80.000	0.562	477.25	...	...	2 000	2 032	14.27	710.08
80	80.000	0.625	530.32	...	...	2 000	2 032	15.88	789.56
80	80.000	0.688	583.32	...	...	2 000	2 032	17.48	868.43
80	80.000	0.750	635.39	...	...	2 000	2 032	19.05	945.69
80	80.000	0.812	687.37	...	...	2 000	2 032	20.62	1 022.83
80	80.000	0.875	740.12	...	...	2 000	2 032	22.23	1 101.81
80	80.000	0.938	792.77	...	...	2 000	2 032	23.83	1 180.17
80	80.000	1.000	844.51	...	...	2 000	2 032	25.40	1 256.94

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TABLE 1 DIMENSIONS AND WEIGHTS OF WELDED AND SEAMLESS WROUGHT STEEL PIPE (CONT'D)

	Customary Units						SI Units		
NPS [Note (1)]	Outside Diameter, in.	Wall Thickness, in.	Plain End Weight, lb/ft	Identification [Standard (STD), Extra-Strong (XS), or Double Extra Strong (XXS)]	Schedule No.	DN [Note (2)]	Outside Diameter, mm	Wall Thickness, mm	Plain End Mass, kg/m
80	80.000	1.062	896.17	...	...	2 000	2 032	26.97	1 333.59
80	80.000	1.125	948.57	...	...	2 000	2 032	28.58	1 412.06
80	80.000	1.188	1,000.89	...	...	2 000	2 032	30.18	1 489.92
80	80.000	1.250	1,052.30	...	...	2 000	2 032	31.75	1 566.20

NOTES:
(1) NPS (Nominal Pipe Size) is a dimensionless designator that has been substituted in the customary units section for the previous term *Inch Nominal Size.*
(2) DN (Nominal Diameter) is a dimensionless designator used in the SI (metric) system to describe pipe size.

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AMERICAN NATIONAL STANDARDS FOR PRODUCT SIZES

Preferred Thicknesses for Uncoated Thin Flat Metals (Under 0.250 In.).. B32.1-1952(R1994)
Preferred Diameters for Round Wire — 0.500 Inches and Under ..... B32.2-1969(R1994)
Preferred Metric Sizes for Flat Metal Products ..... B32.3M-1984(R1994)
Preferred Metric Sizes for Round, Square, Rectangle and Hexagon
Metal Products ..... B32.4M-1980(R1994)
Preferred Metric Sizes for Tubular Metal Products Other Than Pipe ..... B32.5-1977(R1994)
Preferred Metric Equivalents of Inch Sizes for Tubular Metal Products
Other Than Pipe ..... B32.6M-1984(R1994)
Welded and Seamless Wrought Steel Pipe B36.10M-2000
Stainless Steel Pipe ..... B36.19M-1985(R1994)

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STD.ASME B36.10M-ENGL 2000 ■ 0759670 0621961 703 ■

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Specification for Line Pipe

API SPECIFICATION 5L
FORTY-SECOND EDITION, JANUARY 2000

EFFECTIVE DATE: JULY 1, 2000

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Specification for Line Pipe

Upstream Segment

API SPECIFICATION 5L
FORTY-SECOND EDITION, JANUARY 2000

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FOREWORD

Specification 5L covers seamless and welded steel line pipe. It includes plain-end, threaded-end, and belled-end pipe, as well as through-the-flowline (TFL) pipe and pipe with ends prepared for use with special couplings.

Although the plain-end line pipe meeting this specification is primarily intended for field makeup by circumferential welding, the manufacturer will not assume responsibility for field welding.

The purpose of this specification is to provide standards for pipe suitable for use in conveying gas, water, and oil in both the oil and natural gas industries.

This specification is under the jurisdiction of the Committee on Standardization of Tubular Goods and includes changes to the previous edition approved by letter ballot through June 1999. Specifications 5LS and 5LX have been incorporated into this edition of Specification 5L. The last editions of Specifications 5LS and 5LX, published in March 1982, have been withdrawn.

Due to the large numbers of changes from the Forty-first Edition, change bars are not included in this edition.

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Specification for Line Pipe

1 Scope

1.1 PURPOSE AND COVERAGE

The purpose of this specification is to provide standards for pipe suitable for use in conveying gas, water, and oil in both the oil and natural gas industries.

This specification covers seamless and welded steel line pipe. It includes plain-end, threaded-end, and belled-end pipe, as well as through-the-flowline (TFL) pipe and pipe with ends prepared for use with special couplings.

Although the plain-end line pipe meeting this specification is primarily intended for field makeup by circumferential welding, the manufacturer will not assume responsibility for field welding.

1.2 PRODUCT SPECIFICATION LEVEL (PSL)

This specification establishes requirements for two product specification levels (PSL 1 and PSL 2). These two PSL designations define different levels of standard technical requirements. PSL 2 has mandatory requirements for carbon equivalent, notch toughness, maximum yield strength, and maximum tensile strength. These and other differences are summarized in Appendix J.

Requirements that apply to only PSL 1 or only PSL 2 are so designated. Requirements that are not designated to a specific PSL apply to both PSL 1 and PSL 2.

The purchaser may add requirements to purchase orders for either PSL 1 or PSL 2, as provided by the supplementary requirements (Appendix F) and other options (4.2 and 4.3).

1.3 GRADES

The grades (see the note) covered by this specification are the standard Grades A25, A, B, X42, X46, X52, X56, X60, X65, X70 and X80; and any intermediate grades (grades that are higher than X42, intermediate to two sequential standard grades, and agreed upon by the purchaser and manufacturer).

PSL 1 pipe can be supplied in Grades A25 through X70.
PSL 2 pipe can be supplied in Grades B through X80.

Class II (Cl II) steel is rephosphorized and probably has better threading properties than Class I (Cl I). Because Class II (Cl II) has higher phosphorus content than Class I (Cl I), it may be somewhat more difficult to bend.

Pipe manufactured as Grade X60 or higher shall not be substituted for pipe ordered as Grade X52 or lower without purchaser approval.

Note: The grade designations are dimensionless. Grades A and B do not include reference to the specified minimum yield strength; however, other grade designations are composed of the letter A or X, followed by the first two digits of the specified minimum yield strength in U.S. Customary units.

1.4 DIMENSIONS

The sizes used herein are dimensionless designations, which are derived from the specified outside diameter as measured in U.S. Customary units, and provide a convenient method of referencing pipe size within the text and tables (but not for order descriptions). Pipe sizes $2^3/_8$ and larger are expressed as integers and fractions; pipe sizes smaller than $2^3/_8$ are expressed to three decimal places. These sizes replace the "size designation" and the "nominal size designation" used in the previous edition of this specification. Users of this specification who are accustomed to specifying nominal sizes rather than OD sizes are advised to familiarize themselves with these new size designations used in this specification, especially the usage in Tables 4, 5, and 6A.

PSL 1 pipe can be supplied in sizes ranging from 0.405 through 80.
PSL 2 pipe can be supplied in sizes ranging from $4^1/_2$ through 80.

Dimensional requirements on threads and thread gages, stipulations on gaging practice, gage specifications and certification, as well as instruments and methods for inspection of threads are given in API Standard 5B and are applicable to threaded products covered by this specification.

1.5 UNITS

U.S. Customary units are used in this specification; SI (metric) units are shown in parentheses in the text and in many tables. The values stated in either U.S. Customary units or SI units are to be regarded separately as standard. The values stated are not necessarily exact equivalents; therefore, each system is to be used independently of the other, without combining values for any specific order item.

See Appendix M for specific information about rounding procedures and conversion factors.

2 References

2.1 This specification includes by reference, either in total or in part, the latest editions of the following API and industry standards:

API

RP 5A3	*Thread Compounds for Casing, Tubing, and Line Pipe*
Spec 5B	*Specification for Threading, Gauging, and Thread Inspection of Casing, Tubing, and Line Pipe Threads*

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RP 5L1	*Recommended Practice for Railroad Transportation of Line Pipe*
RP 5L3	*Recommended Practice for Conducting Drop-Weight Tear Tests on Line Pipe*
RP 5LW	*Recommended Practice for Transportation of Line Pipe on Barges and Marine Vessels*
Std 1104	*Welding of Pipelines and Related Facilities*

AAR[1]

Section 1	*General Rules Governing the Loading of Commodities on Open Top Cars*
Section 2	*Rules Governing the Loading of Steel Products Including Pipe on Open Top Cars*

ASME[2]

	ASME Boiler and Pressure Vessel Code, Section IX, Welding & Brazing Qualifications
	ASME Code for Pressure Piping B31.8, Gas Transmission and Distribution Piping Systems

ASTM[3]

A 370	*Methods and Definitions for Mechanical Testing of Steel Products*
A 751	*Test Methods, Practices, and Definitions for Chemical Analysis of Steel Products*
E 4	*Practices for Force Verification of Testing Machines*
E 8	*Test Methods for Tension Testing of Metallic Materials*
E 29	*Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*
E 83	*Practice for Verification and Classification of Extensometers*

2.2 Requirements of standards included by reference in this specification are essential to the safety and interchangeability of the equipment produced.

2.3 Standards referenced in this specification may be replaced by other international or national standards that can be shown to meet the requirements of the referenced standard. Manufacturers who use other standards in lieu of standards referenced herein are responsible for documenting the equivalency of the standards.

[1]American Association of Railroads, Operations and Maintenance Department, Mechanical Division, 50 F Street Northwest, Washington DC 20001.

[2]ASME International, 3 Park Avenue, New York, New York 10016-5990.

[3]American Socicty for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959.

3 Definitions

For the purposes of this specification, the following definitions apply:

3.1 carload: The quantity of pipe loaded on a rail car for shipment from the pipe-making facilities.

3.2 defect: An imperfection of sufficient magnitude to warrant rejection of the product based on the stipulations of this specification.

3.3 heat: The metal produced by a single cycle of a batch melting process.

3.4 heat analysis: The chemical analysis representative of a heat as reported by the metal producer.

3.5 imperfection: A discontinuity or irregularity in the product detected by methods outlined in this specification.

3.6 inspection lot: A definite quantity of product manufactured under conditions that are considered uniform for the attribute to be inspected.

3.7 manufacturer: A firm, company, or corporation responsible for marking the product to warrant that it conforms to this specification. The manufacturer may be, as applicable, a pipe mill or processor; a maker of couplings; or a threader. The manufacturer is responsible for compliance with all of the applicable provisions of this specification.

3.8 may: Used as a verb to indicate that a provision is optional.

3.9 pipe mill: A firm, company, or corporation that operates pipe-making facilities.

3.10 processor: A firm, company, or corporation that operates facilities capable of heat treating pipe made by a pipe mill.

3.11 product analysis: A chemical analysis of the pipe, plate, or skelp.

3.12 PSL: Abbreviation for product specification level.

3.13 shall: Used to indicate that a provision is mandatory.

3.14 should: Used to indicate that a provision is not mandatory but is recommended as good practice.

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3.15 special processes: Final operations performed during pipe manufacturing that affect attribute compliance required in this specification (except chemistry and dimensions). The applicable special processes are as follows:

Manufacturing Condition	Special Processes
a. Seamless:	
1. As-rolled (nonexpanded)	Final reheating and hot sizing or stretch reduction. Cold finishing, if applied, and repair welding. Nondestructive inspection.
2. As-rolled (expanded)	Expansion, nondestructive inspection, and repair welding.
3. Heat treated	Heat treatment, nondestructive inspection, and repair welding.
b. Welded without filler metal:	
1. As-rolled (nonexpanded)	Seam welding, nondestructive inspection and sizing. If applicable, seam heat treatment and repair welding.
2. As-rolled (expanded)	Seam welding, expansion, and nondestructive inspection. If applicable, seam heat treatment, and repair welding.
3. Heat treated	Seam welding, full body heat treatment, and nondestructive inspection. If applicable, repair welding.
c. Welded with filler metal:	
1. As-rolled (nonexpanded)	Pipe forming, seam welding, nondestructive inspection, and repair welding.
2. As-rolled (expanded)	Seam welding, expansion, nondestructive inspection, and repair welding.
3. Heat treated	Seam welding, nondestructive inspection, repair welding, and full body heat treatment.
4. As-rolled	Seam welding, sizing, and nondestructive inspection.

4 Information to be Supplied by the Purchaser (See Note 1)

4.1 In placing orders for line pipe to be manufactured in accordance with API Spec 5L, the purchaser should specify the following on the purchase order:

Information	Reference
Specification	API Spec 5L
PSL (Product Specification Level)	Paragraph 1.2 and Table 1
Quantity	
Grade (and class, if applicable)	Tables 2 and 3
Type of pipe	Paragraph 5.1.3
Size or outside diameter	Paragraph 7.1
Wall thickness	Paragraph 7.1
Nominal length	Paragraph 7.5 and Table 11
End finish	Paragraph 7.9
Delivery date and shipping instructions	

4.2 The purchaser should also state on the purchase order his requirements concerning the following stipulations, which are optional with the purchaser:

Information	Reference
Certificate of compliance, general	Paragraph 12.1
Certificate of compliance, with test results	Paragraph 12.1 and SR 15
Cold expanded or nonexpanded pipe	Paragraph 5.2
High carbon equivalent pipe	Paragraph 6.1.3.2
Optional fracture toughness: test type, temperature, and Charpy energy value	Paragraph 6.2.6; SR5; SR6; SR19
Acceptance and maximum percent of jointers	Paragraph 7.7
Jointers for threaded pipe	Paragraph 7.7
Thread compound	Paragraph 7.9.2
Reduced negative tolerance for wall thickness	Tables 9 and 10
Power-tight makeup	Paragraph 7.9.2
Specific edition of Spec 5L for pipe and couplings	Paragraph 7.9.2
Alternative bevel or end preparation, plain-end pipe	Paragraph 7.9.3

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Information	Reference
Alternative minimum hydrostatic test pressure	Paragraph 9.4.3
Hydrostatic test pressure, maximum	Paragraph 9.4.3
Special inspection of electric welded seams	Paragraph 9.7.2.2 and SR17
Alternative inspection of laser welded seams	Paragraph 9.7.2.3 and SR17
Nondestructive testing of seamless pipe	Paragraph 9.7.2.6 and SR4
Type of penetrameter for radiological inspection	Paragraph 9.7.3.4
Bare pipe; temporary and special coatings	Paragraph 11.1
Special nondestructive inspection for laminations	Paragraph 7.8.10
Demonstration of capability of magnetic particle inspection method	Paragraph 9.7.5.2
Through-the-Flowline (TFL) Pipe	SR7
Length tolerance and jointer allowance for TFL pipe	Paragraph SR7.2
Marking Requirements	
Alternative length units	Paragraphs 10.5 and I.5
Additional markings for compatible standards	Paragraphs 10.1.3 and I.1.3
Marking location and sequence for welded pipe, size 16 and larger	Paragraphs 10.2c and I.2.3
Die stamping of pipe or plate	Paragraphs 10.7 and I.7
Method of welding jointers	Paragraph A.1
Purchaser inspection	Paragraph 9.7.1 and Appendix H
Inspection location	Paragraph H.2
Monogram marking (see Note 2)	Paragraph I.1

4.3 The following stipulations are subject to agreement between the purchaser and the manufacturer:

Information	Reference
Alternative heat treatment for electric weld seams	Paragraph 5.1.3.3
Alternative heat treatment for laser weld seams	Paragraph 5.1.3.4
Quenching and tempering of Grade B pipe	Paragraph 5.4
Skelp end welds at pipe ends	Paragraph 5.5
Chemical composition	Paragraph 6.1.1
Intermediate grade	Paragraphs 6.1.1 and 6.2.1
Carbon equivalent limit (PSL 2)	
Grade X80	Paragraph 6.1.3.2
Seamless with wall thickness > 0.800 in (20.3 mm)	Paragraph 6.1.3.2
High carbon equivalent pipe	Paragraph 6.1.3.2
Charpy specimen size for optional fracture toughness	Paragraph SR5.3
Type of notch for drop weight tear test specimens	SR6.3
Internal diameter tolerance	Paragraph 7.2
Intermediate diameter	Paragraph 7.1
Intermediate wall thickness	Paragraph 7.1
Skelp end welds at jointer welds	Paragraph 7.7
Hydrostatic test for threaded and coupled pipe	Paragraph 9.4.1
Higher hydrostatic test pressure	Paragraph 9.4.3
End load compensation for hydrotest producing stress > 90% SMYS	Paragraph 9.4.3 and Appendix K
Supplementary hydrostatic test	Paragraph 9.4.4
Diameter tolerance for nonstandard hydrotest	Table 7
Alternative nondestructive test method for seams at ends of electric welded pipe	Paragraph 9.7.2.2
Alternative nondestructive test method for seams at ends of laser welded pipe	Paragraph 9.7.2.3
Alternative penetrameter for radiological inspection	Paragraph 9.7.3.4
Alternative reinspection method for gas-metal-arc welds	Paragraph 9.7.4.3
Alternative reference standard for nondestructive inspection of seamless	Paragraph SR4.3.2
Technique for nondestructive inspection of electric welds and laser welds	Paragraph SR17.2
Length tolerances applied to carloads	Table 11
Nonstandard length and length tolerances	Paragraph 7.5
Welded couplings	Paragraph 8.1

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Information	Reference
NDT for repair of pipe body by welding	Paragraph B.1.1
Repair of weld seams of electric welded pipe	Paragraphs 9.7.4.4 and B.1.2
Repair of weld seams of laser welded pipe	Paragraphs 9.7.4.4 and B.1.2
Repair of heat-treated pipe by welding	Paragraph B.1.3
Reprocessing by heat-treatment	Paragraphs 9.11 and SR5.4
Disposition of product rejected by purchaser	Paragraph H.4
Marking requirements	
Marking of couplings without die stamping	Paragraphs 10.1.2 and I.1.2
Marking on interior instead of exterior (welded pipe < size 16, and seamless pipe)	Paragraphs 10.2b and I.2.2
Color code marking for grade	Paragraphs 10.3.5 and I.3.5; SR3
Nonstandard units of length	Paragraphs 10.5 and I.5
Location for length markings	Paragraphs 10.5a and I.5a
Use of cold die stamping	Paragraphs 10.7 and I.7

Notes:

1. Nothing in this specification should be interpreted as indicating a preference by the committee for any material or process or as indicating equality between the various materials or processes. In the selection of materials and processes, the purchaser has to be guided by experience and by the service for which the pipe is intended.
2. Users of this specification should note that there is no longer a requirement for marking a product with the API monogram. The American Petroleum Institute continues to license use of the monogram on products covered by this specification, but it is administered by the staff of the Institute separately from the specification. The policy describing use of the monogram is contained in Appendix I. No other use of the monogram is permitted. Licensees mark products in accordance with Appendix I or Section 10, and nonlicensees mark products in accordance with Section 10.

5 Process of Manufacture and Material

5.1 PROCESS OF MANUFACTURE

Pipe furnished to this specification shall be either seamless or welded as defined in 5.1.1, 5.1.2, and 5.1.3 and shall be limited to the product specification levels, grades, types of pipe, and size limitations specified in Table 1.

5.1.1 Seamless Process

The seamless process is a process of hot working steel to form a tubular product without a welded seam. If necessary, the hot worked tubular product may be subsequently cold finished to produce the desired shape, dimensions, and properties.

5.1.2 Welding Processes

5.1.2.1 Without Filler Metal

5.1.2.1.1 Continuous Welding

Continuous welding is a process of forming a seam by heating the skelp in a furnace and mechanically pressing the formed edges together wherein successive coils of skelp have been joined together to provide a continuous flow of steel for the welding mill. (This process is a type of butt-welding.)

5.1.2.1.2 Electric Welding

Electric welding is a process of forming a seam by electric-resistance or electric-induction welding wherein the edges to be welded are mechanically pressed together and the heat for welding is generated by the resistance to flow of the electric current.

5.1.2.1.3 Laser Welding

Laser welding is a welding process that uses a laser beam and a keyholing technique to produce melting and coalescence of the edges to be welded. The edges may be preheated. Shielding is obtained entirely from an externally supplied gas or gas mixture.

5.1.2.2 With Filler Metal

5.1.2.2.1 Submerged-Arc Welding

Submerged-arc welding is a welding process that produces coalescence of metals by heating them with an arc or arcs between a bare metal consumable electrode or electrodes and the work. The arc and molten metal are shielded by a blanket of granular, fusible material on the work. Pressure is not used, and part or all of the filler metal is obtained from the electrodes.

5.1.2.2.2 Gas Metal-Arc Welding

Gas metal-arc welding is a welding process that produces coalescence of metals by heating them with an arc or arcs between a continuous consumable electrode and the work. Shielding is obtained entirely from an externally supplied gas or gas mixture. Pressure is not used, and the filler metal is obtained from the electrode.

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5.1.3 Types of Pipe

5.1.3.1 Seamless Pipe

Seamless pipe is produced by the seamless process defined in 5.1.1.

5.1.3.2 Continuous Welded Pipe

Continuous welded pipe is defined as pipe that has one longitudinal seam produced by the continuous welding process defined in 5.1.2.1.1. (This is a type of butt-welded pipe.)

5.1.3.3 Electric Welded Pipe

Electric welded pipe is defined as pipe that has one longitudinal seam produced by the electric welding process defined in 5.1.2.1.2.

5.1.3.3.1 PSL 1 Electric Welded Pipe

For grades higher than X42, the weld seam and the entire heat affected zone shall be heat treated so as to simulate a normalizing heat treatment (see note), except that by agreement between the purchaser and the manufacturer alternative heat treatments or combinations of heat treatment and chemical composition may be substituted. Where such substitutions are made, the manufacturer shall demonstrate the effectiveness of the method selected using a procedure that is mutually agreed upon. This procedure may include, but is not necessarily limited to, hardness testing, microstructural evaluation, or mechanical testing. For grades X42 and lower, the weld seam shall be similarly heat treated, or the pipe shall be processed in such a manner that no untempered martensite remains.

Note: During the manufacture of electric welded pipe, the product is in motion through the surrounding air. Normalizing is usually defined with "cooling in still air;" hence the phrase "to simulate a normalizing heat treatment" is used here.

5.1.3.3.2 PSL 2 Electric Welded Pipe

Electric welding shall be performed with a minimum welder frequency of 100 kHz.

For all grades, the weld seam and the entire heat affected zone shall be heat treated so as to simulate a normalizing heat treatment (see note in 5.1.3.3.1), except that by agreement between the purchaser and the manufacturer alternative heat treatments or combinations of heat treatment and chemical composition may be substituted. Where such substitutions are made, the manufacturer shall demonstrate the effectiveness of the method selected using a procedure that is mutually agreed upon. This procedure may include, but is not necessarily limited to, hardness testing, microstructural evaluation, or mechanical testing.

5.1.3.4 Laser Welded Pipe

Laser welded pipe is defined as pipe that has one longitudinal seam produced by the laser welding process defined in 5.1.2.1.3.

The weld seam and the entire heat affected zone of laser welded pipe shall be heat treated so as to simulate a normalizing heat treatment, except that by agreement between the purchaser and manufacturer, an alternative process may be substituted. Where such substitution is made, the manufacturer shall demonstrate the effectiveness of the method selected, using a procedure that is mutually agreed upon. This procedure may include, but is not necessarily limited to, hardness testing, microstructural evaluation, or mechanical testing.

Note: During the manufacture of laser welded pipe, the product is in motion through the surrounding air. Normalizing is usually defined with "cooling in still air;" hence the phrase "to simulate a normalizing heat treatment" is used here.

5.1.3.5 Longitudinal Seam Submerged-Arc Welded Pipe

Longitudinal seam submerged-arc welded pipe is defined as pipe that has one longitudinal seam produced by the automatic submerged-arc welding process defined in 5.1.2.2.1. At least one pass shall be on the inside and at least one pass shall be on the outside. (This type of pipe is also known as submerged-arc welded pipe.)

5.1.3.6 Gas Metal-Arc Welded Pipe

Gas metal-arc welded pipe is defined as pipe that has one longitudinal seam produced by the continuous gas metal-arc welding process defined in 5.1.2.2.2. At least one pass shall be on the inside and at least one pass shall be on the outside.

5.1.3.7 Combination Gas Metal-Arc and Submerged-Arc Welded Pipe

Combination gas metal-arc and submerged-arc welded pipe is defined as pipe that has one longitudinal seam produced by a combination of the welding processes defined in 5.1.2.2.1 and 5.1.2.2.2. The gas metal-arc welding process shall be continuous and first, and followed by the automatic submerged-arc welding process with at least one pass on the inside and at least one pass on the outside.

5.1.3.8 Double Seam Submerged-Arc Welded Pipe

Double seam submerged-arc welded pipe is defined as pipe that has two longitudinal seams produced by the automatic submerged-arc welding process defined in 5.1.2.2.1. The seams shall be approximately 180° apart. For each seam, at least one pass shall be on the inside and at least one pass shall be on the outside. All weld tests shall be performed after forming and welding.

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5.1.3.9 Double Seam Gas Metal-Arc Welded Pipe

Double seam gas metal-arc welded pipe is defined as pipe that has two longitudinal seams produced by the gas metal-arc welding process defined in 5.1.2.2.2. The seams shall be approximately 180° apart. For each seam, at least one pass shall be on the inside and at least one pass shall be on the outside. All weld tests shall be performed after forming and welding.

5.1.3.10 Double Seam Combination Gas Metal-Arc and Submerged-Arc Welded Pipe

Double seam combination gas metal-arc and submerged-arc welded pipe is defined as pipe that has two longitudinal seams produced by a combination of the welding processes defined in 5.1.2.2.1 and 5.1.2.2.2. The seams shall be approximately 180° apart. For each seam, the gas metal-arc welding shall be continuous and first, and followed by the automatic submerged-arc welding process with at least one pass on the inside and at least one pass on the outside. All weld tests shall be performed after forming and welding.

5.1.3.11 Helical Seam Submerged-Arc Welded Pipe

Helical seam submerged-arc welded pipe is defined as pipe that has one helical seam produced by the automatic submerged-arc welding process defined in 5.1.2.2.1. At least one pass shall be on the inside and at least one pass shall be on the outside. (This type of pipe is also known as spiral weld pipe.)

5.1.4 Types of Seam Welds

5.1.4.1 Electric Weld

An electric weld is a longitudinal seam weld produced by the electric welding process defined in 5.1.2.1.2.

5.1.4.2 Laser Weld

A laser weld is a longitudinal seam weld produced by the laser welding process defined in 5.1.2.1.3.

5.1.4.3 Submerged-Arc Weld

A submerged-arc weld is a longitudinal or helical seam weld produced by the submerged-arc welding process defined in 5.1.2.2.1.

5.1.4.4 Gas Metal-Arc Weld

A gas metal-arc weld is a longitudinal seam weld produced in whole or in part by the continuous gas metal-arc welding process defined in 5.1.2.2.2.

5.1.4.5 Skelp End Weld

A skelp end weld is a seam weld that joins plate or skelp ends together in helical seam pipe.

5.1.4.6 Jointer Weld

A jointer weld is a circumferential seam weld that joins two pieces of pipe together.

5.1.4.7 Tack Weld

A tack weld is a seam weld used to align the abutting edges until the final seam welds are produced. Tack welds shall be made by the following: (a) manual or semi-automatic submerged-arc welding, (b) electric welding, (c) gas metal-arc welding, (d) flux cored arc welding, or (e) shielded metal-arc welding using low hydrogen electrodes. Tack welds shall be removed by machining or remelting during subsequent welding of the seam.

5.2 COLD EXPANSION

Pipe furnished to this specification, except continuous welded, shall be either nonexpanded or cold expanded at the option of the manufacturer, unless otherwise specified on the purchase order. Suitable provision shall be incorporated to protect the weld from contact with the internal expander during mechanical expansion.

5.3 MATERIAL

5.3.1 Plate and Skelp for Helical Seam Pipe

The width of plate or skelp used to manufacture helical seam pipe shall not be less than 0.8 or more than 3.0 times the outside diameter of the pipe.

5.3.2 Repairs by Welding of Plate or Skelp (PSL 2 Only)

The plate or skelp used for PSL 2 pipe shall not contain any repair welds.

5.4 HEAT TREATMENT

The heat treating process shall be performed in accordance with a documented procedure. Pipe furnished to this specification may be as-rolled, normalized, normalized and tempered, subcritically stress relieved, or subcritically age hardened; and X Grades may be quenched and tempered. Grade B pipe that is quenched and tempered shall be seamless, meet the requirements of Supplementary Requirement 4 (SR4 of Appendix F), and be by agreement between purchaser and manufacturer. See Section 10 for applicable marking requirements.

5.5 SKELP END WELDS IN HELICAL SEAM PIPE

Junctions of skelp end welds and helical seam welds in finished pipe shall be permitted only at distances greater than 12 in. (305 mm) from the pipe ends. By agreement between the purchaser and the manufacturer, skelp end welds shall be permitted at the pipe ends, provided there is a circumferential

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separation of at least 6 in. (152 mm) between the skelp end weld and the helical seam weld at the applicable pipe ends. Skelp end welds in finished pipe shall be properly prepared for welding and shall be made by automatic submerged-arc welding, automatic gas metal-arc welding, or a combination of both processes.

5.6 TRACEABILITY

5.6.1 PSL 1 Traceability Requirements

The manufacturer shall establish and follow procedures for maintaining heat and/or lot identity until all required heat and/or lot tests are performed and conformance with specification requirements is shown.

5.6.2 PSL 2 Traceability Requirements

The manufacturer shall comply with SR 15.2.

6 Material Requirements

6.1 CHEMICAL PROPERTIES

6.1.1 Chemical Composition

The composition of steel used for the manufacture of pipe furnished to this specification shall conform to the chemical requirements given in Table 2A (for PSL 1) or Table 2B (for PSL 2). The composition of intermediate grades (higher than X42) shall conform to the chemical requirements of the next higher standard grade. For Grades X42 and higher, by agreement between the purchaser and the manufacturer, elements other those listed in Tables 2A and 2B (which include columbium [niobium], vanadium, and titanium via the notes to the tables) may be used; however, care should be exercised in determining the alloying content for any given size and wall thickness of pipe, because the addition of such otherwise desirable elements may affect the weldability of the pipe.

6.1.2 Elements Analyzed

As a minimum, each required analysis shall include the following elements:

a. Carbon, manganese, phosphorus, sulfur, chromium, columbium [niobium], copper, molybdenum, nickel, silicon, titanium, and vanadium.

b. Boron. (But if the heat analysis indicates a boron content less than 0.001%, then no boron determination is required for the product analysis.)

c. Any other alloying element added during steelmaking for a purpose other than deoxidation.

6.1.3 Carbon Equivalent (PSL 2 only)

6.1.3.1 Calculation of Carbon Equivalent

For PSL 2 pipe, carbon equivalent (*CE*) calculations shall be based on the product analyses and shall be calculated as follows. All carbon equivalent results shall be reported:

a. When the carbon content is less than or equal to 0.12%, the carbon equivalent shall be calculated using the following formula for *CE(Pcm)* [see Note 1]:

$$CE(Pcm) = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

If the heat analysis indicates a boron content less than 0.001%, then the product analysis need not include boron, and the boron content can be considered as zero for the *CE(Pcm)* calculation.

b. When the carbon content is greater than 0.12%, the carbon equivalent shall be calculated using the following formula for *CE(IIW)* [see Note 2]:

$$CE(IIW) = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15}$$

6.1.3.2 Maximum Carbon Equivalent

The carbon equivalent shall not exceed the following:

a. For Grade X80 pipe, for all grades of seamless pipe having a specified wall thickness greater than 0.800 in. (20.3 mm), and for pipe designated by the purchaser as high carbon equivalent pipe, the value agreed upon between the purchaser and the manufacturer.

b. For pipe not covered in Item a above, a *CE(Pcm)* of 0.25% or a *CE(IIW)* of 0.43%, whichever is applicable.

Note 1: The *CE(Pcm)* formula for low carbon steel is commonly called the Ito-Bessyo formula. *CE(Pcm)* is in fact the chemical portion of the full formula. Reference: Y. Ito & K. Bessyo, "Weldability Formula of High Strength Steels Related to Heat Affected Zone Cracking, *Journal of Japanese Welding Society*, 1968, 37, (9), 938.

Note 2: The *CE(IIW)* formula is commonly called the *IIW* [International Institute of Welding] formula. Reference: Technical Report, 1967, IIW doc. IX-535-67.

6.2 MECHANICAL PROPERTIES

6.2.1 Tensile Properties

PSL 1 Grades A25, A, B, X42, X46, X52, X56, X60, X65, and X70 shall conform to the tensile requirements specified in Table 3A.

PSL 2 Grades B, X42, X46, X52, X56, X60, X65, X70, and X80 shall conform to the tensile requirements specified in Table 3B.

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Other grades intermediate to the listed grades between X42 and X80 shall conform to tensile requirements agreed upon between the purchaser and the manufacturer, and the requirements shall be consistent with those specified in Table 3A (for PSL 1 pipe) or Table 3B (for PSL2 pipe).

For cold expanded pipe, the ratio of body yield strength and body ultimate tensile strength of each test pipe on which body yield strength and body ultimate tensile strength are determined, shall not exceed 0.93. The yield strength shall be the tensile stress required to produce a total elongation of 0.5% of the gage length as determined by an extensometer. When elongation is recorded or reported, the record or report shall show the nominal width of the test specimen when strip specimens are used and the diameter and gage length when round bar specimens are used, or shall state when full section specimens are used. For Grade A25 pipe, the manufacturer may certify that the material furnished has been tested and meets the mechanical requirements of Grade A25.

6.2.2 Flattening Test Acceptance Criteria

Acceptance criteria for flattening tests shall be as follows:

a. For electric welded pipe in grades higher than A25, and laser welded pipe smaller than $12^3/_4$.

1. For all pipe diameter-to-thickness ratios (D/t), flatten to two-thirds of the original OD without weld opening.
2. For pipe with a D/t greater than 10, continue flattening to one-third of the original OD without cracks or breaks other than in the weld.
3. For all pipe D/t, continue flattening until opposite walls of the pipe meet; no evidence of lamination or burnt metal shall develop during the entire test.

b. For grade A25 welded pipe, flatten to three-fourths of the original OD without weld fracture. Continue flattening to 60% of the original OD without cracks or breaks other than in the weld.

For the purpose of mechanical testing of the weld of electric welded pipe of size $2^3/_8$ or larger, the weld extends to a distance of $^1/_2$ in. (12.7 mm) on each side of the fusion line. For pipe smaller than size $2^3/_8$, the weld extends to a distance of $^1/_4$ in. (6.35 mm) on each side of the fusion line.

6.2.3 Bend Tests

Welded Grade A25 pipe of size $2^3/_8$ and smaller shall be tested according to 9.3.3. No cracks shall occur in any portion of the pipe, and no opening shall occur in the weld.

Note: For pipe smaller than size $2^3/_8$, the weld extends to a distance of $^1/_4$ in. (6.35 mm) on each side of the fusion line.

6.2.4 Manipulation Tests for Submerged-Arc, Gas Metal-Arc, and Laser Welds

Submerged-arc and gas metal-arc welds in pipe of all sizes, and laser welds in pipe of sizes $12^3/_4$ and larger, shall be tested by the guided-bend test (see 9.3.4).

6.2.5 Weld Ductility Test

For electric welded pipe in sizes $2^3/_8$ and larger, and for laser welded pipe smaller than size $12^3/_4$, the weld ductility shall be determined by tests on full-section specimens of 2 in. (50.8 mm) minimum length. The specimens shall be flattened cold between parallel plates. The weld shall be placed 90% from the direction of applied force (point of maximum bending). No crack or breaks exceeding $^1/_8$ in. (3.18 mm) in any direction in the weld or the parent metal shall occur on the outside surface until the distance between the plate is less than the value of S calculated by the following equations:

a. Grades less than X52:

$$S = \frac{3.07t}{0.07 + 3d/D}$$

b. Grades X52 or higher:

$$S = \frac{3.05t}{0.05 + 3t/D}$$

where

S = distance between flattening plates, in. (mm),

t = specified wall thickness of the pipe, in. (mm),

D = specified outside diameter of the pipe, in. (mm).

Cracks that originate at the edge of the specimen and are less than 0.25 in. (6.35 mm) long shall not be cause for rejection. One test shall be made on a length of pipe from each lot size as follows:

Grade	Size of Pipe	Lot Size, No. of Lengths
A25, A, and B	$2^3/_8$ through $5^9/_{16}$	400 or less
A25, A, and B	over $5^9/_{16}$ through $12^3/_4$	200 or less
X42 and higher	$2^3/_8$ through $12^3/_4$	200 or less
All grades	over $12^3/_4$	100 or less

For multiple-length pipe, a length shall be considered as each section cut from a particular multiple length. The weld ductility test may also serve as one of the flattening tests of 9.3.2 by compliance with appropriate amounts of flattening.

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Note: For the purpose of mechanical testing of the weld of electric welded pipe of size $2^3/_8$ or larger, the weld extends to a distance of $^1/_2$ in. (12.7 mm) on each side of the fusion line.

6.2.6 Fracture Toughness Tests

6.2.6.1 Charpy Impact Tests for PSL 1

For PSL 1 pipe, Charpy impact testing is not required.

6.2.6.2 Charpy Impact Tests for PSL 2

For pipe sizes and specified wall thicknesses as given in Table 14 (pipe in size and drop-weight test and wall thickness combinations not covered by this table are not required to be tested), the manufacturer shall conduct Charpy V-notch tests that meet the following requirements. (Refer to 9.8.4 for guidance pertaining to subsize specimens.)

a. The test temperature shall be +32°F (0°C); however, pipe tested at a lower temperature is also acceptable if it meets all other applicable fracture toughness requirements below.

b. For all grades, the required minimum average (set of three specimens) absorbed energy for each heat based on full size specimens shall be 20 ft-lb (27 J) for transverse specimens or 30 ft-lb (41 J) for longitudinal specimens, whichever is applicable per Table 14.

c. For X80 only, the required minimum all-heat average absorbed energy for the entire order item, based on full size Charpy specimens shall be 50 ft-lb (68 J) for transverse specimens; or 75 ft-lb (101 J) for longitudinal specimens, whichever is applicable per Table 14. If the all-heat average of the order does not meet the applicable requirement, the manufacturer shall be responsible for the replacement of heats to bring the average up to the required level.

d. For X80 only, the required minimum shear area shall be either 40% for each heat and 70% for the all-heat average of the order based on the Charpy test, or 40% for each heat and 60% for the all-heat average based on the drop-weight tear test. The drop-weight tear test option only applies for welded pipe in sizes 20 or larger. If the all-heat average of the order does not meet the required percentage of shear area, the manufacturer shall be responsible for the replacement of heats as necessary to bring the average up to the required level.

6.2.6.3 Supplementary Fracture Toughness Tests

In addition to the requirements in 6.2.6.1 and 6.2.6.2, when so specified on the purchase order, the manufacturer shall conduct fracture toughness tests in accordance with Supplementary Requirement 5 and/or 6 (see SR5 and SR6 of Appendix F) or any combination of these, and shall furnish a report of results showing compliance with the supplementary requirements specified. The purchaser shall specify on the purchase order the testing temperature for SR5 and SR6 and the Charpy V-notch absorbed energy for SR5B.

6.2.7 Metallographic Examination

For PSL 1 electric welded pipe in grades higher than X42, for PSL 2 electric welded pipe in all grades, and for laser welded pipe in all grades, full body normalized pipe excluded, compliance with the requirement in 5.1.3.3 and 5.1.3.4 to heat treat the entire heat affected zone shall be demonstrated by metallographic examination of a weld cross section. Such examinations shall be performed at least once per operating shift (12 hours maximum) and whenever changes of grade, diameter, or wall thickness are made and whenever significant excursions from operating heat treatment conditions are encountered.

7 Dimensions, Weights, Lengths, Defects, and End Finishes

7.1 SPECIFIED DIMENSIONS

Line pipe shall be furnished in the outside diameters and wall thicknesses specified on the purchase order; such dimensions shall be in accordance with one of the following:

a. As given in Table 4, 5, 6A, 6B, 6C, E-6A, E-6B, or E-6C, whichever is applicable.

b. By agreement between the purchaser and the manufacturer, intermediate to the values given in Table 6A, 6B, 6C, E-6A, E-6B, or E-6C, whichever is applicable.

7.2 DIAMETER

The outside diameter shall be within the tolerances specified in Tables 7 and 8. For threaded pipe, the outside diameter at the threaded ends shall be such that the thread length, L_4, and the number of full-crest threads in that length are within the applicable dimensions and tolerances specified in API Standard 5B.

Pipe of sizes 20 and smaller shall permit the passage over the ends, for a distance of 4 in. (101.6 mm), of a ring gage that has a bore diameter not larger than the pipe's specified outside diameter plus the applicable plus tolerance shown in Table 8. For submerged-arc welded pipe, ring gages may be slotted or notched to permit passage of the gage over the weld reinforcement. Ring gage measurements shall be made at least once per 4 hours per operating shift.

Diameter measurements of pipe larger than size 20 shall be made with a diameter tape. Diameter measurements of pipe sizes 20 and smaller shall be made with a snap gage, caliper, or other device that measures actual diameter across a single plane, except that the manufacturer shall have the option of using a diameter tape. Diameter measurements shall be made at least once per 4 hours per operating shift.

Any pipe found to be out of tolerance is cause for individual diameter measurement of all pipe back to the last, and up to the next, two sequential pipes measured and found to be within tolerance.

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By agreement between the purchaser and the manufacturer, the tolerances on the outside diameter at the pipe ends may be applied instead to the inside diameter at the pipe ends.

7.3 WALL THICKNESS

Each length of pipe shall be measured for conformance to the specified wall thickness requirements. The wall thickness at any location shall be within the tolerances specified in Table 9, except that the weld area shall not be limited by the plus tolerance. Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive inspection device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern. The mechanical caliper shall be fitted with contact pins having circular cross sections of $^1/_4$ in. (6.35 mm) diameter. The end of the pin contacting the inside surface of the pipe shall be rounded to a maximum radius of $1^1/_2$ in. (38.10 mm) for pipe of size $6^5/_8$ or larger, and to a maximum radius of d/4 for pipe smaller than size $6^5/_8$, with a minimum radius of $^1/_8$ in. (3.2 mm). The end of the pin contacting the outside surface of the pipe shall be either flat or rounded to a radius of not less than $1^1/_2$ in. (38.10 mm).

7.4 WEIGHT

Each length of pipe of size $5^9/_{16}$ or larger shall be weighed separately; lengths of pipe smaller than size $5^9/_{16}$ shall be weighed either individually or in convenient groups, at the option of the manufacturer. For all sizes of pipe, the order item weights and, where applicable, the carload weights shall be determined. Threaded-and-coupled pipe shall be weighed with the couplings screwed on but without thread protectors, except for carload determinations for which proper allowance shall be made for the weight of the thread protectors. Threaded-and-coupled pipe may be weighed before the couplings are attached, provided that allowance is made for the weight of the couplings.

For plain-end pipe, the weights determined as described above shall conform to the calculated weights, within the tolerances specified in Table 10. For threaded-and-coupled pipe, the weights determined as described above shall conform to the calculated weights or adjusted calculated weights, within the tolerances specified in Table 10.

Full-length calculated weights shall be determined in accordance with the following equation:

$$W_L = (w_{pe} \times L) + e_w$$

where

W_L = calculated weight of a piece of pipe of length L, lb (kg),

w_{pe} = plain-end weight per unit length rounded to the nearest 0.01 lb/ft (0.01 kg/m),

L = length of pipe, including end finish, as defined in 7.5, ft (m),

e_w = weight gain or loss due to end finish, lb (kg). For plain-end pipe, e_w equals 0.

The plain-end weight per unit length, w_{pe}, shall be calculated using the following equation and rounded to the nearest 0.01 lb/ft (0.01 kg/m):

U.S. Customary unit equation (lb/ft) = $w_{pe} = 10.69\ (D\text{-}t)t$

SI unit equation (kg/m) = $w_{pe} = 0.024\ 66(D\text{-}t)t$

where

D = specified outside diameter, in. (mm),

t = specified wall thickness, in. (mm).

7.5 LENGTH

Unless otherwise agreed between the purchaser and the manufacturer, pipe shall be furnished in the nominal lengths and within the length tolerances shown in Table 11, as specified on the purchase order. For threaded-and-coupled pipe, the length shall be measured to the outer face of the coupling. The length of threaded-and-coupled pipe may be determined before the couplings are attached, provided that proper allowance is made for the length of the couplings. Each length of pipe shall be measured, except that pipe made in lengths that are uniform within 0.1 ft (0.03 m) need not be individually measured, provided that the accuracy of the length is verified at least once per 4 hours per operating shift. Any pipe found to be out of tolerance is cause for individual measurement of all pipe back to the last, and up to the next, two sequential pipes measured and found to be within tolerance.

The accuracy of length measuring devices for lengths of pipe less than 100 ft (30 m) shall be ± 0.1 ft (0.03 m).

7.6 STRAIGHTNESS

Pipe smaller than size $4^1/_2$ in Grades A25, A, and B shall be reasonably straight. All other pipe shall be randomly checked for straightness; deviation from a straight line shall not exceed 0.2% of the length. Measurement may be made using a taut string or wire from end to end along the side of the pipe, measuring the greatest deviation.

7.7 JOINTERS

When specified on the purchase order, jointers (two lengths of pipe coupled together by the manufacturer or two lengths of pipe welded together by the manufacturer in accordance with the requirements of Appendix A) may be furnished; however, no length used in making a jointer shall be less than 5.0 ft (1.52 m).

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For helical seam submerged-arc welded pipe, the junctions of skelp end welds and helical seam welds shall be permitted only at distances greater than 12 in. (304.8 mm) from jointer welds. By agreement between the purchaser and the manufacturer, skelp end welds in finished pipe shall be permitted at jointer welds, provided that there is a circumferential separation of at least 6 in. (152.4 mm) between the junction of the skelp end weld and the jointer weld and the junction of the helical seam and the jointer weld.

Double joints are not within the purview of API Specification 5L. Double joints are defined as lengths of pipe welded together by parties other than the manufacturer or lengths welded together by the manufacturer in accordance with requirements other than those in Appendix A.

7.8 WORKMANSHIP AND DEFECTS

Imperfections of the types described in 7.8.1–7.8.14 that exceed the specified criteria shall be considered defects. The manufacturer shall take all reasonable precautions to minimize recurring imperfections, damage, and defects.

7.8.1 Dents

The pipe shall contain no dents greater than $^1/_4$ in. (6.35 mm), measured as the gap between the lowest point of the dent and a prolongation of the original contour of the pipe. The length of the dent in any direction shall not exceed one-half the diameter of the pipe. All cold-formed dents deeper than $^1/_8$ in. (3.18 mm) with a sharp bottom gouge shall be considered a defect. The gouge may be removed by grinding.

7.8.2 Offset of Plate Edges

For pipe with filler metal welds having specified wall thicknesses of 0.500 in. (12.7 mm) and less, the radial offset (misalignment) of plate edges in the weld seams shall not be greater than $^1/_{16}$ in. (1.59 mm). For pipe with filler metal welds having specified wall thicknesses over 0.500 in. (12.7 mm), the radial offset shall not be greater than 0.125 t or $^1/_8$ in. (3.18 mm), whichever is smaller. For electric welded pipe, the radial offset of plate edges plus flash trim shall be no greater than 0.060 in. (1.52 mm). For laser welded pipe, the radial offset of plate edges plus weld reinforcement trim shall be no greater than 0.060 in. (1.52 mm).

7.8.3 Out-of-Line Weld Bead for Pipe with Filler Metal Welds

Out-of-Line weld bead (off-seam weld) shall not be cause for rejection, provided that complete penetration and complete fusion have been achieved, as indicated by nondestructive inspection.

7.8.4 Height of Outside and Inside Weld Beads—Submerged-Arc Welds

The weld bead shall not extend above the prolongation of the original surface of the pipe by more than the following:

Specified Wall Thickness	Maximum Height of Weld Bead
$^1/_2$ in. (12.70 mm) and under	$^1/_8$ in. (3.18 mm)
Over $^1/_2$ in. (12.70 mm)	$^3/_{16}$ in. (4.76 mm)

Weld beads higher than permitted by the requirements of this paragraph may be ground to acceptable limits at the option of the manufacturer.

The height of the weld bead shall in no case come below a prolongation of the surface of the pipe (outside or inside the weld bead) except that contouring by grinding, otherwise covered in this specification, shall be permitted.

7.8.5 Height of Flash of Electric Welded Pipe

The outside flash of electric welded pipe shall be trimmed to an essentially flush condition.

The inside flash of electric welded pipe shall not extend above the prolongation of the original inside surface of the pipe more than 0.060 in. (1.52 mm).

7.8.6 Height of Weld Reinforcement of Laser Welded Pipe

The outside weld reinforcement of laser welded pipe shall be trimmed to an essentially flush condition. The inside weld reinforcement of laser welded pipe shall not extend above the prolongation of the original inside surface of the pipe more than 0.060 in. (1.52 mm). Laser welds may have underfills, which are acceptable within the limits of 7.8.13.

7.8.7 Trim of Inside Flash of Electric Welded Pipe and Trim of Inside Weld Reinforcement of Laser Welded Pipe

The depth of groove resulting from removal of the internal flash of electric welded pipe or removal of the internal weld reinforcement of laser welded pipe shall not be greater than that listed below for the various wall thicknesses. Depth of groove is defined as the difference between the wall thickness measured approximately 1 in. (25.4 mm) from the weld line and the remaining wall under the groove.

Specified Wall Thickness (t)	Maximum Depth of Trim
≤ 0.150 in. (3.8 mm)	0.10 t
> 0.150 in. (3.8 mm) and < 0.301 in. (7.6 mm)	0.015 in. (0.38 mm)
≥ 0.301 in. (7.6 mm) and greater	0.05 t

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7.8.8 Hard Spots

Any hard spot having a minimum dimension greater than 2 in. (50.8 mm) in any direction and a hardness greater than or equal to 35 HRC (327 HB) shall be rejected. The section of pipe containing the hard spot shall be removed as a cylinder.

The surface of cold-formed welded pipe shall be examined visually to detect irregularities in the curvature of the pipe. When this examination fails to disclose mechanical damage as the cause of the irregular surface but indicates that the irregular surface may be attributed to a hard spot, the hardness and dimensions of the area shall be determined. If hardness and dimensions exceed the aforementioned rejection criteria, the hard spot shall be removed.

7.8.9 Cracks, Sweats, and Leaks

All cracks, sweats, and leaks shall be considered defects.

7.8.10 Laminations (See Note)

Any lamination or inclusion extending into the face or bevel of the pipe and having a visually determined transverse dimension exceeding $^1/_4$ in. (6.35 mm) is considered a defect. Pipe containing such defects shall be cut back until no lamination or inclusion is greater than $^1/_4$ in. (6.35 mm).

Any lamination in the body of the pipe exceeding both of the following is considered a defect:

a. Greater than or equal to $^3/_4$ in. (19.0 mm) in the minor dimension.

b. Greater than or equal to 12 in.^{2} (7742 mm^2) in area.

Disposition of such defects shall be in accordance with 9.7.6, Item c or d. No specific inspection by the manufacturer is required unless the purchaser specifies special nondestructive inspection on the purchase order.

Note: A lamination is an internal metal separation creating layers generally parallel to the surface.

7.8.11 Arc Burns

Arc burns are localized points of surface melting caused by arcing between electrode or ground and pipe surface and shall be considered defects (see note).

Disposition of pipe containing arc burns shall be in accordance with 9.7.6, except that removal of defects by grinding shall be subject to the following additional condition. Arc burns may be removed by grinding, chipping, or machining. The resulting cavity shall be thoroughly cleaned and checked for complete removal of damaged material by etching with a 10% solution of ammonium persulfate or a 5% solution of nital.

Note: Contact marks, defined as intermittent marks adjacent to the weld line, resulting from the electrical contact between the electrodes supplying the welding current and the pipe surface, are not defects.

7.8.12 Undercuts

Undercutting of submerged-arc or gas metal-arc welded pipe is the reduction in thickness of the pipe wall adjacent to the weld where it is fused to the surface of the pipe. Undercutting can best be located and measured visually.

a. Minor undercutting on either the inside or the outside of the pipe is defined as follows and is acceptable without repair or grinding:

1. Maximum depth of $^1/_{32}$ in. (0.79 mm) and not exceeding $12^1/_2\%$ of the specified wall thickness with a maximum length of one-half the specified wall thickness and not more than two such undercuts in any 1 ft (0.30 m) of the weld length.

2. Maximum depth of $^1/_{64}$ in. (0.40 mm) any length.

b. Undercutting not classified as minor shall be considered a defect. Disposition shall be as follows:

1. Undercut defects not exceeding $^1/_{32}$ in. (0.79 mm) in depth and not exceeding $12^1/_2\%$ of the specified wall thickness shall be removed by grinding in accordance with 9.7.6, Item a.

2. Disposition of undercuts greater in depth than $^1/_{32}$ in. (0.79 mm) or $12^1/_2\%$ of the specified wall thickness shall be in accordance with 9.7.6, Item b, c, or d.

7.8.13 Underfills

Underfill of laser welded pipe is a depression on the weld face or root surface extending below the adjacent surface of the base metal. Underfills can best be located visually.

a. Underfills on the inside of the pipe shall be considered a defect.

b. Minor underfills on the outside of the pipe are defined as follows and are acceptable without repair or grinding.

1. Maximum depth not exceeding 5% of the specified wall thickness with a maximum length of two times the specified wall thickness, with a remaining wall thickness of $87^1/_2\%$ of the specified wall thickness, and not more than two such underfills in any 1 ft (0.30 m) of weld length. Furthermore, the coincident combination of underfills, other imperfections, grinds, and weld trim on the outside and inside surfaces of laser welded pipe shall not reduce the remaining wall thickness to less than that permitted in Table 9.

2. Maximum depth of $^1/_{64}$ in. (0.40 mm), any length.

c. Disposition of external underfills that are not classified as minor shall be in accordance with 9.7.6 except that the length of grind to remove underfills shall not exceed 6 in. (152.4 mm) in any 1 ft (0.30 m) of weld length or 12 in. (0.30 m) in any 5 ft (1.52 m) of weld length. Disposition of internal underfills shall be in accordance with 9.7.6, Items b, c, or d.

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7.8.14 Other Defects

Any imperfection having a depth greater than $12^1/_2$% of the specified wall thickness, measured from the surface of the pipe, shall be considered a defect.

7.9 PIPE ENDS

7.9.1 General

The pipe ends shall be plain, threaded, belled, or prepared for special couplings, as specified on the purchase order. Helical seam pipe shall not be threaded. The inside and outside edges of the ends of all pipe shall be free of burrs.

7.9.2 Threaded Ends (PSL 1 only)

Threaded ends shall conform to the threading, thread inspection, and gaging requirements specified in API Standard 5B. One end of each length of threaded pipe shall be provided with a coupling conforming to the requirements of Section 8, in effect at the date of manufacture of each coupling (see Note 1), and the other end with thread protection conforming to the requirements of 11.2. Couplings shall be screwed onto the pipe handling-tight (see Note 2), except that they shall be applied power-tight if so specified on the purchase order. A thread compound shall be applied to cover the full surface of either the coupling or pipe engaged thread before making up the joint. All exposed threads shall be coated with this thread compound. Unless otherwise specified on the purchase order, the manufacturer may use any thread compound that meets the performance objectives set forth in API RP 5A3. A storage compound of distinct color may be substituted for this thread compound on all exposed threads. Whichever compound is used shall be applied to a surface that is clean and reasonably free of moisture and cutting fluids.

Notes:

1. Unless otherwise specified on the purchase order, it is not mandatory that both the pipe and coupling of each threaded and coupled product be manufactured to the same edition of this specification.
2. Handling-tight shall be defined as sufficiently tight that the coupling cannot be removed except by using a wrench. The purpose of making up couplings handling-tight is to facilitate removal of the couplings for cleaning and inspecting threads and applying fresh thread compound before laying the pipe. This procedure has been found necessary to prevent thread leakage, especially in gas lines, because manufacturer-applied couplings made up power-tight, although leak-proof at the time of makeup, may not always remain so after transportation, handling, and laying.

7.9.3 Plain Ends

Unless otherwise specified on the purchase order, plain-end pipe shall be furnished with ends beveled to an angle of 30 degrees (+ 5 degrees, – 0 degrees) measured from a line drawn perpendicular to the axis of the pipe, and with a root face of $^1/_{16}$ in. ± $^1/_{32}$ in. (1.59 ± 0.79 mm) (see note). For seamless pipe where internal machining is required to maintain the root face tolerance, the angle of the internal taper, measured from the longitudinal axis, shall be no larger than the following:

Specified Wall Thickness, in. (mm)	Maximum Angle of Taper (degrees)
Less than 0.418 (10.6)	7
0.418 through 0.555 (10.6 through 14.1)	$9^1/_2$
0.556 through 0.666 (Greater than 14.1 through 16.9)	11
Over 0.666 (16.9)	14

For the removal of an internal burr on welded pipe larger than size $4^1/_2$, the internal taper, measured from the longitudinal axis, shall be no larger than 7°.

For pipe sizes $2^3/_8$ and larger, the pipe ends shall be cut square within $^1/_{16}$ in. (1.59 mm). Pipe ends from each end-finishing machine shall be checked for compliance at least once per 4 hours per operating shift.

Both ends of pipe with filler metal welds shall have the inside reinforcement removed for a distance of approximately 4 in. (101.6 mm) from the end of the pipe.

Note: The purchaser is directed to the applicable code for the recommended angle of pipe bevel.

7.9.4 Belled Ends (PSL 1 only)

When so specified on the purchase order, pipe with specified wall thickness 0.141 in. (3.6 mm) and less shall be furnished with one end belled for bell and spigot joints in accordance with Figure 1. The belled end shall be visually inspected for workmanship and defects.

7.9.5 Ends Prepared for Special Couplings (PSL 1 only)

When so specified on the purchase order, pipe shall be furnished with ends suitable for use with special couplings such as Dresser, Victaulic, or other equivalent special couplings. Such pipe shall be sufficiently free from indentations, projections, or roll marks for a distance of 8 in. (203 mm) from the end of the pipe to permit proper makeup of coupling.

8 Couplings (PSL 1 only)

8.1 MATERIAL

Couplings for Grades A and B pipe shall be seamless and shall be made of a grade of material at least equal in mechanical properties to that of the pipe. Couplings for Grade A25

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pipe shall be seamless or welded and shall be made of steel. By agreement between the purchaser and the manufacturer, welded couplings may be supplied on pipe of sizes 14 and larger, if the couplings are properly marked.

8.2 TENSILE TESTS

A tensile test shall be made on each heat of steel from which couplings are produced, and the coupling manufacturer shall maintain a record of such tests. This record shall be open to inspection by the purchaser. If such a test is made on finished couplings, either round specimens proportioned as specified in ASTM E 8, *Test Methods for Tension Testing of Metallic Materials*, or strip specimens shall be used at the option of the manufacturer.

8.3 DIMENSIONS

Couplings shall conform to the dimensions and tolerances shown in Table 12 (see note) and Figure 2.

Note: Couplings given in Table 12 are suitable for pipe having dimensions as given in Tables 4 and 5.

8.4 INSPECTION

Couplings shall be free from blisters, pits, cinder marks, and other defects that would impair the efficiency of the coupling or break the continuity of the thread.

9 Inspection and Testing

9.1 TEST EQUIPMENT

If test equipment, whose calibration or verification is required under the provisions of the specification, is subjected to unusual or severe conditions sufficient to make its accuracy questionable, recalibration or reverification shall be performed prior to further use of the equipment.

9.2 TESTING OF CHEMICAL COMPOSITION

9.2.1 Heat Analyses

The steel manufacturer shall determine the analysis of each heat of steel used in the manufacture of pipe specified on the purchase order. The analysis so determined shall conform to the requirements of 6.1.1.

For Grade X80, heat analysis limits have not been defined, only product analysis limits.

9.2.2 Product Analyses

9.2.2.1 Sampling Frequency

The manufacturer shall determine the analysis of two samples representing each heat of steel used for the production of pipe under this specification.

9.2.2.2 Sampling Methods

9.2.2.2.1 Seamless Pipe

At the option of the manufacturer, samples used for product analyses shall be taken either from tensile test specimens or from the finished pipe.

9.2.2.2.2 Welded Pipe

At the option of the manufacturer, samples used for product analyses shall be taken from either finished pipe, plate, skelp, tensile test specimens, or flattening test specimens. The location of the samples shall be a minimum of 90° from the weld of longitudinally welded pipe. For helical seam pipe, the sample location shall be at a position not less than one quarter of the distance between adjacent weld convolutions as measured from either edge of the weld. For pipe manufactured from plate or skelp, the product analyses may be made by the supplier of the plate or skelp providing the analyses are made in accordance with the frequency requirement of this specification.

9.2.3 Test Reports

9.2.3.1 When required by the purchaser, for Grade A25, the manufacturer shall certify that the pipe furnished was produced in conformance with the requirements for chemical properties and tests of API Specification 5L.

9.2.3.2 Chemical analyses required by this specification shall be reported to the purchaser when SR15 or PSL 2 is specified.

9.3 TESTING OF MECHANICAL PROPERTIES

9.3.1 Tensile Tests

9.3.1.1 Tensile Test Specimens

Tensile test orientation shall be as shown in Figure 3. At the option of the manufacturer for longitudinal seam welded pipe, the longitudinal specimens may be taken from the skelp parallel to the rolling direction and approximately midway between edge and center. At the option of the manufacturer, the specimen may be either full section, strip specimen, or round bar specimens as specified in 9.3.1.3, 9.3.1.4, and Figure 4. The type, size, and orientation of the specimens shall be reported. Testing of strip specimens shall be with suitable curved-face testing grips, or flat-face testing grips if the grip areas of the specimens have been machined to reduce the curvature or have been flattened without heating. For strip specimens, the specified width in the gage length shall be either $1^1/_2$ in. (38.1 mm) or $^3/_4$ in. (19.0 mm) for pipe of size $3^1/_2$ or smaller; either $1^1/_2$ in. (38.1 mm) or 1 in. (25.4 mm) for pipe of size larger than $3^1/_2$ up to size $6^5/_8$, inclusive; and $1^1/_2$ in. (38.1 mm) for pipe larger than size $6^5/_8$.

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9.3.1.2 Tensile Testing Frequency

Tensile tests shall be made at the frequency of one test per inspection lot as shown in Table 13.

9.3.1.3 Longitudinal Tensile Tests

At the option of the manufacturer, longitudinal tests may utilize a full section specimen (see Figure 4, Subfigure B), a strip specimen (see Figure 4, Subfigure C), or for pipe with wall thickness greater than 0.750 in. (19.1 mm) a 0.500-in. (12.7-mm) diameter round bar specimen (see Figure 4, Subfigure D). The strip specimen shall be tested without flattening.

9.3.1.4 Transverse Tensile Tests

The transverse tensile properties shall be determined, at the option of the manufacturer, by one of the following methods:

a. The yield strength, ultimate tensile strength, and elongation values shall be determined on either a flattened rectangular specimen (see Figure 4, Subfigure E) or on a 0.500-in. (12.7-mm) or 0.350-in. (8.9-mm) round bar specimen (see Figure 4, Subfigure G).

The yield strength shall be determined by the ring expansion method (see Figure 4, Subfigure A) with the ultimate strength and elongation values determined from a flattened rectangular specimen.

The same method of testing shall be employed for all lots in an order item. All transverse tensile specimens shall be as shown in Figure 4. All specimens shall represent the full wall thickness of the pipe from which the specimen was cut, except for round bar tensile specimens.

Transverse round bar specimens are to be secured from nonflattened pipe sections. The 0.500-in. (12.7-mm) diameter round bar specimens shall be used when the pipe size allows, and the 0.350-in. (8.9-mm) diameter round bar specimen shall be used for other sizes. For pipe sizes too small to allow a 0.350-in. (8.9-mm) specimen, round bar tensile specimens are not permitted.

9.3.1.5 Weld Tensile Tests

Weld tensile test specimens shall be taken at 90° to the weld with the weld at the center as shown in Figures 3 and 4 and shall represent the full wall thickness of the pipe from which the specimen was cut. Weld reinforcement may be removed at the manufacturer's option. Weld tensile tests need not include determination of yield strength and elongation.

9.3.1.6 Control Tensile Tests

For pipe other than Grade A25, one tensile test per heat shall be made as a control, and a record of such tests shall be available to the purchaser. For longitudinal seam welded pipe, such tensile tests shall be made using samples taken from either plate, skelp, or finished pipe at the option of the manufacturer.

9.3.2 Flattening Tests

Flattening tests shall be performed for electric welded, continuous welded, and laser welded pipe. Frequency of testing, sample location, test orientation, and applicable pipe sizes shall be as shown in Figure 5. For electric welded pipe that is to be processed through a hot stretch mill, the flattening test specimens shall be obtained either prior to or after such treatment, at the option of the manufacturer.

9.3.3 Bend Tests

One full section specimen of appropriate length, cut from a length of pipe from each lot of 25 tons (22.7 Mg), or fraction thereof, for pipe of nominal size 1.900 and smaller, and from each lot of 50 tons (45.5 Mg), or fraction thereof, for pipe of size $2^3/_8$ shall be bent cold through 90°, around a mandrel having a diameter not greater than twelve times the outside diameter of the pipe being tested, with the weld located approximately 45° from the point of contact of the specimen with the mandrel.

9.3.4 Guided-Bend Tests

The test specimens shall be taken from the helical or each longitudinal seam weld in a length of pipe from each lot of 50 lengths or less of each combination of specified outside diameter, specified wall thickness, and grade; and from a skelp end weld in a length of pipe from each lot of 50 lengths or less of each combination of specified outside diameter, specified wall thickness, and grade of finished helical seam pipe containing skelp end welds. The test specimens shall not contain repair welds.

9.3.5 Fracture Toughness Tests

9.3.5.1 Charpy Test Specimens

The Charpy test specimens shall be prepared in accordance with ASTM A 370, *Methods and Definitions for Mechanical Testing of Steel Products*. The specimen size and orientation shall be as given in Table 14, except that it shall be permissible to use $^2/_3$ or $^1/_2$ size test specimens as required when the absorbed energy is expected to exceed 80% of the full scale capacity of the testing machine. The Charpy specimens shall be taken from the body of the pipe. For welded pipe, the location shall be 90° from the weld seam. Notch orientation shall be through the wall thickness as shown in Figure F-3 of Appendix F.

9.3.5.2 Charpy Testing Frequency

The minimum test frequency shall be one test per heat per combination of pipe size and specified wall thickness. An impact test shall consist of three specimens; the reported results shall be the three individual specimen values and the average of the three specimens.

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9.3.5.3 Drop-Weight Tear Test Specimen and Test Frequency

When the drop-weight tear test option is selected (see 6.2.6.3), refer to SR6.

9.4 HYDROSTATIC TESTS

9.4.1 Hydrostatic Test Requirements

Each length of pipe shall withstand, without leakage, an inspection hydrostatic test to at least the pressure specified in 9.4.3. Test pressures for all sizes of seamless pipe and for welded pipe in sizes 18 and smaller, shall be held for not less than 5 seconds. Test pressures for welded pipe in sizes 20 and larger shall be held for not less than 10 seconds. For threaded-and-coupled pipe, the test shall be applied with the couplings made up power-tight if power-tight makeup is specified on the purchase order, except that pipe sizes larger than $12^3/_4$ may be tested in the plain-end condition. For threaded pipe furnished with couplings made up handling-tight, the hydrostatic test shall be made on the pipe in the plain-end or threads-only condition or with couplings applied, unless otherwise agreed by the purchaser and the manufacturer.

9.4.2 Verification of Hydrostatic Test

In order to ensure that every length of pipe is tested to the required test pressure, each tester (except those on which continuous welded pipe is tested) shall be equipped with a recording gage that will record the test pressure and duration of time the pressure is applied to each length of pipe, or shall be equipped with some positive and automatic or interlocking device to prevent pipe from being classified as tested until the test requirements (pressure and time) have been complied with. Such records or charts shall be available for examination at the manufacturer's facility by the purchaser's inspectors. The test pressure measuring device shall be calibrated by means of a dead weight tester, or equivalent, within the 4 months prior to each use. Retention of calibration records shall be as specified in 12.2.

9.4.3 Test Pressures

The minimum test pressure shall be the standard test pressure given in Tables 4, 5, 6A, 6B, 6C, E-6A, E-6B, or E-6C; the alternative test pressure given in Tables 6A, 6B, 6C, E-6A, E-6B, or E-6C if so specified in the purchase order; a pressure higher than standard, at the discretion of the manufacturer unless specifically limited by the purchaser; or a pressure higher than standard, as agreed between the purchaser and the manufacturer (see Note 1). The minimum test pressures for grades, outside diameters, and specified wall thicknesses not listed shall be computed by the equation given in Note 2 below. For all sizes of Grade A25 pipe smaller than $5^9/_{16}$ and all sizes of Grade A and B pipe smaller than $2^3/_8$, the test pressure has been arbitrarily assigned. Where the unlisted wall thickness is intermediate to wall thicknesses whose test pressures have been arbitrarily assigned, the test pressure for the intermediate wall thickness shall be equal to the test pressure specified for the next heavier wall thickness. When computed pressures are not an exact multiple of 10 psi (100 kPa), they shall be rounded to the nearest 10 psi (100 kPa).

When the purchase order specifies a hydrostatic test pressure that will produce a hoop stress greater than 90% of the specified minimum yield strength, by agreement between the purchaser and the manufacturer, the hydrostatic test pressure shall be determined in accordance with Appendix K.

Note 1: The hydrostatic test pressures given herein are inspection test pressures, are not intended as a basis for design, and do not necessarily have any direct relationship to working pressures.

Note 2: The test pressures given in Tables 4, 5, 6A, 6B, 6C, E-6A, E-6B, and E-6C were computed by the following equations (see Footnotes a through d) and rounded to the nearest 10 psi (100 kPa):

U.S. Customary Unit Equation

$$P = \frac{2St}{D}$$

SI Unit Equation

$$P = \frac{2000St}{D}$$

where

P = hydrostatic test pressure in psi (kPa),

S = fiber stress in psi (MPa), equal to a percentage of the specified minimum yield strength for the various sizes as shown in the tabulation below,

t = specified wall thickness, in. (mm),

D = specified outside diameter, in. (mm).

Grade	Size	Percent of Specified Minimum Yield Strength: Standard Test Pressure	Percent of Specified Minimum Yield Strength: Alternative Test Pressure
A25	$5^9/_{16}$[a]	60	—
A	$\geq 2^3/_8$[b]	60	75
B	$\geq 2^3/_8$[b]	60	75
X42 through X80	$\leq 5^9/_{16}$	60[c]	75[d]
	$> 5^9/_{16}$ and $\leq 8^5/_8$	75[c]	75[d]
	$> 8^5/_8$ and < 20	85[c]	85[d]
	≥ 20	90[c]	90[d]

[a]Test pressures were limited to 2,800 psi (19 300 kPa). Test pressures for other sizes were established arbitrarily.

[b]Test pressures were limited to 2,500 psi (17 200 kPa) for $3^1/_2$ and smaller, and to 2,800 psi (19 300 kPa) for sizes larger than $3^1/_2$. Test pressures for other sizes were established arbitrarily.

[c]Test pressures for Grades X42 through X80 were limited to 3,000 psi (20 700 kPa) to accommodate hydrostatic tester limitations.

[d]Test pressures for Grades X42 through X80 were limited to 7,260 psi (50 000 kPa) for sizes < 16 and 3,630 psi (25 000 kPa) for sizes ≥ 16.

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9.4.4 Supplementary Hydrostatic Tests

By agreement between the purchaser and the manufacturer, for Grade X42 and higher, the manufacturer shall make additional internal pressure tests, which may involve one or more of the following methods. In all supplementary hydrostatic tests, the formula shown in 9.4.3 shall be used for stress calculations. The conditions of testing shall be as agreed upon.

a. Hydrostatic destructive tests in which the minimum length of the specimen is ten times the outside diameter of the pipe, but need not exceed 40 ft (12.2 m).

b. Full-length destructive tests made by the hydrostatic pressure water column method.

c. Hydrostatic transverse yield strength tests using accurate strain gages (see note).

Note: Acceptable gages are the roller-chain ring-expansion gage, the metallic bonded resistance strain gage, or other suitable gages of similar accuracy.

9.5 DIMENSIONAL TESTING

The accuracy of all measuring instruments used for acceptance or rejection, except ring and plug thread gages and weighing devices, shall be verified at least once per operating shift (12 hours maximum).

Verifying the accuracy of measuring devices such as snap gages and drift mandrels shall consist of inspection for wear and conformance to specified dimensions. Verifying the accuracy of rules, length measuring tapes, and other nonadjustable measuring devices shall consist of a visual check for legibility of markings and general wear of fixed reference points. The adjustable and nonadjustable designation of measuring devices utilized by the manufacturer shall be documented.

The verification procedure for working ring and plug thread gages shall be documented. The accuracy of all weighing devices shall be verified at periods not to exceed those required by the manufacturer's documented procedure in accordance with National Institute of Standards and Technology (NIST) standards or equivalent regulations in the country of manufacture of products made to this specification.

If measuring equipment, whose calibration or verification is required under the provisions of the specification, is subjected to unusual or severe conditions sufficient to make its accuracy questionable, recalibration or reverification shall be performed before using the equipment.

9.6 VISUAL INSPECTION

All pipe shall be visually examined and shall be free of defects in the finished condition.

9.7 NONDESTRUCTIVE INSPECTION

9.7.1 Purchaser Inspection

When inspection by the purchaser is stated on the purchase order, the provisions of Appendix H shall apply.

9.7.2 Methods of Inspection

Except for Grade A25 pipe, the weld seams of welded pipe of sizes $2^3/_8$ and larger shall be inspected full length (100%) in accordance with the methods specified below. In addition, the skelp end weld in finished helical seam pipe shall be so inspected.

The location of equipment in the manufacturer's facility shall be at the discretion of the manufacturer, except that final inspection of weld seams of cold expanded pipe shall be performed after cold expansion.

9.7.2.1 Submerged-arc welds shall be inspected by radiological methods in accordance with 9.7.3.1 through 9.7.3.12. Such inspection shall be full length or for a minimum distance of 8 in. (203 mm) from each end if the balance of the weld length is inspected by ultrasonic methods in accordance with 9.7.4.1 through 9.7.4.4.

9.7.2.2 Electric welds shall be inspected by ultrasonic or electromagnetic methods in accordance with 9.7.4.1 through 9.7.4.4. If necessary to meet the full length (100%) inspection requirements of 9.7.2, pipe ends shall be inspected by using hand-held ultrasonic shear wave equipment or other NDT method agreed to by the manufacturer and the purchaser.

By agreement between the purchaser and the manufacturer and when specified on the purchase order, electric welds shall be nondestructively inspected in accordance with SR17 (see Appendix F).

9.7.2.3 Laser welds shall be inspected by ultrasonic methods in accordance with 9.7.4.1 through 9.7.4.4. If necessary to meet the full length (100%) inspection requirements of 9.7.2, pipe ends shall be inspected by using hand-held or automatic ultrasonic shear wave equipment, or other NDT method agreed to by the manufacturer and the purchaser.

By agreement between the purchaser and the manufacturer and when specified on the purchase order, laser welds shall be ultrasonically inspected in accordance with SR17 (see Appendix F).

9.7.2.4 Gas metal-arc welds shall be inspected full length by ultrasonic methods in accordance with 9.7.4.1 through 9.7.4.4. In addition, the weld at each end of the pipe shall be inspected by radiological methods in accordance with 9.7.3.1 through 9.7.3.12 for a minimum distance of 8 in. (203 mm) from each end.

9.7.2.5 Skelp end welds in finished helical seam pipe shall have been inspected in accordance with one or more of the

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methods specified above for the weld type. Radiological inspection shall include the junction of the skelp end weld with the helical seam weld. For cold expanded pipe, radiological inspection shall be performed after expansion.

9.7.2.6 All PSL 2 seamless pipe and PSL 1 Grade B quenched and tempered seamless pipe (see 5.4) shall be nondestructively inspected in accordance with SR4 (see Appendix F). By agreement between the purchaser and the manufacturer and when specified on the purchase order, other PSL 1 seamless pipe shall be nondestructively inspected in accordance with SR4 (see Appendix F).

9.7.3 Radiological Inspection

9.7.3.1 Radiological Inspection Equipment

The homogeneity of weld seams examined by radiological methods shall be determined by means of X-rays directed through the weld material in order to create a suitable image on radiographic film or fluorescent screen or a television screen, provided adequate sensitivity can be obtained.

9.7.3.2 Fluoroscopic Operator Qualification

Operators of fluoroscopic equipment shall be trained, tested, and certified by the pipe manufacturer.

Details of such training, testing, and certification programs shall be available to the purchaser. This program shall include the following:

a. Classroom instruction in the fundamentals of radiological inspection techniques.

b. On-the-job training designed to familiarize the operator with specific installations, including the appearance and interpretation of weld imperfections and defects. The duration of such training shall be sufficient to ensure adequate assimilation of the knowledge required for conducting the inspection.

c. Knowledge of appropriate requirements of this specification.

d. A physical examination at least once per year to determine the operator's optical capability to perform the required inspection.

e. Upon completion of Items a and b above, an examination shall be given by the manufacturer to determine if the operator is qualified to properly perform fluoroscopic examinations.

9.7.3.3 Operation Certification

Certified operators whose work has not included fluoroscopic inspection for a period of one year or more shall be recertified by successfully completing the examination (Item e above) and also passing the physical examination (Item d above). Substantial changes in procedure or equipment shall require recertification of the operators.

9.7.3.4 NDT Reference Standards

Unless otherwise specified, the reference standard shall be the API standard penetrameter described in 9.7.3.5, or at the option of the manufacturer the ISO wire penetrameter described in 9.7.3.6. By agreement between the purchaser and the manufacturer, other standard penetrameters may be used.

9.7.3.5 API Standard Penetrameter

The API standard penetrameter shall be as shown in Figure 6 and made of a material with the same radiological characteristics as the pipe. The thickness of the penetrameter shall be a maximum of 4% of the specified wall thickness. Either 2% or 4% penetrameters may be used (see Tables 15 and 16 for sizes).

9.7.3.6 ISO Wire Penetrameter

The ISO wire penetrameter shall be Fe 1/7, Fe 6/12, or Fe 10/16 in accordance with Tables 17 and 18 for the appropriate wall thickness. When the wire penetrameter is placed across the weld, the diameter of the wire employed shall be based on the specified wall thickness plus the estimated thickness of the weld reinforcement (not to exceed the maximum allowed) at the penetrameter location. When the penetrameter is placed on the base metal, the diameter of the wire employed shall be based on the specified wall thickness..

9.7.3.7 Frequency of Calibration

When the fluoroscopic method is used full length and on each film when film is used, the penetrameter shall be used to check the sensitivity and adequacy of the radiographic technique on one pipe in every lot of 50 pipe, at least once per 4 hours per operating shift. When film is used full length, one penetrameter shall be used for each length of pipe. The pipe shall be held in a stationary position during the adjustment of the radiographic technique by use of the penetrameter. Proper definition and sensitivity is attained when all three holes of the API standard penetrameter or individual wires of the ISO penetrameter are clearly discernible.

9.7.3.8 Procedure for Evaluating In-Motion Operation of a Fluoroscope

To evaluate the definition of defects at operational speeds, a pipe section having a minimum wall thickness of 0.375 in. (9.5 mm) shall be used. Series of $^{1}/_{32}$ in. (0.79 mm) holes, as shown in Example 6 of Figure 7 shall be drilled into the center of the weld to a depth of 100% of the total thickness. At least four such series shall be used, spaced 1 foot apart. As an alternative to the use of the pipe section described above, a penetrameter as described in 9.7.3.4, 9.7.3.5, and 9.7.3.6 may be used at the option of the manufacturer. The speed of operation shall be adjusted so that the holes in the pipe section or

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API penetrameter, or individual wires in the ISO penetrameter, are clearly visible to the operator.

9.7.3.9 Acceptance Limits for Radiological Inspection

Radiological examination shall be capable of detecting weld imperfections and defects as described in 9.7.3.10 and 9.7.3.11.

9.7.3.10 Imperfections Observed During Radiological Inspection

The maximum acceptable size and distribution of slag inclusion and/or gas pocket discontinuities are shown in Tables 19 and 20 and Figures 7 and 8 (see note).

The important factors to be considered in determining rejection or acceptance limits are size and spacing of discontinuities and the sum of the diameters in an established distance. For simplicity, the distance is established as any 6 in. (152.4 mm) length. Discontinuities of this type usually occur in an aligned pattern, but no distinction is made between aligned or scattered patterns. Also, the distribution pattern may be of assorted sizes.

Note: Unless the discontinuities are elongated, it cannot be determined with assurance whether the radiological indications represent slag inclusions or gas pockets. Therefore, the same limits apply to all circular-type discontinuities.

9.7.3.11 Defects Observed During Radiological Inspection

Cracks, lack of complete penetration, lack of complete fusion, and discontinuities greater in size and/or distribution than shown in Tables 19 and 20 and Figures 7 and 8, as indicated by radiological examination, shall be considered defects. See 9.7.6 for disposition of pipe containing defects.

9.7.3.12 Disposition of Defects Observed During Radiological Inspection

Any weld defect detected as a result of radiological examination shall be rejected. Disposition of the pipe containing the defect shall be in accordance with 9.7.6.

9.7.4 Ultrasonic and Electromagnetic Inspection

9.7.4.1 Equipment

Any equipment utilizing the ultrasonic or electromagnetic principles and capable of continuous and uninterrupted inspection of the weld seam shall be used. The equipment shall be checked with an applicable reference standard as described in 9.7.4.2 at least once per 8 hours per operating shift to demonstrate its effectiveness and the inspection procedures. The equipment shall be adjusted to produce well-defined indications when the reference standard used by the manufacturer is scanned by the inspection unit in a manner simulating the inspection of the product and shall be capable of inspecting $^1/_{16}$ in. (1.6 mm) on each side of the weld line for the entire wall thickness. Restrictions on residual magnetism in pipe are given in 9.7.7.

9.7.4.2 NDT Reference Standards

Reference standards shall have the same specified diameter and thickness as the product being inspected and may be of any convenient length as determined by the manufacturer. Reference standards shall contain machined notches, one on the inside surface and one on the outside surface, or a drilled hole as shown in Figure 9, at the option of the manufacturer. The notches shall be parallel to the weld seam and shall be separated by a distance sufficient to produce two separate and distinguishable signals. The $^1/_{16}$ in. (1.6 mm) or $^1/_8$ in. (3.2 mm) hole shall be drilled through the wall and perpendicular to the surface of the reference standard as shown in Figure 9 (see note).

Note: The reference standards defined above are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

9.7.4.3 Acceptance Limits

Table 21 gives the height of acceptance limit signals produced by reference standards. An imperfection that produces a signal greater than the acceptance limit signal given in Table 21 shall be considered a defect unless it can be demonstrated by the manufacturer that the imperfection does not exceed the provisions of 7.8. Alternatively, indicated imperfections in submerged-arc welds may be reinspected by film radiological methods using 2% penetrameters, in accordance with 9.7.3.1 through 9.7.3.12.

In addition, for gas metal-arc welds, continuous flaw signals greater than 1 in. in length, regardless of signal height, but greater than the background signal (noise) shall be reinspected by radiological methods in accordance with 9.7.3.1 through 9.7.3.12 or by other techniques as agreed upon between the purchaser and the manufacturer.

9.7.4.4 Weld Repair

Defects in the filler-metal welds found by ultrasonic methods of inspection may be repaired by welding and reexamined nondestructively in accordance with Appendix B.

For PSL 1 pipe, defects in weld seams made without filler metal found by ultrasonic or electromagnetic methods of inspection may be repaired by welding and reexamined nondestructively in accordance with Appendix B, only by agreement between the purchaser and the manufacturer.

For PSL 2 pipe, defects in weld seams made without filler metal shall not be repaired by welding.

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9.7.5 Magnetic Particle Inspection (PSL 1 only)

Note: For weld repairs to the pipe body, as permitted in Appendix B for PSL 1 pipe.

9.7.5.1 Equipment

The equipment used for magnetic particle inspection shall produce a magnetic field of sufficient intensity to indicate weld area defects of the following character in the external surface of the pipe: open welds, partial or incomplete welds, intermittent welds, cracks, seams, and slivers.

9.7.5.2 Reference Standard

If requested by the purchaser, arrangements shall be made by the manufacturer to perform a demonstration for the purchaser or his representative during production of his order. Such demonstration shall be based on pipe in process or sample lengths of similar pipe retained by the manufacturer for that purpose that exhibit natural or artificially produced defects of the character stated in 9.7.5.1.

9.7.5.3 Acceptance Limits

The manufacturer shall mark each magnetic particle indication and subsequently explore each indication with respect to the depth of the imperfection. Imperfections that require grinding or chipping to determine their depth shall be completely removed by grinding, or by cutting off, or may be repaired by welding and reexamined nondestructively in accordance with Appendix B.

9.7.6 Disposition of Defects

Pipe containing a defect shall be given one of the following dispositions:

a. The defect shall be removed by grinding in such a way that the ground area blends in smoothly with the contour of the pipe. Complete removal of the defect shall be verified by visual inspection of the ground area, and the wall thickness in the ground area shall be as specified in 7.3. (For arc burns, see also 7.8.11.)

b. The defect shall be repaired by welding in accordance with Appendix B, except that, for PSL 2 pipe, defects in pipe body or in seam welds made without filler metal shall not be repaired by welding.

c. The section of pipe containing the defect shall be cut off within the limits of requirements on length.

d. The entire pipe shall be rejected.

9.7.7 Residual Magnetism Measurement Requirements

The requirements of this paragraph apply only to testing within the pipe manufacturing facility. Measurements of residual magnetism on pipe, subsequent to leaving the pipe manufacturing facility, may be affected by procedures and conditions imposed on the pipe during and after shipment.

a. The longitudinal magnetic field shall be measured on the root face or square cut face of finished plain-end pipe size $6^5/_8$ and larger, and all smaller plain-end pipe that is inspected full length by magnetic methods or that is handled by magnetic equipment prior to loading.

b. Measurements shall be made using a Hall-effect gaussmeter or other type of calibrated instrument. However, in case of dispute, measurements made with a Hall-effect gaussmeter shall govern. The gaussmeter shall be operated in accordance with written instructions demonstrated to produce accurate results. The accuracy shall be verified at least once each day that the gaussmeter is used.

c. Measurements shall be made on each end of a pipe to be selected at least once per 4 hours per operating shift.

d. Pipe magnetism shall be measured subsequent to any inspection that utilizes a magnetic field, prior to loading for shipment from the manufacturer's facility. For pipe handled with electromagnetic equipment after measurement of magnetism, such handling shall be performed in a manner demonstrated not to cause residual magnetism in excess of the levels stipulated in Item e.

e. As a minimum, four readings shall be taken approximately 90° apart around the circumference of each end of the pipe. The average of the four readings shall not exceed 30 gauss (3.0 mT), and no one reading shall exceed 35 gauss (3.5 mT) when measured with a Hall-effect gaussmeter, or equivalent values when measured with other types of instruments.

f. Any pipe that does not meet the requirements of 9.7.7, Item e, shall be considered defective. In addition, all pipe produced between the defective pipe and the last acceptable pipe shall be individually measured. Alternatively, if the pipe production sequence is documented, pipe may be measured in reverse sequence beginning with the pipe produced prior to the defective pipe until at least three consecutively produced pipes meet the requirements; pipe produced prior to the three acceptable pipes need not be measured.

Pipe produced after the defective pipe shall be measured individually until at least three consecutive pipes meet the requirements.

Measurements made on pipe in stacks or bundles are not considered valid.

All defective pipe shall be degaussed full length, and remeasured until at least three consecutive pipes meet the requirements.

9.8 TEST METHODS

9.8.1 Methods of Chemical Analysis

Methods and practices relating to chemical analysis shall be performed in accordance with ASTM A 751, *Methods, Practices, and Definitions for Chemical Analysis of Steel Products*. Calibrations performed shall be traceable to established standards.

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9.8.2 Tensile Test

9.8.2.1 Test Method

The tensile testing procedure shall conform to the requirements of ASTM A 370, *Methods and Definitions for Mechanical Testing of Steel Products*. All tensile tests, except transverse weld and ring tests, shall include yield strength, ultimate tensile strength, and elongation determinations and shall be performed with the specimens at room temperature. The strain rate shall be in accordance with the requirements of ASTM A 370.

9.8.2.2 Equipment

Tensile test machines shall have been calibrated within 15 months preceding any test in accordance with the procedures of ASTM E 4, *Practices for Load Verification of Testing Machines*. Where yield strength is determined by the use of extensometers, such extensometers shall be calibrated within the preceding 15 months in accordance with the procedures of ASTM E 83, *Method of Verification and Classification of Extensometers*.

9.8.3 Guided-Bend Test

One face-bend and one root-bend specimen, both conforming to Figure 10, shall be bent approximately 180° in a jig substantially in accordance with Figure 11. For any combination of specified outside diameter, specified wall thickness, and grade, the maximum value for jig dimension A in Figure 11 may be calculated using the equation shown. The manufacturer shall use a jig based on this dimension, or a smaller dimension at his option; however, to minimize the number of jigs required, standard values for dimension A have been selected for pipe sizes $12^3/_4$ and larger. These values are listed for each size, specified wall thickness, and grade in Appendix G. For intermediate grades or specified wall thicknesses, the next smaller standard value for dimension A shall be used. When dimension A is greater than 9 in. (228.6 mm), the length of the specimen required to contact the male die need not exceed 9 in. (228.6 mm). For pipe with wall thickness over 0.750 in. (19.1 mm), a reduced wall specimen as shown in Figure 10 may be used at the option of the manufacturer. Reduced wall specimens shall be tested in a jig with the A dimension calculated for 0.750 in. (19.1 mm) wall pipe of the appropriate size and grade. The specimens (a) shall not fracture completely; (b) shall not reveal any cracks or ruptures in the weld metal greater than $^1/_8$ in. (3.18 mm) in length regardless of depth; and (c) shall not reveal any cracks or ruptures in the parent metal, heat affected zone, or fusion line longer than $^1/_8$ in. (3.18 mm) and deeper than $12^1/_2\%$ of the specified wall thickness; except cracks that occur at the edges of the specimen and are less than $^1/_4$ in. (6.35 mm) long shall not be cause for rejection in (b) or (c) above regardless of depth.

9.8.4 Charpy Test

Charpy tests shall be performed by the manufacturer in accordance with ASTM A370, *Methods and Definitions for Mechanical Testing of Steel Products*.

For purposes of determining conformance with these Charpy V-notch fracture toughness requirements, observed and calculated values shall be rounded to the nearest whole number in accordance with the rounding method of ASTM E 29, *Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*. Observed values that are rounded will be referred to as individual readings.

When subsize specimens are used, the individual readings and the average of the three readings are divided by the ratio of the specimen width tested to the full-size specimen width and compared with the full-size acceptance criteria.

For acceptance, the average absorbed energy of the three individual specimens from a length shall not be less than the required full-size value. In addition, the individual test value for any specimen shall not be less than three-fourths of the required minimum average absorbed energy value.

9.9 INVALIDATION OF TESTS

9.9.1 Defective Tensile Test Specimens

When the elongation of any tensile test specimen is less than that specified and if any part of the fracture is outside the middle third of the gage length as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

9.9.2 Defective Mechanical Test Specimens

For any of the mechanical tests in Section 6, any test specimen that shows defective preparation or material imperfections unrelated to the intent of the particular mechanical test, whether observed before or after testing, may be discarded and replaced by another specimen from the same length of pipe.

9.10 RETESTS

9.10.1 Recheck Analyses

If the product analyses of both samples representing the heat fail to conform to the specified requirements, at the manufacturer's option either the heat shall be rejected or the remainder of the heat shall be tested individually for conformance to the specified requirements. If the product analysis of only one of the samples representing the heat fails to conform to the specified requirements, at the manufacturer's option either the heat shall be rejected or two recheck analyses shall be made using two additional samples from the heat. If both recheck analyses conform to the specified requirements, the heat shall be accepted, except for the pipe, plate, or skelp from which the initial sample that failed was taken. If one or both recheck analyses fail to conform to the specified

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requirements, at the manufacturer's option either the heat shall be rejected or the remainder of the heat shall be tested individually for conformance to the specified requirements.

For such individual testing, analyses for only the rejecting element or elements need be determined.

Samples for recheck analyses shall be taken in the same location as specified for product analysis samples

9.10.2 Retests

If the tensile test specimen representing a lot of pipe fails to conform to the specified requirements, the manufacturer may elect to retest two additional lengths from the same lot. If both retested specimens conform to the specified requirements, all the lengths in a lot shall be accepted, except the length from which the initial specimen was taken. If one or both of the retested specimens fail to conform to the specified requirements, the manufacturer may elect to individually test the remaining lengths in the lot, in which case determinations are required only for the particular requirements with which the specimens failed to comply in the preceding tests. Specimens for retest shall be taken in the same manner as the specimen that failed to meet the minimum requirements.

9.10.3 Flattening Retest

Flattening retest provisions are as follows:

a. Nonexpanded electric welded pipe in grades higher than A25 and nonexpanded laser welded pipe smaller than $12^3/_4$, produced in single lengths—The manufacturer may elect to retest any failed end until the requirements are met, providing the finished pipe is not less than 80% of its length after initial cropping.

b. Nonexpanded electric welded pipe produced in grades higher than A25 and nonexpanded laser-welded pipe smaller than $12^3/_4$, produced in multiple lengths—The manufacturer may elect to retest each end of each individual length if any test fails. The retests for each end of each individual length shall be made with the weld alternately at 0° and 90°.

c. Cold-expanded electric welded pipe in grades higher than A25; all welded Grade A25 in sizes $2^7/_8$ and larger; and cold-expanded laser welded pipe smaller than size $12^3/_4$—The manufacturer may elect to retest one end from each of two additional lengths of the same lot. If both retests are acceptable, all lengths in the lot shall be accepted, except the original failed length. If one or both retests fail, the manufacturer may elect to repeat the test on specimens cut from one end of each of the remaining individual lengths in the lot.

9.10.4 Bend Retest

If the specimen fails to conform to the specified requirements, the manufacturer may elect to make retests on specimens cut from two additional lengths from the same lot. If all retest specimens conform to the specified requirements, all lengths in the lot shall be accepted, except the length from which the initial specimen was taken. If one or more of the retest specimens fail to conform to the specified requirements, the manufacturer may elect to repeat the test on specimens cut from the individual lengths remaining in the lot.

9.10.5 Guided-Bend Retest

If one or both of the guided-bend specimens fail to conform to the specified requirements, the manufacturer may elect to repeat the tests on specimens cut from two additional lengths of pipe from the same lot. If such specimens conform to the specified requirements, all lengths in the lot shall be accepted, except the length initially selected for test. If any of the retested specimens fail to pass the specified requirements, the manufacturer may elect to test specimens cut from the individual lengths remaining in the lot. The manufacturer may also elect to retest any length that has failed to pass the test by cropping back and cutting two additional specimens from the same end. If the requirements of the original test are met by both of these additional tests, that length shall be acceptable. No further cropping and retesting is permitted. Specimens for retests shall be taken in the same manner as specified in 9.8.3.

9.10.6 Weld Ductility Retest

If the weld ductility test specimen representing a lot of pipe fails to conform to the requirements of 6.2.5, the manufacturer may elect to retest two additional lengths from the same lot. If both retested specimens conform to the specified requirements, all the lengths in the lot shall be accepted, except the length from which the initial specimen was taken. If one or both of the retested specimens fail to conform to the specified requirements, the manufacturer may elect to test specimens cut from one end of the individual lengths remaining in the lot. Precaution shall be taken so that the specimens can be identified with the length of pipe from which they were cut. The manufacturer may also elect to retest any length that has failed to pass the above test procedure by cropping back and cutting two additional specimens from the same end. If the weld ductility test requirements are met by both of these additional tests, that length shall be acceptable. No further cropping and retesting is permitted.

9.10.7 Charpy Retests

In the event that a set of Charpy test specimens fails to meet the acceptance criteria, the manufacturer may elect to replace the lot of material involved or alternatively to test two more lengths from that lot. If both of the new tests meet the acceptance criteria, then all pipe in that heat, with the exception of the original selected length, shall be considered to meet the

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requirement. Failure of either of the two additional tests shall require testing of each length in the lot for acceptance.

9.11 REPROCESSING

If any mechanical property test result for a lot of pipe, as defined in 9.3, fails to conform to the applicable requirements, the manufacturer may elect to heat treat the lot of pipe in accordance with the requirements of 5.4, consider it a new lot, test it in accordance with all requirements of 6.2 and 9.3, SR5, and SR6 that are applicable to the order item, and proceed in accordance with the applicable requirements of this specification. After one reprocessing heat treatment, any additional reprocessing heat treatment shall be subject to agreement with the purchaser.

For non-heat treated pipe, any reprocessing heat treatment shall be subject to agreement with the purchaser. For heat treated pipe, any reprocessing with a different type of heat treatment (see 5.4) shall be subject to agreement with the purchaser.

10 Marking

10.1 GENERAL

Pipe and pipe couplings manufactured in conformance with this specification shall be marked by the manufacturer as specified herein (see note).

Note: Users of this specification should note that there is no longer a requirement for marking a product with the API monogram. API continues to license use of the monogram on products covered by this specification, but it is administered by the staff of the Institute separately from the specification. The policy describing use of the monogram is contained in Appendix I. No other use of the monogram is permitted. Licensees mark products in conformance with Section 10 or Appendix I and nonlicensees mark products in conformance with Section 10.

10.1.1 The required marking on pipe shall be as specified hereinafter.

10.1.2 The required marking on couplings shall be die stamped unless otherwise agreed between the purchaser and the manufacturer, in which case it shall be paint stenciled.

10.1.3 Additional markings including those for compatible standards following the specification marking are allowed and may be applied as desired by the manufacturer or as requested by the purchaser.

10.2 LOCATION OF MARKINGS

The location of identification markings shall be as follows:

a. Size 1.900 or smaller—Die stamped on a metal tag fixed to the bundle or may be printed on the straps or banding clips used to tie the bundle.

b. Seamless pipe in all other sizes and welded pipe smaller than size 16—Paint stencil on the outside surface starting at a point between 18 in. and 30 in. (457.2 mm and 762 mm) from the end of the pipe in the sequence shown in 10.3, except when agreed between the purchaser and the manufacturer some or all of the markings may be placed on the inside surface in a sequence convenient to the manufacturer.

c. Welded pipe size 16 and larger—Paint stencil on the inside surface starting at a point no less than 6 in. (152.4 mm) from the end of the pipe in a sequence convenient to the manufacturer, unless otherwise specified by the purchaser.

10.3 SEQUENCE OF MARKINGS

The sequence of identification markings shall be as specified in 10.3.1 through 10.3.10.

10.3.1 Manufacturer

Manufacturer's name or mark shall be the first identifying mark.

10.3.2 Specification

"Spec 5L" shall be marked when the product is in complete compliance with this specification.

10.3.3 Compatible Standards

Products in compliance with multiple compatible standards may be marked with the name of each standard.

10.3.4 Specified Dimensions

The specified outside diameter and the specified wall thickness shall be marked, except that, for the specified outside diameter, any ending zero digits to the right of the decimal need not be included in such markings.

10.3.5 Grade and Class

The symbols to be used are as follows:

Grade (see Note)	Symbol
A25, Class I	A25
A25, Class II	A25R
A	A
B	B
X42	X42
X46	X46
X52	X52
X56	X56
X60	X60
X65	X65
X70	X70
X80	X80

For grades intermediate to X42 and X80, the symbol shall be X followed by the first two digits of the specified minimum yield strength in U.S. Customary units.

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By agreement between the purchaser and the manufacturer and when so specified on the purchase order, the grade shall be identified by color in accordance with SR3 (see Appendix F).

Note: See 1.3 for limitations on downgrading.

10.3.6 Product Specification Level

The symbols to be used are as follows:

a. PSL 1	PSL1
b. PSL 2	PSL2

The PSL marking shall be placed immediately after the grade symbol.

10.3.7 Process of Manufacture

The symbols to be used are as follows:

a. Seamless pipe	S
b. Welded pipe, except continuous welded and laser welded	E
c. Continuous welded pipe	F
d. Laser welded pipe	L

10.3.8 Heat Treatment

The symbols to be used are as follows:

a. Normalized or normalized and tempered	HN
b. Subcritical stress relieved	HS
c. Subcritical age hardened	HA
d. Quench and tempered	HQ

10.3.9 Test Pressure

When the specified hydrostatic test pressure is higher than the tabulated pressure (Tables 4, 5, 6A, 6B, 6C, E-6A, E-6B, or E-6C, whichever is applicable), the word "TESTED" shall be marked, immediately followed by the specified test pressure (in pounds per square inch for pipe ordered in U.S. Customary units, or in hundreds of kilopascals for pipe ordered in SI units).

10.3.10 Supplementary Requirements

See Appendix F for supplementary requirements.

10.3.11 Examples

a. Size 14, 0.375 in. (9.5 mm) specified wall thickness, Grade B, PSL 2, seamless, plain-end pipe should be paint stenciled as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

AB CO Spec 5L 14 0.375 B PSL2 S
or
AB CO Spec 5L 355.6 9.5 B PSL2 S

b. Size $6^5/_8$, 0.280 in. (7.1 mm) specified wall thickness, Grade B, PSL 1, electric welded, plain-end pipe should be paint stenciled as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

AB CO Spec 5L 6.625 0.280 B PSL1 E
or
AB CO Spec 5L 168.3 7.1 B PSL1 E

c. Size $4^1/_2$, 0.237 in. (6.0 mm) specified wall thickness, Grade A25, Class I, continuous welded, threaded-end pipe should be paint stenciled as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

AB CO Spec 5L 4.5 0.237 A25 PSL1 F
or
AB CO Spec 5L 114.3 6.0 A25 PSL1 F

d. Size 14, 0.375 in. (9.5 mm) specified wall thickness, Grade X70, PSL 2, seamless, quenched and tempered, plain-end pipe should be paint stenciled as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

AB CO Spec 5L 14 0.375 X70 PSL2 S HQ
or
AB CO Spec 5L 355.6 9.5 X70 PSL2 S HQ

e. Size $12^3/_4$, 0.330 in. (8.4 mm) specified wall thickness, Grade X42, PSL 1, seamless plain-end pipe should be paint stenciled as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

AB CO Spec 5L 12.75 0.330 X42 PSL1 S
or
AB CO Spec 5L 323.9 8.4 X42 PSL1 S

f. Size $6^5/_8$, 0.216 in. (5.5 mm) specified wall thickness, Grade X42, PSL 1, laser welded, plain-end pipe should be paint stenciled as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

AB CO Spec 5L 6.625 0.216 X42 PSL1 L
or
AB CO Spec 5L 168.3 5.5 X42 PSL1 L

g. Size 24, 0.406 in. (10.3 mm) specified wall thickness, Grade X42, PSL 2 helical seam submerged-arc welded plain-end pipe should be paint stenciled as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

AB CO Spec 5L 24 0.406 X42 PSL2 E
or
AB CO Spec 5L 610 10.3 X42 PSL2 E

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10.4 BUNDLE IDENTIFICATION

For pipe of size 1.900 or smaller, the identification markings specified in 10.3 shall be placed on the tag, strap, or clip used to tie the bundle. For example, size 1.900, 0.145 in. (3.7 mm) specified wall thickness, Grade B, electric welded, plain-end pipe should have the following marking, using the values that are appropriate for the pipe dimensions specified on the purchase order:

AB CO Spec 5L 1.9 0.145 B PSL1 E
or
AB CO Spec 5L 48.3 3.7 B PSL1 E

10.5 LENGTH

In addition to the identification markings stipulated in 10.2, 10.3, and 10.4, the length shall be marked as follows, using feet and tenths of a foot for pipe ordered in U.S. Customary units, or meters to two decimal places for pipe ordered in SI units, unless a different measuring and marking format has been agreed upon by the purchaser and the manufacturer:

a. For pipe larger than size 1.900, the length, as measured on the finished pipe, shall be paint stenciled on the outside surface at a location convenient to the manufacturer, or by agreement between the purchaser and the manufacturer, on the inside surface at a convenient location.
b. For pipe of size 1.900 or smaller, the total length of pipe in the bundle shall be marked on the tag, band, or clip.

10.6 COUPLINGS

All couplings in sizes $2^3/_8$ and larger shall be identified with the manufacturer's name or mark and "Spec 5L".

10.7 DIE STAMPING

Cold die stamping is prohibited on all pipe with specified wall thickness of 0.156 in. (4.0 mm) or less and all pipe of grades higher than A25 and not subsequently heat treated, except by agreement between the purchaser and the manufacturer and when so specified on the purchase order, pipe or plate may be cold die stamped. The manufacturer at his option may hot die stamp [200°F (93°C) or higher] plate or pipe, cold die stamp plate or pipe if it is subsequently heat treated, and cold die stamp couplings. Cold die stamping shall be done with rounded or blunt dies. All die stamping shall be at least 1 in. (25.4 mm) from the weld for all grades except Grade A25.

10.8 THREAD IDENTIFICATION

At the manufacturer's option, threaded-end pipe may be identified by stamping or stenciling the pipe adjacent to the threaded ends, with the manufacturer's name or mark, "Spec 5B" (to indicate the applicable threading specification), the specified outside diameter of the pipe, and the letters "LP" (to indicate the type of thread). The thread marking may be applied to products that do or do not bear the API monogram. For example, size $6^5/_8$ threaded-end pipe may be marked as follows, using the value that is appropriate for the pipe outside diameter specified on the purchase order:

AB CO Spec 5B 6.625 LP
or
AB CO Spec 5B 168.3 LP

If the product is clearly marked elsewhere with the manufacturer's identification, his name or mark, as above, may be omitted.

10.9 THREAD CERTIFICATION

The use of the letters "Spec 5B" as provided in 10.8 shall constitute a certification by the manufacturer that the threads so marked comply with the requirements in API Standard 5B but should not be construed by the purchaser as a representation that the product so marked is, in its entirety, in accordance with any API specification. Manufacturers who use the letters "Spec 5B" for thread identification are required to have access to properly certified API master pipe gages.

10.10 PIPE PROCESSOR MARKINGS

Pipe heat treated by a processor other than the original pipe manufacturer shall be marked as stipulated in 10.1, 10.2, 10.3, 10.4, 10.5, 10.6, and 10.7. The processor shall remove any marking that does not indicate the new condition of the product as a result of heat treating (such as prior grade identity and original pipe manufacturer's name or logo).

11 Coating and Protection

11.1 COATINGS

Unless otherwise specified in the purchase order, pipe shall be supplied either uncoated (bare) or with a temporary external coating to minimize rusting in transit, at the option of the manufacturer. Temporary coatings should be hard to the touch and smooth, with minimum sags.

If the purchaser requires pipe to be uncoated, or to have a temporary or special coating, the purchase order should so state.

For special coatings, the purchase order should state whether the coating is to be applied full length, or with a specified cutback (uncoated distance at each pipe end). Unless otherwise specified, the manufacturer has the option to leave the pipe ends either coated or uncoated, and the option to apply a temporary coating to the pipe ends.

11.2 THREAD PROTECTORS

On pipe smaller than size $2^3/_8$, the thread protectors shall be suitable fabric wrappings or suitable metal, fiber, or plastic protectors. On pipe of sizes $2^3/_8$ and larger, the thread protectors shall be of such design, material, and mechanical strength to protect the thread and end of the pipe from damage under normal handling and transportation conditions. The thread protectors shall cover the full length of the thread on the pipe and

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exclude water and dirt from the thread during transportation and the period of normal storage. The normal storage period shall be considered approximately one year. The thread forms in protectors shall be such that the pipe threads are not damaged by the protectors. Protector material shall contain no compounds capable of causing corrosion or promoting adherence of the protectors to the threads and shall be suitable for service temperatures of – 50°F to + 150°F (– 46°C to + 66°C).

12 Documents

12.1 CERTIFICATION

12.1.1 PSL 1 Certification Requirements

The manufacturer shall, upon request by the purchaser, furnish to the purchaser a certificate of compliance stating that the material has been manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements.

A Material Test Report, Certificate of Compliance or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of this specification and conform to any existing EDI agreement between the purchaser and supplier.

Where additional information is required, including the results of mechanical testing, SR15 shall be specified on the purchase order (see Appendix F).

12.1.2 PSL 2 Certification Requirements

The manufacturer shall provide to the purchaser certificates of compliance and test results in compliance with SR15.1 (see Appendix F).

12.2 RETENTION OF RECORDS

Tests and inspections requiring retention of records in this specification are shown in Table 22. Such records shall be retained by the manufacturer and shall be made available to the purchaser upon request for a 3-year period after the date of purchase from the manufacturer.

13 Pipe Loading

When the manufacturer is responsible for the shipment of pipe, the manufacturer shall prepare and follow loading diagrams which detail how the pipe is arranged, protected, and secured on trucks, railcars, barges or oceangoing vessels, as applicable. The loading shall be designed to prevent end damage, abrasion, peening, and fatigue cracking. The loading shall comply with any rules, codes, standards, or recommended practices which are applicable. Examples of these may include but are not limited to:

American Association of Railroads—*General Rules Governing the Loading of Commodities on Open Top Cars*

American Association of American Railroads—*Rules Governing the Loading of Steel Products Including Pipe on Open Top Cars*

API RP 5L1—*Recommended Practice for Railroad Transportation of Line Pipe*

API RP 5LW—*Recommended Practice for Transportation of Line Pipe on Barges and Marine Vessels*

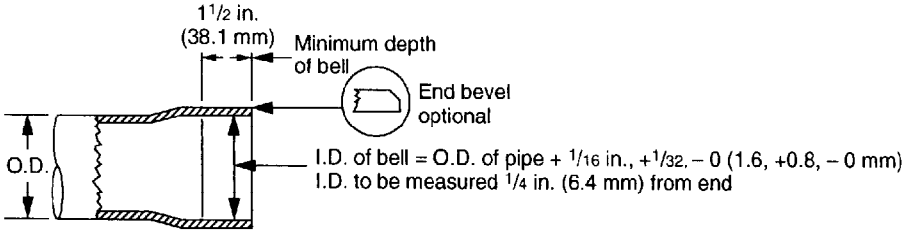
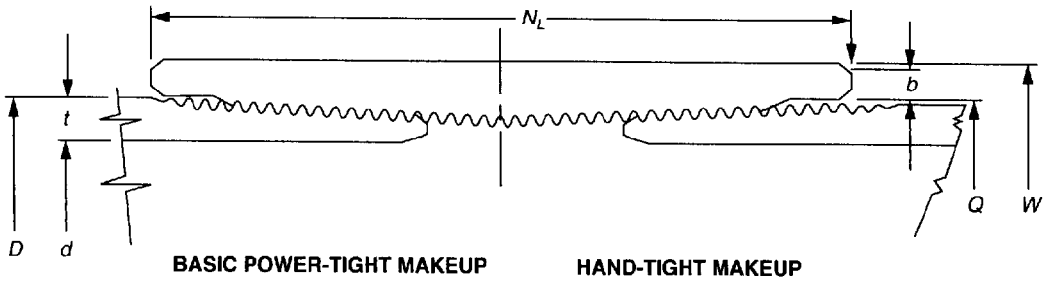


Figure 1—Belled End for Bell and Spigot Joint



Note: See Tables 4 and 5 for pipe dimensions, Table 12 for coupling dimensions, and API Standard 5B for thread details.

Figure 2—Line Pipe and Coupling

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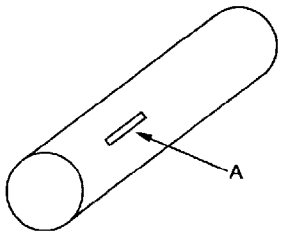
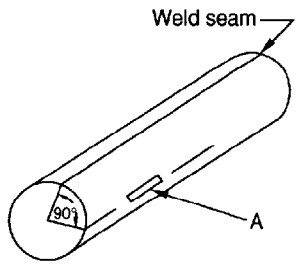
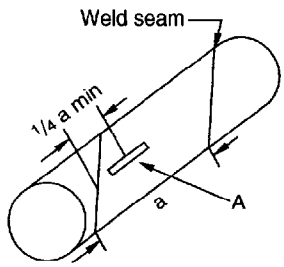
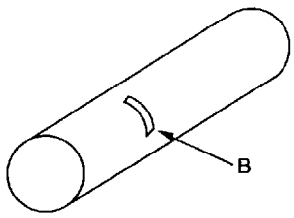
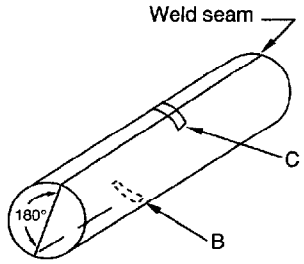
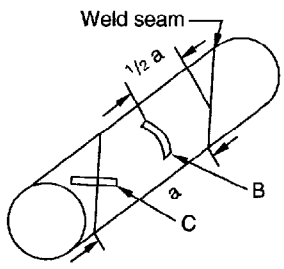
SIZE	SEAMLESS PIPE	WELDED PIPE	
		Longitudinal Seam	Helical Seam
< 8⅝			
≥ 8⅝			

Notes:
A = Strip specimen (any circumferential location for seamless).
B = Transverse specimen (any circumferential location for seamless). For double seam pipe, the specimen shall be taken from a location midway between the welds.
C = Transverse weld specimen.

Figure 3—Orientation of Tensile Test Specimens

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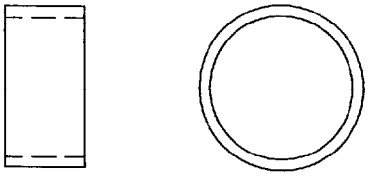
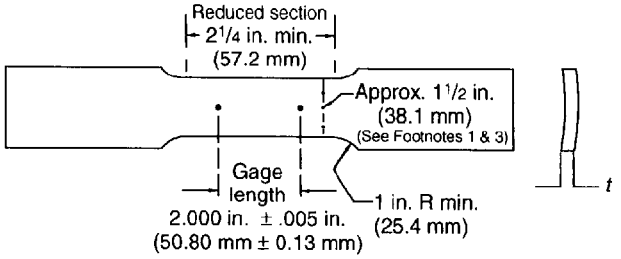
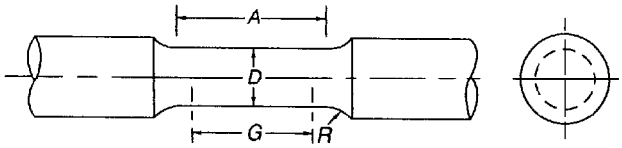


A – Ring Expansion Specimen

B – Full Section Specimen



C – Strip Specimen

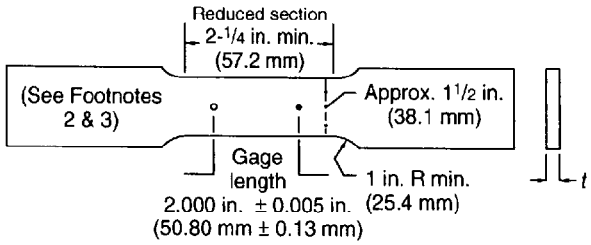


		in.	mm
G	Gage length	2.000 ± 0.005	50.8 ± 0.13
D	Diameter	0.500 ± 0.010	12.7 ± 0.25
R	Radius of fillet, min.	3/8	10
A	Length of reduced section, min.	2¼	60

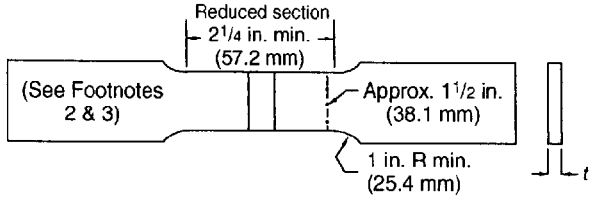
D – Round Bar Specimen

For pipe with wall thickness of 0.750 in. (19.1 mm) or greater

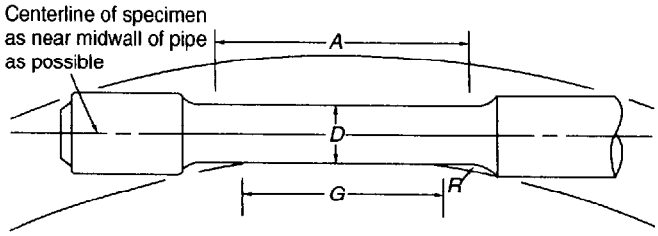
LONGITUDINAL SPECIMENS



E – Strip Specimen, Base Metal



F – Strip Specimen, Weld



		0.500-in. (12.7 mm) Specimen		0.350-in. (8.9 mm) Specimen	
		in.	mm	in.	mm
G	Gage length	2.000 ± 0.005	50.8 ± 0.13	1.400 ± 0.005	35.6 ± 0.13
D	Diameter	0.500 ± 0.010	12.7 ± 0.25	0.350 ± 0.007	8.9 ± 0.18
R	Radius of fillet, min.	3/8	10	1/4	6
A	Length of reduced Section, min.	2¼	60	1¾	45

G – Round Bar Specimen

The larger possible of either the 0.500-in. (12.7 mm) or 0.350-in. (8.9 mm) diameter specimen shall be used.

TRANSVERSE SPECIMENS

Notes:
1. See 9.3.1.1 for alternative gage width.
2. Flattening of transverse and weld specimens shall be performed at room temperature.
3. Hot flattening, artificial aging, or heat treatment of tensile specimens is not permitted.

Figure 4—Tensile Test Specimens

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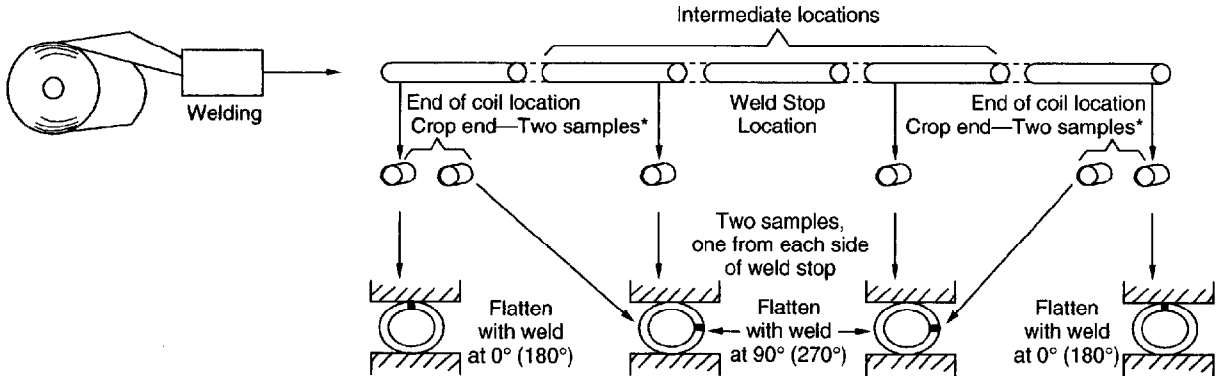
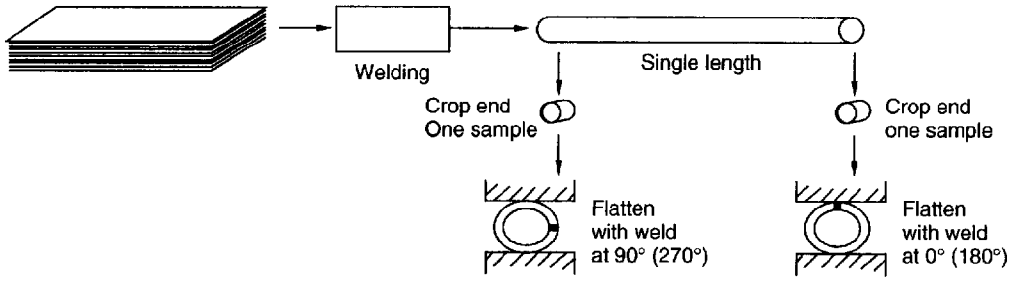
ELECTRIC WELDED PIPE GRADES HIGHER THAN A25 AND LASER WELDED PIPE SMALLER THAN SIZE 12 3/4—NONEXPANDED IN MULTIPLE LENGTHS

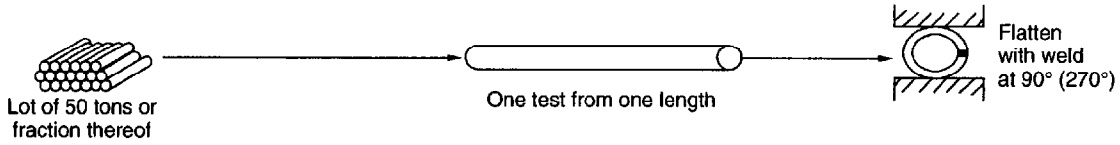


*For 0° (180°) orientation tests, intermediate locations may be substituted for coil end locations.

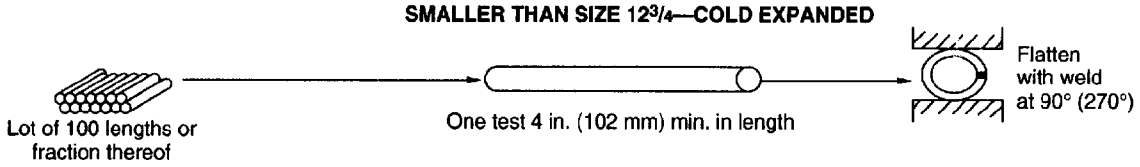
ELECTRIC WELDED PIPE IN GRADES HIGHER THAN A25—NONEXPANDED PRODUCED IN SINGLE LENGTHS



GRADE A25 WELDED PIPE SIZE 2 7/8 AND LARGER

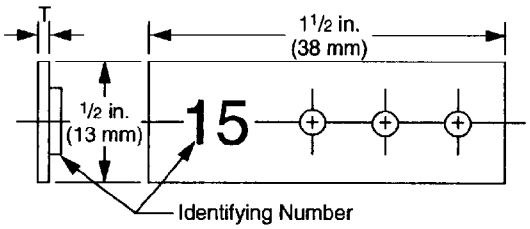


ELECTRIC WELDED PIPE IN GRADES HIGHER THAN A25 AND LASER WELDED PIPE SMALLER THAN SIZE 12 3/4—COLD EXPANDED



Note: See 9.3.2

Figure 5—Flattening Tests



Notes:
1. The diameter of each hole shall be 1/16 in. (1.6 mm).
2. Holes shall be round and drilled perpendicular to the surface.
3. Holes shall be free of burrs, but edges shall not be chamfered.
4. Each penetrameter shall carry a lead identification number as given in Tables 14 and 15.

Figure 6—API Standard Penetrameter

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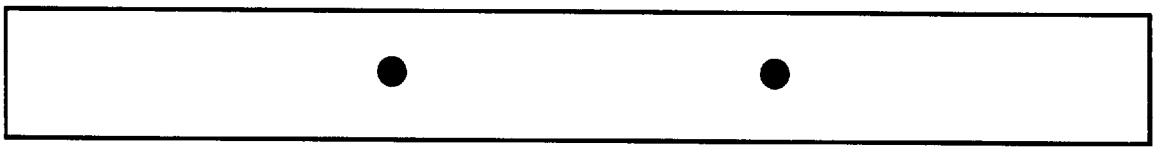
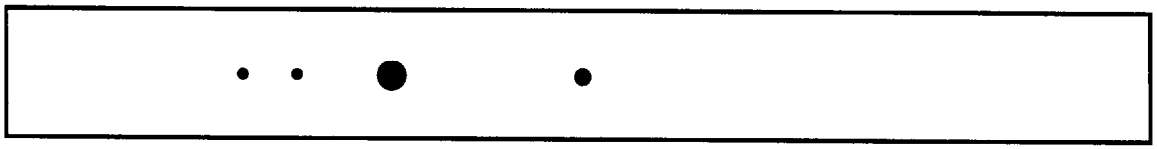
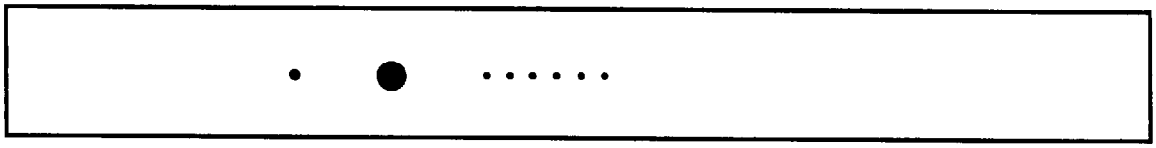


Example 1: Two 1/8 in. (3.2 mm) discontinuities

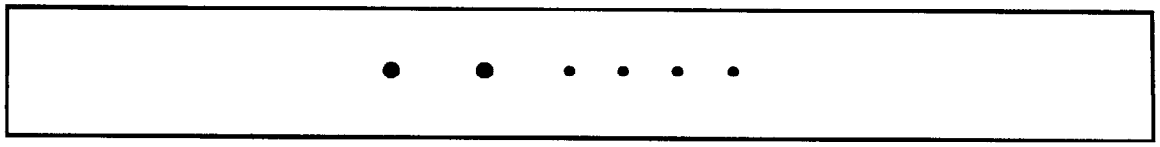


Example 2: One 1/8 in. (3.2 mm), one 1/16 in. (1.6 mm), two 1/32 in. (0.8 mm) discontinuities

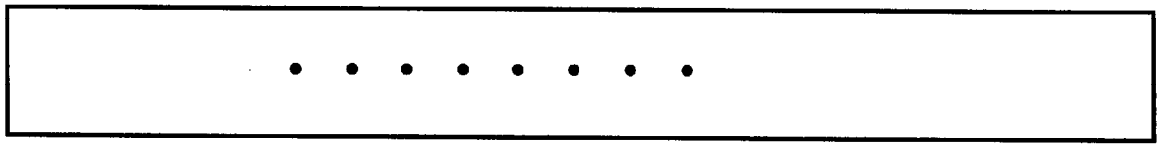


Example 3: One 1/8 in. (3.2 mm), one 1/32 in. (0.8 mm), six 1/64 in. (0.4 mm) discontinuities

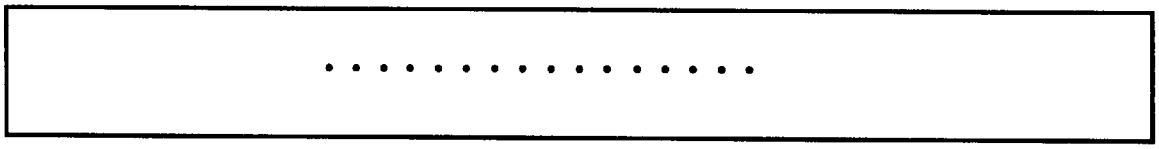
Example 4: Four 1/16 in. (1.6 mm) discontinuities



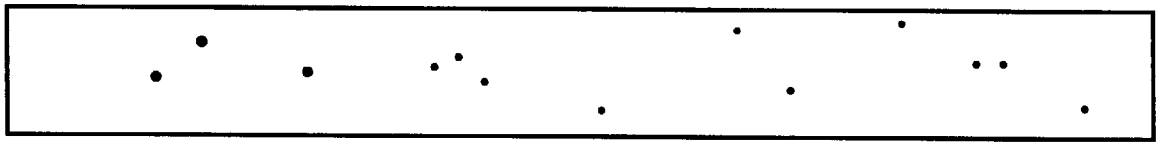
Example 5: Two 1/16 in. (1.6 mm), four 1/32 in. (0.8 mm) discontinuities



Example 6: Eight 1/32 in. (0.8 mm) discontinuities



Example 7: Sixteen 1/64 in. (0.4 mm) discontinuities



Example 8: Scattered, Three 1/32 in. (0.8 mm), ten 1/64 in. (0.4 mm) discontinuities

Figure 7—Examples of Maximum Distribution Patterns of Indicated Circular Slag-Inclusion and Gas-Pocket-Type Discontinuities

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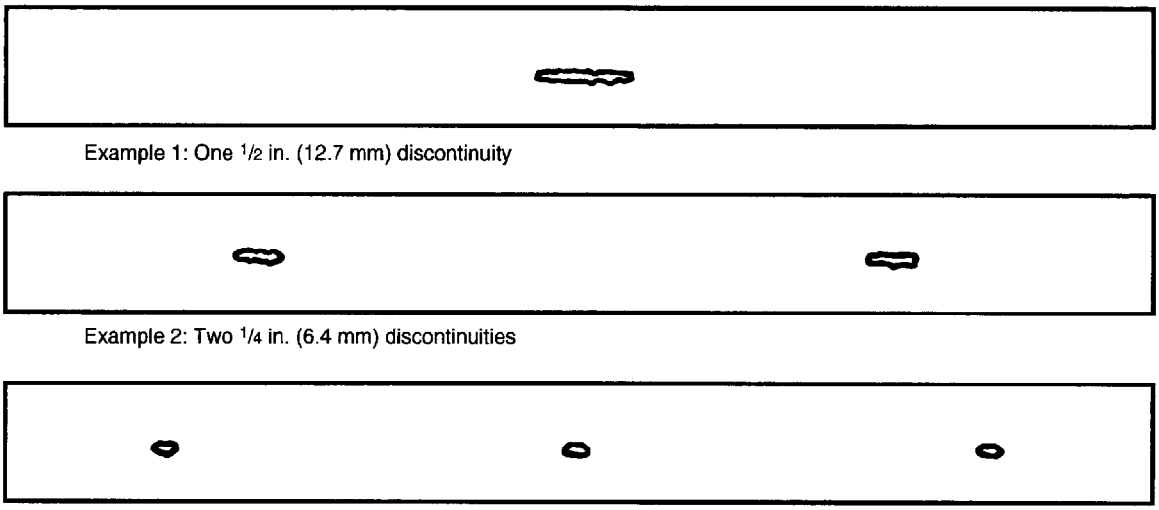

Example 1: One 1/2 in. (12.7 mm) discontinuity

Example 2: Two 1/4 in. (6.4 mm) discontinuities

Example 3: Three 1/8 in. (3.2 mm) discontinuities

Figure 8—Examples of Maximum Distribution Patterns of Indicated Elongated Slag-Inclusion-Type Discontinuities

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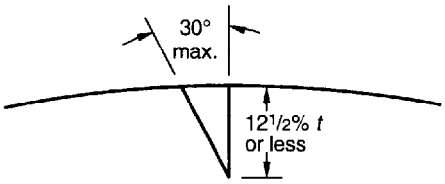
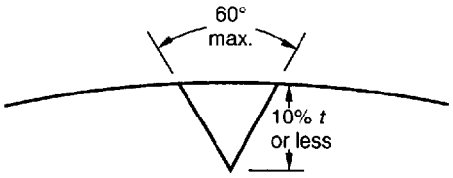
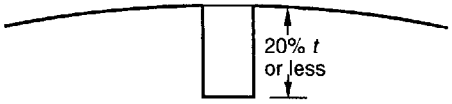


B (BUTTRESS) NOTCH

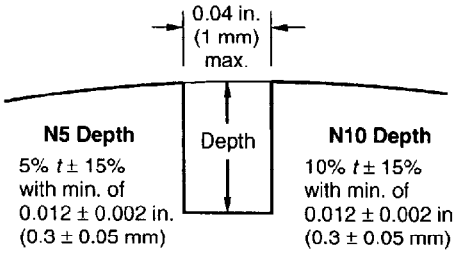


V10 NOTCH



Area of each side, 0.006 sq. in. (3.87 mm²) max.

P (PARALLEL SIDED) NOTCH

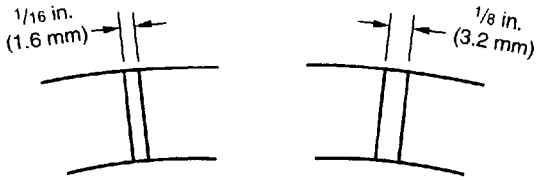


Length

For Eddy Current – 1.5 in. (38 mm) max. total length

For Diverted Flux
and Ultrasonic – 2 in. (50 mm) max. at full depth

N5 AND N10 NOTCH



DRILLED HOLE

Note: See 9.7.4.2.

Figure 9—Reference Standards

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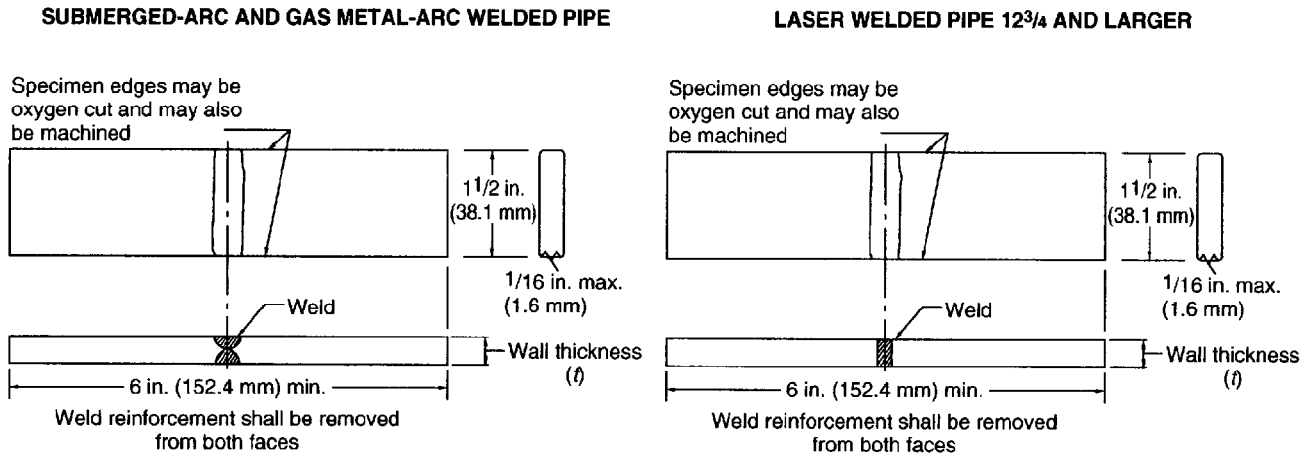

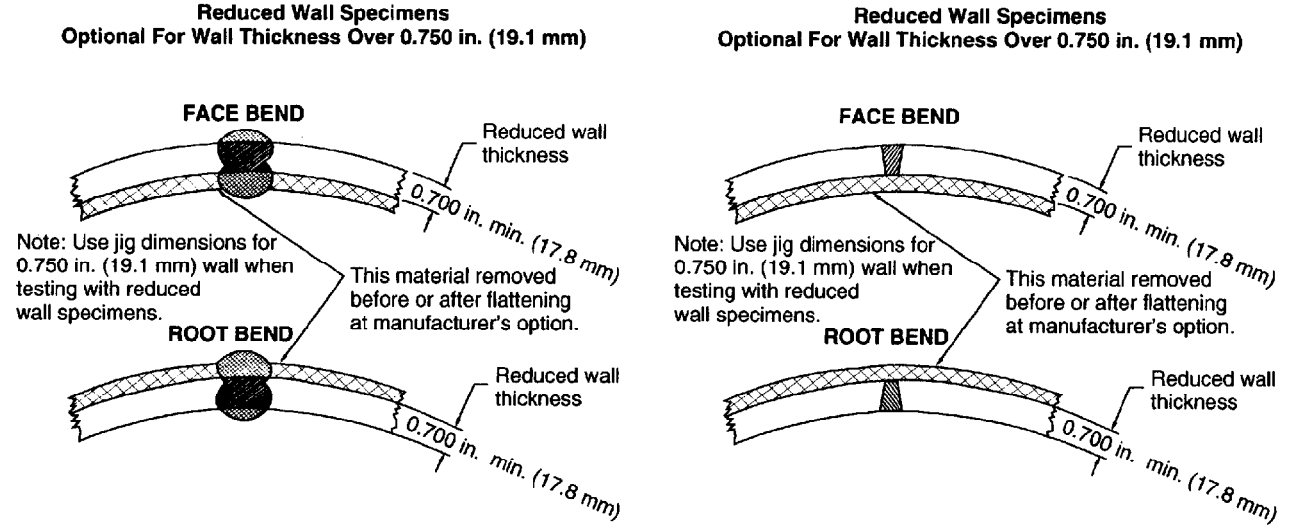

See 9.8.3.

Figure 10—Guided-Bend Test Specimen

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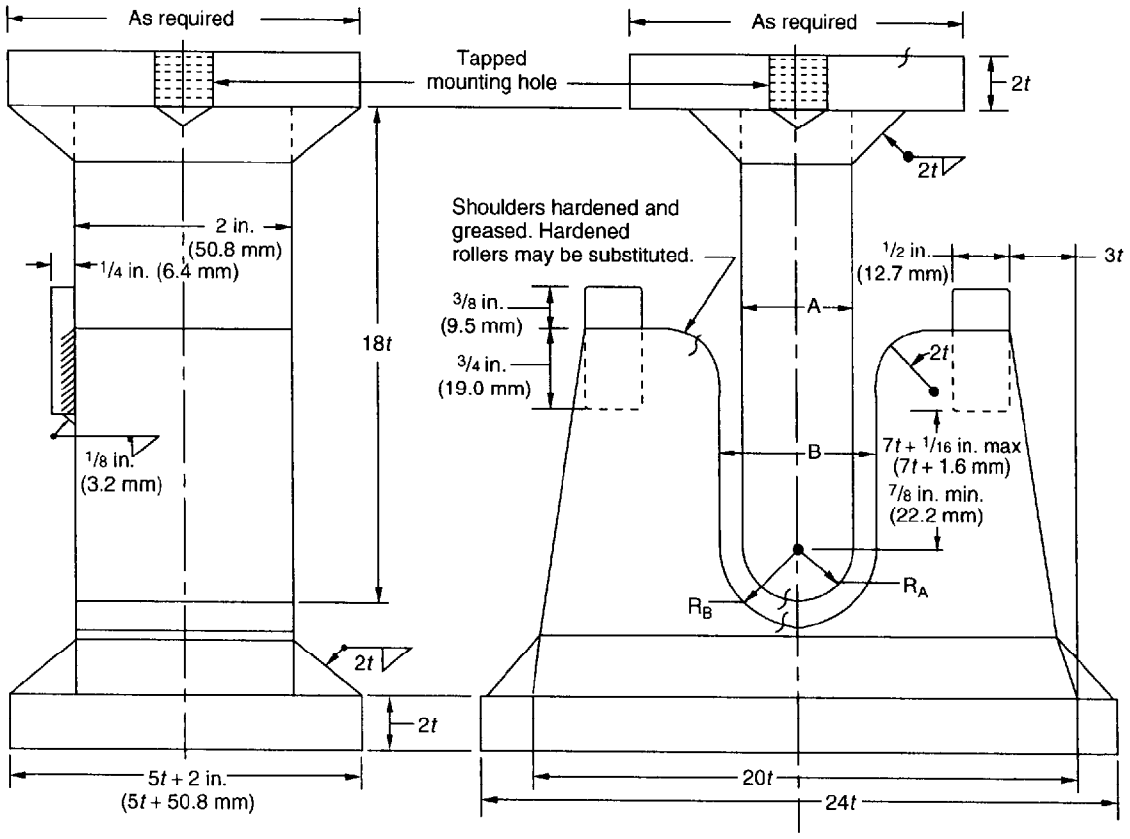


$$A = \frac{1.15\,(D - 2t)}{(e\,\frac{D}{t} - 2e - 1)} - t$$

where

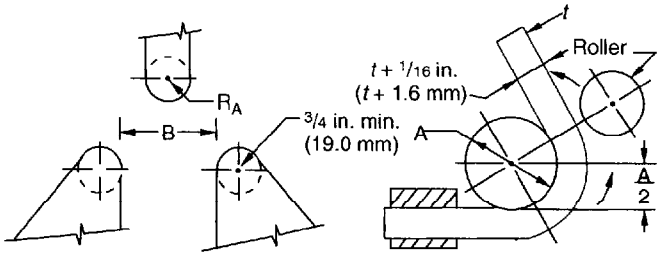
1.15 = Peaking factor,
D = Specified OD, in. (mm),
t = Specified wall thickness of pipe,
e = Strain.

	in./in. (mm/mm)
for Grade A =	0.1675
for Grade B =	0.1375
for Grade X42 =	0.1375
for Grade X46 =	0.1325
for Grade X52 =	0.1250
for Grade X56 =	0.1175
for Grade X60 =	0.1125
for Grade X65 =	0.1100
for Grade X70 =	0.1025
for Grade X80 =	0.0900

R_A = 1/2 A
B (in.) = $A + 2t + 0.125$ in.
B (mm) = $A + 2t + 3.2$ mm
R_B = 1/2 B

Note: See 9.8.3

Alternate Jigs



Adjustable Type **Wrap-Around Type**

Figure 11—Jig for Guided-Bend Test

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Table 1—Process of Manufacture and Product Specification Level (PSL)

	PSL 1[a]			PSL 2[b]
	Grade			Grade
Process of Manufacture	A25[c]	A & B	X42 through X70	B through X80
Type of Pipe				
Seamless	X	X	X	X
Welded without Filler Metal				
Continuous welded[c]	X			
Electric welded	X	X	X	X
Laser welded	X	X	X	
Welded with Filler Metal				
Longitudinal seam submerged-arc welded		X	X	X
Gas metal-arc welded		X	X	X
Combination gas metal-arc welded		X	X	X
Double seam submerged-arc welded[d]		X	X	X
Double seam gas metal-arc welded[d]		X	X	X
Double seam combination gas metal-arc welded and submerged-arc welded[d]		X	X	X
Helical seam submerged-arc welded[e]		X	X	X
Type of Pipe End				
Belled End[f]	X	X	X	
Plain End	X	X	X	X
Plain End for Special Coupling	X	X	X	
Threaded End[g]	X	X		

[a]PSL 1 is limited to sizes from 0.405 through 80.

[b]PSL 2 is limited to sizes from $4^1/_2$ through 80.

[c]Grade A25, and thus continuous welded pipe (which is limited to A25), is limited to sizes $5^9/_{16}$ and smaller.

[d]Double seam pipe is limited to sizes 36 and larger.

[e]Helical seam pipe is limited to sizes $4^1/_2$ and larger.

[f]Belled end pipe is limited to wall thicknesses of 0.141 in. (3.6 mm) and less; sizes are limited to $8^5/_8$ and smaller.

[g]Threaded pipe and couplings are limited to sizes 20 and smaller; helical seam pipe is excluded.

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Table 2A—PSL 1 Chemical Requirements for Heat and Product Analyses by Percentage of Weight

(1)	(2)	(3)	(4)		(5)	(6)
Grade & Class	Carbon, Maximum[a]	Manganese, Maximum[a]	Phosphorus Minimum	Phosphorus Maximum	Sulfur, Maximum	Other
			Seamless			
A25, Cl I	0.21	0.60		0.030	0.030	
A25, Cl II	0.21	0.60	0.045	0.080	0.030	
A	0.22	0.90		0.030	0.030	
B	0.28	1.20		0.030	0.030	b, d
X42	0.28	1.30		0.030	0.030	c, d
X46, X52, X56	0.28	1.40		0.030	0.030	c, d
X60[e], X65[e], X70[e]	0.28	1.40		0.030	0.030	c, d
			Welded			
A25, Cl I	0.21	0.60		0.030	0.030	
A25, Cl II	0.21	0.60	0.045	0.080	0.030	
A	0.22	0.90		0.030	0.030	
B	0.26	1.20		0.030	0.030	b, d
X42	0.26	1.30		0.030	0.030	c, d
X46, X52, X56	0.26	1.40		0.030	0.030	c, d
X60[e]	0.26	1.40		0.030	0.030	c, d
X65[e]	0.26	1.45		0.030	0.030	c, d
X70[e]	0.26	1.65		0.030	0.030	c, d

Table 2B—PSL 2 Chemical Requirements for Heat and Product Analyses by Percentage of Weight

(1)	(2)	(3)	(4)	(5)	(6)
Grade	Carbon, Maximum[a]	Manganese, Maximum[a]	Phosphorus, Maximum	Sulfur, Maximum	Other
		Seamless			
B	0.24	1.20	0.025	0.015	b, d
X42	0.24	1.30	0.025	0.015	c, d
X46, X52, X56	0.24	1.40	0.025	0.015	c, d
X60[e], X65[e], X70[e], X80[e]	0.24	1.40	0.025	0.015	c, d
		Welded			
B	0.22	1.20	0.025	0.015	b, d
X42	0.22	1.30	0.025	0.015	c, d
X46, X52, X56	0.22	1.40	0.025	0.015	c, d
X60[e]	0.22	1.40	0.025	0.015	c, d
X65[e]	0.22	1.45	0.025	0.015	c, d
X70[e]	0.22	1.65	0.025	0.015	c, d
X80[e]	0.22	1.85	0.025	0.015	c, d

Footnotes to Tables 2A and 2B:

[a]For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.05% above the specified maximum manganese content is permissible, up to a maximum of 1.50% for Grades X42 through X52, up to a maximum of 1.65% for grades higher than X52 but less than X70, and up to 2.00% for Grades X70 and higher.

[b]Columbium [niobium], vanadium, titanium, or combinations thereof may be used by agreement between the purchaser and manufacturer.

[c]Columbium [niobium], vanadium, titanium, or combinations thereof may be used at the discretion of the manufacturer.

[d]The sum of the columbium [niobium], vanadium, and titanium contents shall not exceed 0.15%.

[e]Other chemical compositions may be furnished by agreement between purchaser and manufacturer, providing that the limits of Footnote d, and the tabular limits for phosphorus and sulfur are met.

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Table 3A—Tensile Requirements for PSL 1

(1)	(2)		(3)		(4)
	Yield Strength, Minimum		Ultimate Tensile Strength, Minimum		Elongation in 2 in. (50.8 mm), Minimum, Percent
Grade	psi	MPa	psi	MPa	
A25	25,000	(172)	45,000	(310)	a
A	30,000	(207)	48,000	(331)	a
B	35,000	(241)	60,000	(414)	a
X42	42,000	(290)	60,000	(414)	a
X46	46,000	(317)	63,000	(434)	a
X52	52,000	(359)	66,000	(455)	a
X56	56,000	(386)	71,000	(490)	a
X60	60,000	(414)	75,000	(517)	a
X65	65,000	(448)	77,000	(531)	a
X70	70,000	(483)	82,000	(565)	a

Table 3B—Tensile Requirements for PSL 2

(1)	(2)		(3)		(4)		(5)		(6)
	Yield Strength, Minimum		Yield Strength, Maximum[b]		Ultimate Tensile Strength, Minimum		Ultimate Tensile Strength, Maximum[c]		Elongation in 2 in. (50.8 mm), Minimum, Percent
Grade	psi	MPa	psi	MPa	psi	MPa	psi	MPa	
B	35,000	(241)	65,000[d]	(448)	60,000	(414)	110,000	(758)	a
X42	42,000	(290)	72,000	(496)	60,000	(414)	110,000	(758)	a
X46	46,000	(317)	76,000	(524)	63,000	(434)	110,000	(758)	a
X52	52,000	(359)	77,000	(531)	66,000	(455)	110,000	(758)	a
X56	56,000	(386)	79,000	(544)	71,000	(490)	110,000	(758)	a
X60	60,000	(414)	82,000	(565)	75,000	(517)	110,000	(758)	a
X65	65,000	(448)	87,000	(600)	77,000	(531)	110,000	(758)	a
X70	70,000	(483)	90,000	(621)	82,000	(565)	110,000	(758)	a
X80	80,000	(552)	100,000[e]	(690)	90,000	(621)	120,000	(827)	a

Footnotes to Tables 3A and 3B:

[a]The minimum elongation in 2 in. (50.8 mm) shall be that determined by the following equation:

U.S. Customary Unit Equation

$$e = 625{,}000\frac{A^{0.2}}{U^{0.9}}$$

SI Unit Equation

$$e = 1{,}944\frac{A^{0.2}}{U^{0.9}}$$

where

e = minimum elongation in 2 in. (50.8 mm) in percent rounded to the nearest percent.

A = applicable tensile test specimen area, as follows:

a. For both sizes of round bar specimens, 0.20 in.^{2} (130 mm^2);

b. For full section specimens, the smaller of (i) 0.75 in.^{2} (485 mm^2) and (ii) the cross-sectional area of the test specimen, calculated using the specified outside diameter of the pipe and the specified wall thickness of the pipe, rounded to the nearest 0.01 in.^{2} (10 mm^2); and

c. For strip specimens, the smaller of (i) 0.75 in.^{2} (485 mm^2) and (ii) the cross-sectional area of the test specimen, calculated using the specified width of the test specimen and the specified wall thickness of the pipe, rounded to the nearest 0.01 in.^{2} (10 mm^2).

U = specified minimum ultimate tensile strength in psi (MPa).

See Appendix D for the specified minimum elongation values for various tensile specimen sizes and grades.

[b]Maximum yield strength for an intermediate grade shall be the maximum for the next higher listed grade.

[c]All intermediate grades have a maximum ultimate tensile strength of 110,000 psi (758 MPa).

[d]Maximum yield strength for Grade B pipe in sizes subject to longitudinal testing is 72,000 psi (496 MPa).

[e]For wall thickness greater than 0.984 inch (25.0 mm), the maximum yield strength shall be determined by agreement between the purchaser and the manufacturer.

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Table 4—Standard-Wall Threaded Line Pipe Dimensions, Weights, and Test Pressures (U.S. Customary and SI Units)

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)	
					Calculated Weight											
	Specified Outside Diameter D		Specified Wall Thickness t		Plain-End Weight per Unit Length w_{pe}		Threads and Coupling[a] e_w		Calculated Inside Diameter[b] d		Minimum Test Pressure					
											Grade A25		Grade A		Grade B	
Size	in.	mm	in.	mm	lb/ft	kg/m	lb	kg	in.	mm	psi	100 kPa[c]	psi	100 kPa[c]	psi	100 kPa[c]
0.405	0.405	10.3	0.068	1.7	0.24	0.36	0.20	0.09	0.269	6.9	700	48	700	48	700	48
0.540	0.540	13.7	0.088	2.2	0.43	0.62	0.20	0.09	0.364	9.3	700	48	700	48	700	48
0.675	0.675	17.1	0.091	2.3	0.57	0.84	0.20	0.09	0.493	12.5	700	48	700	48	700	48
0.840	0.840	21.3	0.109	2.8	0.85	1.28	0.20	0.09	0.622	15.7	700	48	700	48	700	48
1.050	1.050	26.7	0.113	2.9	1.13	1.70	0.20	0.09	0.824	20.9	700	48	700	48	700	48
1.315	1.315	33.4	0.133	3.4	1.68	2.52	0.20	0.09	1.049	26.6	700	48	700	48	700	48
1.660	1.660	42.2	0.140	3.6	2.27	3.43	0.60	0.27	1.380	35.0	1000	69	1000	69	1100	76
1.900	1.900	48.3	0.145	3.7	2.72	4.07	0.40	0.18	1.610	40.9	1000	69	1000	69	1100	76
$2^3/_8$	2.375	60.3	0.154	3.9	3.66	5.42	1.20	0.54	2.067	52.5	1000	69	1000	69	1100	76
$2^7/_8$	2.875	73.0	0.203	5.2	5.80	8.69	1.80	0.82	2.469	62.6	1000	69	1000	69	1100	76
$3^1/_2$	3.500	88.9	0.216	5.5	7.58	11.31	1.80	0.82	3.068	77.9	1000	69	1000	69	1100	76
4	4.000	101.6	0.226	5.7	9.12	13.48	3.20	1.45	3.548	90.2	1200	83	1200	83	1300	90
$4^1/_2$	4.500	114.3	0.237	6.0	10.80	16.02	4.40	2.00	4.026	102.3	1200	83	1200	83	1300	90
$5^9/_{16}$	5.563	141.3	0.258	6.6	14.63	21.92	5.60	2.54	5.047	128.1	1200	83	1200	83	1300	90
$6^5/_8$	6.625	168.3	0.280	7.1	18.99	28.22	7.20	3.27	6.065	154.1	—	—	1200	83	1300	90
$8^5/_8$	8.625	219.1	0.277	7.0	24.72	36.61	14.80	6.72	8.071	205.1	—	—	1160	79	1350	92
$8^5/_8$	8.625	219.1	0.322	8.2	28.58	42.65	14.00	6.36	7.981	202.7	—	—	1340	93	1570	108
$10^3/_4$	10.750	273.1	0.279	7.1	31.23	46.57	20.00	9.08	10.192	258.9	—	—	930	65	1090	75
$10^3/_4$	10.750	273.1	0.307	7.8	34.27	51.03	19.20	8.72	10.136	257.5	—	—	1030	71	1200	83
$10^3/_4$	10.750	273.1	0.365	9.3	40.52	60.50	17.40	7.90	10.020	254.5	—	—	1220	85	1430	98
$12^3/_4$	12.750	323.9	0.330	8.4	43.81	65.35	32.60	14.80	12.090	307.1	—	—	930	64	1090	75
$12^3/_4$	12.750	323.9	0.375	9.5	49.61	73.65	30.80	13.98	12.000	304.9	—	—	1060	73	1240	85
14	14.000	355.6	0.375	9.5	54.62	81.08	24.60	11.17	13.250	336.6	—	—	960	66	1130	77
16	16.000	406.4	0.375	9.5	62.64	92.98	30.00	13.62	15.250	387.4	—	—	840	58	980	68
18	18.000	457.0	0.375	9.5	70.65	104.84	35.60	16.16	17.250	438.0	—	—	750	52	880	60
20	20.000	508.0	0.375	9.5	78.67	116.78	42.00	19.07	19.250	489.0	—	—	680	46	790	54

Note: See Figure 2.

[a]Weight gain due to end finishing. See 7.4.

[b]The calculated inside diameters are given here for information (see 7.2).

[c]100 kPa = 1 bar

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Table 5—Heavy-Wall Threaded Line Pipe Dimensions, Weights, and Test Pressures (U.S. Customary and SI Units)

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)	
					Calculated Weight						Minimum Test Pressure					
	Specified Outside Diameter D		Specified Wall Thickness t		Plain-End Weight per Unit Length w_{pe}		Threads and Coupling[a] e_w		Calculated Inside Diameter[b] d		Grade A25		Grade A		Grade B	
Size	in.	mm	in.	mm	lb/ft	kg/m	lb	kg	in.	mm	psi	100 kPa[c]	psi	100 kPa[c]	psi	100 kPa[c]
0.405	0.405	10.3	0.095	2.4	0.31	0.47	0.02	0.01	0.215	5.5	850	59	850	59	850	59
0.540	0.540	13.7	0.119	3.0	0.54	0.79	0.05	0.02	0.302	7.7	850	59	850	59	850	59
0.675	0.675	17.1	0.126	3.2	0.74	1.10	0.07	0.03	0.423	10.7	850	59	850	59	850	59
0.840	0.840	21.3	0.147	3.7	1.09	1.61	0.12	0.05	0.546	13.9	850	59	850	59	850	59
1.050	1.050	26.7	0.154	3.9	1.48	2.19	0.18	0.08	0.742	18.9	850	59	850	59	850	59
1.315	1.315	33.4	0.179	4.5	2.17	3.21	0.23	0.10	0.957	24.4	850	59	850	59	850	59
1.660	1.660	42.2	0.191	4.9	3.00	4.51	0.58	0.56	1.278	32.4	1300	90	1500	103	1600	110
1.900	1.900	48.3	0.200	5.1	3.63	5.43	0.36	0.16	1.500	38.1	1300	90	1500	103	1600	110
$2^3/_8$	2.375	60.3	0.218	5.5	5.03	7.43	1.09	0.50	1.939	49.3	1300	90	2500	172	2500	172
$2^7/_8$	2.875	73.0	0.276	7.0	7.67	11.39	1.57	0.71	2.323	59.0	1300	90	2500	172	2500	172
$3^1/_2$	3.500	88.9	0.300	7.6	10.26	15.24	1.76	0.80	2.900	73.7	1300	90	2500	172	2500	172
4	4.000	101.6	0.318	8.1	12.52	18.68	3.00	1.36	3.364	85.4	1700	117	2800	193	2800	193
$4^1/_2$	4.500	114.3	0.337	8.6	15.00	22.42	3.99	1.81	3.826	97.1	1700	117	2700	187	2800	193
$5^9/_{16}$	5.563	141.3	0.375	9.5	20.80	30.88	4.94	2.24	4.813	122.3	1700	117	2430	167	2800	193
$6^5/_8$	6.625	168.3	0.432	11.0	28.60	42.67	5.65	2.56	5.761	146.3	—	—	2350	162	2740	189
$8^5/_8$	8.625	219.1	0.500	12.7	43.43	64.64	11.47	5.20	7.625	193.7	—	—	2090	144	2430	168
$10^3/_4$	10.750	273.1	0.500	12.7	54.79	81.55	15.32	6.95	9.750	247.7	—	—	1670	116	1950	134
$12^3/_4$	12.750	323.9	0.500	12.7	65.48	97.46	28.74	13.04	11.750	298.5	—	—	1410	97	1650	113

[a]Weight gain due to end finishing. See 7.4.
[b]The calculated inside diameters are given here for information (see 7.2).
[c]100 kPa = 1 bar

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Table 6A—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes 0.405 Through 1.900 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
						Minimum Test Pressure (psi)[b]			
						Grade A		Grade B	
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)	Grade A25	Std.	Alt.	Std.	Alt.
0.405	0.405	0.068	0.24	0.269	700	700	—	700	—
0.405	0.405	0.095	0.31	0.215	850	850	—	850	—
0.540	0.540	0.088	0.43	0.364	700	700	—	700	—
0.540	0.540	0.119	0.54	0.302	850	850	—	850	—
0.675	0.675	0.091	0.57	0.493	700	700	—	700	—
0.675	0.675	0.126	0.74	0.423	850	850	—	850	—
0.840	0.840	0.109	0.85	0.622	700	700	—	700	—
0.840	0.840	0.147	1.09	0.546	850	850	—	850	—
0.840	0.840	0.294	1.72	0.252	1000	1000	—	1000	—
1.050	1.050	0.113	1.13	0.824	700	700	—	700	—
1.050	1.050	0.154	1.48	0.742	850	850	—	850	—
1.050	1.050	0.308	2.44	0.434	1000	1000	—	1000	—
1.315	1.315	0.133	1.68	1.049	700	700	—	700	—
1.315	1.315	0.179	2.17	0.957	850	850	—	850	—
1.315	1.315	0.358	3.66	0.599	1000	1000	—	1000	—
1.660	1.660	0.140	2.27	1.380	1000	1200	—	1300	—
1.660	1.660	0.191	3.00	1.278	1300	1800	—	1900	—
1.660	1.660	0.382	5.22	0.896	1400	2200	—	2300	—
1.900	1.900	0.145	2.72	1.610	1000	1200	—	1300	—
1.900	1.900	0.200	3.63	1.500	1300	1800	—	1900	—
1.900	1.900	0.400	6.41	1.100	1400	2200	—	2300	—

Note: See Table E-6A for SI unit values corresponding to the U.S. Customary unit values given in this table.

[a]The calculated inside diameters are given here for information (see 7.2).

[b]The test pressures given in Tables 6A, 6B, and 6C apply to Grades A25, A, B, X42, X46, X52, X56, X60, X65, X70, and X80 only. See 9.4.3 for pressures applicable to other grades.

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Table 6B —Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $2^3/_8$ through $5^9/_{16}$ (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure (psi)[b]										
Size	D (in.)	t (in.)	w_{pe} (lb/ft)	d (in.)		Grade A25	Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$2^3/_8$[c]	2.375	0.083	2.03	2.209	Std.	600	1260	1470	1760	1930	2180	2350	2520	2730	2940	—
					Alt.	—	1570	1830	2200	2410	2730	2940	3150	3410	3670	—
$2^3/_8$[c]	2.375	0.109	2.64	2.157	Std.	800	1650	1930	2310	2530	2860	3000	3000	3000	3000	—
					Alt.	—	2070	2410	2890	3170	3580	3860	4130	4470	4820	—
$2^3/_8$[c]	2.375	0.125	3.01	2.125	Std.	1000	1890	2210	2650	2910	3000	3000	3000	3000	3000	—
					Alt.	—	2370	2500	3320	3630	4110	4420	4740	5130	5530	—
$2^3/_8$[c]	2.375	0.141	3.37	2.093	Std.	1000	2140	2490	2990	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	3740	4100	4630	4990	5340	5790	6230	—
$2^3/_8$	2.375	0.154	3.66	2.067	Std.	1000	2330	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	4090	4470	5060	5450	5840	6320	6810	—
$2^3/_8$	2.375	0.172	4.05	2.031	Std.	1100	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	4560	5000	5650	6080	6520	7060	7260	—
$2^3/_8$	2.375	0.188	4.40	1.999	Std.	1200	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	4990	5460	6170	6650	7120	7260	7260	—
$2^3/_8$	2.375	0.218	5.03	1.939	Std.	1300	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	5780	6330	7160	7260	7260	7260	7260	—
$2^3/_8$	2.375	0.250	5.68	1.875	Std.	1400	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	6630	7260	7260	7260	7260	7260	7260	—
$2^3/_8$	2.375	0.281	6.29	1.813	Std.	1400	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	7260	7260	7260	7260	7260	7260	7260	—
$2^3/_8$	2.375	0.436	9.04	1.503	Std.	1400	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	7260	7260	7260	7260	7260	7260	7260	—
$2^7/_8$[c]	2.875	0.083	2.48	2.709	Std.	600	1040	1210	1460	1590	1800	1940	2080	2250	2430	—
					Alt.	—	1300	1520	1820	1990	2250	2430	2600	2810	3030	—
$2^7/_8$[c]	2.875	0.109	3.22	2.657	Std.	800	1360	1590	1910	2090	2370	2550	2730	2960	3000	—
					Alt.	—	1710	1990	2390	2620	2960	3180	3410	3700	3980	—
$2^7/_8$[c]	2.875	0.125	3.67	2.625	Std.	1000	1570	1830	2190	2400	2710	2920	3000	3000	3000	—
					Alt.	—	1960	2280	2740	3000	3390	3650	3910	4240	4570	—
$2^7/_8$[c]	2.875	0.141	4.12	2.593	Std.	1000	1770	2060	2470	2710	3000	3000	3000	3000	3000	—
					Alt.	—	2210	2500	3090	3380	3830	4120	4410	4780	5150	—
$2^7/_8$	2.875	0.156	4.53	2.563	Std.	1000	1950	2280	2730	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2440	2500	3420	3740	4230	4560	4880	5290	5700	—
$2^7/_8$	2.875	0.172	4.97	2.531	Std.	1000	2150	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	3770	4130	4670	5030	5380	5830	6280	—
$2^7/_8$	2.875	0.188	5.40	2.499	Std.	1000	2350	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	4120	4510	5100	5490	5890	6380	6870	—
$2^7/_8$	2.875	0.203	5.80	2.469	Std.	1000	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	4450	4870	5510	5930	6350	6880	7260	—
$2^7/_8$	2.875	0.216	6.14	2.443	Std.	1100	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	4730	5180	5860	6310	6760	7260	7260	—
$2^7/_8$	2.875	0.250	7.02	2.375	Std.	1200	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	5480	6000	6780	7260	7260	7260	7260	—
$2^7/_8$	2.875	0.276	7.67	2.323	Std.	1300	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	6050	6620	7260	7260	7260	7260	7260	—
$2^7/_8$	2.875	0.552	13.71	1.771	Std.	1400	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	7260	7260	7260	7260	7260	7260	7260	—
$3^1/_2$[c]	3.500	0.083	3.03	3.334	Std.	600	850	1000	1200	1310	1480	1590	1710	1850	1990	—
					Alt.	—	1070	1250	1490	1640	1850	1990	2130	2310	2490	—
$3^1/_2$[c]	3.500	0.109	3.95	3.282	Std.	800	1120	1310	1570	1720	1940	2090	2240	2430	2620	—
					Alt.	—	1400	1640	1960	2150	2430	2620	2800	3040	3270	—

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Table 6B (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $2^3/_8$ through $5^9/_{16}$ (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure (psi)[b]										
Size	D (in.)	t (in.)	w_{pe} (lb/ft)	d (in.)		Grade A25	Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$3^1/_2$[c]	3.500	0.125	4.51	3.250	Std.	1000	1290	1500	1800	1970	2230	2400	2570	2790	3000	—
					Alt.	—	1610	1880	2250	2460	2790	3000	3210	3480	3750	—
$3^1/_2$[c]	3.500	0.141	5.06	3.218	Std.	1000	1450	1690	2030	2220	2510	2710	2900	3000	3000	—
					Alt.	—	1810	2120	2540	2780	3140	3380	3630	3930	4230	—
$3^1/_2$[c]	3.500	0.156	5.58	3.188	Std.	1000	1600	1870	2250	2460	2780	3000	3000	3000	3000	—
					Alt.	—	2010	2340	2810	3080	3480	3740	4010	4350	4680	—
$3^1/_2$	3.500	0.172	6.12	3.156	Std.	1000	1770	2060	2480	2710	3000	3000	3000	3000	3000	—
					Alt.	—	2210	2500	3100	3390	3830	4130	4420	4790	5160	—
$3^1/_2$	3.500	0.188	6.66	3.124	Std.	1000	1930	2260	2710	2970	3000	3000	3000	3000	3000	—
					Alt.	—	2420	2500	3380	3710	4190	4510	4830	5240	5640	—
$3^1/_2$	3.500	0.216	7.58	3.068	Std.	1000	2220	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	3890	4260	4810	5180	5550	6020	6480	—
$3^1/_2$	3.500	0.250	8.69	3.000	Std.	—	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	4500	4930	5570	6000	6430	6960	7260	—
$3^1/_2$	3.500	0.281	9.67	2.938	Std.	—	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	5060	5540	6260	6740	7230	7260	7260	—
$3^1/_2$	3.500	0.300	10.26	2.900	Std.	1300	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	5400	5910	6690	7200	7260	7260	7260	—
$3^1/_2$	3.500	0.600	18.60	2.300	Std.	—	2500	2500	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2500	2500	7260	7260	7260	7260	7260	7260	7260	—
4[c]	4.000	0.083	3.48	3.834	Std.	—	750	870	1050	1150	1290	1390	1490	1620	1740	—
					Alt.	—	930	1090	1310	1430	1620	1740	1870	2020	2180	—
4[c]	4.000	0.109	4.53	3.782	Std.	600	980	1140	1370	1500	1700	1830	1960	2130	2290	—
					Alt.	—	1230	1430	1720	1880	2130	2290	2450	2660	2860	—
4[c]	4.000	0.125	5.18	3.750	Std.	—	1130	1310	1580	1730	1950	2100	2250	2440	2630	—
					Alt.	—	1410	1640	1970	2160	2440	2630	2810	3050	3280	—
4[c]	4.000	0.141	5.82	3.718	Std.	800	1270	1480	1780	1950	2200	2370	2540	2750	2960	—
					Alt.	—	1590	1850	2220	2430	2750	2960	3170	3440	3700	—
4[c]	4.000	0.156	6.41	3.688	Std.	—	1400	1640	1970	2150	2430	2620	2810	3000	3000	—
					Alt.	—	1760	2050	2460	2690	3040	3280	3510	3800	4100	—
4	4.000	0.172	7.04	3.656	Std.	1000	1550	1810	2170	2370	2680	2890	3000	3000	3000	—
					Alt.	—	1940	2260	2710	2970	3350	3610	3870	4190	4520	—
4	4.000	0.188	7.66	3.624	Std.	1200	1690	1970	2370	2590	2930	3000	3000	3000	3000	—
					Alt.	—	2120	2470	2960	3240	3670	3950	4230	4580	4940	—
4	4.000	0.226	9.12	3.548	Std.	1200	2030	2370	2850	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2540	2800	3560	3900	4410	4750	5090	5510	5930	—
4	4.000	0.250	10.02	3.500	Std.	—	2250	2630	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2800	2800	3940	4310	4880	5250	5630	6090	6560	—
4	4.000	0.281	11.17	3.438	Std.	—	2530	2800	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2800	2800	4430	4850	5480	5900	6320	6850	7260	—
4	4.000	0.318	12.52	3.364	Std.	1700	2800	2800	3000	3000	3000	3000	3000	3000	3000	—
					Alt.	—	2800	2800	5010	5490	6200	6680	7160	7260	7260	—
$4^1/_2$[c]	4.500	0.083	3.92	4.334	Std.	—	660	770	930	1020	1150	1240	1330	1440	1550	1770
					Alt.	—	830	970	1160	1270	1440	1550	1660	1800	1940	2210
$4^1/_2$[c]	4.500	0.125	5.85	4.250	Std.	800	1000	1170	1400	1530	1730	1870	2000	2170	2330	2670
					Alt.	—	1250	1460	1750	1920	2170	2330	2500	2710	2920	3330
$4^1/_2$[c]	4.500	0.141	6.57	4.218	Std.	—	1130	1320	1580	1730	1960	2110	2260	2440	2630	3000
					Alt.	—	1410	1650	1970	2160	2440	2630	2820	3060	3290	3760
$4^1/_2$[c]	4.500	0.156	7.24	4.188	Std.	1000	1250	1460	1750	1910	2160	2330	2500	2700	2910	3000
					Alt.	—	1560	1820	2180	2390	2700	2910	3120	3380	3640	4160

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Table 6B (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $2^3/_8$ through $5^9/_{16}$ (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure (psi)[b]										
Size	D (in.)	t (in.)	w_{pe} (lb/ft)	d (in.)		Grade A25	Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$4^1/_2$	4.500	0.172	7.96	4.156	Std.	—	1380	1610	1930	2110	2390	2570	2750	2980	3000	3000
					Alt.	—	1720	2010	2410	2640	2980	3210	3440	3730	4010	4590
$4^1/_2$	4.500	0.188	8.67	4.124	Std.	1200	1500	1750	2110	2310	2610	2810	3000	3000	3000	3000
					Alt.	—	1880	2190	2630	2880	3260	3510	3760	4070	4390	5010
$4^1/_2$	4.500	0.203	9.32	4.094	Std.	—	1620	1890	2270	2490	2810	3000	3000	3000	3000	3000
					Alt.	—	2030	2370	2840	3110	3520	3790	4060	4400	4740	5410
$4^1/_2$	4.500	0.219	10.02	4.062	Std.	1200	1750	2040	2450	2690	3000	3000	3000	3000	3000	3000
					Alt.	—	2190	2560	3070	3360	3800	4090	4380	4750	5110	5840
$4^1/_2$	4.500	0.237	10.80	4.026	Std.	1200	1900	2210	2650	2910	3000	3000	3000	3000	3000	3000
					Alt.	—	2370	2770	3320	3630	4110	4420	4740	5140	5530	6320
$4^1/_2$	4.500	0.250	11.36	4.000	Std.	—	2000	2330	2800	3000	3000	3000	3000	3000	3000	3000
					Alt.	—	2500	2800	3500	3830	4330	4670	5000	5420	5830	6670
$4^1/_2$	4.500	0.281	12.67	3.938	Std.	—	2250	2620	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	—	2800	2800	3930	4310	4870	5250	5620	6090	6560	7260
$4^1/_2$	4.500	0.312	13.97	3.876	Std.	—	2500	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	—	2800	2800	4370	4780	5410	5820	6240	6760	7260	7260
$4^1/_2$	4.500	0.337	15.00	3.826	Std.	1700	2700	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	—	2800	2800	4720	5170	5840	6290	6740	7260	7260	7260
$4^1/_2$	4.500	0.438	19.02	3.624	Std.	—	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	—	2800	2800	6130	6720	7260	7260	7260	7260	7260	7260
$4^1/_2$	4.500	0.531	22.53	3.438	Std.	—	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	—	2800	2800	7260	7260	7260	7260	7260	7260	7260	7260
$4^1/_2$	4.500	0.674	27.57	3.152	Std.	—	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	—	2800	2800	7260	7260	7260	7260	7260	7260	7260	7260
$5^9/_{16}$[c]	5.563	0.083	4.86	5.397	Std.	—	540	630	750	820	930	1000	1070	1160	1250	1430
					Alt.	—	670	780	940	1030	1160	1250	1340	1450	1570	1790
$5^9/_{16}$[c]	5.563	0.125	7.27	5.313	Std.	670	810	940	1130	1240	1400	1510	1620	1750	1890	2160
					Alt.	—	1010	1180	1420	1550	1750	1890	2020	2190	2360	2700
$5^9/_{16}$[c]	5.563	0.156	9.02	5.251	Std.	840	1010	1180	1410	1550	1750	1880	2020	2190	2360	2690
					Alt.	—	1260	1470	1770	1930	2190	2360	2520	2730	2940	3370
$5^9/_{16}$	5.563	0.188	10.80	5.187	Std.	1010	1220	1420	1700	1870	2110	2270	2430	2640	2840	3000
					Alt.	—	1520	1770	2130	2330	2640	2840	3040	3290	3550	4060
$5^9/_{16}$	5.563	0.219	12.51	5.125	Std.	1180	1420	1650	1980	2170	2460	2650	2830	3000	3000	3000
					Alt.	—	1770	2070	2480	2720	3070	3310	3540	3840	4130	4720
$5^9/_{16}$	5.563	0.258	14.63	5.047	Std.	1200	1670	1950	2340	2560	2890	3000	3000	3000	3000	3000
					Alt.	—	2090	2430	2920	3200	3620	3900	4170	4520	4870	5570
$5^9/_{16}$	5.563	0.281	15.87	5.001	Std.	1520	1820	2120	2550	2790	3000	3000	3000	3000	3000	3000
					Alt.	—	2270	2650	3180	3490	3940	4240	4550	4920	5300	6060
$5^9/_{16}$	5.563	0.312	17.51	4.939	Std.	1680	2020	2360	2830	3000	3000	3000	3000	3000	3000	3000
					Alt.	—	2520	2800	3530	3870	4370	4710	5050	5470	5890	6730
$5^9/_{16}$	5.563	0.344	19.19	4.875	Std.	1860	2230	2600	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	—	2780	2800	3900	4270	4820	5190	5570	6030	6490	7260
$5^9/_{16}$	5.563	0.375	20.80	4.813	Std.	2020	2430	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	—	2800	2800	4250	4650	5260	5660	6070	6570	7080	7260
$5^9/_{16}$	5.563	0.500	27.06	4.563	Std.	2700	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	—	2800	2800	5660	6200	7010	7260	7260	7260	7260	7260
$5^9/_{16}$	5.563	0.625	32.99	4.313	Std.	2800	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	—	2800	2800	7080	7260	7260	7260	7260	7260	7260	7260

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Table 6B (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $2^3/_8$ through $5^9/_{16}$ (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure (psi)[b]										
Size	D (in.)	t (in.)	w_{pe} (lb/ft)	d (in.)		Grade A25	Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$5^9/_{16}$	5.563	0.750	38.59	4.063	Std.	2800	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	—	2800	2800	7260	7260	7260	7260	7260	7260	7260	7260

Note: See Table E-6B for SI unit values corresponding to the U.S. Customary unit values given in this table.

[a]The calculated inside diameters are given here for information (see 7.2).

[b]The test pressures given in Tables 6A, 6B, and 6C apply to Grades A25, A, B, X42, X46, X52, X56, X60, X65, X70, and X80 only. See 9.4.3 for pressures applicable to other grades.

[c]Pipe that has this combination of specified outside diameter and specified wall thickness is special plain-end pipe; other combinations given in this table are regular plain-end pipe. Pipe that has a combination of specified outside diameter and specified wall thickness that is intermediate to the tabulated values is considered to be special plain-end pipe if the next lower tabulated value is for special plain-end pipe; other intermediate combinations are considered to be regular plain-end pipe. (See Table 10 for the applicable weight tolerances.)

Table 6C —Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure (psi)[b]									
Size	D (in.)	t (in.)	w_{pe} (lb/ft)	d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$6^5/_8$[c]	6.625	0.083	5.80	6.459	Std.	450	530	790	860	980	1050	1130	1220	1320	1500
					Alt.	560	660	790	860	980	1050	1130	1220	1320	1500
$6^5/_8$[c]	6.625	0.109	7.59	6.407	Std.	590	690	1040	1140	1280	1380	1480	1600	1730	1970
					Alt.	740	860	1040	1140	1280	1380	1480	1600	1730	1970
$6^5/_8$[c]	6.625	0.125	8.69	6.375	Std.	680	790	1190	1300	1470	1580	1700	1840	1980	2260
					Alt.	850	990	1190	1300	1470	1580	1700	1840	1980	2260
$6^5/_8$[c]	6.625	0.141	9.77	6.343	Std.	770	890	1340	1470	1660	1790	1920	2080	2230	2550
					Alt.	960	1120	1340	1470	1660	1790	1920	2080	2230	2550
$6^5/_8$[c]	6.625	0.156	10.79	6.313	Std.	850	990	1480	1620	1840	1980	2120	2300	2470	2830
					Alt.	1060	1240	1480	1620	1840	1980	2120	2300	2470	2830
$6^5/_8$	6.625	0.172	11.87	6.281	Std.	930	1090	1640	1790	2030	2180	2340	2530	2730	3000
					Alt.	1170	1360	1640	1790	2030	2180	2340	2530	2730	3120
$6^5/_8$	6.625	0.188	12.94	6.249	Std.	1020	1190	1790	1960	2210	2380	2550	2770	2980	3000
					Alt.	1280	1490	1790	1960	2210	2380	2550	2770	2980	3410
$6^5/_8$	6.625	0.203	13.94	6.219	Std.	1100	1290	1930	2110	2390	2570	2760	2990	3000	3000
					Alt.	1380	1610	1930	2110	2390	2570	2760	2990	3220	3680
$6^5/_8$	6.625	0.219	15.00	6.187	Std.	1190	1390	2080	2280	2580	2780	2980	3000	3000	3000
					Alt.	1490	1740	2080	2280	2580	2780	2980	3220	3470	3970
$6^5/_8$	6.625	0.250	17.04	6.125	Std.	1360	1580	2380	2600	2940	3000	3000	3000	3000	3000
					Alt.	1700	1980	2380	2600	2940	3170	3400	3680	3960	4530
$6^5/_8$	6.625	0.280	18.99	6.065	Std.	1520	1780	2660	2920	3000	3000	3000	3000	3000	3000
					Alt.	1900	2220	2660	2920	3300	3550	3800	4120	4440	5070
$6^5/_8$	6.625	0.312	21.06	6.001	Std.	1700	1980	2970	3000	3000	3000	3000	3000	3000	3000
					Alt.	2120	2470	2970	3250	3670	3960	4240	4590	4940	5650
$6^5/_8$	6.625	0.344	23.10	5.937	Std.	1870	2180	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2340	2730	3270	3580	4050	4360	4670	5060	5450	6230
$6^5/_8$	6.625	0.375	25.05	5.875	Std.	2040	2380	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2550	2800	3570	3910	4420	4750	5090	5520	5940	6790
$6^5/_8$	6.625	0.432	28.60	5.761	Std.	2350	2740	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	4110	4500	5090	5480	5870	6360	6850	7260
$6^5/_8$	6.625	0.500	32.74	5.625	Std.	2720	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	4750	5210	5890	6340	6790	7260	7260	7260

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure (psi)[b]									
Size	D (in.)	t (in.)	w_{pe} (lb/ft)	d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$6^5/_8$	6.625	0.562	36.43	5.501	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	5340	5850	6620	7130	7260	7260	7260	7260
$6^5/_8$	6.625	0.625	40.09	5.375	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	5940	6510	7260	7260	7260	7260	7260	7260
$6^5/_8$	6.625	0.719	45.39	5.187	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	6840	7260	7260	7260	7260	7260	7260	7260
$6^5/_8$	6.625	0.750	47.10	5.125	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	7130	7260	7260	7260	7260	7260	7260	7260
$6^5/_8$	6.625	0.864	53.21	4.897	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	7260	7260	7260	7260	7260	7260	7260	7260
$6^5/_8$	6.625	0.875	53.78	4.875	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	7260	7260	7260	7260	7260	7260	7260	7260
$8^5/_8$[c]	8.625	0.125	11.36	8.375	Std.	520	610	910	1000	1130	1220	1300	1410	1520	1740
					Alt.	650	760	910	1000	1130	1220	1300	1410	1520	1740
$8^5/_8$[c]	8.625	0.156	14.12	8.313	Std.	650	760	1140	1250	1410	1520	1630	1760	1900	2170
					Alt.	810	950	1140	1250	1410	1520	1630	1760	1900	2170
$8^5/_8$	8.625	0.188	16.96	8.249	Std.	780	920	1370	1500	1700	1830	1960	2130	2290	2620
					Alt.	980	1140	1370	1500	1700	1830	1960	2130	2290	2620
$8^5/_8$	8.625	0.203	18.28	8.219	Std.	850	990	1480	1620	1840	1980	2120	2290	2470	2820
					Alt.	1060	1240	1480	1620	1840	1980	2120	2290	2470	2820
$8^5/_8$	8.625	0.219	19.68	8.187	Std.	910	1070	1600	1750	1980	2130	2290	2480	2670	3000
					Alt.	1140	1330	1600	1750	1980	2130	2290	2480	2670	3050
$8^5/_8$	8.625	0.250	22.38	8.125	Std.	1040	1220	1830	2000	2260	2430	2610	2830	3000	3000
					Alt.	1300	1520	1830	2000	2260	2430	2610	2830	3040	3480
$8^5/_8$	8.625	0.277	24.72	8.071	Std.	1160	1350	2020	2220	2510	2700	2890	3000	3000	3000
					Alt.	1450	1690	2020	2220	2510	2700	2890	3130	3370	3850
$8^5/_8$	8.625	0.312	27.73	8.001	Std.	1300	1520	2280	2500	2820	3000	3000	3000	3000	3000
					Alt.	1630	1900	2280	2500	2820	3040	3260	3530	3800	4340
$8^5/_8$	8.625	0.322	28.58	7.981	Std.	1340	1570	2350	2580	2910	3000	3000	3000	3000	3000
					Alt.	1680	1960	2350	2580	2910	3140	3360	3640	3920	4480
$8^5/_8$	8.625	0.344	30.45	7.937	Std.	1440	1680	2510	2750	3000	3000	3000	3000	3000	3000
					Alt.	1790	2090	2510	2750	3110	3350	3590	3890	4190	4790
$8^5/_8$	8.625	0.375	33.07	7.875	Std.	1570	1830	2740	3000	3000	3000	3000	3000	3000	3000
					Alt.	1960	2280	2740	3000	3390	3650	3910	4240	4570	5220
$8^5/_8$	8.625	0.438	38.33	7.749	Std.	1830	2130	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2290	2670	3200	3500	3960	4270	4570	4950	5330	6090
$8^5/_8$	8.625	0.500	43.43	7.625	Std.	2090	2430	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2610	2800	3650	4000	4520	4870	5220	5650	6090	6960
$8^5/_8$	8.625	0.562	48.44	7.501	Std.	2350	2740	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	4110	4500	5080	5470	5860	6350	6840	7260
$8^5/_8$	8.625	0.625	53.45	7.375	Std.	2610	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	4570	5000	5650	6090	6520	7070	7260	7260
$8^5/_8$	8.625	0.719	60.77	7.187	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	5250	5750	6500	7000	7260	7260	7260	7260
$8^5/_8$	8.625	0.750	63.14	7.125	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	5480	6000	6780	7260	7260	7260	7260	7260
$8^5/_8$	8.625	0.812	67.82	7.001	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	5930	6500	7260	7260	7260	7260	7260	7260
$8^5/_8$	8.625	0.875	72.49	6.875	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	6390	7000	7260	7260	7260	7260	7260	7260

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$8^5/_8$	8.625	1.000	81.51	6.625	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	7260	7260	7260	7260	7260	7260	7260	7260
$10^3/_4$[c]	10.750	0.156	17.67	10.438	Std.	520	610	1040	1130	1280	1380	1480	1600	1730	1970
					Alt.	650	760	1040	1130	1280	1380	1480	1600	1730	1970
$10^3/_4$[c]	10.750	0.188	21.23	10.374	Std.	630	730	1250	1370	1550	1660	1780	1930	2080	2380
					Alt.	790	920	1250	1370	1550	1660	1780	1930	2080	2380
$10^3/_4$[c]	10.750	0.203	22.89	10.344	Std.	680	790	1350	1480	1670	1800	1930	2090	2250	2570
					Alt.	850	990	1350	1480	1670	1800	1930	2090	2250	2570
$10^3/_4$	10.750	0.219	24.65	10.312	Std.	730	860	1450	1590	1800	1940	2080	2250	2420	2770
					Alt.	920	1070	1450	1590	1800	1940	2080	2250	2420	2770
$10^3/_4$	10.750	0.250	28.06	10.250	Std.	840	980	1660	1820	2060	2210	2370	2570	2770	3000
					Alt.	1050	1220	1660	1820	2060	2210	2370	2570	2770	3160
$10^3/_4$	10.750	0.279	31.23	10.192	Std.	930	1090	1850	2030	2290	2470	2650	2870	3000	3000
					Alt.	1170	1360	1850	2030	2290	2470	2650	2870	3090	3530
$10^3/_4$	10.750	0.307	34.27	10.136	Std.	1030	1200	2040	2230	2520	2720	2910	3000	3000	3000
					Alt.	1290	1500	2040	2230	2520	2720	2910	3160	3400	3880
$10^3/_4$	10.750	0.344	38.27	10.062	Std.	1150	1340	2280	2500	2830	3000	3000	3000	3000	3000
					Alt.	1440	1680	2280	2500	2830	3050	3260	3540	3810	4350
$10^3/_4$	10.750	0.365	40.52	10.020	Std.	1220	1430	2420	2660	3000	3000	3000	3000	3000	3000
					Alt.	1530	1780	2420	2660	3000	3230	3460	3750	4040	4620
$10^3/_4$	10.750	0.438	48.28	9.874	Std.	1470	1710	2910	3000	3000	3000	3000	3000	3000	3000
					Alt.	1830	2140	2910	3190	3600	3880	4160	4500	4850	5540
$10^3/_4$	10.750	0.500	54.79	9.750	Std.	1670	1950	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2090	2440	3320	3640	4110	4430	4740	5140	5530	6330
$10^3/_4$	10.750	0.562	61.21	9.626	Std.	1880	2200	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2350	2740	3730	4090	4620	4980	5330	5780	6220	7110
$10^3/_4$	10.750	0.625	67.65	9.500	Std.	2090	2440	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2620	2800	4150	4550	5140	5530	5930	6420	6920	7260
$10^3/_4$	10.750	0.719	77.10	9.312	Std.	2410	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	4780	5230	5910	6370	6820	7260	7260	7260
$10^3/_4$	10.750	0.812	86.26	9.126	Std.	2720	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	5390	5910	6680	7190	7260	7260	7260	7260
$10^3/_4$	10.750	0.875	92.37	9.000	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	5810	6370	7200	7260	7260	7260	7260	7260
$10^3/_4$	10.750	0.938	98.39	8.874	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	6230	6820	7260	7260	7260	7260	7260	7260
$10^3/_4$	10.750	1.000	104.23	8.750	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	6640	7260	7260	7260	7260	7260	7260	7260
$10^3/_4$	10.750	1.250	126.94	8.250	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	7260	7260	7260	7260	7260	7260	7260	7260
$12^3/_4$[c]	12.750	0.172	23.13	12.406	Std.	490	570	960	1050	1190	1280	1380	1490	1610	1830
					Alt.	610	710	960	1050	1190	1280	1380	1490	1610	1830
$12^3/_4$[c]	12.750	0.188	25.25	12.374	Std.	530	620	1050	1150	1300	1400	1500	1630	1750	2010
					Alt.	660	770	1050	1150	1300	1400	1500	1630	1750	2010
$12^3/_4$[c]	12.750	0.203	27.23	12.344	Std.	570	670	1140	1250	1410	1520	1620	1760	1890	2170
					Alt.	720	840	1140	1250	1410	1520	1620	1760	1890	2170
$12^3/_4$[c]	12.750	0.219	29.34	12.312	Std.	620	720	1230	1340	1520	1640	1750	1900	2040	2340
					Alt.	770	900	1230	1340	1520	1640	1750	1900	2040	2340
$12^3/_4$	12.750	0.250	33.41	12.250	Std.	710	820	1400	1530	1730	1870	2000	2170	2330	2670
					Alt.	880	1030	1400	1530	1730	1870	2000	2170	2330	2670

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$12^3/_4$	12.750	0.281	37.46	12.188	Std.	790	930	1570	1720	1950	2100	2250	2440	2620	3000
					Alt.	990	1160	1570	1720	1950	2100	2250	2440	2620	3000
$12^3/_4$	12.750	0.312	41.48	12.126	Std.	880	1030	1750	1910	2160	2330	2500	2700	2910	3000
					Alt.	1100	1280	1750	1910	2160	2330	2500	2700	2910	3330
$12^3/_4$	12.750	0.330	43.81	12.090	Std.	930	1090	1850	2020	2290	2460	2640	2860	3000	3000
					Alt.	1160	1360	1850	2020	2290	2460	2640	2860	3080	3520
$12^3/_4$	12.750	0.344	45.62	12.062	Std.	970	1130	1930	2110	2390	2570	2750	2980	3000	3000
					Alt.	1210	1420	1930	2110	2390	2570	2750	2980	3210	3670
$12^3/_4$	12.750	0.375	49.61	12.000	Std.	1060	1240	2100	2300	2600	2800	3000	3000	3000	3000
					Alt.	1320	1540	2100	2300	2600	2800	3000	3250	3500	4000
$12^3/_4$	12.750	0.406	53.57	11.938	Std.	1150	1340	2270	2490	2810	3000	3000	3000	3000	3000
					Alt.	1430	1670	2270	2490	2810	3030	3250	3520	3790	4330
$12^3/_4$	12.750	0.438	57.65	11.874	Std.	1240	1440	2450	2690	3000	3000	3000	3000	3000	3000
					Alt.	1550	1800	2450	2690	3040	3270	3500	3800	4090	4670
$12^3/_4$	12.750	0.500	65.48	11.750	Std.	1410	1650	2800	3000	3000	3000	3000	3000	3000	3000
					Alt.	1760	2060	2800	3070	3470	3730	4000	4330	4670	5330
$12^3/_4$	12.750	0.562	73.22	11.626	Std.	1590	1850	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	1980	2310	3150	3450	3900	4200	4500	4870	5250	5990
$12^3/_4$	12.750	0.625	81.01	11.500	Std.	1760	2060	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2210	2570	3500	3830	4330	4670	5000	5420	5830	6670
$12^3/_4$	12.750	0.688	88.71	11.374	Std.	1940	2270	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2430	2800	3850	4220	4770	5140	5500	5960	6420	7260
$12^3/_4$	12.750	0.750	96.21	11.250	Std.	2120	2470	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2650	2800	4200	4600	5200	5600	6000	6500	7000	7260
$12^3/_4$	12.750	0.812	103.63	11.126	Std.	2290	2670	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	4550	4980	5630	6060	6500	7040	7260	7260
$12^3/_4$	12.750	0.875	111.08	11.000	Std.	2470	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	4900	5370	6070	6530	7000	7260	7260	7260
$12^3/_4$	12.750	0.938	118.44	10.874	Std.	2650	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	5250	5750	6500	7000	7260	7260	7260	7260
$12^3/_4$	12.750	1.000	125.61	10.750	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	5600	6130	6930	7260	7260	7260	7260	7260
$12^3/_4$	12.750	1.062	132.69	10.626	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	5950	6510	7260	7260	7260	7260	7260	7260
$12^3/_4$	12.750	1.125	139.81	10.500	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	6300	6900	7260	7260	7260	7260	7260	7260
$12^3/_4$	12.750	1.250	153.67	10.250	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	7000	7260	7260	7260	7260	7260	7260	7260
14[c]	14.000	0.188	27.76	13.624	Std.	480	560	960	1050	1190	1280	1370	1480	1600	1830
					Alt.	600	710	960	1050	1190	1280	1370	1480	1600	1830
14[c]	14.000	0.203	29.94	13.594	Std.	520	610	1040	1130	1280	1380	1480	1600	1730	1970
					Alt.	650	760	1040	1130	1280	1380	1480	1600	1730	1970
14[c]	14.000	0.210	30.96	13.580	Std.	540	630	1070	1170	1330	1430	1530	1660	1790	2040
					Alt.	680	790	1070	1170	1330	1430	1530	1660	1790	2040
14[c]	14.000	0.219	32.26	13.562	Std.	560	660	1120	1220	1380	1490	1600	1730	1860	2130
					Alt.	700	820	1120	1220	1380	1490	1600	1730	1860	2130
14[c]	14.000	0.250	36.75	13.500	Std.	640	750	1280	1400	1580	1700	1820	1970	2130	2430
					Alt.	800	940	1280	1400	1580	1700	1820	1970	2130	2430
14[c]	14.000	0.281	41.21	13.438	Std.	720	840	1430	1570	1770	1910	2050	2220	2390	2730
					Alt.	900	1050	1430	1570	1770	1910	2050	2220	2390	2730

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
14	14.000	0.312	45.65	13.376	Std.	800	940	1590	1740	1970	2120	2270	2460	2650	3000
					Alt.	1000	1170	1590	1740	1970	2120	2270	2460	2650	3030
14	14.000	0.344	50.22	13.312	Std.	880	1030	1750	1920	2170	2340	2510	2720	2920	3000
					Alt.	1110	1290	1750	1920	2170	2340	2510	2720	2920	3340
14	14.000	0.375	54.62	13.250	Std.	960	1130	1910	2090	2370	2550	2730	2960	3000	3000
					Alt.	1210	1410	1910	2090	2370	2550	2730	2960	3190	3640
14	14.000	0.406	59.00	13.188	Std.	1040	1220	2070	2270	2560	2760	2960	3000	3000	3000
					Alt.	1310	1520	2070	2270	2560	2760	2960	3200	3450	3940
14	14.000	0.438	63.50	13.124	Std.	1130	1310	2230	2450	2770	2980	3000	3000	3000	3000
					Alt.	1410	1640	2230	2450	2770	2980	3190	3460	3720	4250
14	14.000	0.469	67.84	13.062	Std.	1210	1410	2390	2620	2960	3000	3000	3000	3000	3000
					Alt.	1510	1760	2390	2620	2960	3190	3420	3700	3990	4560
14	14.000	0.500	72.16	13.000	Std.	1290	1500	2550	2790	3000	3000	3000	3000	3000	3000
					Alt.	1610	1880	2550	2790	3160	3400	3640	3950	4250	4860
14	14.000	0.562	80.73	12.876	Std.	1450	1690	2870	3000	3000	3000	3000	3000	3000	3000
					Alt.	1810	2110	2870	3140	3550	3820	4090	4440	4780	5460
14	14.000	0.625	89.36	12.750	Std.	1610	1880	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2010	2340	3190	3490	3950	4250	4550	4930	5310	6070
14	14.000	0.688	97.91	12.624	Std.	1770	2060	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2210	2580	3510	3840	4340	4680	5010	5430	5850	6680
14	14.000	0.750	106.23	12.500	Std.	1930	2250	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2410	2800	3830	4190	4740	5100	5460	5920	6380	7260
14	14.000	0.812	114.48	12.376	Std.	2090	2440	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2610	2800	4140	4540	5130	5520	5920	6410	6900	7260
14	14.000	0.875	122.77	12.250	Std.	2250	2630	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	4460	4890	5530	5950	6380	6910	7260	7260
14	14.000	0.938	130.98	12.124	Std.	2410	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	4780	5240	5920	6380	6830	7260	7260	7260
14	14.000	1.000	138.97	12.000	Std.	2570	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	5100	5590	6310	6800	7260	7260	7260	7260
14	14.000	1.062	146.88	11.876	Std.	2730	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	5420	5930	6710	7220	7260	7260	7260	7260
14	14.000	1.125	154.84	11.750	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	5740	6280	7100	7260	7260	7260	7260	7260
14	14.000	1.250	170.37	11.500	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	6380	6980	7260	7260	7260	7260	7260	7260
16[c]	16.000	0.188	31.78	15.624	Std.	420	490	840	920	1040	1120	1200	1300	1400	1600
					Alt.	530	620	840	920	1040	1120	1200	1300	1400	1600
16[c]	16.000	0.203	34.28	15.594	Std.	460	530	910	990	1120	1210	1290	1400	1510	1730
					Alt.	570	670	910	990	1120	1210	1290	1400	1510	1730
16[c]	16.000	0.219	36.95	15.562	Std.	490	570	980	1070	1210	1300	1400	1510	1630	1860
					Alt.	620	720	980	1070	1210	1300	1400	1510	1630	1860
16[c]	16.000	0.250	42.09	15.500	Std.	560	660	1120	1220	1380	1490	1590	1730	1860	2130
					Alt.	700	820	1120	1220	1380	1490	1590	1730	1860	2130
16[c]	16.000	0.281	47.22	15.438	Std.	630	740	1250	1370	1550	1670	1790	1940	2090	2390
					Alt.	790	920	1250	1370	1550	1670	1790	1940	2090	2390
16	16.000	0.312	52.32	15.376	Std.	700	820	1390	1520	1720	1860	1990	2150	2320	2650
					Alt.	880	1020	1390	1520	1720	1860	1990	2150	2320	2650
16	16.000	0.344	57.57	15.312	Std.	770	900	1540	1680	1900	2050	2190	2380	2560	2920
					Alt.	970	1130	1540	1680	1900	2050	2190	2380	2560	2920

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
16	16.000	0.375	62.64	15.250	Std.	840	980	1670	1830	2070	2230	2390	2590	2790	3000
					Alt.	1050	1230	1670	1830	2070	2230	2390	2590	2790	3190
16	16.000	0.406	67.68	15.188	Std.	910	1070	1810	1980	2240	2420	2590	2800	3000	3000
					Alt.	1140	1330	1810	1980	2240	2420	2590	2800	3020	3450
16	16.000	0.438	72.86	15.124	Std.	990	1150	1950	2140	2420	2610	2790	3000	3000	3000
					Alt.	1230	1440	1950	2140	2420	2610	2790	3020	3260	3630
16	16.000	0.469	77.87	15.062	Std.	1060	1230	2090	2290	2590	2790	2990	3000	3000	3000
					Alt.	1320	1540	2090	2290	2590	2790	2990	3240	3490	3630
16	16.000	0.500	82.85	15.000	Std.	1130	1310	2230	2440	2760	2980	3000	3000	3000	3000
					Alt.	1410	1640	2230	2440	2760	2980	3190	3450	3630	3630
16	16.000	0.562	92.75	14.876	Std.	1260	1480	2510	2750	3000	3000	3000	3000	3000	3000
					Alt.	1580	1840	2510	2750	3110	3340	3580	3630	3630	3630
16	16.000	0.625	102.72	14.750	Std.	1410	1640	2790	3000	3000	3000	3000	3000	3000	3000
					Alt.	1760	2050	2790	3050	3450	3630	3630	3630	3630	3630
16	16.000	0.688	112.62	14.624	Std.	1550	1810	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	1940	2260	3070	3360	3630	3630	3630	3630	3630	3630
16	16.000	0.750	122.27	14.500	Std.	1690	1970	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2110	2460	3350	3630	3630	3630	3630	3630	3630	3630
16	16.000	0.812	131.84	14.376	Std.	1830	2130	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2280	2660	3620	3630	3630	3630	3630	3630	3630	3630
16	16.000	0.875	141.48	14.250	Std.	1970	2300	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2460	2800	3630	3630	3630	3630	3630	3630	3630	3630
16	16.000	0.938	151.03	14.124	Std.	2110	2460	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2640	2800	3630	3630	3630	3630	3630	3630	3630	3630
16	16.000	1.000	160.35	14.000	Std.	2250	2630	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
16	16.000	1.062	169.59	13.876	Std.	2390	2790	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
16	16.000	1.125	178.89	13.750	Std.	2530	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
16	16.000	1.188	188.11	13.624	Std.	2670	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
16	16.000	1.250	197.10	13.500	Std.	2800	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
18[c]	18.000	0.188	35.80	17.624	Std.	380	440	750	820	920	990	1070	1150	1240	1420
					Alt.	470	550	750	820	920	990	1070	1150	1240	1420
18[c]	18.000	0.219	41.63	17.562	Std.	440	510	870	950	1080	1160	1240	1340	1450	1650
					Alt.	550	640	870	950	1080	1160	1240	1340	1450	1650
18[c]	18.000	0.250	47.44	17.500	Std.	500	580	990	1090	1230	1320	1420	1530	1650	1890
					Alt.	630	730	990	1090	1230	1320	1420	1530	1650	1890
18[c]	18.000	0.281	53.23	17.438	Std.	560	660	1110	1220	1380	1490	1590	1730	1860	2120
					Alt.	700	820	1110	1220	1380	1490	1590	1730	1860	2120
18	18.000	0.312	58.99	17.376	Std.	620	730	1240	1360	1530	1650	1770	1920	2060	2360
					Alt.	780	910	1240	1360	1530	1650	1770	1920	2060	2360
18	18.000	0.344	64.93	17.312	Std.	690	800	1360	1490	1690	1820	1950	2110	2270	2600
					Alt.	860	1000	1360	1490	1690	1820	1950	2110	2270	2600
18	18.000	0.375	70.65	17.250	Std.	750	880	1490	1630	1840	1980	2130	2300	2480	2830
					Alt.	940	1090	1490	1630	1840	1980	2130	2300	2480	2830
18	18.000	0.406	76.36	17.188	Std.	810	950	1610	1760	1990	2150	2300	2490	2680	3000
					Alt.	1020	1180	1610	1760	1990	2150	2300	2490	2680	3070

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
18	18.000	0.438	82.23	17.124	Std.	880	1020	1740	1900	2150	2320	2480	2690	2900	3000
					Alt.	1100	1280	1740	1900	2150	2320	2480	2690	2900	3310
18	18.000	0.469	87.89	17.062	Std.	940	1090	1860	2040	2300	2480	2660	2880	3000	3000
					Alt.	1170	1370	1860	2040	2300	2480	2660	2880	3100	3540
18	18.000	0.500	93.54	17.000	Std.	1000	1170	1980	2170	2460	2640	2830	3000	3000	3000
					Alt.	1250	1460	1980	2170	2460	2640	2830	3070	3310	3630
18	18.000	0.562	104.76	16.876	Std.	1120	1310	2230	2440	2760	2970	3000	3000	3000	3000
					Alt.	1410	1640	2230	2440	2760	2970	3180	3450	3630	3630
18	18.000	0.625	116.09	16.750	Std.	1250	1460	2480	2720	3000	3000	3000	3000	3000	3000
					Alt.	1560	1820	2480	2720	3070	3310	3540	3630	3630	3630
18	18.000	0.688	127.32	16.624	Std.	1380	1610	2730	2990	3000	3000	3000	3000	3000	3000
					Alt.	1720	2010	2730	2990	3380	3630	3630	3630	3630	3630
18	18.000	0.750	138.30	16.500	Std.	1500	1750	2980	3000	3000	3000	3000	3000	3000	3000
					Alt.	1880	2190	2980	3260	3630	3630	3630	3630	3630	3630
18	18.000	0.812	149.20	16.376	Std.	1620	1890	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2030	2370	3220	3530	3630	3630	3630	3630	3630	3630
18	18.000	0.875	160.18	16.250	Std.	1750	2040	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2190	2550	3470	3630	3630	3630	3630	3630	3630	3630
18	18.000	0.938	171.08	16.124	Std.	1880	2190	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2350	2740	3630	3630	3630	3630	3630	3630	3630	3630
18	18.000	1.000	181.73	16.000	Std.	2000	2330	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2500	2800	3630	3630	3630	3630	3630	3630	3630	3630
18	18.000	1.062	192.29	15.876	Std.	2120	2480	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2660	2800	3630	3630	3630	3630	3630	3630	3630	3630
18	18.000	1.125	202.94	15.750	Std.	2250	2630	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
18	18.000	1.188	213.51	15.624	Std.	2380	2770	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
18	18.000	1.250	223.82	15.500	Std.	2500	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
20[c]	20.000	0.219	46.31	19.562	Std.	390	460	830	910	1020	1100	1180	1280	1380	1580
					Alt.	490	570	830	910	1020	1100	1180	1280	1380	1580
20[c]	20.000	0.250	52.78	19.500	Std.	450	530	950	1040	1170	1260	1350	1460	1580	1800
					Alt.	560	660	950	1040	1170	1260	1350	1460	1580	1800
20[c]	20.000	0.281	59.23	19.438	Std.	510	590	1060	1160	1320	1420	1520	1640	1770	2020
					Alt.	630	740	1060	1160	1320	1420	1520	1640	1770	2020
20	20.000	0.312	65.66	19.376	Std.	560	660	1180	1290	1460	1570	1680	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1570	1680	1830	1970	2250
20	20.000	0.344	72.28	19.312	Std.	620	720	1300	1420	1610	1730	1860	2010	2170	2480
					Alt.	770	900	1300	1420	1610	1730	1860	2010	2170	2480
20	20.000	0.375	78.67	19.250	Std.	680	790	1420	1550	1760	1890	2030	2190	2360	2700
					Alt.	840	980	1420	1550	1760	1890	2030	2190	2360	2700
20	20.000	0.406	85.04	19.188	Std.	730	850	1530	1680	1900	2050	2190	2380	2560	2920
					Alt.	910	1070	1530	1680	1900	2050	2190	2380	2560	2920
20	20.000	0.438	91.59	19.124	Std.	790	920	1660	1810	2050	2210	2370	2560	2760	3000
					Alt.	990	1150	1660	1810	2050	2210	2370	2560	2760	3150
20	20.000	0.469	97.92	19.062	Std.	840	980	1770	1940	2190	2360	2530	2740	2950	3000
					Alt.	1060	1230	1770	1940	2190	2360	2530	2740	2950	3380
20	20.000	0.500	104.23	19.000	Std.	900	1050	1890	2070	2340	2520	2700	2930	3000	3000
					Alt.	1130	1310	1890	2070	2340	2520	2700	2930	3150	3600

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure (psi)[b]									
Size	D (in.)	t (in.)	w_{pe} (lb/ft)	d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
20	20.000	0.562	116.78	18.876	Std.	1010	1180	2120	2330	2630	2830	3000	3000	3000	3000
					Alt.	1260	1480	2120	2330	2630	2830	3030	3290	3540	3630
20	20.000	0.625	129.45	18.750	Std.	1130	1310	2360	2590	2930	3000	3000	3000	3000	3000
					Alt.	1410	1640	2360	2590	2930	3150	3380	3630	3630	3630
20	20.000	0.688	142.03	18.624	Std.	1240	1440	2600	2850	3000	3000	3000	3000	3000	3000
					Alt.	1550	1810	2600	2850	3220	3630	3630	3630	3630	3630
20	20.000	0.750	154.34	18.500	Std.	1350	1580	2840	3000	3000	3000	3000	3000	3000	3000
					Alt.	1690	1970	2840	3110	3510	3630	3630	3630	3630	3630
20	20.000	0.812	166.56	18.376	Std.	1460	1710	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	1830	2130	3070	3360	3630	3630	3630	3630	3630	3630
20	20.000	0.875	178.89	18.250	Std.	1580	1840	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	1970	2300	3310	3620	3630	3630	3630	3630	3630	3630
20	20.000	0.938	191.14	18.124	Std.	1690	1970	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2110	2460	3550	3630	3630	3630	3630	3630	3630	3630
20	20.000	1.000	203.11	18.000	Std.	1800	2100	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2250	2630	3630	3630	3630	3630	3630	3630	3630	3630
20	20.000	1.062	215.00	17.876	Std.	1910	2230	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2390	2790	3630	3630	3630	3630	3630	3630	3630	3630
20	20.000	1.125	227.00	17.750	Std.	2030	2360	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2530	2800	3630	3630	3630	3630	3630	3630	3630	3630
20	20.000	1.188	238.91	17.624	Std.	2140	2490	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2670	2800	3630	3630	3630	3630	3630	3630	3630	3630
20	20.000	1.250	250.55	17.500	Std.	2250	2630	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
20	20.000	1.312	262.10	17.376	Std.	2360	2760	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
20	20.000	1.375	273.76	17.250	Std.	2480	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
22[c]	22.000	0.219	50.99	21.562	Std.	360	420	750	820	930	1000	1080	1160	1250	1430
					Alt.	450	520	750	820	930	1000	1080	1160	1250	1430
22[c]	22.000	0.250	58.13	21.500	Std.	410	480	860	940	1060	1150	1230	1330	1430	1640
					Alt.	510	600	860	940	1060	1150	1230	1330	1430	1640
22[c]	22.000	0.281	65.24	21.438	Std.	460	540	970	1060	1200	1290	1380	1490	1610	1840
					Alt.	570	670	970	1060	1200	1290	1380	1490	1610	1840
22	22.000	0.312	72.34	21.376	Std.	510	600	1070	1170	1330	1430	1530	1660	1790	2040
					Alt.	640	740	1070	1170	1330	1430	1530	1660	1790	2040
22	22.000	0.344	79.64	21.312	Std.	560	660	1180	1290	1460	1580	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1580	1690	1830	1970	2250
22	22.000	0.375	86.69	21.250	Std.	610	720	1290	1410	1600	1720	1840	1990	2150	2450
					Alt.	770	890	1290	1410	1600	1720	1840	1990	2150	2450
22	22.000	0.406	93.72	21.188	Std.	660	780	1400	1530	1730	1860	1990	2160	2330	2660
					Alt.	830	970	1400	1530	1730	1860	1990	2160	2330	2660
22	22.000	0.438	100.96	21.124	Std.	720	840	1510	1650	1860	2010	2150	2330	2510	2870
					Alt.	900	1050	1510	1650	1860	2010	2150	2330	2510	2870
22	22.000	0.469	107.95	21.062	Std.	770	900	1610	1770	2000	2150	2300	2490	2690	3000
					Alt.	960	1120	1610	1770	2000	2150	2300	2490	2690	3070
22	22.000	0.500	114.92	21.000	Std.	820	950	1720	1880	2130	2290	2450	2660	2860	3000
					Alt.	1020	1190	1720	1880	2130	2290	2450	2660	2860	3270
22	22.000	0.562	128.79	20.876	Std.	920	1070	1930	2120	2390	2570	2760	2990	3000	3000
					Alt.	1150	1340	1930	2120	2390	2570	2760	2990	3220	3630

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
22	22.000	0.625	142.81	20.750	Std.	1020	1190	2150	2350	2660	2860	3000	3000	3000	3000
					Alt.	1280	1490	2150	2350	2660	2860	3070	3320	3580	3630
22	22.000	0.688	156.74	20.624	Std.	1130	1310	2360	2590	2930	3000	3000	3000	3000	3000
					Alt.	1410	1640	2360	2590	2930	3150	3380	3630	3630	3630
22	22.000	0.750	170.37	20.500	Std.	1230	1430	2580	2820	3000	3000	3000	3000	3000	3000
					Alt.	1530	1790	2580	2820	3190	3630	3630	3630	3630	3630
22	22.000	0.812	183.92	20.376	Std.	1330	1550	2790	3000	3000	3000	3000	3000	3000	3000
					Alt.	1660	1940	2790	3060	3450	3630	3630	3630	3630	3630
22	22.000	0.875	197.60	20.250	Std.	1430	1670	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	1790	2090	3010	3290	3630	3630	3630	3630	3630	3630
22	22.000	0.938	211.19	20.124	Std.	1530	1790	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	1920	2240	3220	3530	3630	3630	3630	3630	3630	3630
22	22.000	1.000	224.49	20.000	Std.	1640	1910	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2050	2390	3440	3630	3630	3630	3630	3630	3630	3630
22	22.000	1.062	237.70	19.876	Std.	1740	2030	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2170	2530	3630	3630	3630	3630	3630	3630	3630	3630
22	22.000	1.125	251.05	19.750	Std.	1840	2150	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2300	2680	3630	3630	3630	3630	3630	3630	3630	3630
22	22.000	1.188	264.31	19.624	Std.	1940	2270	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2430	2800	3630	3630	3630	3630	3630	3630	3630	3630
22	22.000	1.250	277.27	19.500	Std.	2050	2390	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2560	2800	3630	3630	3630	3630	3630	3630	3630	3630
22	22.000	1.312	290.15	19.376	Std.	2150	2500	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2680	2800	3630	3630	3630	3630	3630	3630	3630	3630
22	22.000	1.375	303.16	19.250	Std.	2250	2630	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
22	22.000	1.438	316.08	19.124	Std.	2350	2750	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
22	22.000	1.500	328.72	19.000	Std.	2450	2800	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
24[c]	24.000	0.250	63.47	23.500	Std.	380	440	790	860	980	1050	1130	1220	1310	1500
					Alt.	470	550	790	860	980	1050	1130	1220	1310	1500
24[c]	24.000	0.281	71.25	23.438	Std.	420	490	890	970	1100	1180	1260	1370	1480	1690
					Alt.	530	610	890	970	1100	1180	1260	1370	1480	1690
24	24.000	0.312	79.01	23.376	Std.	470	550	980	1080	1220	1310	1400	1520	1640	1870
					Alt.	590	680	980	1080	1220	1310	1400	1520	1640	1870
24	24.000	0.344	86.99	23.312	Std.	520	600	1080	1190	1340	1440	1550	1680	1810	2060
					Alt.	650	750	1080	1190	1340	1440	1550	1680	1810	2060
24	24.000	0.375	94.71	23.250	Std.	560	660	1180	1290	1460	1580	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1580	1690	1830	1970	2250
24	24.000	0.406	102.40	23.188	Std.	610	710	1280	1400	1580	1710	1830	1980	2130	2440
					Alt.	760	890	1280	1400	1580	1710	1830	1980	2130	2440
24	24.000	0.438	110.32	23.124	Std.	660	770	1380	1510	1710	1840	1970	2140	2300	2630
					Alt.	820	960	1380	1510	1710	1840	1970	2140	2300	2630
24	24.000	0.469	117.98	23.062	Std.	700	820	1480	1620	1830	1970	2110	2290	2460	2810
					Alt.	880	1030	1480	1620	1830	1970	2110	2290	2460	2810
24	24.000	0.500	125.61	23.000	Std.	750	880	1580	1730	1950	2100	2250	2440	2630	3000
					Alt.	940	1090	1580	1730	1950	2100	2250	2440	2630	3000
24	24.000	0.562	140.81	22.876	Std.	840	980	1770	1940	2190	2360	2530	2740	2950	3000
					Alt.	1050	1230	1770	1940	2190	2360	2530	2740	2950	3370

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure (psi)[b]									
Size	D (in.)	t (in.)	w_{pe} (lb/ft)	d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
24	24.000	0.625	156.17	22.750	Std.	940	1090	1970	2160	2440	2630	2810	3000	3000	3000
					Alt.	1170	1370	1970	2160	2440	2630	2810	3050	3280	3630
24	24.000	0.688	171.45	22.624	Std.	1030	1200	2170	2370	2680	2890	3000	3000	3000	3000
					Alt.	1290	1510	2170	2370	2680	2890	3100	3350	3610	3630
24	24.000	0.750	186.41	22.500	Std.	1130	1310	2360	2590	2930	3000	3000	3000	3000	3000
					Alt.	1410	1640	2360	2590	2930	3150	3380	3630	3630	3630
24	24.000	0.812	201.28	22.376	Std.	1220	1420	2560	2800	3000	3000	3000	3000	3000	3000
					Alt.	1520	1780	2560	2800	3170	3630	3630	3630	3630	3630
24	24.000	0.875	216.31	22.250	Std.	1310	1530	2760	3000	3000	3000	3000	3000	3000	3000
					Alt.	1640	1910	2760	3020	3410	3630	3630	3630	3630	3630
24	24.000	0.938	231.25	22.124	Std.	1410	1640	2950	3000	3000	3000	3000	3000	3000	3000
					Alt.	1760	2050	2950	3240	3630	3630	3630	3630	3630	3630
24	24.000	1.000	245.87	22.000	Std.	1500	1750	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	1880	2190	3150	3450	3630	3630	3630	3630	3630	3630
24	24.000	1.062	260.41	21.876	Std.	1590	1860	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	1990	2320	3350	3630	3630	3630	3630	3630	3630	3630
24	24.000	1.125	275.10	21.750	Std.	1690	1970	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2110	2460	3540	3630	3630	3630	3630	3630	3630	3630
24	24.000	1.188	289.71	21.624	Std.	1780	2080	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2230	2600	3630	3630	3630	3630	3630	3630	3630	3630
24	24.000	1.250	304.00	21.500	Std.	1880	2190	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2340	2730	3630	3630	3630	3630	3630	3630	3630	3630
24	24.000	1.312	318.21	21.376	Std.	1970	2300	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2460	2800	3630	3630	3630	3630	3630	3630	3630	3630
24	24.000	1.375	332.56	21.250	Std.	2060	2410	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2580	2800	3630	3630	3630	3630	3630	3630	3630	3630
24	24.000	1.438	346.83	21.124	Std.	2160	2520	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2700	2800	3630	3630	3630	3630	3630	3630	3630	3630
24	24.000	1.500	360.79	21.000	Std.	2250	2630	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
24	24.000	1.562	374.66	20.876	Std.	2340	2730	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	2800	2800	3630	3630	3630	3630	3630	3630	3630	3630
26[c]	26.000	0.250	68.82	25.500	Std.	350	400	730	800	900	970	1040	1130	1210	1380
					Alt.	430	500	730	800	900	970	1040	1130	1210	1380
26[c]	26.000	0.281	77.26	25.438	Std.	390	450	820	890	1010	1090	1170	1260	1360	1560
					Alt.	490	570	820	890	1010	1090	1170	1260	1360	1560
26	26.000	0.312	85.68	25.376	Std.	430	500	910	990	1120	1210	1300	1400	1510	1730
					Alt.	540	630	910	990	1120	1210	1300	1400	1510	1730
26	26.000	0.344	94.35	25.312	Std.	480	560	1000	1100	1240	1330	1430	1550	1670	1910
					Alt.	600	690	1000	1100	1240	1330	1430	1550	1670	1910
26	26.000	0.375	102.72	25.250	Std.	520	610	1090	1190	1350	1450	1560	1690	1820	2080
					Alt.	650	760	1090	1190	1350	1450	1560	1690	1820	2080
26	26.000	0.406	111.08	25.188	Std.	560	660	1180	1290	1460	1570	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1570	1690	1830	1970	2250
26	26.000	0.438	119.69	25.124	Std.	610	710	1270	1390	1580	1700	1820	1970	2120	2430
					Alt.	760	880	1270	1390	1580	1700	1820	1970	2120	2430
26	26.000	0.469	128.00	25.062	Std.	650	760	1360	1490	1690	1820	1950	2110	2270	2600
					Alt.	810	950	1360	1490	1690	1820	1950	2110	2270	2600
26	26.000	0.500	136.30	25.000	Std.	690	810	1450	1590	1800	1940	2080	2250	2420	2770
					Alt.	870	1010	1450	1590	1800	1940	2080	2250	2420	2770

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
26	26.000	0.562	152.83	24.876	Std.	780	910	1630	1790	2020	2180	2330	2530	2720	3000
					Alt.	970	1130	1630	1790	2020	2180	2330	2530	2720	3110
26	26.000	0.625	169.54	24.750	Std.	870	1010	1820	1990	2250	2420	2600	2810	3000	3000
					Alt.	1080	1260	1820	1990	2250	2420	2600	2810	3030	3460
26	26.000	0.688	186.16	24.624	Std.	950	1110	2000	2190	2480	2670	2860	3000	3000	3000
					Alt.	1190	1390	2000	2190	2480	2670	2860	3100	3330	3630
26	26.000	0.750	202.44	24.500	Std.	1040	1210	2180	2390	2700	2910	3000	3000	3000	3000
					Alt.	1300	1510	2180	2390	2700	2910	3120	3380	3630	3630
26	26.000	0.812	218.64	24.376	Std.	1120	1310	2360	2590	2920	3000	3000	3000	3000	3000
					Alt.	1410	1640	2360	2590	2920	3150	3370	3630	3630	3630
26	26.000	0.875	235.01	24.250	Std.	1210	1410	2540	2790	3000	3000	3000	3000	3000	3000
					Alt.	1510	1770	2540	2790	3150	3630	3630	3630	3630	3630
26	26.000	0.938	251.30	24.124	Std.	1300	1520	2730	2990	3000	3000	3000	3000	3000	3000
					Alt.	1620	1890	2730	2990	3380	3630	3630	3630	3630	3630
26	26.000	1.000	267.25	24.000	Std.	1380	1620	2910	3000	3000	3000	3000	3000	3000	3000
					Alt.	1730	2020	2910	3180	3600	3630	3630	3630	3630	3630
28[c]	28.000	0.250	74.16	27.500	Std.	320	380	680	740	840	900	960	1040	1130	1290
					Alt.	400	470	680	740	840	900	960	1040	1130	1290
28[c]	28.000	0.281	83.26	27.438	Std.	360	420	760	830	940	1010	1080	1170	1260	1450
					Alt.	450	530	760	830	940	1010	1080	1170	1260	1450
28	28.000	0.312	92.35	27.376	Std.	400	470	840	920	1040	1120	1200	1300	1400	1600
					Alt.	500	590	840	920	1040	1120	1200	1300	1400	1600
28	28.000	0.344	101.70	27.312	Std.	440	520	930	1020	1150	1240	1330	1440	1550	1770
					Alt.	550	650	930	1020	1150	1240	1330	1440	1550	1770
28	28.000	0.375	110.74	27.250	Std.	480	560	1010	1110	1250	1350	1450	1570	1690	1930
					Alt.	600	700	1010	1110	1250	1350	1450	1570	1690	1930
28	28.000	0.406	119.76	27.188	Std.	520	610	1100	1200	1360	1460	1570	1700	1830	2090
					Alt.	650	760	1100	1200	1360	1460	1570	1700	1830	2090
28	28.000	0.438	129.05	27.124	Std.	560	660	1180	1300	1460	1580	1690	1830	1970	2250
					Alt.	700	820	1180	1300	1460	1580	1690	1830	1970	2250
28	28.000	0.469	138.03	27.062	Std.	600	700	1270	1390	1570	1690	1810	1960	2110	2410
					Alt.	750	880	1270	1390	1570	1690	1810	1960	2110	2410
28	28.000	0.500	146.99	27.000	Std.	640	750	1350	1480	1670	1800	1930	2090	2250	2570
					Alt.	800	940	1350	1480	1670	1800	1930	2090	2250	2570
28	28.000	0.562	164.84	26.876	Std.	720	840	1520	1660	1880	2020	2170	2350	2530	2890
					Alt.	900	1050	1520	1660	1880	2020	2170	2350	2530	2890
28	28.000	0.625	182.90	26.750	Std.	800	940	1690	1850	2090	2250	2410	2610	2810	3000
					Alt.	1000	1170	1690	1850	2090	2250	2410	2610	2810	3210
28	28.000	0.688	200.87	26.624	Std.	880	1030	1860	2030	2300	2480	2650	2870	3000	3000
					Alt.	1110	1290	1860	2030	2300	2480	2650	2870	3100	3540
28	28.000	0.750	218.48	26.500	Std.	960	1130	2030	2220	2510	2700	2890	3000	3000	3000
					Alt.	1210	1410	2030	2220	2510	2700	2890	3130	3380	3630
28	28.000	0.812	236.00	26.376	Std.	1040	1220	2190	2400	2710	2920	3000	3000	3000	3000
					Alt.	1310	1520	2190	2400	2710	2920	3130	3390	3630	3630
28	28.000	0.875	253.72	26.250	Std.	1130	1310	2360	2590	2930	3000	3000	3000	3000	3000
					Alt.	1410	1640	2360	2590	2930	3150	3380	3630	3630	3630
28	28.000	0.938	271.36	26.124	Std.	1210	1410	2530	2770	3000	3000	3000	3000	3000	3000
					Alt.	1510	1760	2530	2770	3140	3630	3620	3630	3630	3630
28	28.000	1.000	288.63	26.000	Std.	1290	1500	2700	2960	3000	3000	3000	3000	3000	3000
					Alt.	1610	1880	2700	2960	3340	3630	3630	3630	3630	3630

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
30[c]	30.000	0.250	79.51	29.500	Std.	300	350	630	690	780	840	900	980	1050	1200
					Alt.	380	440	630	690	780	840	900	980	1050	1200
30[c]	30.000	0.281	89.27	29.438	Std.	340	390	710	780	880	940	1010	1100	1180	1350
					Alt.	420	490	710	780	880	940	1010	1100	1180	1350
30	30.000	0.312	99.02	29.376	Std.	370	440	790	860	970	1050	1120	1220	1310	1500
					Alt.	470	550	790	860	970	1050	1120	1220	1310	1500
30	30.000	0.344	109.06	29.312	Std.	410	480	870	950	1070	1160	1240	1340	1440	1650
					Alt.	520	600	870	950	1070	1160	1240	1340	1440	1650
30	30.000	0.375	118.76	29.250	Std.	450	530	950	1040	1170	1260	1350	1460	1580	1800
					Alt.	560	660	950	1040	1170	1260	1350	1460	1580	1800
30	30.000	0.406	128.44	29.188	Std.	490	570	1020	1120	1270	1360	1460	1580	1710	1950
					Alt.	610	710	1020	1120	1270	1360	1460	1580	1710	1950
30	30.000	0.438	138.42	29.124	Std.	530	610	1100	1210	1370	1470	1580	1710	1840	2100
					Alt.	660	770	1100	1210	1370	1470	1580	1710	1840	2100
30	30.000	0.469	148.06	29.062	Std.	560	660	1180	1290	1460	1580	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1580	1690	1830	1970	2250
30	30.000	0.500	157.68	29.000	Std.	600	700	1260	1380	1560	1680	1800	1950	2100	2400
					Alt.	750	880	1260	1380	1560	1680	1800	1950	2100	2400
30	30.000	0.562	176.86	28.876	Std.	670	790	1420	1550	1750	1890	2020	2190	2360	2700
					Alt.	840	980	1420	1550	1750	1890	2020	2190	2360	2700
30	30.000	0.625	196.26	28.750	Std.	750	880	1580	1730	1950	2100	2250	2440	2630	3000
					Alt.	940	1090	1580	1730	1950	2100	2250	2440	2630	3000
30	30.000	0.688	215.58	28.624	Std.	830	960	1730	1900	2150	2310	2480	2680	2890	3000
					Alt.	1030	1200	1730	1900	2150	2310	2480	2680	2890	3300
30	30.000	0.750	234.51	28.500	Std.	900	1050	1890	2070	2340	2520	2700	2930	3000	3000
					Alt.	1130	1310	1890	2070	2340	2520	2700	2930	3150	3600
30	30.000	0.812	253.36	28.376	Std.	970	1140	2050	2240	2530	2730	2920	3000	3000	3000
					Alt.	1220	1420	2050	2240	2530	2730	2920	3170	3410	3630
30	30.000	0.875	272.43	28.250	Std.	1050	1230	2210	2420	2730	2940	3000	3000	3000	3000
					Alt.	1310	1530	2210	2420	2730	2940	3150	3410	3630	3630
30	30.000	0.938	291.41	28.124	Std.	1130	1310	2360	2590	2930	3000	3000	3000	3000	3000
					Alt.	1410	1640	2360	2590	2930	3150	3380	3630	3630	3630
30	30.000	1.000	310.01	28.000	Std.	1200	1400	2520	2760	3000	3000	3000	3000	3000	3000
					Alt.	1500	1750	2520	2760	3120	3360	3600	3630	3630	3630
30	30.000	1.062	328.53	27.876	Std.	1270	1490	2680	2930	3000	3000	3000	3000	3000	3000
					Alt.	1590	1860	2680	2930	3310	3630	3630	3630	3630	3630
30	30.000	1.125	347.26	27.750	Std.	1350	1580	2840	3000	3000	3000	3000	3000	3000	3000
					Alt.	1690	1970	2840	3110	3510	3630	3630	3630	3630	3630
30	30.000	1.188	365.90	27.624	Std.	1430	1660	2990	3000	3000	3000	3000	3000	3000	3000
					Alt.	1780	2080	2990	3280	3630	3630	3630	3630	3630	3630
30	30.000	1.250	384.17	27.500	Std.	1500	1750	3000	3000	3000	3000	3000	3000	3000	3000
					Alt.	1880	2190	3150	3450	3630	3630	3630	3630	3630	3630
32[c]	32.000	0.250	84.85	31.500	Std.	280	330	590	650	730	790	840	910	980	1130
					Alt.	350	410	590	650	730	790	840	910	980	1130
32[c]	32.000	0.281	95.28	31.438	Std.	320	370	660	730	820	890	950	1030	1110	1260
					Alt.	400	460	660	730	820	890	950	1030	1110	1260
32	32.000	0.312	105.69	31.376	Std.	350	410	740	810	910	980	1050	1140	1230	1400
					Alt.	440	510	740	810	910	980	1050	1140	1230	1400
32	32.000	0.344	116.41	31.312	Std.	390	450	810	890	1010	1080	1160	1260	1350	1550
					Alt.	480	560	810	890	1010	1080	1160	1260	1350	1550

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
32	32.000	0.375	126.78	31.250	Std.	420	490	890	970	1100	1180	1270	1370	1480	1690
					Alt.	530	620	890	970	1100	1180	1270	1370	1480	1690
32	32.000	0.406	137.12	31.188	Std.	460	530	960	1050	1190	1280	1370	1480	1600	1830
					Alt.	570	670	960	1050	1190	1280	1370	1480	1600	1830
32	32.000	0.438	147.78	31.124	Std.	490	570	1030	1130	1280	1380	1480	1600	1720	1970
					Alt.	620	720	1030	1130	1280	1380	1480	1600	1720	1970
32	32.000	0.469	158.08	31.062	Std.	530	620	1110	1210	1370	1480	1580	1710	1850	2110
					Alt.	660	770	1110	1210	1370	1480	1580	1710	1850	2110
32	32.000	0.500	168.37	31.000	Std.	560	660	1180	1290	1460	1580	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1580	1690	1830	1970	2250
32	32.000	0.562	188.87	30.876	Std.	630	740	1330	1450	1640	1770	1900	2050	2210	2530
					Alt.	790	920	1330	1450	1640	1770	1900	2050	2210	2530
32	32.000	0.625	209.62	30.750	Std.	700	820	1480	1620	1830	1970	2110	2290	2460	2810
					Alt.	880	1030	1480	1620	1830	1970	2110	2290	2460	2810
32	32.000	0.688	230.29	30.624	Std.	770	900	1630	1780	2010	2170	2320	2520	2710	3000
					Alt.	970	1130	1630	1780	2010	2170	2320	2520	2710	3100
32	32.000	0.750	250.55	30.500	Std.	840	980	1770	1940	2190	2360	2530	2740	2950	3000
					Alt.	1050	1230	1770	1940	2190	2360	2530	2740	2950	3380
32	32.000	0.812	270.72	30.376	Std.	910	1070	1920	2100	2380	2560	2740	2970	3000	3000
					Alt.	1140	1330	1920	2100	2380	2560	2740	2970	3200	3630
32	32.000	0.875	291.14	30.250	Std.	980	1150	2070	2260	2560	2760	2950	3000	3000	3000
					Alt.	1230	1440	2070	2260	2560	2760	2950	3200	3450	3630
32	32.000	0.938	311.47	30.124	Std.	1060	1230	2220	2430	2740	2950	3000	3000	3000	3000
					Alt.	1320	1540	2220	2430	2740	2950	3170	3430	3630	3630
32	32.000	1.000	331.39	30.000	Std.	1130	1310	2360	2590	2930	3000	3000	3000	3000	3000
					Alt.	1410	1640	2360	2590	2930	3150	3380	3630	3630	3630
32	32.000	1.062	351.23	29.876	Std.	1190	1390	2510	2750	3000	3000	3000	3000	3000	3000
					Alt.	1490	1740	2510	2750	3110	3350	3580	3630	3630	3630
32	32.000	1.125	371.31	29.750	Std.	1270	1480	2660	2910	3000	3000	3000	3000	3000	3000
					Alt.	1580	1850	2660	2910	3290	3540	3630	3630	3630	3630
32	32.000	1.188	391.30	29.624	Std.	1340	1560	2810	3000	3000	3000	3000	3000	3000	3000
					Alt.	1670	1950	2810	3070	3470	3630	3630	3630	3630	3630
32	32.000	1.250	410.90	29.500	Std.	1410	1640	2950	3000	3000	3000	3000	3000	3000	3000
					Alt.	1760	2050	2950	3230	3630	3630	3630	3630	3630	3630
34[c]	34.000	0.250	90.20	33.500	Std.	260	310	560	610	690	740	790	860	930	1060
					Alt.	330	390	560	610	690	740	790	860	930	1060
34[c]	34.000	0.281	101.29	33.438	Std.	300	350	620	680	770	830	890	970	1040	1190
					Alt.	370	430	620	680	770	830	890	970	1040	1190
34	34.000	0.312	112.36	33.376	Std.	330	390	690	760	860	920	990	1070	1160	1320
					Alt.	410	480	690	760	860	920	990	1070	1160	1320
34	34.000	0.344	123.77	33.312	Std.	360	420	760	840	950	1020	1090	1180	1270	1460
					Alt.	460	530	760	840	950	1020	1090	1180	1270	1460
34	34.000	0.375	134.79	33.250	Std.	400	460	830	910	1030	1110	1190	1290	1390	1590
					Alt.	500	580	830	910	1030	1110	1190	1290	1390	1590
34	34.000	0.406	145.80	33.188	Std.	430	500	900	990	1120	1200	1290	1400	1500	1720
					Alt.	540	630	900	990	1120	1200	1290	1400	1500	1720
34	34.000	0.438	157.14	33.124	Std.	460	540	970	1070	1210	1300	1390	1510	1620	1860
					Alt.	580	680	970	1070	1210	1300	1390	1510	1620	1860
34	34.000	0.469	168.11	33.062	Std.	500	580	1040	1140	1290	1390	1490	1610	1740	1990
					Alt.	620	720	1040	1140	1290	1390	1490	1610	1740	1990

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure (psi)[b]									
Size	D (in.)	t (in.)	w_{pe} (lb/ft)	d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
34	34.000	0.500	179.06	33.000	Std.	530	620	1110	1220	1380	1480	1590	1720	1850	2120
					Alt.	660	770	1110	1220	1380	1480	1590	1720	1850	2120
34	34.000	0.562	200.89	32.876	Std.	600	690	1250	1370	1550	1670	1790	1930	2080	2380
					Alt.	740	870	1250	1370	1550	1670	1790	1930	2080	2380
34	34.000	0.625	222.99	32.750	Std.	660	770	1390	1520	1720	1850	1990	2150	2320	2650
					Alt.	830	970	1390	1520	1720	1850	1990	2150	2320	2650
34	34.000	0.688	245.00	32.624	Std.	730	850	1530	1680	1890	2040	2190	2370	2550	2910
					Alt.	910	1060	1530	1680	1890	2040	2190	2370	2550	2910
34	34.000	0.750	266.58	32.500	Std.	790	930	1670	1830	2060	2220	2380	2580	2780	3000
					Alt.	990	1160	1670	1830	2060	2220	2380	2580	2780	3180
34	34.000	0.812	288.08	32.376	Std.	860	1000	1810	1980	2240	2410	2580	2790	3000	3000
					Alt.	1070	1250	1810	1980	2240	2410	2580	2790	3010	3440
34	34.000	0.875	309.84	32.250	Std.	930	1080	1950	2130	2410	2590	2780	3000	3000	3000
					Alt.	1160	1350	1950	2130	2410	2590	2780	3010	3240	3630
34	34.000	0.938	331.52	32.124	Std.	990	1160	2090	2280	2580	2780	2980	3000	3000	3000
					Alt.	1240	1450	2090	2280	2580	2780	2980	3230	3480	3630
34	34.000	1.000	352.77	32.000	Std.	1060	1240	2220	2440	2750	2960	3000	3000	3000	3000
					Alt.	1320	1540	2220	2440	2750	2960	3180	3440	3630	3630
34	34.000	1.062	373.94	31.876	Std.	1120	1310	2360	2590	2920	3000	3000	3000	3000	3000
					Alt.	1410	1640	2360	2590	2920	3150	3370	3630	3630	3630
34	34.000	1.125	395.36	31.750	Std.	1190	1390	2500	2740	3000	3000	3000	3000	3000	3000
					Alt.	1490	1740	2500	2740	3100	3340	3570	3630	3630	3630
34	34.000	1.188	416.70	31.624	Std.	1260	1470	2640	2890	3000	3000	3000	3000	3000	3000
					Alt.	1570	1830	2640	2890	3270	3520	3630	3630	3630	3630
34	34.000	1.250	437.62	31.500	Std.	1320	1540	2780	3000	3000	3000	3000	3000	3000	3000
					Alt.	1650	1930	2780	3040	3440	3630	3630	3630	3630	3630
36[c]	36.000	0.250	95.54	35.500	Std.	250	290	530	580	650	700	750	810	880	1000
					Alt.	310	360	530	580	650	700	750	810	880	1000
36[c]	36.000	0.281	107.30	35.438	Std.	280	330	590	650	730	790	840	910	980	1120
					Alt.	350	410	590	650	730	790	840	910	980	1120
36	36.000	0.312	119.03	35.376	Std.	310	360	660	720	810	870	940	1010	1090	1250
					Alt.	390	460	660	720	810	870	940	1010	1090	1250
36	36.000	0.344	131.12	35.312	Std.	340	400	720	790	890	960	1030	1120	1200	1380
					Alt.	430	500	720	790	890	960	1030	1120	1200	1380
36	36.000	0.375	142.81	35.250	Std.	380	440	790	860	980	1050	1130	1220	1310	1500
					Alt.	470	550	790	860	980	1050	1130	1220	1310	1500
36	36.000	0.406	154.48	35.188	Std.	410	470	850	930	1060	1140	1220	1320	1420	1620
					Alt.	510	590	850	930	1060	1140	1220	1320	1420	1620
36	36.000	0.438	166.51	35.124	Std.	440	510	920	1010	1140	1230	1310	1420	1530	1750
					Alt.	550	640	920	1010	1140	1230	1310	1420	1530	1750
36	36.000	0.469	178.14	35.062	Std.	470	550	980	1080	1220	1310	1410	1520	1640	1880
					Alt.	590	680	980	1080	1220	1310	1410	1520	1640	1880
36	36.000	0.500	189.75	35.000	Std.	500	580	1050	1150	1300	1400	1500	1630	1750	2000
					Alt.	630	730	1050	1150	1300	1400	1500	1630	1750	2000
36	36.000	0.562	212.90	34.876	Std.	560	660	1180	1290	1460	1570	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1570	1690	1830	1970	2250
36	36.000	0.625	236.35	34.750	Std.	630	730	1310	1440	1630	1750	1880	2030	2190	2500
					Alt.	780	910	1310	1440	1630	1750	1880	2030	2190	2500
36	36.000	0.688	259.71	34.624	Std.	690	800	1440	1580	1790	1930	2060	2240	2410	2750
					Alt.	860	1000	1440	1580	1790	1930	2060	2240	2410	2750

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
36	36.000	0.750	282.62	34.500	Std.	750	880	1580	1730	1950	2100	2250	2440	2630	3000
					Alt.	940	1090	1580	1730	1950	2100	2250	2440	2630	3000
36	36.000	0.812	305.44	34.376	Std.	810	950	1710	1870	2110	2270	2440	2640	2840	3000
					Alt.	1020	1180	1710	1870	2110	2270	2440	2640	2840	3250
36	36.000	0.875	328.55	34.250	Std.	880	1020	1840	2010	2280	2450	2630	2840	3000	3000
					Alt.	1090	1280	1840	2010	2280	2450	2630	2840	3060	3500
36	36.000	0.938	351.57	34.124	Std.	940	1090	1970	2160	2440	2630	2810	3000	3000	3000
					Alt.	1170	1370	1970	2160	2440	2630	2810	3050	3280	3630
36	36.000	1.000	374.15	34.000	Std.	1000	1170	2100	2300	2600	2800	3000	3000	3000	3000
					Alt.	1250	1460	2100	2300	2600	2800	3000	3250	3500	3630
36	36.000	1.062	396.64	33.876	Std.	1060	1240	2230	2440	2760	2970	3000	3000	3000	3000
					Alt.	1330	1550	2230	2440	2760	2970	3190	3450	3630	3630
36	36.000	1.125	419.42	33.750	Std.	1130	1310	2360	2590	2930	3000	3000	3000	3000	3000
					Alt.	1410	1640	2360	2590	2930	3150	3380	3630	3630	3630
36	36.000	1.188	442.10	33.624	Std.	1190	1390	2490	2730	3000	3000	3000	3000	3000	3000
					Alt.	1490	1730	2490	2730	3090	3330	3560	3630	3630	3630
36	36.000	1.250	464.35	33.500	Std.	1250	1460	2630	2880	3000	3000	3000	3000	3000	3000
					Alt.	1560	1820	2630	2880	3250	3500	3630	3630	3630	3630
38	38.000	0.312	125.70	37.376	Std.	300	340	620	680	770	830	890	960	1030	1180
					Alt.	370	430	620	680	770	830	890	960	1030	1180
38	38.000	0.344	138.47	37.312	Std.	330	380	680	750	850	910	980	1060	1140	1300
					Alt.	410	480	680	750	850	910	980	1060	1140	1300
38	38.000	0.375	150.83	37.250	Std.	360	410	750	820	920	990	1070	1150	1240	1420
					Alt.	440	520	750	820	920	990	1070	1150	1240	1420
38	38.000	0.406	163.16	37.188	Std.	380	450	810	880	1000	1080	1150	1250	1350	1540
					Alt.	480	560	810	880	1000	1080	1150	1250	1350	1540
38	38.000	0.438	175.87	37.124	Std.	410	480	870	950	1080	1160	1240	1350	1450	1660
					Alt.	520	610	870	950	1080	1160	1240	1350	1450	1660
38	38.000	0.469	188.17	37.062	Std.	440	520	930	1020	1160	1240	1330	1440	1560	1780
					Alt.	560	650	930	1020	1160	1240	1330	1440	1560	1780
38	38.000	0.500	200.44	37.000	Std.	470	550	990	1090	1230	1330	1420	1540	1660	1890
					Alt.	590	690	990	1090	1230	1330	1420	1540	1660	1890
38	38.000	0.562	224.92	36.876	Std.	530	620	1120	1220	1380	1490	1600	1730	1860	2130
					Alt.	670	780	1120	1220	1380	1490	1600	1730	1860	2130
38	38.000	0.625	249.71	36.750	Std.	590	690	1240	1360	1540	1660	1780	1920	2070	2370
					Alt.	740	860	1240	1360	1540	1660	1780	1920	2070	2370
38	38.000	0.688	274.42	36.624	Std.	650	760	1370	1500	1690	1830	1960	2120	2280	2610
					Alt.	810	950	1370	1500	1690	1830	1960	2120	2280	2610
38	38.000	0.750	298.65	36.500	Std.	710	830	1490	1630	1850	1990	2130	2310	2490	2840
					Alt.	890	1040	1490	1630	1850	1990	2130	2310	2490	2840
38	38.000	0.812	322.80	36.376	Std.	770	900	1620	1770	2000	2150	2310	2500	2690	3000
					Alt.	960	1120	1620	1770	2000	2150	2310	2500	2690	3080
38	38.000	0.875	347.26	36.250	Std.	830	970	1740	1910	2160	2320	2490	2690	2900	3000
					Alt.	1040	1210	1740	1910	2160	2320	2490	2690	2900	3320
38	38.000	0.938	371.63	36.124	Std.	890	1040	1870	2040	2310	2490	2670	2890	3000	3000
					Alt.	1110	1300	1870	2040	2310	2490	2670	2890	3110	3550
38	38.000	1.000	395.53	36.000	Std.	950	1110	1990	2180	2460	2650	2840	3000	3000	3000
					Alt.	1180	1380	1990	2180	2460	2650	2840	3080	3320	3630
38	38.000	1.062	419.35	35.876	Std.	1010	1170	2110	2310	2620	2820	3000	3000	3000	3000
					Alt.	1260	1470	2110	2310	2620	2820	3020	3270	3520	3630

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure (psi)[b]									
Size	D (in.)	t (in.)	w_{pe} (lb/ft)	d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
38	38.000	1.125	443.47	35.750	Std.	1070	1240	2240	2450	2770	2980	3000	3000	3000	3000
					Alt.	1330	1550	2240	2450	2770	2980	3200	3460	3630	3630
38	38.000	1.188	467.50	35.624	Std.	1130	1310	2360	2590	2930	3000	3000	3000	3000	3000
					Alt.	1410	1640	2360	2590	2930	3150	3380	3630	3630	3630
38	38.000	1.250	491.07	35.500	Std.	1180	1380	2490	2720	3000	3000	3000	3000	3000	3000
					Alt.	1480	1730	2490	2720	3080	3320	3550	3630	3630	3630
40	40.000	0.312	132.37	39.376	Std.	280	330	590	650	730	790	840	910	980	1120
					Alt.	350	410	590	650	730	790	840	910	980	1120
40	40.000	0.344	145.83	39.312	Std.	310	360	650	710	800	870	930	1010	1080	1240
					Alt.	390	450	650	710	800	870	930	1010	1080	1240
40	40.000	0.375	158.85	39.250	Std.	340	390	710	780	880	950	1010	1100	1180	1350
					Alt.	420	490	710	780	880	950	1010	1100	1180	1350
40	40.000	0.406	171.84	39.188	Std.	370	430	770	840	950	1020	1100	1190	1280	1460
					Alt.	460	530	770	840	950	1020	1100	1190	1280	1460
40	40.000	0.438	185.24	39.124	Std.	390	460	830	910	1020	1100	1180	1280	1380	1580
					Alt.	490	570	830	910	1020	1100	1180	1280	1380	1580
40	40.000	0.469	198.19	39.062	Std.	420	490	890	970	1100	1180	1270	1370	1480	1690
					Alt.	530	620	890	970	1100	1180	1270	1370	1480	1690
40	40.000	0.500	211.13	39.000	Std.	450	530	950	1040	1170	1260	1350	1460	1580	1800
					Alt.	560	660	950	1040	1170	1260	1350	1460	1580	1800
40	40.000	0.562	236.93	38.876	Std.	510	590	1060	1160	1320	1420	1520	1640	1770	2020
					Alt.	630	740	1060	1160	1320	1420	1520	1640	1770	2020
40	40.000	0.625	263.07	38.750	Std.	560	660	1180	1290	1460	1580	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1580	1690	1830	1970	2250
40	40.000	0.688	289.13	38.624	Std.	620	720	1300	1420	1610	1730	1860	2010	2170	2480
					Alt.	770	900	1300	1420	1610	1730	1860	2010	2170	2480
40	40.000	0.750	314.69	38.500	Std.	680	790	1420	1550	1760	1890	2030	2190	2360	2700
					Alt.	840	980	1420	1550	1760	1890	2030	2190	2360	2700
40	40.000	0.812	340.16	38.376	Std.	730	850	1530	1680	1900	2050	2190	2380	2560	2920
					Alt.	910	1070	1530	1680	1900	2050	2190	2380	2560	2920
40	40.000	0.875	365.97	38.250	Std.	790	920	1650	1810	2050	2210	2360	2560	2760	3000
					Alt.	980	1150	1650	1810	2050	2210	2360	2560	2760	3150
40	40.000	0.938	391.68	38.124	Std.	840	980	1770	1940	2190	2360	2530	2740	2950	3000
					Alt.	1060	1230	1770	1940	2190	2360	2530	2740	2950	3380
40	40.000	1.000	416.91	38.000	Std.	900	1050	1890	2070	2340	2520	2700	2930	3000	3000
					Alt.	1130	1310	1890	2070	2340	2520	2700	2930	3150	3600
40	40.000	1.062	442.05	37.876	Std.	960	1120	2010	2200	2490	2680	2870	3000	3000	3000
					Alt.	1190	1390	2010	2200	2490	2680	2870	3110	3350	3630
40	40.000	1.125	467.52	37.750	Std.	1010	1180	2130	2330	2630	2840	3000	3000	3000	3000
					Alt.	1270	1480	2130	2330	2630	2840	3040	3290	3540	3630
40	40.000	1.188	492.90	37.624	Std.	1070	1250	2250	2460	2780	2990	3000	3000	3000	3000
					Alt.	1340	1560	2250	2460	2780	2990	3210	3470	3630	3630
40	40.000	1.250	517.80	37.500	Std.	1130	1310	2360	2590	2930	3000	3000	3000	3000	3000
					Alt.	1410	1640	2360	2590	2930	3150	3380	3630	3630	3630
42	42.000	0.344	153.18	41.312	Std.	290	340	620	680	770	830	880	960	1030	1180
					Alt.	370	430	620	680	770	830	880	960	1030	1180
42	42.000	0.375	166.86	41.250	Std.	320	380	680	740	840	900	960	1040	1130	1290
					Alt.	400	470	680	740	840	900	960	1040	1130	1290
42	42.000	0.406	180.52	41.188	Std.	350	410	730	800	900	970	1040	1130	1220	1390
					Alt.	440	510	730	800	900	970	1040	1130	1220	1390

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
42	42.000	0.438	194.60	41.124	Std.	380	440	790	860	980	1050	1130	1220	1310	1500
					Alt.	470	550	790	860	980	1050	1130	1220	1310	1500
42	42.000	0.469	208.22	41.062	Std.	400	470	840	920	1050	1130	1210	1310	1410	1610
					Alt.	500	590	840	920	1050	1130	1210	1310	1410	1610
42	42.000	0.500	221.82	41.000	Std.	430	500	900	990	1110	1200	1290	1390	1500	1710
					Alt.	540	630	900	990	1110	1200	1290	1390	1500	1710
42	42.000	0.562	248.95	40.876	Std.	480	560	1010	1110	1250	1350	1450	1570	1690	1930
					Alt.	600	700	1010	1110	1250	1350	1450	1570	1690	1930
42	42.000	0.625	276.44	40.750	Std.	540	630	1130	1230	1390	1500	1610	1740	1880	2140
					Alt.	670	780	1130	1230	1390	1500	1610	1740	1880	2140
42	42.000	0.688	303.84	40.624	Std.	590	690	1240	1360	1530	1650	1770	1920	2060	2360
					Alt.	740	860	1240	1360	1530	1650	1770	1920	2060	2360
42	42.000	0.750	330.72	40.500	Std.	640	750	1350	1480	1670	1800	1930	2090	2250	2570
					Alt.	800	940	1350	1480	1670	1800	1930	2090	2250	2570
42	42.000	0.812	357.52	40.376	Std.	700	810	1460	1600	1810	1950	2090	2260	2440	2780
					Alt.	870	1020	1460	1600	1810	1950	2090	2260	2440	2780
42	42.000	0.875	384.67	40.250	Std.	750	880	1580	1730	1950	2100	2250	2440	2630	3000
					Alt.	940	1090	1580	1730	1950	2100	2250	2440	2630	3000
42	42.000	0.938	411.74	40.124	Std.	800	940	1690	1850	2090	2250	2410	2610	2810	3000
					Alt.	1010	1170	1690	1850	2090	2250	2410	2610	2810	3220
42	42.000	1.000	438.29	40.000	Std.	860	1000	1800	1970	2230	2400	2570	2790	3000	3000
					Alt.	1070	1250	1800	1970	2230	2400	2570	2790	3000	3430
42	42.000	1.062	464.76	39.876	Std.	910	1060	1910	2090	2370	2550	2730	2960	3000	3000
					Alt.	1140	1330	1910	2090	2370	2550	2730	2960	3190	3630
42	42.000	1.125	491.57	39.750	Std.	960	1130	2030	2220	2510	2700	2890	3000	3000	3000
					Alt.	1210	1410	2030	2220	2510	2700	2890	3130	3380	3630
42	42.000	1.188	518.30	39.624	Std.	1020	1190	2140	2340	2650	2850	3000	3000	3000	3000
					Alt.	1270	1490	2140	2340	2650	2850	3050	3310	3560	3630
42	42.000	1.250	544.52	39.500	Std.	1070	1250	2250	2460	2790	3000	3000	3000	3000	3000
					Alt.	1340	1560	2250	2460	2790	3000	3210	3480	3630	3630
44	44.000	0.344	160.54	43.312	Std.	280	330	590	650	730	790	840	910	990	1130
					Alt.	350	410	590	650	730	790	840	910	990	1130
44	44.000	0.375	174.88	43.250	Std.	310	360	640	710	800	860	920	1000	1070	1230
					Alt.	380	450	640	710	800	860	920	1000	1070	1230
44	44.000	0.406	189.20	43.188	Std.	330	390	700	760	860	930	1000	1080	1160	1330
					Alt.	420	480	700	760	860	930	1000	1080	1160	1330
44	44.000	0.438	203.97	43.124	Std.	360	420	750	820	930	1000	1080	1160	1250	1430
					Alt.	450	520	750	820	930	1000	1080	1160	1250	1430
44	44.000	0.469	218.25	43.062	Std.	380	450	810	880	1000	1070	1150	1250	1340	1530
					Alt.	480	560	810	880	1000	1070	1150	1250	1340	1530
44	44.000	0.500	232.51	43.000	Std.	410	480	860	940	1060	1150	1230	1330	1430	1640
					Alt.	510	600	860	940	1060	1150	1230	1330	1430	1640
44	44.000	0.562	260.97	42.876	Std.	460	540	970	1060	1200	1290	1380	1490	1610	1840
					Alt.	570	670	970	1060	1200	1290	1380	1490	1610	1840
44	44.000	0.625	289.80	42.750	Std.	510	600	1070	1180	1330	1430	1530	1660	1790	2050
					Alt.	640	750	1070	1180	1330	1430	1530	1660	1790	2050
44	44.000	0.688	318.55	42.624	Std.	560	660	1180	1290	1460	1580	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1580	1690	1830	1970	2250
44	44.000	0.750	346.76	42.500	Std.	610	720	1290	1410	1600	1720	1840	1990	2150	2450
					Alt.	770	890	1290	1410	1600	1720	1840	1990	2150	2450

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure (psi)[b]									
Size	D (in.)	t (in.)	w_{pe} (lb/ft)	d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
44	44.000	0.812	374.88	42.376	Std.	660	780	1400	1530	1730	1860	1990	2160	2330	2660
					Alt.	830	970	1400	1530	1730	1860	1990	2160	2330	2660
44	44.000	0.875	403.38	42.250	Std.	720	840	1500	1650	1860	2000	2150	2330	2510	2860
					Alt.	890	1040	1500	1650	1860	2000	2150	2330	2510	2860
44	44.000	0.938	431.79	42.124	Std.	770	900	1610	1770	2000	2150	2300	2490	2690	3000
					Alt.	960	1120	1610	1770	2000	2150	2300	2490	2690	3070
44	44.000	1.000	459.67	42.000	Std.	820	950	1720	1880	2130	2290	2450	2660	2860	3000
					Alt.	1020	1190	1720	1880	2130	2290	2450	2660	2860	3270
44	44.000	1.062	487.47	41.876	Std.	870	1010	1820	2000	2260	2430	2610	2820	3000	3000
					Alt.	1090	1270	1820	2000	2260	2430	2610	2820	3040	3480
44	44.000	1.125	515.63	41.750	Std.	920	1070	1930	2120	2390	2580	2760	2990	3000	3000
					Alt.	1150	1340	1930	2120	2390	2580	2760	2990	3220	3630
44	44.000	1.188	543.70	41.624	Std.	970	1130	2040	2240	2530	2720	2920	3000	3000	3000
					Alt.	1220	1420	2040	2240	2530	2720	2920	3160	3400	3630
44	44.000	1.250	571.25	41.500	Std.	1020	1190	2150	2350	2660	2860	3000	3000	3000	3000
					Alt.	1280	1490	2150	2350	2660	2860	3070	3320	3580	3630
46	46.000	0.344	167.89	45.312	Std.	270	310	570	620	700	750	810	870	940	1080
					Alt.	340	390	570	620	700	750	810	870	940	1080
46	46.000	0.375	182.90	45.250	Std.	290	340	620	680	760	820	880	950	1030	1170
					Alt.	370	430	620	680	760	820	880	950	1030	1170
46	46.000	0.406	197.88	45.188	Std.	320	370	670	730	830	890	950	1030	1110	1270
					Alt.	400	460	670	730	830	890	950	1030	1110	1270
46	46.000	0.438	213.33	45.124	Std.	340	400	720	790	890	960	1030	1110	1200	1370
					Alt.	430	500	720	790	890	960	1030	1110	1200	1370
46	46.000	0.469	228.27	45.062	Std.	370	430	770	840	950	1030	1100	1190	1280	1470
					Alt.	460	540	770	840	950	1030	1100	1190	1280	1470
46	46.000	0.500	243.20	45.000	Std.	390	460	820	900	1020	1100	1170	1270	1370	1570
					Alt.	490	570	820	900	1020	1100	1170	1270	1370	1570
46	46.000	0.562	272.98	44.876	Std.	440	510	920	1010	1140	1230	1320	1430	1540	1760
					Alt.	550	640	920	1010	1140	1230	1320	1430	1540	1760
46	46.000	0.625	303.16	44.750	Std.	490	570	1030	1130	1270	1370	1470	1590	1710	1960
					Alt.	610	710	1030	1130	1270	1370	1470	1590	1710	1960
46	46.000	0.688	333.26	44.624	Std.	540	630	1130	1240	1400	1510	1620	1750	1880	2150
					Alt.	670	790	1130	1240	1400	1510	1620	1750	1880	2150
46	46.000	0.750	362.79	44.500	Std.	590	680	1230	1350	1530	1640	1760	1910	2050	2350
					Alt.	730	860	1230	1350	1530	1640	1760	1910	2050	2350
46	46.000	0.812	392.24	44.376	Std.	640	740	1330	1460	1650	1780	1910	2070	2220	2540
					Alt.	790	930	1330	1460	1650	1780	1910	2070	2220	2540
46	46.000	0.875	422.09	44.250	Std.	680	800	1440	1580	1780	1920	2050	2230	2400	2740
					Alt.	860	1000	1440	1580	1780	1920	2050	2230	2400	2740
46	46.000	0.938	451.85	44.124	Std.	730	860	1540	1690	1910	2060	2200	2390	2570	2940
					Alt.	920	1070	1540	1690	1910	2060	2200	2390	2570	2940
46	46.000	1.000	481.05	44.000	Std.	780	910	1640	1800	2030	2190	2350	2540	2740	3000
					Alt.	980	1140	1640	1800	2030	2190	2350	2540	2740	3130
46	46.000	1.062	510.17	43.876	Std.	830	970	1750	1910	2160	2330	2490	2700	2910	3000
					Alt.	1040	1210	1750	1910	2160	2330	2490	2700	2910	3320
46	46.000	1.125	539.68	43.750	Std.	880	1030	1850	2030	2290	2470	2640	2860	3000	3000
					Alt.	1100	1280	1850	2030	2290	2470	2640	2860	3080	3520
46	46.000	1.188	569.10	43.624	Std.	930	1080	1950	2140	2420	2600	2790	3000	3000	3000
					Alt.	1160	1360	1950	2140	2420	2600	2790	3020	3250	3630

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
46	46.000	1.250	597.97	43.500	Std.	980	1140	2050	2250	2540	2740	2930	3000	3000	3000
					Alt.	1220	1430	2050	2250	2540	2740	2930	3180	3420	3630
48	48.000	0.344	175.25	47.312	Std.	260	300	540	590	670	720	770	840	900	1030
					Alt.	320	380	540	590	670	720	770	840	900	1030
48	48.000	0.375	190.92	47.250	Std.	280	330	590	650	730	790	840	910	980	1130
					Alt.	350	410	590	650	730	790	840	910	980	1130
48	48.000	0.406	206.56	47.188	Std.	300	360	640	700	790	850	910	990	1070	1220
					Alt.	380	440	640	700	790	850	910	990	1070	1220
48	48.000	0.438	222.70	47.124	Std.	330	380	690	760	850	920	990	1070	1150	1310
					Alt.	410	480	690	760	850	920	990	1070	1150	1310
48	48.000	0.469	238.30	47.062	Std.	350	410	740	810	910	980	1060	1140	1230	1410
					Alt.	440	510	740	810	910	980	1060	1140	1230	1410
48	48.000	0.500	253.89	47.000	Std.	380	440	790	860	980	1050	1130	1220	1310	1500
					Alt.	470	550	790	860	980	1050	1130	1220	1310	1500
48	48.000	0.562	285.00	46.876	Std.	420	490	890	970	1100	1180	1260	1370	1480	1690
					Alt.	530	610	890	970	1100	1180	1260	1370	1480	1690
48	48.000	0.625	316.52	46.750	Std.	470	550	980	1080	1220	1310	1410	1520	1640	1880
					Alt.	590	680	980	1080	1220	1310	1410	1520	1640	1880
48	48.000	0.688	347.97	46.624	Std.	520	600	1080	1190	1340	1440	1550	1680	1810	2060
					Alt.	650	750	1080	1190	1340	1440	1550	1680	1810	2060
48	48.000	0.750	378.83	46.500	Std.	560	660	1180	1290	1460	1580	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1580	1690	1830	1970	2250
48	48.000	0.812	409.61	46.376	Std.	610	710	1280	1400	1580	1710	1830	1980	2130	2440
					Alt.	760	890	1280	1400	1580	1710	1830	1980	2130	2440
48	48.000	0.875	440.80	46.250	Std.	660	770	1380	1510	1710	1840	1970	2130	2300	2630
					Alt.	820	960	1380	1510	1710	1840	1970	2130	2300	2630
48	48.000	0.938	471.90	46.124	Std.	700	820	1480	1620	1830	1970	2110	2290	2460	2810
					Alt.	880	1030	1480	1620	1830	1970	2110	2290	2460	2810
48	48.000	1.000	502.43	46.000	Std.	750	880	1580	1730	1950	2100	2250	2440	2630	3000
					Alt.	940	1090	1580	1730	1950	2100	2250	2440	2630	3000
48	48.000	1.062	532.88	45.876	Std.	800	930	1670	1830	2070	2230	2390	2590	2790	3000
					Alt.	1000	1160	1670	1830	2070	2230	2390	2590	2790	3190
48	48.000	1.125	563.73	45.750	Std.	840	980	1770	1940	2190	2360	2530	2740	2950	3000
					Alt.	1050	1230	1770	1940	2190	2360	2530	2740	2950	3380
48	48.000	1.188	594.50	45.624	Std.	890	1040	1870	2050	2320	2490	2670	2900	3000	3000
					Alt.	1110	1300	1870	2050	2320	2490	2670	2900	3120	3560
48	48.000	1.250	624.70	45.500	Std.	940	1090	1970	2160	2440	2630	2810	3000	3000	3000
					Alt.	1170	1370	1970	2160	2440	2630	2810	3050	3280	3630
52	52.000	0.375	206.95	51.250	Std.	260	300	550	600	680	730	780	840	910	1040
					Alt.	320	380	550	600	680	730	780	840	910	1040
52	52.000	0.406	223.93	51.188	Std.	280	330	590	650	730	790	840	910	980	1120
					Alt.	350	410	590	650	730	790	840	910	980	1120
52	52.000	0.438	241.42	51.124	Std.	300	350	640	700	790	850	910	990	1060	1210
					Alt.	380	440	640	700	790	850	910	990	1060	1210
52	52.000	0.469	258.36	51.062	Std.	320	380	680	750	840	910	970	1060	1140	1300
					Alt.	410	470	680	750	840	910	970	1060	1140	1300
52	52.000	0.500	275.27	51.000	Std.	350	400	730	800	900	970	1040	1130	1210	1380
					Alt.	430	500	730	800	900	970	1040	1130	1210	1380
52	52.000	0.562	309.03	50.876	Std.	390	450	820	890	1010	1090	1170	1260	1360	1560
					Alt.	490	570	820	890	1010	1090	1170	1260	1360	1560

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure (psi)[b]									
Size	D (in.)	t (in.)	w_{pe} (lb/ft)	d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
52	52.000	0.625	343.25	50.750	Std.	430	500	910	1000	1130	1210	1300	1410	1510	1730
					Alt.	540	630	910	1000	1130	1210	1300	1410	1510	1730
52	52.000	0.688	377.39	50.624	Std.	480	560	1000	1100	1240	1330	1430	1550	1670	1910
					Alt.	600	690	1000	1100	1240	1330	1430	1550	1670	1910
52	52.000	0.750	410.90	50.500	Std.	520	610	1090	1190	1350	1450	1560	1690	1820	2080
					Alt.	650	760	1090	1190	1350	1450	1560	1690	1820	2080
52	52.000	0.812	444.33	50.376	Std.	560	660	1180	1290	1460	1570	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1570	1690	1830	1970	2250
52	52.000	0.875	478.21	50.250	Std.	610	710	1270	1390	1580	1700	1820	1970	2120	2420
					Alt.	760	880	1270	1390	1580	1700	1820	1970	2120	2420
52	52.000	0.938	512.01	50.124	Std.	650	760	1360	1490	1690	1820	1950	2110	2270	2600
					Alt.	810	950	1360	1490	1690	1820	1950	2110	2270	2600
52	52.000	1.000	545.19	50.000	Std.	690	810	1450	1590	1800	1940	2080	2250	2420	2770
					Alt.	870	1010	1450	1590	1800	1940	2080	2250	2420	2770
52	52.000	1.062	578.29	49.876	Std.	740	860	1540	1690	1910	2060	2210	2390	2570	2940
					Alt.	920	1070	1540	1690	1910	2060	2210	2390	2570	2940
52	52.000	1.125	611.84	49.750	Std.	780	910	1640	1790	2030	2180	2340	2530	2730	3000
					Alt.	970	1140	1640	1790	2030	2180	2340	2530	2730	3120
52	52.000	1.188	645.30	49.624	Std.	820	960	1730	1890	2140	2300	2470	2670	2880	3000
					Alt.	1030	1200	1730	1890	2140	2300	2470	2670	2880	3290
52	52.000	1.250	678.15	49.500	Std.	870	1010	1820	1990	2250	2420	2600	2810	3000	3000
					Alt.	1080	1260	1820	1990	2250	2420	2600	2810	3030	3460
56	56.000	0.375	222.99	55.250	Std.	240	280	510	550	630	680	720	780	840	960
					Alt.	300	350	510	550	630	680	720	780	840	960
56	56.000	0.406	241.29	55.188	Std.	260	300	550	600	680	730	780	850	910	1040
					Alt.	330	380	550	600	680	730	780	850	910	1040
56	56.000	0.438	260.15	55.124	Std.	280	330	590	650	730	790	840	920	990	1130
					Alt.	350	410	590	650	730	790	840	920	990	1130
56	56.000	0.469	278.41	55.062	Std.	300	350	630	690	780	840	900	980	1060	1210
					Alt.	380	440	630	690	780	840	900	980	1060	1210
56	56.000	0.500	296.65	55.000	Std.	320	380	680	740	840	900	960	1040	1130	1290
					Alt.	400	470	680	740	840	900	960	1040	1130	1290
56	56.000	0.562	333.06	54.876	Std.	360	420	760	830	940	1010	1080	1170	1260	1450
					Alt.	450	530	760	830	940	1010	1080	1170	1260	1450
56	56.000	0.625	369.97	54.750	Std.	400	470	840	920	1040	1130	1210	1310	1410	1610
					Alt.	500	590	840	920	1040	1130	1210	1310	1410	1610
56	56.000	0.688	406.80	54.624	Std.	440	520	930	1020	1150	1240	1330	1440	1550	1770
					Alt.	550	650	930	1020	1150	1240	1330	1440	1550	1770
56	56.000	0.750	442.97	54.500	Std.	480	560	1010	1110	1250	1350	1450	1570	1690	1930
					Alt.	600	700	1010	1110	1250	1350	1450	1570	1690	1930
56	56.000	0.812	479.05	54.376	Std.	520	610	1100	1200	1360	1460	1570	1700	1830	2090
					Alt.	650	760	1100	1200	1360	1460	1570	1700	1830	2090
56	56.000	0.875	515.63	54.250	Std.	560	660	1180	1290	1460	1580	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1580	1690	1830	1970	2250
56	56.000	0.938	552.12	54.124	Std.	600	700	1270	1390	1570	1690	1810	1960	2110	2410
					Alt.	750	880	1270	1390	1570	1690	1810	1960	2110	2410
56	56.000	1.000	587.95	54.000	Std.	640	750	1350	1480	1670	1800	1930	2090	2250	2570
					Alt.	800	940	1350	1480	1670	1800	1930	2090	2250	2570
56	56.000	1.062	623.70	53.876	Std.	680	800	1430	1570	1780	1910	2050	2220	2390	2730
					Alt.	850	1000	1430	1570	1780	1910	2050	2220	2390	2730

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
56	56.000	1.125	659.94	53.750	Std.	720	840	1520	1660	1880	2030	2170	2350	2530	2890
					Alt.	900	1050	1520	1660	1880	2030	2170	2350	2530	2890
56	56.000	1.188	696.10	53.624	Std.	760	890	1600	1760	1990	2140	2290	2480	2670	3000
					Alt.	950	1110	1600	1760	1990	2140	2290	2480	2670	3050
56	56.000	1.250	731.60	53.500	Std.	800	940	1690	1850	2090	2250	2410	2610	2810	3000
					Alt.	1000	1170	1690	1850	2090	2250	2410	2610	2810	3210
60	60.000	0.375	239.02	59.250	Std.	230	260	470	520	590	630	680	730	790	900
					Alt.	280	330	470	520	590	630	680	730	790	900
60	60.000	0.406	258.65	59.188	Std.	240	280	510	560	630	680	730	790	850	970
					Alt.	300	360	510	560	630	680	730	790	850	970
60	60.000	0.438	278.88	59.124	Std.	260	310	550	600	680	740	790	850	920	1050
					Alt.	330	380	550	600	680	740	790	850	920	1050
60	60.000	0.469	298.47	59.062	Std.	280	330	590	650	730	790	840	910	980	1130
					Alt.	350	410	590	650	730	790	840	910	980	1130
60	60.000	0.500	318.03	59.000	Std.	300	350	630	690	780	840	900	980	1050	1200
					Alt.	380	440	630	690	780	840	900	980	1050	1200
60	60.000	0.562	357.09	58.876	Std.	340	390	710	780	880	940	1010	1100	1180	1350
					Alt.	420	490	710	780	880	940	1010	1100	1180	1350
60	60.000	0.625	396.70	58.750	Std.	380	440	790	860	980	1050	1130	1220	1310	1500
					Alt.	470	550	790	860	980	1050	1130	1220	1310	1500
60	60.000	0.688	436.22	58.624	Std.	410	480	870	950	1070	1160	1240	1340	1440	1650
					Alt.	520	600	870	950	1070	1160	1240	1340	1440	1650
60	60.000	0.750	475.04	58.500	Std.	450	530	950	1040	1170	1260	1350	1460	1580	1800
					Alt.	560	660	950	1040	1170	1260	1350	1460	1580	1800
60	60.000	0.812	513.77	58.376	Std.	490	570	1020	1120	1270	1360	1460	1580	1710	1950
					Alt.	610	710	1020	1120	1270	1360	1460	1580	1710	1950
60	60.000	0.875	553.04	58.250	Std.	530	610	1100	1210	1370	1470	1580	1710	1840	2100
					Alt.	660	770	1100	1210	1370	1470	1580	1710	1840	2100
60	60.000	0.938	592.23	58.124	Std.	560	660	1180	1290	1460	1580	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1580	1690	1830	1970	2250
60	60.000	1.000	630.71	58.000	Std.	600	700	1260	1380	1560	1680	1800	1950	2100	2400
					Alt.	750	880	1260	1380	1560	1680	1800	1950	2100	2400
60	60.000	1.062	669.11	57.876	Std.	640	740	1340	1470	1660	1780	1910	2070	2230	2550
					Alt.	800	930	1340	1470	1660	1780	1910	2070	2230	2550
60	60.000	1.125	708.05	57.750	Std.	680	790	1420	1550	1760	1890	2030	2190	2360	2700
					Alt.	840	980	1420	1550	1760	1890	2030	2190	2360	2700
60	60.000	1.188	746.90	57.624	Std.	710	830	1500	1640	1850	2000	2140	2320	2490	2850
					Alt.	890	1040	1500	1640	1850	2000	2140	2320	2490	2850
60	60.000	1.250	785.05	57.500	Std.	750	880	1580	1730	1950	2100	2250	2440	2630	3000
					Alt.	940	1090	1580	1730	1950	2100	2250	2440	2630	3000
64	64.000	0.375	255.06	63.250	Std.	210	250	440	490	550	590	630	690	740	840
					Alt.	260	310	440	490	550	590	630	690	740	840
64	64.000	0.406	276.01	63.188	Std.	230	270	480	530	590	640	690	740	800	910
					Alt.	290	330	480	530	590	640	690	740	800	910
64	64.000	0.438	297.61	63.124	Std.	250	290	520	570	640	690	740	800	860	990
					Alt.	310	360	520	570	640	690	740	800	860	990
64	64.000	0.469	318.52	63.062	Std.	260	310	550	610	690	740	790	860	920	1060
					Alt.	330	380	550	610	690	740	790	860	920	1060
64	64.000	0.500	339.41	63.000	Std.	280	330	590	650	730	790	840	910	980	1130
					Alt.	350	410	590	650	730	790	840	910	980	1130

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
64	64.000	0.562	381.12	62.876	Std.	320	370	660	730	820	890	950	1030	1110	1260
					Alt.	400	460	660	730	820	890	950	1030	1110	1260
64	64.000	0.625	423.42	62.750	Std.	350	410	740	810	910	980	1050	1140	1230	1410
					Alt.	440	510	740	810	910	980	1050	1140	1230	1410
64	64.000	0.688	465.64	62.624	Std.	390	450	810	890	1010	1080	1160	1260	1350	1550
					Alt.	480	560	810	890	1010	1080	1160	1260	1350	1550
64	64.000	0.750	507.11	62.500	Std.	420	490	890	970	1100	1180	1270	1370	1480	1690
					Alt.	530	620	890	970	1100	1180	1270	1370	1480	1690
64	64.000	0.812	548.49	62.376	Std.	460	530	960	1050	1190	1280	1370	1480	1600	1830
					Alt.	570	670	960	1050	1190	1280	1370	1480	1600	1830
64	64.000	0.875	590.46	62.250	Std.	490	570	1030	1130	1280	1380	1480	1600	1720	1970
					Alt.	620	720	1030	1130	1280	1380	1480	1600	1720	1970
64	64.000	0.938	632.34	62.124	Std.	530	620	1110	1210	1370	1480	1580	1710	1850	2110
					Alt.	660	770	1110	1210	1370	1480	1580	1710	1850	2110
64	64.000	1.000	673.47	62.000	Std.	560	660	1180	1290	1460	1580	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1580	1690	1830	1970	2250
64	64.000	1.062	714.52	61.876	Std.	600	700	1250	1370	1550	1670	1790	1940	2090	2390
					Alt.	750	870	1250	1370	1550	1670	1790	1940	2090	2390
64	64.000	1.125	756.15	61.750	Std.	630	740	1330	1460	1650	1770	1900	2060	2210	2530
					Alt.	790	920	1330	1460	1650	1770	1900	2060	2210	2530
64	64.000	1.188	797.69	61.624	Std.	670	780	1400	1540	1740	1870	2000	2170	2340	2670
					Alt.	840	970	1400	1540	1740	1870	2000	2170	2340	2670
64	64.000	1.250	838.50	61.500	Std.	700	820	1480	1620	1830	1970	2110	2290	2460	2810
					Alt.	880	1030	1480	1620	1830	1970	2110	2290	2460	2810
68	68.000	0.469	338.57	67.062	Std.	250	290	520	570	650	700	740	810	870	990
					Alt.	310	360	520	570	650	700	740	810	870	990
68	68.000	0.500	360.79	67.000	Std.	260	310	560	610	690	740	790	860	930	1060
					Alt.	330	390	560	610	690	740	790	860	930	1060
68	68.000	0.562	405.15	66.876	Std.	300	350	620	680	770	830	890	970	1040	1190
					Alt.	370	430	620	680	770	830	890	970	1040	1190
68	68.000	0.625	450.15	66.750	Std.	330	390	690	760	860	930	990	1080	1160	1320
					Alt.	410	480	690	760	860	930	990	1080	1160	1320
68	68.000	0.688	495.06	66.624	Std.	360	420	760	840	950	1020	1090	1180	1270	1460
					Alt.	460	530	760	840	950	1020	1090	1180	1270	1460
68	68.000	0.750	539.18	66.500	Std.	400	460	830	910	1030	1110	1190	1290	1390	1590
					Alt.	500	580	830	910	1030	1110	1190	1290	1390	1590
68	68.000	0.812	583.21	66.376	Std.	430	500	900	990	1120	1200	1290	1400	1500	1720
					Alt.	540	630	900	990	1120	1200	1290	1400	1500	1720
68	68.000	0.875	627.87	66.250	Std.	460	540	970	1070	1200	1300	1390	1510	1620	1850
					Alt.	580	680	970	1070	1200	1300	1390	1510	1620	1850
68	68.000	0.938	672.45	66.124	Std.	500	580	1040	1140	1290	1390	1490	1610	1740	1990
					Alt.	620	720	1040	1140	1290	1390	1490	1610	1740	1990
68	68.000	1.000	716.23	66.000	Std.	530	620	1110	1220	1380	1480	1590	1720	1850	2120
					Alt.	660	770	1110	1220	1380	1480	1590	1720	1850	2120
68	68.000	1.062	759.93	65.876	Std.	560	660	1180	1290	1460	1570	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1570	1690	1830	1970	2250
68	68.000	1.125	804.26	65.750	Std.	600	690	1250	1370	1550	1670	1790	1940	2080	2380
					Alt.	740	870	1250	1370	1550	1670	1790	1940	2080	2380
68	68.000	1.188	848.49	65.624	Std.	630	730	1320	1450	1640	1760	1890	2040	2200	2520
					Alt.	790	920	1320	1450	1640	1760	1890	2040	2200	2520

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
68	68.000	1.250	891.95	65.500	Std.	660	770	1390	1520	1720	1850	1990	2150	2320	2650
					Alt.	830	970	1390	1520	1720	1850	1990	2150	2320	2650
72	72.000	0.500	382.17	71.000	Std.	250	290	530	580	650	700	750	810	880	1000
					Alt.	310	360	530	580	650	700	750	810	880	1000
72	72.000	0.562	429.18	70.876	Std.	280	330	590	650	730	790	840	910	980	1120
					Alt.	350	410	590	650	730	790	840	910	980	1120
72	72.000	0.625	476.87	70.750	Std.	310	360	660	720	810	880	940	1020	1090	1250
					Alt.	390	460	660	720	810	880	940	1020	1090	1250
72	72.000	0.688	524.48	70.624	Std.	340	400	720	790	890	960	1030	1120	1200	1380
					Alt.	430	500	720	790	890	960	1030	1120	1200	1380
72	72.000	0.750	571.25	70.500	Std.	380	440	790	860	980	1050	1130	1220	1310	1500
					Alt.	470	550	790	860	980	1050	1130	1220	1310	1500
72	72.000	0.812	617.93	70.376	Std.	410	470	850	930	1060	1140	1220	1320	1420	1620
					Alt.	510	590	850	930	1060	1140	1220	1320	1420	1620
72	72.000	0.875	665.29	70.250	Std.	440	510	920	1010	1140	1230	1310	1420	1530	1750
					Alt.	550	640	920	1010	1140	1230	1310	1420	1530	1750
72	72.000	0.938	712.55	70.124	Std.	470	550	980	1080	1220	1310	1410	1520	1640	1880
					Alt.	590	680	980	1080	1220	1310	1410	1520	1640	1880
72	72.000	1.000	758.99	70.000	Std.	500	580	1050	1150	1300	1400	1500	1630	1750	2000
					Alt.	630	730	1050	1150	1300	1400	1500	1630	1750	2000
72	72.000	1.062	805.34	69.876	Std.	530	620	1120	1220	1380	1490	1590	1730	1860	2120
					Alt.	660	770	1120	1220	1380	1490	1590	1730	1860	2120
72	72.000	1.125	852.36	69.750	Std.	560	660	1180	1290	1460	1580	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1580	1690	1830	1970	2250
72	72.000	1.188	899.29	69.624	Std.	590	690	1250	1370	1540	1660	1780	1930	2080	2380
					Alt.	740	870	1250	1370	1540	1660	1780	1930	2080	2380
72	72.000	1.250	945.40	69.500	Std.	630	730	1310	1440	1630	1750	1880	2030	2190	2500
					Alt.	780	910	1310	1440	1630	1750	1880	2030	2190	2500
76	76.000	0.500	403.55	75.000	Std.	240	280	500	540	620	660	710	770	830	950
					Alt.	300	350	500	540	620	660	710	770	830	950
76	76.000	0.562	453.21	74.876	Std.	270	310	560	610	690	750	800	870	930	1060
					Alt.	330	390	560	610	690	750	800	870	930	1060
76	76.000	0.625	503.60	74.750	Std.	300	350	620	680	770	830	890	960	1040	1180
					Alt.	370	430	620	680	770	830	890	960	1040	1180
76	76.000	0.688	553.90	74.624	Std.	330	380	680	750	850	910	980	1060	1140	1300
					Alt.	410	480	680	750	850	910	980	1060	1140	1300
76	76.000	0.750	603.32	74.500	Std.	360	410	750	820	920	990	1070	1150	1240	1420
					Alt.	440	520	750	820	920	990	1070	1150	1240	1420
76	76.000	0.812	652.65	74.376	Std.	380	450	810	880	1000	1080	1150	1250	1350	1540
					Alt.	480	560	810	880	1000	1080	1150	1250	1350	1540
76	76.000	0.875	702.70	74.250	Std.	410	480	870	950	1080	1160	1240	1350	1450	1660
					Alt.	520	600	870	950	1080	1160	1240	1350	1450	1660
76	76.000	0.938	752.66	74.124	Std.	440	520	930	1020	1160	1240	1330	1440	1560	1780
					Alt.	560	650	930	1020	1160	1240	1330	1440	1560	1780
76	76.000	1.000	801.75	74.000	Std.	470	550	990	1090	1230	1330	1420	1540	1660	1890
					Alt.	590	690	990	1090	1230	1330	1420	1540	1660	1890
76	76.000	1.062	850.75	73.876	Std.	500	590	1060	1160	1310	1410	1510	1630	1760	2010
					Alt.	630	730	1060	1160	1310	1410	1510	1630	1760	2010
76	76.000	1.125	900.47	73.750	Std.	530	620	1120	1230	1390	1490	1600	1730	1870	2130
					Alt.	670	780	1120	1230	1390	1490	1600	1730	1870	2130

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Table 6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (U.S. Customary Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure (psi)[b]									
Size	Specified Outside Diameter D (in.)	Specified Wall Thickness t (in.)	Plain-End Weight per Unit Length w_{pe} (lb/ft)	Calculated Inside Diameter[a] d (in.)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
76	76.000	1.188	950.09	73.624	Std.	560	660	1180	1290	1460	1580	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1580	1690	1830	1970	2250
76	76.000	1.250	998.85	73.500	Std.	590	690	1240	1360	1540	1660	1780	1920	2070	2370
					Alt.	740	860	1240	1360	1540	1660	1780	1920	2070	2370
80	80.000	0.562	477.25	78.876	Std.	250	300	530	580	660	710	760	820	890	1010
					Alt.	320	370	530	580	660	710	760	820	890	1010
80	80.000	0.625	530.32	78.750	Std.	280	330	590	650	730	790	840	910	980	1130
					Alt.	350	410	590	650	730	790	840	910	980	1130
80	80.000	0.688	583.32	78.624	Std.	310	360	650	710	800	870	930	1010	1080	1240
					Alt.	390	450	650	710	800	870	930	1010	1080	1240
80	80.000	0.750	635.39	78.500	Std.	340	390	710	780	880	950	1010	1100	1180	1350
					Alt.	420	490	710	780	880	950	1010	1100	1180	1350
80	80.000	0.812	687.37	78.376	Std.	370	430	770	840	950	1020	1100	1190	1280	1460
					Alt.	460	530	770	840	950	1020	1100	1190	1280	1460
80	80.000	0.875	740.12	78.250	Std.	390	460	830	910	1020	1100	1180	1280	1380	1580
					Alt.	490	570	830	910	1020	1100	1180	1280	1380	1580
80	80.000	0.938	792.77	78.124	Std.	420	490	890	970	1100	1180	1270	1370	1480	1690
					Alt.	530	620	890	970	1100	1180	1270	1370	1480	1690
80	80.000	1.000	844.51	78.000	Std.	450	530	950	1040	1170	1260	1350	1460	1580	1800
					Alt.	560	660	950	1040	1170	1260	1350	1460	1580	1800
80	80.000	1.062	896.17	77.876	Std.	480	560	1000	1100	1240	1340	1430	1550	1670	1910
					Alt.	600	700	1000	1100	1240	1340	1430	1550	1670	1910
80	80.000	1.125	948.57	77.750	Std.	510	590	1060	1160	1320	1420	1520	1650	1770	2030
					Alt.	630	740	1060	1160	1320	1420	1520	1650	1770	2030
80	80.000	1.188	1000.89	77.624	Std.	530	620	1120	1230	1390	1500	1600	1740	1870	2140
					Alt.	670	780	1120	1230	1390	1500	1600	1740	1870	2140
80	80.000	1.250	1052.30	77.500	Std.	560	660	1180	1290	1460	1580	1690	1830	1970	2250
					Alt.	700	820	1180	1290	1460	1580	1690	1830	1970	2250

Note: See Table E-6C for SI unit values corresponding to the U.S. Customary unit values given in this table.

[a]The calculated inside diameters are given here for information (see 7.2).

[b]The test pressures given in Tables 6A, 6B, and 6C apply to Grades A25, A, B, X42, X46, X52, X56, X60, X65, X70, and X80 only. See 9.4.3 for pressures applicable to other grades.

[c]Pipe that has this combination of specified outside diameter and specified wall thickness is special plain-end pipe; other combinations given in this table are regular plain-end pipe. Pipe that has a combination of specified outside diameter and specified wall thickness that is intermediate to the tabulated values is considered to be special plain-end pipe if the next lower tabulated value is for special plain-end pipe; other intermediate combinations are considered to be regular plain-end pipe. (See Table 10 for the applicable weight tolerances.)

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Table 7—Tolerances for Diameter of Pipe Body

Size	Tolerance[a] (with respect to specified outside diameter)
< $2^3/_8$	+ 0.016 in., – 0.031 in. (+ 0.41 mm, – 0.79 mm)
≥ $2^3/_8$ and ≤ $4^1/_2$, continuous welded	± 1.00%
≥ $2^3/_8$ and < 20	± 0.75%
≥ 20, seamless	± 1.00%
≥ 20 and ≤ 36, welded	+ 0.75%, – 0.25%
> 36, welded	+ $^1/_4$ in., – $^1/_8$ in. (+ 6.35 mm, – 3.20 mm)

[a]In the case of pipe hydrostatically tested to pressures in excess of standard test pressures, other tolerances may be agreed upon between the manufacturer and the purchaser.

Table 8—Tolerance for Diameter at Pipe Ends

				Out-of-Roundness	
Size	Minus Tolerance	Plus Tolerance	End-to-End Tolerance	Diameter, Axis Tolerance (Percent of Specified OD)[a]	Maximum Differential Between Minimum and Maximum Diameters (Applies Only to Pipe With $D/t \leq 75$)
≤ $10^3/_4$	$^1/_{64}$ (0.40 mm)	$^1/_{16}$ (1.59 mm)	—	—	—
> $10^3/_4$ and ≤ 20	$^1/_{32}$ (0.79 mm)	$^3/_{32}$ (2.38 mm)	—	—	—
> 20 and ≤ 42	$^1/_{32}$ (0.79 mm)	$^3/_{32}$ (2.38 mm)	b	± 1%	≤ 0.500 in. (12.7 mm)
> 42	$^1/_{32}$ (0.79 mm)	$^3/_{32}$ (2.38 mm)	b	± 1%	≤ 0.625 in. (15.9 mm)

[a]Out-of-roundness tolerances apply to maximum and minimum diameters as measured with a bar gage, caliper, or device measuring actual maximum and minimum diameters.

[b]The average diameter (as measured with a diameter tape) of one end of pipe shall not differ by more than $^3/_{32}$ in. (2.38 mm) from that of the other end.

Table 9—Tolerances for Wall Thickness

		Tolerance[a] (Percent of Specified Wall Thickness)	
Size	Type of Pipe	Grade B or Lower	Grade X42 or Higher
≤ $2^7/_8$	All	+ 20.0, – 12.5	+ 15.0, –12.5
> $2^7/_8$ and < 20	All	+ 15.0, – 12.5	+ 15.0, –12.5
≥ 20	Welded	+ 17.5, –12.5	+ 19.5, –8.0
≥ 20	Seamless	+ 15.0, –12.5	+ 17.5, –10.0

[a]Where negative tolerances smaller than those listed are specified by the purchaser, the positive tolerance shall be increased to the applicable total tolerance range in percent less the wall thickness negative tolerance.

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Table 10—Tolerances for Weight

Quantity	Tolerance (percent)
Single lengths, special plain-end pipe or A25 pipe	+10, −5.0
Single lengths, other pipe	+10, −3.5
Carloads, Grade A25, 40,000 lb (18 144 kg) or more	−2.5
Carloads, other than Grade A25, 40,000 lb (18 144 kg) or more	−1.75
Carloads, all grades, less than 40,000 lb (18 144 kg)	−3.5
Order items, Grade A25, 40,000 lb (18 144 kg) or more	−3.5
Order items, other than Grade A25, 40,000 lb (18 144 kg) or more	−1.75
Order items, all grades, less than 40,000 lb (18 144 kg)	−3.5

Notes:
1. Weight tolerances apply to the calculated weights for threaded-and-coupled pipe and to the tabulated or calculated weights for plain-end pipe. Where negative wall thickness tolerances smaller than those listed in Table 9 are specified by the purchaser, the plus weight tolerance for single lengths shall be increased to 22.5 percent less the wall thickness negative tolerance.
2. For carloads composed of pipe from more than one order item, the carload tolerances are to be applied on an individual order item basis.
3. The tolerances for order items apply to the overall quantity of pipe shipped for the order item.

Table 11—Tolerances on Lengths

Nominal Length[a]		Minimum Length		Minimum Average Length for Each Order Item[b]		Maximum Length	
ft	m	ft	m	ft	m	ft	m
			Threaded-and-Coupled Pipe				
20	6	16.0	4.88	17.5	5.33	22.5	6.86
40	12	22.0	6.71	35.0	10.67	45.0	13.72
			Plain-End Pipe				
20	6	9.0	2.74	17.5	5.33	22.5	6.86
40	12	14.0	4.27	35.0	10.67	45.0	13.72
50	15	17.5	5.33	43.8	13.35	55.0	16.76
60	18	21.0	6.40	52.5	16.00	65.0	19.81
80	24	28.0	8.53	70.0	21.34	85.0	25.91

[a]Nominal lengths of 20 ft (6 m) were formerly designated "single random lengths" and those of 40 ft (12 m) "double random lengths."
[b]By agreement between the purchaser and the manufacturer, these tolerances shall apply to each carload.

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Table 12— Coupling Dimensions, Weights, and Tolerances

(1)	(2)		(3)		(4)		(5)		(6)	
	Specified Outside Diameter of Coupling,[a] W		Specified Minimum Length, N_L		Specified Diameter of Recess, Q		Specified Width of Bearing Face, b		Calculated Coupling Weight	
Size	in.	mm	in.	mm	in.	mm	in.	mm	lb	kg
0.405	0.563	14.3	1 1/16	27.0	0.468	11.9	1/32	0.8	0.04	0.02
0.540	0.719	18.3	1 5/8	41.3	0.603	15.3	1/32	0.8	0.09	0.04
0.675	0.875	22.2	1 5/8	41.3	0.738	18.8	1/32	0.8	0.13	0.06
0.840	1.063	27.0	2 1/8	54.0	0.903	22.9	1/16	1.6	0.24	0.11
1.050	1.313	33.4	2 1/8	54.0	1.113	28.3	1/16	1.6	0.34	0.15
1.315	1.576	40.0	2 5/8	66.7	1.378	35.0	3/32	2.4	0.54	0.25
1.660	2.054	52.2	2 3/4	69.8	1.723	43.8	3/32	2.4	1.03	0.47
1.900	2.200	55.9	2 3/4	69.8	1.963	49.9	3/32	2.4	0.90	0.41
2 3/8	2.875	73.0	2 7/8	73.0	2.469	62.7	1/8	3.2	1.86	0.84
2 7/8	3.375	85.7	4 1/8	104.8	2.969	75.4	3/16	4.8	3.27	1.48
3 1/2	4.000	101.6	4 1/4	108.0	3.594	91.3	3/16	4.8	4.09	1.86
4	4.625	117.5	4 3/8	111.1	4.094	104.0	3/16	4.8	5.92	2.69
4 1/2	5.200	132.1	4 1/2	114.3	4.594	116.7	1/4	6.4	7.60	3.45
5 9/16	6.296	159.9	4 5/8	117.5	5.657	143.7	1/4	6.4	9.99	4.53
6 5/8	7.390	187.7	4 7/8	123.8	6.719	170.7	1/4	6.4	12.93	5.87
8 5/8	9.625	244.5	5 1/4	133.4	8.719	221.5	1/4	6.4	23.20	10.52
10 3/4	11.750	298.4	5 3/4	146.0	10.844	275.4	3/8	9.5	31.58	14.32
12 3/4	14.000	355.6	6 1/8	155.6	12.844	326.2	3/8	9.5	49.32	22.37
14	15.000	381.0	6 3/8	161.9	14.094	358.0	3/8	9.5	45.88	20.81
16	17.000	431.8	6 3/4	171.4	16.094	408.8	3/8	9.5	55.89	23.35
18	19.000	482.6	7 1/8	181.0	18.094	459.6	3/8	9.5	66.61	30.20
20	21.000	533.4	7 5/8	193.7	20.094	510.4	3/8	9.5	79.45	36.03

Note: See Figure 2.

[a]Tolerance on outside diameter, W, is ± 1%.

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Table 13—Maximum Inspection Lot Size for Tensile Testing

(1)	(2)	(3)	(4)
Size	Tensile Tests	Weld Tensile Tests	Control Tensile Tests
≤ 1.900, A25 Welded	25 tons (22.7 Mg)	—	—
> 1.900, A25 Welded	50 tons (45.5 Mg)	—	—
≤ $5^{9}/_{16}$, except A25 Welded	400 lengths	—	Heat of steel
> $5^{9}/_{16}$ and < $8^{5}/_{8}$	200 lengths[a]	—	Heat of steel
≥ $8^{5}/_{8}$ through $12^{3}/_{4}$	200 lengths[a]	200 lengths	Heat of steel
> $12^{3}/_{4}$	100 lengths[a] per cold expansion amount[b]	100 lengths[c] per cold expansion amount[b]	Heat of steel

[a]An inspection lot shall consist of pipe that is made to the same size and the same specified wall thickness by the same process and under the same manufacturing conditions. For pipe of grades higher than A25 in sizes greater than $5^{9}/_{16}$, an inspection lot shall not contain more than one heat of steel.
[b]Pipe manufactured with the same nominal amount of cold expansion, ± 0.2%, shall be considered to have the same cold expansion amount.
[c]Each weld for two-seam pipe.

Note: The test frequency is one test per inspection lot. (See 9.3.1.2.)

Table 14—Relationship Between Pipe Dimensions and Required Charpy Specimens

	Minimum Wall Thickness, in. (mm)				
Size	Full Size Transverse	$^{2}/_{3}$ Size Transverse	$^{1}/_{2}$ Size Transverse	$^{2}/_{3}$ Size Longitudinal	$^{1}/_{2}$ Size Longitudinal
≥ $4^{1}/_{2}$ and < $5^{9}/_{16}$	≥ 0.495 (12.6)	0.429 – 0.494 (10.9 – 12.5)	0.397 – 0.428 (10.1 – 10.8)	0.312 – 0.396 (7.9 – 10.0)	0.246 – 0.311 (6.2 – 7.8)
≥ $5^{9}/_{16}$ and < $6^{5}/_{8}$	≥ 0.469 (11.9)	0.371 – 0.468 (9.4 – 11.8)	0.338 – 0.370 (8.6 – 9.3)	0.310 – 0.337 (7.9 – 9.2)	0.245 – 0.309 (6.2 – 7.8)
≥ $6^{5}/_{8}$ and < $8^{5}/_{8}$	≥ 0.460 (11.7)	0.334 – 0.459 (8.6 – 11.6)	0.301 – 0.333 (7.6 – 8.4)		0.244 – 0.300 (6.2 – 7.5)
≥ $8^{5}/_{8}$ and < $10^{3}/_{4}$	≥ 0.450 (11.4)	0.318 – 0.449 (8.1 – 11.3)	0.257 – 0.317 (6.5 – 8.0)		0.242 – 0.256 (6.1 – 6.4)
≥ $10^{3}/_{4}$ and < $12^{3}/_{4}$	≥ 0.443 (11.3)	0.311 – 0.442 (7.9 – 11.2)	0.246 – 0.310 (6.2 –7.8)		0.241 – 0.245 (6.1)
≥ $12^{3}/_{4}$ and < 14	≥ 0.438 (11.1)	0.307 – 0.437 (7.8 – 11.0)	0.241 – 0.306 (6.1 – 7.7)		
≥ 14 and < 16	≥ 0.436 (11.1)	0.305 – 0.435 (7.7 – 11.0)	0.239 – 0.304 (6.1 – 7.6)		
≥ 16	≥ 0.434 (11.0)	0.304 – 0.433 (7.7 – 10.9)	0.237 – 0.303 (5.0 – 7.6)		

Notes:
1. This table provides a description of the required specimens and the relationship between pipe dimensions and acceptable specimens. The size limits for transverse specimens shown are based upon the use of nonflattened, tapered end, test specimens.
2. All specimen dimension limits include machining tolerances.
3. Pipe in size and wall thickness combinations not covered by this table are not required to be tested.

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Table 15—API Standard 4 Percent Penetrameters

(1)		(2)		(3)		(4)
Specified Wall Thickness				Maximum Penetrameter Thickness		Identifying Number
Over		Through				
in.	mm	in.	mm	in.	mm	
3/16 or 0.188	4.8	1/4 or 0.250	6.4	0.010	0.25	10
1/4 or 0.250	6.4	3/16 or 0.313	7.9	0.0125	0.32	12
5/16 or 0.313	7.9	3/8 or 0.375	9.5	0.015	0.38	15
3/8 or 0.375	9.5	7/16 or 0.438	11.1	0.0175	0.45	17
7/16 or 0.438	11.1	1/2 or 0.500	12.7	0.020	0.51	20
1/2 or 0.500	12.7	5/8 or 0.625	15.9	0.025	0.64	25
5/8 or 0.625	15.9	3/4 or 0.750	19.1	0.030	0.76	30
3/4 or 0.750	19.1	1 or 1.000	25.4	0.040	1.02	40
1 or 1.000	25.4	1 1/4 or 1.250	31.8	0.050	1.27	50
1 1/4 or 1.250	31.8	1 1/2 or 1.500	38.1	0.060	1.52	60

Table 16—API Standard 2 Percent Penetrameters

(1)		(2)		(3)		(4)
Specified Wall Thickness				Maximum Penetrameter Thickness		Identifying Number
Over		Through				
in.	mm	in.	mm	in.	mm	
7/32 or 0.219	5.1	1/4 or 0.250	6.4	0.005	0.13	5
1/4 or 0.250	6.4	5/16 or 0.313	7.9	0.006	0.15	6
5/16 or 0.313	7.9	3/8 or 0.375	9.5	0.0075	0.19	7
3/8 or 0.375	9.5	1/2 or 0.500	12.7	0.010	0.25	10
1/2 or 0.500	12.7	5/8 or 0.625	15.9	0.0125	0.32	12
5/8 or 0.625	15.9	3/4 or 0.750	19.1	0.015	0.38	15
3/4 or 0.750	19.1	7/8 or 0.875	22.2	0.0175	0.45	17
7/8 or 0.875	22.2	1 or 1.000	25.4	0.020	0.51	20
1 or 1.000	25.4	1 1/4 or 1.250	31.8	0.025	0.64	25
1 1/4 or 1.250	31.8	1 1/2 or 1.500	38.1	0.030	0.76	30

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Table 17—ISO Wire 4 Percent Penetrameters

(1)	(2)		(3)		(4)	
	Specified Wall Thickness					
	Over		Through		Wire Diameter	
Wire Number	in.	mm	in.	mm	in.	mm
			Fe 1/7			
1	2.50	63.5	3.25	82.6	0.13	3.20
2	2.00	50.8	2.50	63.5	0.10	2.50
3	1.62	41.1	2.00	50.8	0.08	2.00
4	1.25	31.8	1.62	41.1	0.065	1.60
5	1.00	25.4	1.25	31.8	0.050	1.25
6	0.80	20.3	1.00	25.4	0.040	1.00
7	0.63	15.9	0.80	20.3	0.032	0.80
			Fe 6/12			
6	0.800	20.3	1.000	25.4	0.040	1.00
7	0.625	15.9	0.800	20.3	0.032	0.80
8	0.500	12.7	0.625	15.9	0.025	0.63
9	0.400	10.2	0.500	12.7	0.020	0.50
10	0.325	8.3	0.400	10.2	0.016	0.40
11	0.250	6.4	0.325	8.3	0.013	0.32
12	0.200	5.1	0.250	6.4	0.010	0.25
			Fe 10/16			
10	0.325	8.3	0.400	10.2	0.016	0.40
11	0.250	6.4	0.325	8.3	0.013	0.32
12	0.200	5.1	0.250	6.4	0.010	0.25
13	0.162	4.1	0.200	5.1	0.008	0.20
14	0.125	3.2	0.162	4.1	0.006	0.16
15	0.100	2.5	0.125	3.2	0.005	0.13
16	0.080	2.0	0.100	2.5	0.004	0.10

Table 18—ISO Wire 2 Percent Penetrameters

(1)	(2)		(3)		(4)	
	Specified Wall Thickness					
	Over		Through		Wire Diameter	
Wire Number	in.	mm	in.	mm	in.	mm
			Fe 1/7			
1	5.00	127.0	6.50	165.2	0.13	3.20
2	4.00	101.6	5.00	127.0	0.10	2.50
3	3.25	82.6	4.00	101.6	0.08	2.00
4	2.50	63.5	3.25	82.6	0.065	1.60
5	2.00	50.8	2.50	63.5	0.050	1.25
6	1.60	40.6	2.00	50.8	0.040	1.00
7	1.25	31.8	1.60	40.6	0.032	0.80
			Fe 6/12			
6	1.600	40.6	2.000	50.8	0.040	1.00
7	1.250	31.8	1.600	40.6	0.032	0.80
8	1.000	25.4	1.250	31.8	0.025	0.63
9	0.800	20.3	1.000	25.4	0.020	0.50
10	0.650	16.5	0.800	20.3	0.016	0.40
11	0.500	12.7	0.650	16.5	0.013	0.32
12	0.400	10.1	0.500	12.7	0.010	0.25
			Fe 10/16			
10	0.650	16.5	0.800	20.3	0.016	0.40
11	0.500	12.7	0.650	16.5	0.013	0.32
12	0.400	10.1	0.500	12.7	0.010	0.25
13	0.325	8.3	0.400	10.1	0.008	0.20
14	0.250	6.4	0.325	8.3	0.006	0.16
15	0.200	5.1	0.250	6.4	0.005	0.13
16	0.160	4.1	0.200	5.1	0.004	0.10

Table 19—Elongated Slag-Inclusion-Type Discontinuities[a]

(1)		(2)		(3)
Maximum Dimensions		Minimum Separation		Maximum Number in any 6 in. (152.4 mm)
in.	mm	in.	mm	
$1/16 \times 1/2$	1.6 × 12.7	6	152.4	1
$1/6 \times 1/4$	1.6 × 6.4	3	76.2	2
$1/16 \times 1/8$	1.6 × 3.2	2	50.8	3

Note: See Figure 8.

[a]Maximum accumulated length of discontinuities in any 6 in. (152.4 mm) shall not exceed $1/2$ in. (12.7 mm).

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Table 20—Circular Slag-Inclusion-Type and Gas-Pocket-Type Discontinuities[a]

(1)		(2)		(3)		(4)
Size		Adjacent Size		Minimum Separation		Maximum Number in any 6 in. (152.4 mm)
in.	mm	in.	mm	in.	mm	
1/8[b]	3.2	1/8[b]	3.2	2	50.8	2
1/8[b]	3.2	1/16	1.6	1	25.4	Varies
1/8[b]	3.2	1/32	0.8	1/2	12.7	Varies
1/8[b]	3.2	1/64	0.4	3/8	9.5	Varies
1/16	1.6	1/16	1.6	1/2	12.7	4
1/16	1.6	1/32	0.8	3/8	9.5	Varies
1/16	1.6	1/64	0.4	1/4	6.4	Varies
1/32	0.8	1/32	0.8	1/4[c]	6.4	8
1/32	0.8	1/64	0.4	3/16	4.8	Varies
1/64	0.4	1/64	0.4	1/8	3.2	16

Note: See Figure 7.

[a]The sum of the diameters of all discontinuities in any 6 in. (152.4 mm) not to exceed 1/4 in. (6.4 mm).

[b]Maximum size discontinuity for 0.250 in. (6.4 mm) wall and lighter shall be 3/32 in. (2.4 mm).

[c]Two discontinuities 1/32 in. (0.8 mm) or smaller may be as close as one diameter apart provided they are separated from any other discontinuity by at least 1/2 in. (12.7 mm).

Table 21—Acceptance Limits

(1)	(2)	(3)		(4)
		Size Hole		Acceptance Limit Signal (percent)
Weld Type	Notch Type	in.	mm	
Submerged-arc, gas-metal arc, laser, and repair welds	N5	1/16	1.6	100
	All other	1/8	3.2	33 1/3
Electric weld	N10, V10	1/8	3.2	100
	B, P	—	—	80

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Table 22—Retention of Records

Requirement	Reference
Chemical Properties	
Heat Analyses	Paragraph 9.2.1
Product Analyses	Paragraph 9.2.2
Mechanical Tests	
Tensile Tests	Paragraph 9.3.1
Weld Tensile Tests	Paragraph 9.3.1.5
Mill Control Tests	Paragraph 9.3.1.6
Guided-Bend Tests	Paragraph 9.3.4
Fracture Toughness Tests	Paragraph 9.3.5, SR5, SR6, SR19
Hydrostatic Tests	
Tester Recorder Charts (where used)	Paragraph 9.4.2
Supplementary Hydrostatic Tests	Paragraph 9.4.4
Nondestructive Inspection	
Film (where used)	Paragraph 9.7.2
Fluoroscopic	
Operator Qualifications	Paragraph 9.7.3.2; 9.7.3.3
Welded Jointers	
Film	Paragraph A.4
Repair Welding Procedure	Paragraph C.1
Transverse Tensile Test	Paragraph C.2.2.2
Transverse Guided-Bend Test	Paragraph C.2.2.3
Nick-Break Test	Paragraph C.2.2.4

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APPENDIX A—SPECIFICATION FOR WELDED JOINTERS (NORMATIVE)

A.1 Method

Welding of any type that uses deposited filler metal and is generally recognized as sound practice shall be permitted unless the purchaser specifies a particular method. Welding procedures, welders, and welding machine operators (hereafter called operators) shall be qualified in accordance with API Standard 1104. Copies of the welding procedure specification and procedure qualification record shall be provided to the purchaser upon request.

A.2 Workmanship

The ends of the pipe to be welded together shall be prepared in accordance with the requirements of the procedure to be used. Pipe weld seams (straight, helical, or skelp end) shall be staggered between 2 in. and 8 in. (51 mm and 203 mm) unless otherwise specified by the purchaser. The completed jointers shall be straight within the limits of 7.6 of this specification. Each weld shall have a substantially uniform cross section around the entire circumference of the pipe. At no point shall its crowned surface be below the outside surface of the parent metal nor shall it rise above the parent metal by more than $^1/_8$ in. (3.18 mm) if submerged-arc welded, or by more than $^1/_{16}$ in. (1.59 mm), if welded by another process.

A.3 Marking

Each jointer shall be marked using paint to identify the welder or operator.

A.4 Nondestructive Testing

The girth welds of jointers shall be 100% radiographed in accordance with the procedures and standards of acceptability in API Standard 1104 (see note). Jointer welds failing to pass this radiographic testing may be repaired and re-radiographed in accordance with the procedures and acceptance criteria of API Standard 1104.

Note: See 7.7 for length requirements on jointers.

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APPENDIX B—REPAIR OF DEFECTS BY WELDING (NORMATIVE)

B.1 Types Of Pipe

B.1.1 SEAMLESS PIPE AND PARENT METAL OF WELDED PIPE

For PSL 1 pipe, the repair of defects in seamless pipe and parent metal of welded pipe is permissible except (a) when the depth of the defect exceeds $33^1/_3$% of the specified wall thickness of the pipe and the length of that portion of the defect in which the depth exceeds $12^1/_2$% is greater than 25% of the specified outside diameter of the pipe; or (b) when more than one repair is required in any length equivalent to 10 times the specified outside diameter of the pipe. Repairs shall be made in accordance with B.2. Repair welds shall be inspected by the magnetic particle method in accordance with 9.7.5.1 through 9.7.5.3; by liquid penetrant; or by other NDT methods as agreed start between purchaser and the manufacturer.

For PSL 2, seamless pipe, the parent metal (body) of welded pipe, plate, and skelp shall not be repaired by welding.

B.1.2 WELD SEAM OF WELDED PIPE

B.1.2.1 Defects in filler metal welds may be repaired at the option of the manufacturer; such repairs shall be in accordance with B.3. All repair welds shall be inspected by ultrasonic methods in accordance with 9.7.4.1 through 9.7.4.3, except that the equipment need not be capable of continuous and uninterrupted operation and, at the option of the manufacturer, repairs made by submerged-arc welding or by shielded metal-arc welding may alternatively be inspected by radiological methods in 9.7.3.

B.1.2.2 For PSL 1 pipe, weld seams made without filler metal (electric and laser welds) may be repaired by welding only by agreement between the purchaser and the manufacturer; such repairs shall be in accordance with B.4.

B.1.2.3 For PSL 2 pipe, weld seams made without filler metal shall not be repaired by welding.

B.1.3 HEAT TREATED PIPE

When heat treated pipe has been repaired by welding, the need for and type of reheat treatment shall be based on the effect of the repair on the structure and properties of the heat treated pipe, by agreement between the purchaser and the manufacturer.

B.2 Procedure for Repair by Welding of Seamless Pipe and Parent Metal of Welded Pipe (PSL 1 Only)

The repair of defects in seamless pipe and parent metal of welded pipe shall conform to the requirements listed in B.2.1–B.2.5. Conformance to the repair procedure is subject to approval of the purchaser's inspector.

B.2.1 The defect shall be removed completely by chipping and/or grinding. The resulting cavity shall be thoroughly cleaned and shall be inspected before welding by magnetic particle methods in accordance with 9.7.5 to ensure complete removal of the defect.

B.2.2 The minimum length of repair weld shall be 2 in. (50.8 mm). Where the orientation of the defect permits, the repair weld shall be placed in the circumferential direction.

B.2.3 The repair weld shall be made either by automatic submerged-arc welding, gas metal-arc welding, or manual shielded metal-arc welding using low-hydrogen electrodes. The metal temperature in the area to be repaired shall be a minimum of 50°F (10°C). The welding procedure and performance shall be qualified in accordance with Appendix C.

B.2.4 The repair weld shall be ground to merge smoothly into the original contour of the pipe.

B.2.5 Repaired pipe shall be tested hydrostatically after repairing, in accordance with 9.4.

B.3 Procedure for Repair of Submerged-Arc and Gas Metal-Arc Welds

The repair of submerged-arc and gas metal-arc welds shall conform to the requirements listed in B.3.1–B.3.3. Conformance is subject to approval of purchaser's inspector.

B.3.1 The defect shall be completely removed and the cavity thoroughly cleaned. Where multiple pass repairs are used, the size of the cavity shall be sufficiently large [at least 2 in. (50.8 mm) in length] to avoid coincidence of starts and stops of individual passes.

B.3.2 The minimum length of each repair weld shall be 2 in. (50.8 mm). The repair weld shall be made either by automatic submerged-arc welding, gas metal-arc welding, or manual shielded metal-arc welding using low-hydrogen electrodes. The welding procedure and performance shall be qualified in accordance with Appendix C.

B.3.3 Each length of repaired pipe shall be tested hydrostatically in accordance with 9.4.

B.4 Procedure for Repair of Electric and Laser Welds (PSL 1 Only)

The repair of electric and laser welds shall conform to the requirements in B.4.1 through B.4.6 and shall include the weld zone, which is defined for the purposes of repair as $^1/_2$ in. (12.7 mm) on each side of the fusion line.

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Conformance to the repair procedure is subject to approval of the purchaser's inspector.

B.4.1 The weld zone defect shall be removed completely by chipping and/or grinding, and the resulting cavity shall be thoroughly cleaned.

B.4.2 The minimum length of repair weld shall be 2 in. (50.8 mm), and individual weld repairs shall be separated by at least 10 ft (3 m).

B.4.3 The repair weld shall be made by either automatic submerged-arc welding, gas metal-arc welding, or manual shielded metal-arc welding using low-hydrogen electrodes. The metal temperature in the area to be repaired shall be a minimum of 50°F (10°C). The welding procedure and performance shall be qualified in accordance with Appendix C.

B.4.4 When a repair weld is made through the full wall thickness, it shall include weld passes made from both the ID and the OD of the pipe. Starts and stops of the ID and OD repair welds shall not coincide.

B.4.5 The repair shall be ground to merge smoothly into the original contour of the pipe and shall have a maximum crown of 0.06 in. (1.52 mm).

B.4.6 Repaired pipe shall be hydrostatically tested after repair in accordance with 9.4.

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APPENDIX C—REPAIR WELDING PROCEDURE (NORMATIVE)

C.1 General

All repair welds shall be made in the flat position according to a qualified procedure and by a welding machine operator (hereafter called operator) or repair welder who is qualified in a flat position as specified in C.2. Repair welds may be made by one of the following methods:

a. Automatic submerged arc.
b. Automatic or semi-automatic gas metal arc.
c. Manual shielded metal arc using low-hydrogen electrodes.

All welding materials shall be properly handled and stored in accordance with the manufacturer's recommendations so as to preclude moisture or other contamination. Test welds may be made on either plate stock or pipe stock at the option of the manufacturer.

The manufacturer shall maintain a record of the welding procedure and procedure qualification test results. Copies of the welding procedure specification and procedure qualification record shall be provided to the purchaser upon request.

C.2 Repair Welding Procedure Qualification

Welding procedures shall be qualified by preparing and testing welds in accordance with this appendix. At the option of the manufacturer, the tests specified in the *ASME Boiler and Pressure Vessel Code*, Section IX, may be substituted herein. For the purpose of this appendix, the term automatic welding includes both machine welding and automatic welding as defined in the *ASME Boiler and Pressure Vessel Code*, Section IX.

C.2.1 ESSENTIAL VARIABLES

An existing procedure shall not be applicable and new procedure shall be qualified when any of the following essential variables is changed beyond the stated limits:

a. Welding process:
   1. A change in the welding process, such as submerged arc to gas metal arc.
   2. A change in the method, such as manual to semi-automatic.
b. Pipe material:
   1. A change in grade category. When different alloying systems are used within one grade category, each alloying composition shall be separately qualified. Grade categories are as follows:
      ≤ X42
      > X42 and < X65
      each grade ≥ X65
   2. Within each grade category, a thicker material than the material qualified.
   3. Within the grade category and thickness range, a carbon equivalent, CE (see note), based on product analysis for the material to be repaired, that is more than 0.04% greater than the CE of the material qualified.

Note:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

c. Welding materials:
   1. A change in filler metal classification.
   2. A change in electrode diameter.
   3. A change of more than 5% in the composition of shielding gas.
   4. A change of more than 10% in the flow rate of shielding gas.
   5. A change in submerged-arc welding flux from one designation to another.
d. Welding parameters:
   1. A change in the type of current (such as AC versus DC).
   2. A change in polarity.
   3. For automatic and semi-automatic welding, schedules of welding current, voltage, and speed may be established to cover ranges of wall thicknesses. Within the schedule, appropriately selected points shall be tested to qualify the entire schedule. Thereafter, a new qualification is required if there is a deviation from the qualified schedule greater than the following:
      10% in amperage
      7% in voltage
      10% in travel speed for automatic welding
e. Weld bead: For manual and semi-automatic welding, a change in bead width greater than 50%.
f. Preheat and post-weld heat treatment:
   1. Repair welding at a pipe temperature lower than the pipe temperature of the qualification test.
   2. The addition or deletion of post-weld heat treatment.

C.2.2 MECHANICAL TESTING

C.2.2.1 Number of Tests

Two specimens of each type are required from each procedure qualification test.

C.2.2.2 Transverse Tensile Test

The transverse tensile test specimens shall be approximately 1.5 in. (38.1 mm) wide and shall have the transverse butt weld perpendicular to the longitudinal axis at the center of the test specimen (See Figure C-1 or Figure 4.) The weld reinforcement shall be removed from both faces. The ultimate

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tensile strength shall be at least equal to the minimum specified for the pipe grade.

C.2.2.3 Transverse Guided-Bend Test

The transverse guided-bend test specimens shall conform to Figure C-2. The weld shall be made in a groove as shown. Each specimen shall be placed on the die with the weld at mid-span and shall be bent approximately 180° in a jig in accordance with Figure C-3 and Table C-1, with the exposed surface of the weld in tension. The bend test shall be considered acceptable if no crack or other defect exceeding $^1/_8$ in. (3.18 mm) in any direction is present in the weld metal or base metal after bending. Cracks that both originate along the edges of the specimen during testing and measure less than $^1/_4$ in. (6.35 mm) in all directions shall not be considered.

C.2.2.4 Nick-Break Test

The nick-break specimens shall conform to Figure C-4. The weld shall be made in a groove as shown. Each specimen shall be saw-notched from both edges at the center of the weld and shall be broken by pulling or hammer blows at the center of one end. The exposed surface of the specimen shall be visually examined and shall be considered acceptable if it meets the following criteria:

a. No gas pockets exceeding $^1/_{16}$ in. (1.59 mm) in any direction.

b. Not more than one gas pocket of any size for specified wall thicknesses of 0.250 in. (6.4 mm) and less.

c. Not more than two gas pockets of any size for specified wall thicknesses of 0.500 in. (12.7 mm) or less but greater than 0.250 in. (6.4 mm).

d. Not more than three gas pockets of any size for specified wall thicknesses greater than 0.500 in. (12.7 mm).

e. Slag inclusions shall be separated by at least $^1/_2$ in. (12.7 mm) of sound metal and shall appear no greater than $^1/_{16}$ in. (1.59 mm) in width or $^3/_{16}$ in. (4.76 mm) in length.

C.3 Welding Personnel Performance Qualification

C.3.1 QUALIFICATION

C.3.1.1 General

Each repair welder and operator is required to qualify. A repair welder or operator qualified on one grade category is qualified for any lower grade category provided the same welding process is used.

C.3.1.2 Testing

To qualify, a repair welder or operator shall produce welds that are acceptable in the following tests:

a. Film radiographic examination per Section 9 of this specification.

b. Two transverse guided-bend tests per C.2.2.3 of this appendix.

c. Two nick-break tests per C.2.2.4 of this appendix.

C.3.1.3 Test Failures

If one or more of the tests in C.3.1.2 fail to meet the specified requirements, the welder or operator may make one additional qualification weld. If that weld fails one or more of the tests in C.3.1.2, the welder or operator is disqualified. No further retests shall be permitted until the welder has completed additional training.

C.3.2 REQUALIFICATION

Requalification in accordance with C.3.1 is required under the following circumstances:

a. One year has elapsed since the last prior applicable qualification.

b. The individual has not been welding using qualified procedures for a period of 3 months.

c. There is reason to question the individual's ability.

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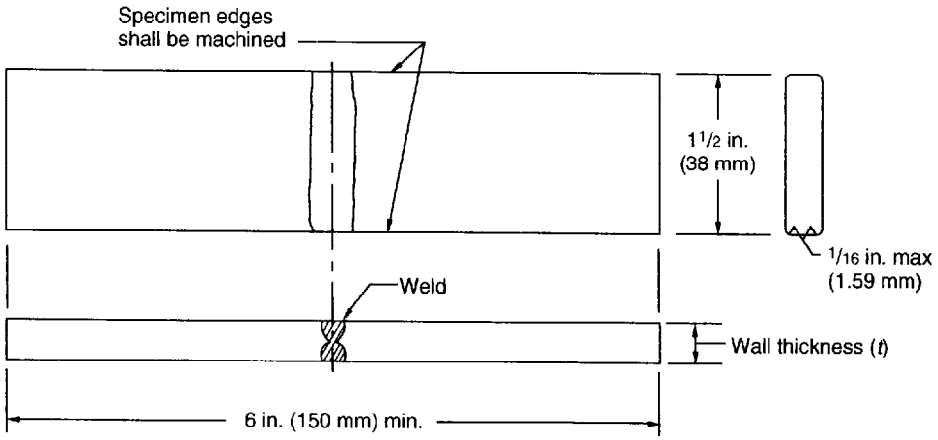
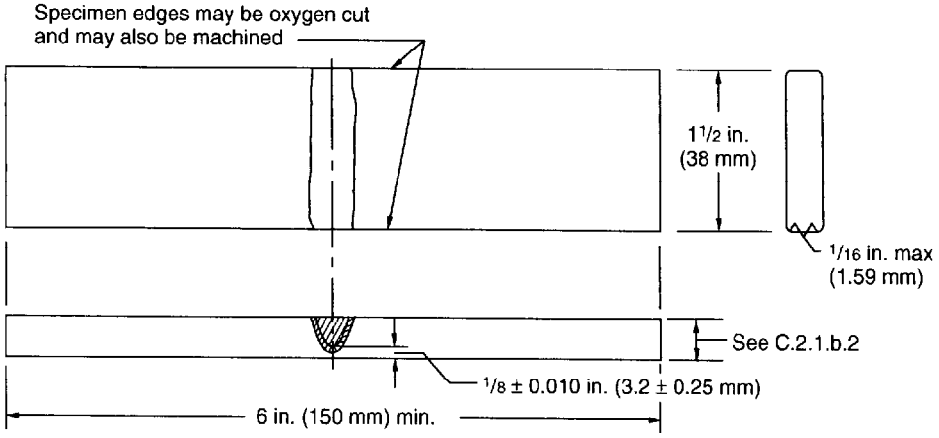


Note: Weld reinforcement shall be removed from both faces.

Figure C-1—Transverse Tensile Test Specimen



Note: Weld reinforcement shall be removed.

Figure C-2—Guided-Bend Test Specimen

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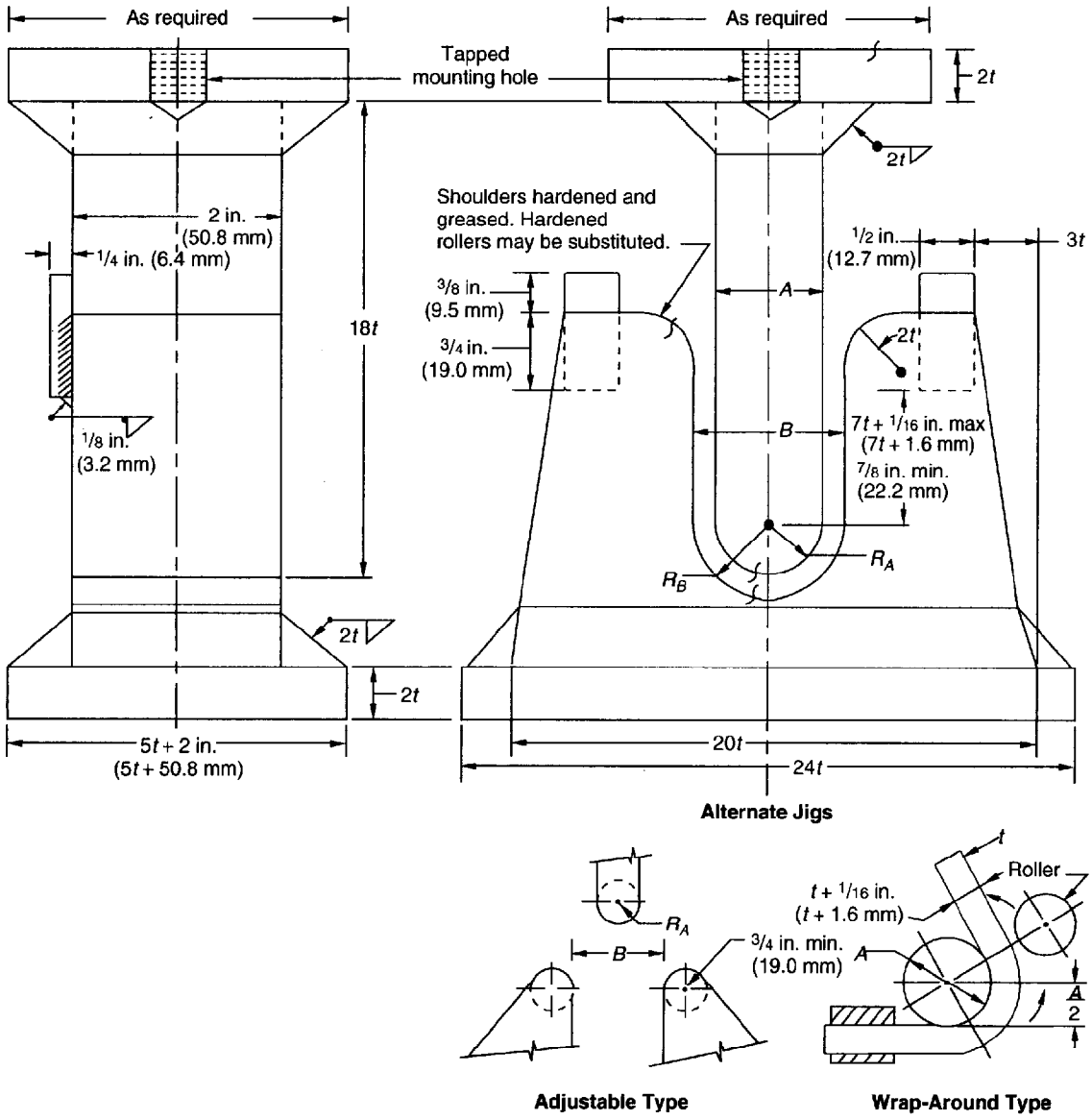

t = Specified wall thickness of pipe,

Note: See Table C-1.

Figure C-3—Jig for Guided-Bend Test

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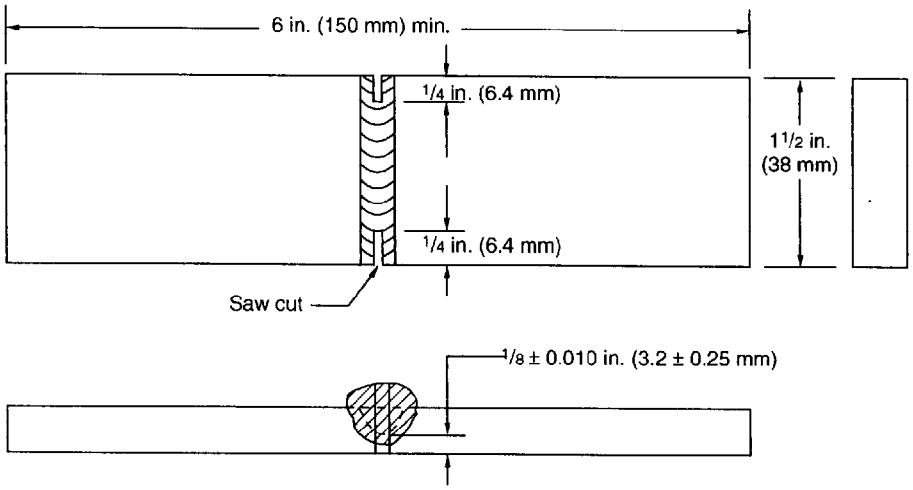

Figure C-4—Nick-Break Test Specimen

Table C-1—Guided-Bend Test Jig Dimensions

(1)	(2)	(3)	(4)	(5)	(6)
	Pipe Grade[a]				
Member Dimension	A, B, & X42	X46	X52 & X56	X60 & X65	X70 & X80
Radius of male member, R_A	$3t$	$3\frac{1}{2}t$	$4t$	$4\frac{1}{2}t$	$5t$
Radius of female member, R_B	$4t + \frac{1}{16}$ in. ($4t$ + 1.6 mm)	$4\frac{1}{2}t + \frac{1}{16}$ in. ($4\frac{1}{2}t$ + 1.6 mm)	$5t + \frac{1}{16}$ in. ($5t$ + 1.6 mm)	$5\frac{1}{2}t + \frac{1}{16}$ in. ($5\frac{1}{2}t$ + 1.6 mm)	$6t + \frac{1}{16}$ in. ($6t$ + 1.6 mm)
Width of male member, A	$6t$	$7t$	$8t$	$9t$	$10t$
Width of groove in female member, B	$8t + \frac{1}{8}$ in. ($8t$ + 3.2 mm)	$9t + \frac{1}{8}$ in. ($9t$ + 3.2 mm)	$10t + \frac{1}{8}$ in. ($10t$ + 3.2 mm)	$11t + \frac{1}{8}$ in. ($11t$ + 3.2 mm)	$12t + \frac{1}{8}$ in. ($12t$ + 3.2 mm)

Notes:

1. See Figure C-3.
2. t = specified wall thickness of the pipe.

[a]For intermediate grades of pipe, the dimensions of the bending jig shall conform to those shown for the next lower grade or shall be proportional thereto.

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APPENDIX D—ELONGATION TABLE (NORMATIVE)

These minimum elongation values were calculated by the equation in Footnote a of Tables 3A and 3B.

Table D-1 —Elongation Table (U. S. Customary Units)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
				Elongation in 2 inches, Minimum (percent)									
Tensile Test Specimen Area ($in.^2$)	Specified Wall Thickness for Strip Specimen Testing (in.)			Grade									
				A25	A	B & X42	X46	X52	X56	X60	X65	X70	X80
	Strip Specimen Specified Width			Specified Ultimate Tensile Strength (psi)									
	$^3/_4$ in.	1 in.	$1^1/_2$ in.	45,000	48,000	60,000	63,000	66,000	71,000	75,000	77,000	82,000	90,000
0.75	—	≥ 0.746	≥ 0497	38	36	30	28	27	25	24	24	22	21
0.74	—	.735 – .745	.490 – .496	38	36	29	28	27	25	24	24	22	20
0.73	—	.726 – .734	.434 – .489	38	36	29	28	27	25	24	23	22	20
0.72	—	.715 – .725	.477 – .483	38	36	29	28	27	25	24	23	22	20
0.71	—	.706 – .714	.471 – .476	38	36	29	28	27	25	24	23	22	20
0.70	—	.695 – .705	.464 – .470	38	36	29	28	27	25	24	23	22	20
0.69	—	.686 – .694	.457 – .463	38	36	29	28	27	25	24	23	22	20
0.68	—	.675 – .685	.450 – .456	38	35	29	28	27	25	24	23	22	20
0.67	—	.666 – .674	.444 – .449	37	35	29	28	27	25	24	23	22	20
0.66	—	.655 – .655	.437 – .443	37	35	29	28	26	25	24	23	22	20
0.65	—	.646 – .656	.431 – .436	37	35	29	27	26	25	23	23	22	20
0.64	—	.636 – .645	.424 – .430	37	35	29	27	26	25	23	23	22	20
0.63	—	.626 – .634	.417 – .423	37	35	29	27	26	25	23	23	22	20
0.62	—	.615 – .625	.410 – .416	37	35	28	27	26	24	23	23	21	20
0.61	—	.606 – .614	.404 – .409	37	35	28	27	26	24	23	23	21	20
0.60	—	.595 – .605	.397 – .403	37	35	28	27	26	24	23	23	21	20
0.59	—	.586 – .594	.391 – .396	36	34	28	27	26	24	23	23	21	20
0.58	—	.575 – .585	.384 – .390	36	34	28	27	26	24	23	22	21	19
0.57	—	.566 – .574	.377 – .383	36	34	28	27	26	24	23	22	21	19
0.56		.555 – .565	.370 – .376	36	34	28	27	26	24	23	22	21	19
0.55	—	.546 – .554	.364 – .369	36	34	28	27	25	24	23	22	21	19
0.54	—	.535 – .545	.357 – .363	36	34	28	26	25	24	23	22	21	19
0.53	—	.526 – .534	.351 – .356	36	34	28	26	25	24	23	22	21	19
0.52	—	.515 – .525	.344 – .350	36	34	27	26	25	24	22	22	21	19
0.51	—	.506 – .514	.337 – .343	35	33	27	26	25	24	22	22	21	19
0.50	—	.495 – .505	.330 – .336	35	33	27	26	25	23	22	22	21	19
0.49	—	.486 – .494	.324 – .329	35	33	27	26	25	23	22	22	20	19
0.48	—	.475 – .485	.317 – .323	35	33	27	26	25	23	22	22	20	19
0.47	—	.466 – .474	.311 – .316	35	33	27	26	25	23	22	22	20	19
0.46	—	455 – .465	.304 – .310	35	33	27	26	25	23	22	21	20	19
0.45	.594 – .600	.446 – .454	.297 – .303	35	33	27	26	24	23	22	21	20	19
0.44	.580 – .593	.435 – .445	.290 – .296	34	32	27	25	24	23	22	21	20	18
0.43	.567 – .579	.426 – .434	.284 – .289	34	32	26	25	24	23	22	21	20	18
0.42	.554 – .566	.415 – .425	.277 – .283	34	32	26	25	24	23	22	21	20	18
0.41	.541 – .553	.406 – .414	.271 – .276	34	32	26	25	24	23	21	21	20	18
0.40	.527 – .540	.395 – .405	.264 – .270	34	32	26	25	24	22	21	21	20	18
0.39	.514 – .526	.386 – .394	.257 – .263	34	32	26	25	24	22	21	21	20	18
0.38	.500 – .513	.375 – .385	.250 – .265	33	32	26	25	24	22	21	21	19	18
0.37	.487 – .499	.366 – .374	.244 – .249	33	31	26	25	24	22	21	20	19	18
0.36	.474 – .486	.355 – .365	.237 – .243	33	31	26	24	23	22	21	20	19	18
0.35	.461 – .473	.346 – .354	.231 – .236	33	31	25	24	23	22	21	20	19	18

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Table D-1 (Continued)—Elongation Table (U. S. Customary Units)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
				Elongation in 2 inches, Minimum (percent)									
Tensile Test Specimen Area ($in.^2$)	Specified Wall Thickness for Strip Specimen Testing (in.)			Grade									
				A25	A	B & X42	X46	X52	X56	X60	X65	X70	X80
	Strip Specimen Specified Width			Specified Ultimate Tensile Strength (psi)									
	3/4 in.	1 in.	1 1/2 in.	45,000	48,000	60,000	63,000	66,000	71,000	75,000	77,000	82,000	90,000
0.34	.447 – .460	.335 – .345	.224 – .230	33	31	25	24	23	22	21	20	19	18
0.33	.434 – .446	.326 – .334	.217 – .223	32	31	25	24	23	22	21	20	19	17
0.32	420 – .433	.315 – .325	.210 – .216	32	30	25	24	23	21	20	20	19	17
0.31	.407 – .419	.306 – .314	.204 – .209	32	30	25	24	23	21	20	20	19	17
0.30	.394 – .406	.295 – .305	.197 – .203	32	30	25	24	23	21	20	20	19	17
0.29	.381 – .393	.286 – .294	.191 – .196	32	30	24	23	22	21	20	20	18	17
0.28	.367 – .380	.275 – .285	.184 – .190	31	30	24	23	22	21	20	19	18	17
0.27	.354 – .366	.266 – .274	.177 – .183	31	29	24	23	22	21	20	19	18	17
0.26	.340 – .353	.255 – .265	.170 – .176	31	29	24	23	22	21	20	19	18	17
0.25	.327 – .339	.246 – .254	.164 – .169	31	29	24	23	22	20	19	19	18	16
0.24	.314 – .326	.235 – .245	.157 – .163	30	29	24	23	22	20	19	19	18	16
0.23	.301 – .313	.226 – .234	.151 – 156	30	29	23	22	21	20	19	19	18	16
0.22	.287 – .300	.215 – .225	.144 – .150	30	28	23	22	21	20	19	18	17	16
0.21	.274 – .286	.206 – .214	.137 – .143	30	28	23	22	21	20	19	18	17	16
0.20	.260 – .273	.195 – .205	.130 – .136	29	28	23	22	21	19	19	18	17	16
0.19	.247 – .259	.186 – .194	.124 – .129	29	27	22	21	21	19	18	18	17	16
0.18	.234 – .246	.175 – .185	.117 – .123	29	27	22	21	20	19	18	18	17	15
0.17	.221 – .233	.166 – .174	.111 – .116	28	27	22	21	20	19	18	18	17	15
0.16	.207 – .220	.155 – .165	.104 – .110	28	27	22	21	20	19	18	17	16	15
0.15	.194 – .206	.146 – .154	.097 – .103	28	26	21	20	20	18	18	17	16	15
0.14	.180 – .193	.135 – .145	.091 – .096	27	26	21	20	19	18	17	17	16	15
0.13	.167 – .169	.126 – .134	.084 – .090	27	25	21	20	19	18	17	17	16	14
0.12	.154 – 1.66	.115 – .125	.083	27	25	20	20	19	18	17	16	15	14
0.11	.141 – .153	.106 – .114	—	26	25	20	19	18	17	16	16	15	14
0.10	.127 – .140	.095 – .105	—	26	24	20	19	18	17	16	16	15	14
0.09	.114 – .126	.086 – .094	—	25	24	19	19	18	17	16	15	15	13
0.08	.100 – .113	.083 – .085	—	24	23	19	18	17	16	15	15	14	13
0.07	.087 – .099	—	—	24	22	18	18	17	16	15	15	14	13
0.06	.083 – .086	—	—	23	22	18	17	16	15	15	14	13	12

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Table D-2—Elongation Table (SI Units)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
				Elongation in 50.8 mm, Minimum (percent)									
Tensile Test Specimen Area (mm^2)	Specified Wall Thickness for Strip Specimen Testing (in.)			Grade									
	Strip Specimen Specified Width			A25	A	B & X42	X46	X52	X56	X60	X65	X70	X80
				Specified Ultimate Tensile Strength (MPa)									
	19.0 mm	25.4 mm	38.1 mm	310	331	414	434	445	490	517	531	565	621
485	—	≥ 19.1	≥ 12.7	38	36	30	28	27	25	24	24	22	21
480	—	18.7 – 19.0	12.5 – 12.6	38	36	29	28	27	25	24	24	22	20
470	—	18.3 – 18.6	12.2 – 12.4	38	36	29	28	27	25	24	23	22	20
460	—	17.9 – 18.2	11.9 – 12.1	38	36	29	28	27	25	24	23	22	20
450	—	17.5 – 17.8	11.7 – 11.8	38	36	29	28	27	25	24	23	22	20
440	—	17.1 – 17.4	11.4 – 11.6	38	35	29	28	27	25	24	23	22	20
430	—	16.7 – 17.0	11.2 – 11.3	37	35	29	28	26	25	24	23	22	20
420	—	16.3 – 16.6	10.9 – 11.1	37	35	29	28	26	25	24	23	22	20
410	—	15.9 – 16.2	10.6 – 10.8	37	35	29	27	26	25	23	23	22	20
400	—	15.6 – 15.8	10.4 – 10.5	37	35	28	27	26	24	23	23	21	20
390	—	15.2 – 15.5	10.1 – 10.3	37	35	28	27	26	24	23	23	21	20
380	—	14.8 – 15.1	9.8 – 10.0	37	34	28	27	26	24	23	22	21	20
370	—	14.4 – 14.7	9.6 – 9.7	36	34	28	27	26	24	23	22	21	19
360	—	14.0 – 14.3	9.3 – 9.5	36	34	28	27	26	24	23	22	21	19
350	—	13.6 – 13.9	9.1 – 9.2	36	34	28	27	25	24	23	22	21	19
340	—	13.2 – 13.5	8.8 – 9.0	36	34	28	26	25	24	23	22	21	19
330	—	12.8 – 13.1	8.5 – 8.7	35	33	27	26	25	24	22	22	21	19
320	—	12.4 – 12.7	8.3 – 8.4	35	33	27	26	25	23	22	22	21	19
310	—	12.0 – 12.3	8.0 – 8.2	35	33	27	26	25	23	22	22	20	19
300	—	11.6 – 11.9	7.7 – 7.9	35	33	27	26	25	23	22	21	20	19
290	15.0 – 15.2	11.2 – 11.5	7.5 – 7.6	35	33	27	26	24	23	22	21	20	19
280	14.5 – 14.9	10.8 – 11.1	7.2 – 7.4	34	32	26	25	24	23	22	21	20	18
270	13.9 – 14.4	10.4 – 10.7	7.0 – 7.1	34	32	26	25	24	23	22	21	20	18
260	13.4 – 13.8	10.0 – 10.3	6.7 – 6.9	34	32	26	25	24	22	21	21	20	18
250	12.9 – 13.3	9.6 – 9.9	6.4 – 6.6	34	32	26	25	24	22	21	21	20	18
240	12.4 – 12.8	9.3 – 9.5	6.2 – 6.3	33	31	26	25	24	22	21	21	19	18
230	11.8 – 12.3	8.9 – 9.2	5.9 – 6.1	33	31	25	24	23	22	21	20	19	18
220	11.3 – 11.7	8.5 – 8.8	5.6 – 5.8	33	31	25	24	23	22	21	20	19	18
210	10.8 – 11.2	8.1 – 8.4	5.4 – 5.5	32	31	25	24	23	21	20	20	19	17
200	10.3 – 10.7	7.7 – 8.0	5.1 – 5.3	32	30	25	24	23	21	20	20	19	17
190	9.7 – 10.2	7.3 – 7.6	4.9 – 5.0	32	30	24	23	23	21	20	20	19	17
180	9.2 – 9.6	6.9 – 7.2	4.6 – 4.8	31	30	24	23	22	21	20	19	18	17
170	8.7 – 9.1	6.5 – 6.8	4.3 – 4.5	31	29	24	23	22	21	20	19	18	17
160	8.2 – 8.6	6.1 – 6.4	4.1 – 4.2	3.1	29	24	23	22	20	19	19	18	16
150	7.6 – 8.1	5.7 – 6.0	3.8 – 4.0	30	29	23	22	21	20	19	19	18	16
140	7.1 – 7.5	5.3 – 5.6	3.5 – 3.7	30	28	23	22	21	20	19	18	17	16
130	6.6 – 7.0	4.9 – 5.2	3.3 – 3.4	29	28	23	22	21	20	19	18	17	16
120	6.1 – 6.5	4.5 – 4.8	3.0 – 3.2	29	27	22	21	21	19	18	18	17	16
110	5.5 – 6.0	4.1 – 4.4	2.8 – 2.9	28	27	22	21	20	19	18	18	17	15
100	5.0 5.4	3.7 – 4.0	2.5 – 2.7	28	26	22	21	20	19	18	17	16	15
90	4.5 – 4.9	3.3 – 3.6	2.2 – 2.4	27	26	21	20	19	18	17	17	16	15
80	3.9 – 4.4	3.0 – 3.2	2.1	27	25	21	20	19	18	17	16	16	14
70	3.4 – 3.8	2.6 – 2.9	—	26	25	20	19	18	17	16	16	15	14
60	2.9 – 3.3	2.2 – 2.5	—	25	24	19	19	18	17	16	16	15	14
50	2.4 – 2.8	2.1	—	24	23	19	18	17	16	15	15	14	13
40	2.1 – 2.3	—	—	23	22	18	17	16	15	15	14	14	12

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APPENDIX E—DIMENSIONS, WEIGHTS, AND TEST PRESSURES—SI UNITS (NORMATIVE)

Tables E-6A, E-6B, and E-6C provide the SI unit values for dimensions, weights per unit length, and test pressures, corresponding to the U.S. Customary unit values given in Tables 6A, 6B, and 6C.

Table E-6A—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes 0.405 Through 1.900 (SI Units)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
						Minimum Test Pressure[b] (kPa × 100)[c]			
						Grade A		Grade B	
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)	Grade A25	Std.	Alt.	Std.	Alt.
0.405	10.3	1.7	0.36	6.9	48	48	—	48	—
0.405	10.3	2.4	0.47	5.5	59	59	—	59	—
0.540	13.7	2.2	0.62	9.3	48	48	—	48	—
0.540	13.7	3.0	0.79	7.7	59	59	—	59	—
0.675	17.1	2.3	0.84	12.5	48	48	—	48	—
0.675	17.1	3.2	1.10	10.7	59	59	—	59	—
0.840	21.3	2.8	1.28	15.7	48	48	—	48	—
0.840	21.3	3.7	1.61	13.9	59	59	—	59	—
0.840	21.3	7.5	2.55	6.3	69	69	—	69	—
1.050	26.7	2.9	1.70	20.9	48	48	—	48	—
1.050	26.7	3.9	2.19	18.9	59	59	—	59	—
1.050	26.7	7.8	3.64	11.1	69	69	—	69	—
1.315	33.4	3.4	2.52	26.6	48	48	—	48	—
1.315	33.4	4.5	3.21	24.4	59	59	—	59	—
1.315	33.4	9.1	5.45	15.2	69	69	—	69	—
1.660	42.2	3.6	3.43	35.0	69	83	—	90	—
1.660	42.2	4.9	4.51	32.4	90	124	—	131	—
1.660	42.2	9.7	7.77	22.8	96	152	—	158	—
1.900	48.3	3.7	4.07	40.9	69	83	—	90	—
1.900	48.3	5.1	5.43	38.1	90	124	—	131	—
1.900	48.3	10.2	9.58	27.9	96	152	—	158	—

Note: See Table 6A for U.S. Customary unit values corresponding to the SI unit values given in this table.
[a]The calculated inside diameters are given here for information (see 7.2).
[b]The test pressures given in E-6A, E-6B, and E-6C apply to Grades A25, A, B, X42, X46, X52, X56, X60, X65, X70, and X80 only. See 9.4.3 for pressures applicable to other grades.
[c]100 kPa = 1 bar.

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Table E-6B —Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $2^3/_8$ through $5^9/_{16}$ (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure[b] (kPa × 100)[c]										
Size	D (mm)	t (mm)	w_{pe} (kg/m)	d (mm)		Grade A25	Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$2^3/_8$[d]	60.3	2.1	3.01	56.1	Std.	41	87	101	121	132	150	161	173	187	202	207
					Alt.	—	108	126	151	166	188	202	216	234	252	288
$2^3/_8$[d]	60.3	2.8	3.97	54.7	Std.	55	115	134	162	177	200	207	207	207	207	207
					Alt.	—	144	168	202	221	250	269	288	312	336	384
$2^3/_8$[d]	60.3	3.2	4.51	53.9	Std.	69	132	153	185	202	207	207	207	207	207	207
					Alt.	—	165	172	231	252	286	307	330	357	384	439
$2^3/_8$[d]	60.3	3.6	5.03	53.1	Std.	69	148	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	260	284	321	346	371	401	433	494
$2^3/_8$	60.3	3.9	5.42	52.5	Std.	69	161	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	281	308	348	374	402	435	469	500
$2^3/_8$	60.3	4.4	6.07	51.5	Std.	76	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	317	347	393	422	453	490	500	500
$2^3/_8$	60.3	4.8	6.57	50.7	Std.	83	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	346	379	429	461	494	500	500	500
$2^3/_8$	60.3	5.5	7.43	49.3	Std.	90	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	397	434	491	500	500	500	500	500
$2^3/_8$	60.3	6.4	8.51	47.5	Std.	96	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	462	500	500	500	500	500	500	500
$2^3/_8$	60.3	7.1	9.31	46.1	Std.	96	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	500	500	500	500	500	500	500	500
$2^3/_8$	60.3	11.1	13.47	38.1	Std.	96	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	500	500	500	500	500	500	500	500
$2^7/_8$[d]	73.0	2.1	3.67	68.8	Std.	41	71	83	100	109	124	133	143	155	167	191
					Alt.	—	89	104	125	137	155	167	179	193	208	238
$2^7/_8$[d]	73.0	2.8	4.85	67.4	Std.	55	95	111	133	146	165	178	191	206	207	207
					Alt.	—	119	139	167	182	207	222	238	258	278	318
$2^7/_8$[d]	73.0	3.2	5.51	66.6	Std.	69	109	127	153	167	189	203	207	207	207	207
					Alt.	—	136	158	191	208	236	254	272	295	318	363
$2^7/_8$[d]	73.0	3.6	6.16	65.8	Std.	69	122	143	172	188	207	207	207	207	207	207
					Alt.	—	153	172	215	234	266	286	306	331	357	408
$2^7/_8$	73.0	4.0	6.81	65.0	Std.	69	136	158	191	207	207	207	207	207	207	207
					Alt.	—	170	172	238	261	295	317	340	368	397	454
$2^7/_8$	73.0	4.4	7.44	64.2	Std.	69	150	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	262	287	325	349	374	405	437	499
$2^7/_8$	73.0	4.8	8.07	63.4	Std.	69	163	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	286	313	354	381	408	442	476	500
$2^7/_8$	73.0	5.2	8.69	62.6	Std.	69	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	310	339	384	412	442	479	500	500
$2^7/_8$	73.0	5.5	9.16	62.0	Std.	76	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	328	358	406	436	468	500	500	500
$2^7/_8$	73.0	6.4	10.51	60.2	Std.	83	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	381	417	472	500	500	500	500	500
$2^7/_8$	73.0	7.0	11.39	59.0	Std.	90	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	417	456	500	500	500	500	500	500
$2^7/_8$	73.0	14.0	20.37	45.0	Std.	96	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	500	500	500	500	500	500	500	500
$3^1/_2$[d]	88.9	2.1	4.50	84.7	Std.	41	59	68	82	90	102	109	117	127	137	156
					Alt.	—	73	85	103	112	127	137	147	159	171	196
$3^1/_2$[d]	88.9	2.8	5.95	83.3	Std.	55	78	91	110	120	136	146	156	169	183	207
					Alt.	—	98	114	137	150	170	182	196	212	228	261

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Table E-6B (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $2^3/_8$ through $5^9/_{16}$ (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure[b] (kPa × 100)[c]										
Size	D (mm)	t (mm)	w_{pe} (kg/m)	d (mm)		Grade A25	Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$3^1/_2$[d]	88.9	3.2	6.76	82.5	Std.	69	89	104	125	137	155	167	179	194	207	207
					Alt.	—	112	130	157	171	194	208	224	242	261	298
$3^1/_2$[d]	88.9	3.6	7.57	81.7	Std.	69	101	117	141	154	174	188	201	207	207	207
					Alt.	—	126	146	176	193	218	234	251	272	293	335
$3^1/_2$[d]	88.9	4.0	8.37	80.9	Std.	69	112	130	157	171	194	207	207	207	207	207
					Alt.	—	140	163	196	214	242	261	279	302	326	373
$3^1/_2$	88.9	4.4	9.17	80.1	Std.	69	123	143	172	188	207	207	207	207	207	207
					Alt.	—	154	172	215	235	267	287	307	333	359	410
$3^1/_2$	88.9	4.8	9.95	79.3	Std.	69	134	156	188	205	207	207	207	207	207	207
					Alt.	—	168	172	235	257	291	313	335	363	391	447
$3^1/_2$	88.9	5.5	11.31	77.9	Std.	69	154	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	269	294	333	358	384	416	448	500
$3^1/_2$	88.9	6.4	13.02	76.1	Std.	—	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	313	342	388	417	447	484	500	500
$3^1/_2$	88.9	7.1	14.32	74.7	Std.	—	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	347	380	430	462	496	500	500	500
$3^1/_2$	88.9	7.6	15.24	73.7	Std.	90	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	372	407	460	495	500	500	500	500
$3^1/_2$	88.9	15.2	27.63	58.5	Std.	—	172	172	207	207	207	207	207	207	207	207
					Alt.	—	172	172	500	500	500	500	500	500	500	500
4[d]	101.6	2.1	5.15	97.4	Std.	—	51	60	72	79	89	96	103	111	120	137
					Alt.	—	64	75	90	98	111	120	128	139	150	171
4[d]	101.6	2.8	6.82	96.0	Std.	41	68	80	96	105	119	128	137	148	160	183
					Alt.	—	86	100	120	131	148	160	171	185	200	228
4[d]	101.6	3.2	7.76	95.2	Std.	—	78	91	110	120	136	146	156	169	183	207
					Alt.	—	98	114	137	150	170	182	196	212	228	261
4[d]	101.6	3.6	8.70	94.4	Std.	55	88	102	123	135	153	164	176	190	205	207
					Alt.	—	110	128	154	168	191	205	220	238	257	293
4[d]	101.6	4.0	9.63	93.6	Std.	—	98	114	137	150	170	182	196	207	207	207
					Alt.	—	122	142	171	187	212	228	244	265	285	326
4	101.6	4.4	10.55	92.8	Std.	69	108	125	151	165	187	201	207	207	207	207
					Alt.	—	134	157	188	206	233	251	269	291	314	359
4	101.6	4.8	11.46	92.0	Std.	83	117	137	164	180	204	207	207	207	207	207
					Alt.	—	147	171	206	225	254	274	293	317	342	391
4	101.6	5.7	13.48	90.2	Std.	83	139	162	195	207	207	207	207	207	207	207
					Alt.	—	174	193	244	267	302	325	348	377	406	465
4	101.6	6.4	15.02	88.8	Std.	—	156	182	207	207	207	207	207	207	207	207
					Alt.	—	193	193	274	300	339	365	391	423	456	500
4	101.6	7.1	16.55	87.4	Std.	—	174	193	207	207	207	207	207	207	207	207
					Alt.	—	193	193	304	332	376	405	434	470	500	500
4	101.6	8.1	18.68	85.4	Std.	117	193	193	207	207	207	207	207	207	207	207
					Alt.	—	193	193	347	379	429	462	495	500	500	500
$4^1/_2$[d]	114.3	2.1	5.81	110.1	Std.	—	46	53	64	70	79	85	91	99	106	122
					Alt.	—	57	66	80	87	99	106	114	123	133	152
$4^1/_2$[d]	114.3	3.2	8.77	107.9	Std.	55	70	81	97	106	121	130	139	151	162	185
					Alt.	—	87	101	122	133	151	162	174	188	203	232
$4^1/_2$[d]	114.3	3.6	9.83	107.1	Std.	—	78	91	110	120	136	146	156	169	183	207
					Alt.	—	98	114	137	150	170	182	196	212	228	261
$4^1/_2$[d]	114.3	4.0	10.88	106.3	Std.	69	87	101	122	133	151	162	174	188	203	207
					Alt.	—	109	127	152	166	188	203	217	235	254	290

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Table E-6B (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $2^3/_8$ through $5^9/_{16}$ (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure[b] (kPa × 100)[c]										
Size	D (mm)	t (mm)	w_{pe} (kg/m)	d (mm)		Grade A25	Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$4^1/_2$	114.3	4.4	11.92	105.5	Std.	—	96	111	134	146	166	178	191	207	207	207
					Alt.	—	120	139	167	183	207	223	239	259	279	319
$4^1/_2$	114.3	4.8	12.96	104.7	Std.	83	104	121	146	160	181	195	207	207	207	207
					Alt.	—	130	152	183	200	226	243	261	282	304	348
$4^1/_2$	114.3	5.2	13.99	103.9	Std.	—	113	132	158	173	196	207	207	207	207	207
					Alt.	—	141	164	198	216	245	263	283	306	330	377
$4^1/_2$	114.3	5.6	15.01	103.1	Std.	83	122	142	170	186	207	207	207	207	207	207
					Alt.	—	152	177	213	233	264	284	304	329	355	406
$4^1/_2$	114.3	6.0	16.02	102.3	Std.	83	130	152	183	200	207	207	207	207	207	207
					Alt.	—	163	190	228	250	283	304	326	353	380	435
$4^1/_2$	114.3	6.4	17.03	101.5	Std.	—	139	162	195	207	207	207	207	207	207	207
					Alt.	—	174	193	244	266	302	324	348	376	406	464
$4^1/_2$	114.3	7.1	18.77	100.1	Std.	—	154	180	207	207	207	207	207	207	207	207
					Alt.	—	193	193	270	295	335	360	386	417	450	500
$4^1/_2$	114.3	7.9	20.73	98.5	Std.	—	172	193	207	207	207	207	207	207	207	207
					Alt.	—	193	193	301	329	372	400	429	464	500	500
$4^1/_2$	114.3	8.6	22.42	97.1	Std.	117	187	193	207	207	207	207	207	207	207	207
					Alt.	—	193	193	327	358	405	436	467	500	500	500
$4^1/_2$	114.3	11.1	28.25	92.1	Std.	—	193	193	207	207	207	207	207	207	207	207
					Alt.	—	193	193	422	462	500	500	500	500	500	500
$4^1/_2$	114.3	13.5	33.56	87.3	Std.	—	193	193	207	207	207	207	207	207	207	207
					Alt.	—	193	193	500	500	500	500	500	500	500	500
$4^1/_2$	114.3	17.1	40.99	80.1	Std.	—	193	193	207	207	207	207	207	207	207	207
					Alt.	—	193	193	500	500	500	500	500	500	500	500
$5^9/_{16}$[d]	141.3	2.1	7.21	137.1	Std.	—	37	43	52	57	64	69	74	80	86	98
					Alt.	—	46	54	65	71	80	86	92	100	108	123
$5^9/_{16}$[d]	141.3	3.2	10.90	134.9	Std.	46	56	65	79	86	98	105	113	122	131	150
					Alt.	—	70	82	99	108	122	131	141	152	164	188
$5^9/_{16}$[d]	141.3	4.0	13.54	133.3	Std.	58	70	82	99	108	122	131	141	152	164	188
					Alt.	—	88	102	123	135	152	164	176	190	205	234
$5^9/_{16}$	141.3	4.8	16.16	131.7	Std.	70	84	98	118	129	146	157	169	183	197	207
					Alt.	—	105	123	148	162	183	197	211	228	246	281
$5^9/_{16}$	141.3	5.6	18.74	130.1	Std.	81	98	115	138	151	171	184	197	207	207	207
					Alt.	—	123	143	172	188	213	229	246	266	287	328
$5^9/_{16}$	141.3	6.6	21.92	128.1	Std.	83	116	135	163	178	201	207	207	207	207	207
					Alt.	—	145	169	203	222	252	270	290	314	338	387
$5^9/_{16}$	141.3	7.1	23.50	127.1	Std.	105	125	145	175	191	207	207	207	207	207	207
					Alt.	—	156	182	219	239	271	291	312	338	364	416
$5^9/_{16}$	141.3	7.9	25.99	125.5	Std.	116	139	162	195	207	207	207	207	207	207	207
					Alt.	—	174	193	243	266	301	324	347	376	405	463
$5^9/_{16}$	141.3	8.7	28.45	123.9	Std.	128	153	178	207	207	207	207	207	207	207	207
					Alt.	—	191	193	268	293	332	356	382	414	446	500
$5^9/_{16}$	141.3	9.5	30.88	122.3	Std.	139	167	193	207	207	207	207	207	207	207	207
					Alt.	—	193	193	292	320	362	389	418	452	487	500
$5^9/_{16}$	141.3	12.7	40.28	115.9	Std.	186	193	193	207	207	207	207	207	207	207	207
					Alt.	—	193	193	391	427	484	500	500	500	500	500
$5^9/_{16}$	141.3	15.9	49.17	109.5	Std.	193	193	193	207	207	207	207	207	207	207	207
					Alt.	—	193	193	489	500	500	500	500	500	500	500

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Table E-6B (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $2^3/_8$ through $5^9/_{16}$ (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure[b] (kPa × 100)[c]										
Size	D (mm)	t (mm)	w_{pe} (kg/m)	d (mm)		Grade A25	Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$5^9/_{16}$	141.3	19.1	57.56	103.1	Std.	193	193	193	207	207	207	207	207	207	207	207
					Alt.	—	193	193	500	500	500	500	500	500	500	500

Note: See Table 6B for US Customary unit values corresponding to the SI unit values given in this table.

[a]The calculated inside diameters are given here for information (see 7.2).

[b]The test pressures given in Tables E-6A, E-6B, and E-6C apply to Grades A25, A, B, X42, X46, X52, X56, X60, X65, X70, and X80 only. See 9.4.3 for pressures applicable to other grades.

[c]100 kPa = 1 bar.

[d]Pipe that has this combination of specified outside diameter and specified wall thickness is special plain-end pipe; other combinations given in this table are regular plain-end pipe. Pipe that has a combination of specified outside diameter and specified wall thickness that is intermediate to the tabulated values is considered to be special plain-end pipe if the next lower tabulated value is for special plain-end pipe; other intermediate combinations are considered to be regular plain-end pipe. (See Table 10 for the applicable weight tolerances.)

Table E-6C —Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure[b] (kPa × 100)[c]									
Size	D (mm)	t (mm)	w_{pe} (kg/m)	d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$6^5/_8$[d]	168.3	2.1	8.61	164.1	Std.	31	36	54	59	67	72	77	84	90	103
					Alt.	39	45	54	59	67	72	77	84	90	103
$6^5/_8$[d]	168.3	2.8	11.43	162.7	Std.	41	48	72	79	90	96	103	112	121	138
					Alt.	52	60	72	79	90	96	103	112	121	138
$6^5/_8$[d]	168.3	3.2	13.03	161.9	Std.	47	55	83	90	102	110	118	128	138	157
					Alt.	59	69	83	90	102	110	118	128	138	157
$6^5/_8$[d]	168.3	3.6	14.62	161.1	Std.	53	62	93	102	115	124	133	144	155	177
					Alt.	66	77	93	102	115	124	133	144	155	177
$6^5/_8$[d]	168.3	4.0	16.21	160.3	Std.	59	69	103	113	128	138	148	160	172	197
					Alt.	74	86	103	113	128	138	148	160	172	197
$6^5/_8$	168.3	4.4	17.78	159.5	Std.	65	76	114	124	141	151	162	176	189	207
					Alt.	81	95	114	124	141	151	162	176	189	216
$6^5/_8$	168.3	4.8	19.35	158.7	Std.	71	82	124	136	154	165	177	192	207	207
					Alt.	89	103	124	136	154	165	177	192	207	236
$6^5/_8$	168.3	5.2	20.91	157.9	Std.	77	89	134	147	166	179	192	207	207	207
					Alt.	96	112	134	147	166	179	192	208	224	256
$6^5/_8$	168.3	5.6	22.47	157.1	Std.	83	96	145	158	179	193	207	207	207	207
					Alt.	103	120	145	158	179	193	207	224	241	276
$6^5/_8$	168.3	6.4	25.55	155.5	Std.	94	110	165	181	205	207	207	207	207	207
					Alt.	118	137	165	181	205	220	236	256	276	315
$6^5/_8$	168.3	7.1	28.22	154.1	Std.	105	122	184	201	207	207	207	207	207	207
					Alt.	131	153	184	201	227	244	262	283	306	349
$6^5/_8$	168.3	7.9	31.25	152.5	Std.	117	136	204	207	207	207	207	207	207	207
					Alt.	146	170	204	223	253	272	291	315	340	389
$6^5/_8$	168.3	8.7	34.24	150.9	Std.	128	149	207	207	207	207	207	207	207	207
					Alt.	161	187	225	246	278	299	321	347	375	428
$6^5/_8$	168.3	9.5	37.20	149.3	Std.	140	163	207	207	207	207	207	207	207	207
					Alt.	175	193	246	268	304	327	351	379	409	467
$6^5/_8$	168.3	11.0	42.67	146.3	Std.	162	189	207	207	207	207	207	207	207	207
					Alt.	193	193	284	311	352	378	406	439	474	500

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure[b] (kPa × 100)[c]									
Size	D (mm)	t (mm)	w_{pe} (kg/m)	d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$6^5/_8$	168.3	12.7	48.73	142.9	Std.	187	193	207	207	207	207	207	207	207	207
					Alt.	193	193	328	359	406	437	469	500	500	500
$6^5/_8$	168.3	14.3	54.31	139.7	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	370	404	458	492	500	500	500	500
$6^5/_8$	168.3	15.9	59.76	136.5	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	411	449	500	500	500	500	500	500
$6^5/_8$	168.3	18.3	67.69	131.7	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	473	500	500	500	500	500	500	500
$6^5/_8$	168.3	19.1	70.27	130.1	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	494	500	500	500	500	500	500	500
$6^5/_8$	168.3	21.9	79.06	124.5	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	500	500	500	500	500	500	500	500
$6^5/_8$	168.3	22.2	79.98	123.9	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	500	500	500	500	500	500	500	500
$8^5/_8$[d]	219.1	3.2	17.04	212.7	Std.	36	42	64	69	79	85	91	98	106	121
					Alt.	45	53	64	69	79	85	91	98	106	121
$8^5/_8$[d]	219.1	4.0	21.22	211.1	Std.	45	53	79	87	98	106	113	123	132	151
					Alt.	57	66	79	87	98	106	113	123	132	151
$8^5/_8$	219.1	4.8	25.37	209.5	Std.	54	63	95	104	118	127	136	147	159	181
					Alt.	68	79	95	104	118	127	136	147	159	181
$8^5/_8$	219.1	5.2	27.43	208.7	Std.	59	69	103	113	128	137	147	159	172	197
					Alt.	74	86	103	113	128	137	147	159	172	197
$8^5/_8$	219.1	5.6	29.48	207.9	Std.	63	74	111	122	138	148	159	172	185	207
					Alt.	79	92	111	122	138	148	159	172	185	212
$8^5/_8$	219.1	6.4	33.57	206.3	Std.	73	84	127	139	157	169	181	196	207	207
					Alt.	91	106	127	139	157	169	181	196	212	242
$8^5/_8$	219.1	7.0	36.61	205.1	Std.	79	92	139	152	172	185	198	207	207	207
					Alt.	99	115	139	152	172	185	198	215	231	265
$8^5/_8$	219.1	7.9	41.14	203.3	Std.	90	104	157	171	194	207	207	207	207	207
					Alt.	112	130	157	171	194	209	224	242	261	299
$8^5/_8$	219.1	8.2	42.65	202.7	Std.	93	108	163	178	202	207	207	207	207	207
					Alt.	116	135	163	178	202	217	232	252	271	310
$8^5/_8$	219.1	8.7	45.14	201.7	Std.	99	115	173	189	207	207	207	207	207	207
					Alt.	123	144	173	189	214	230	247	267	288	329
$8^5/_8$	219.1	9.5	49.10	200.1	Std.	108	125	189	206	207	207	207	207	207	207
					Alt.	135	157	189	206	233	251	269	291	314	359
$8^5/_8$	219.1	11.1	56.94	196.9	Std.	126	147	207	207	207	207	207	207	207	207
					Alt.	157	183	220	241	273	293	315	340	367	419
$8^5/_8$	219.1	12.7	64.64	193.7	Std.	144	168	207	207	207	207	207	207	207	207
					Alt.	180	193	252	276	312	336	360	390	420	480
$8^5/_8$	219.1	14.3	72.22	190.5	Std.	162	189	207	207	207	207	207	207	207	207
					Alt.	193	193	284	310	351	378	405	439	473	500
$8^5/_8$	219.1	15.9	79.67	187.3	Std.	180	193	207	207	207	207	207	207	207	207
					Alt.	193	193	316	345	391	420	451	488	500	500
$8^5/_8$	219.1	18.3	90.62	182.5	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	363	397	450	484	500	500	500	500
$8^5/_8$	219.1	19.1	94.20	180.9	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	379	415	469	500	500	500	500	500
$8^5/_8$	219.1	20.6	100.84	177.9	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	409	447	500	500	500	500	500	500

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$8^5/_8$	219.1	22.2	107.79	174.7	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	441	482	500	500	500	500	500	500
$8^5/_8$	219.1	25.4	121.33	168.3	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	500	500	500	500	500	500	500	500
$10^3/_4$[d]	273.1	4.0	26.54	265.1	Std.	36	42	72	79	89	96	103	112	120	137
					Alt.	45	53	72	79	89	96	103	112	120	137
$10^3/_4$[d]	273.1	4.8	31.76	263.5	Std.	44	51	87	95	107	115	124	134	144	165
					Alt.	55	64	87	95	107	115	124	134	144	165
$10^3/_4$[d]	273.1	5.2	34.35	262.7	Std.	47	55	94	103	116	125	134	145	156	179
					Alt.	59	69	94	103	116	125	134	145	156	179
$10^3/_4$	273.1	5.6	36.94	261.9	Std.	51	59	101	111	125	135	144	156	168	192
					Alt.	64	74	101	111	125	135	144	156	168	192
$10^3/_4$	273.1	6.4	42.09	260.3	Std.	58	68	116	126	143	154	165	178	192	207
					Alt.	73	85	116	126	143	154	165	178	192	220
$10^3/_4$	273.1	7.1	46.57	258.9	Std.	65	75	128	140	159	171	183	198	207	207
					Alt.	81	94	128	140	159	171	183	198	213	244
$10^3/_4$	273.1	7.8	51.03	257.5	Std.	71	83	141	154	174	187	201	207	207	207
					Alt.	89	103	141	154	174	187	201	218	235	268
$10^3/_4$	273.1	8.7	56.72	255.7	Std.	79	92	157	172	194	207	207	207	207	207
					Alt.	99	115	157	172	194	209	224	243	262	299
$10^3/_4$	273.1	9.3	60.50	254.5	Std.	85	98	168	184	207	207	207	207	207	207
					Alt.	106	123	168	184	208	223	240	259	280	320
$10^3/_4$	273.1	11.1	71.72	250.9	Std.	101	118	200	207	207	207	207	207	207	207
					Alt.	126	147	200	219	248	267	286	310	334	381
$10^3/_4$	273.1	12.7	81.55	247.7	Std.	116	134	207	207	207	207	207	207	207	207
					Alt.	144	168	229	251	284	305	327	354	382	436
$10^3/_4$	273.1	14.3	91.26	244.5	Std.	130	151	207	207	207	207	207	207	207	207
					Alt.	163	189	258	282	320	344	369	399	430	491
$10^3/_4$	273.1	15.9	100.85	241.3	Std.	145	168	207	207	207	207	207	207	207	207
					Alt.	181	193	287	314	355	382	410	443	478	500
$10^3/_4$	273.1	18.3	114.99	236.5	Std.	166	193	207	207	207	207	207	207	207	207
					Alt.	193	193	330	361	409	440	472	500	500	500
$10^3/_4$	273.1	20.6	128.27	231.9	Std.	187	193	207	207	207	207	207	207	207	207
					Alt.	193	193	372	406	460	495	500	500	500	500
$10^3/_4$	273.1	22.2	137.36	228.7	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	401	438	496	500	500	500	500	500
$10^3/_4$	273.1	23.8	146.32	225.5	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	430	470	500	500	500	500	500	500
$10^3/_4$	273.1	25.4	155.15	222.3	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	459	500	500	500	500	500	500	500
$10^3/_4$	273.1	31.8	189.22	209.5	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	500	500	500	500	500	500	500	500
$12^3/_4$[d]	323.9	4.4	34.67	315.1	Std.	34	39	67	73	83	89	96	103	112	127
					Alt.	42	49	67	73	83	89	96	103	112	127
$12^3/_4$[d]	323.9	4.8	37.77	314.3	Std.	37	43	73	80	90	97	104	113	122	139
					Alt.	46	54	73	80	90	97	104	113	122	139
$12^3/_4$[d]	323.9	5.2	40.87	313.5	Std.	40	46	79	87	98	105	113	122	132	151
					Alt.	50	58	79	87	98	105	113	122	132	151
$12^3/_4$[d]	323.9	5.6	43.96	312.7	Std.	43	50	85	93	106	113	122	132	142	162
					Alt.	54	63	85	93	106	113	122	132	142	162

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
$12^3/_4$	323.9	6.4	50.11	311.1	Std.	49	57	97	106	121	130	139	150	162	185
					Alt.	61	71	97	106	121	130	139	150	162	185
$12^3/_4$	323.9	7.1	55.47	309.7	Std.	54	63	108	118	134	144	154	167	180	206
					Alt.	68	79	108	118	134	144	154	167	180	206
$12^3/_4$	323.9	7.9	61.56	308.1	Std.	61	71	120	131	149	160	172	186	200	207
					Alt.	76	88	120	131	149	160	172	186	200	229
$12^3/_4$	323.9	8.4	65.35	307.1	Std.	64	75	128	140	158	170	183	198	207	207
					Alt.	81	94	128	140	158	170	183	198	213	243
$12^3/_4$	323.9	8.7	67.62	306.5	Std.	67	78	132	145	164	176	189	205	207	207
					Alt.	83	97	132	145	164	176	189	205	221	252
$12^3/_4$	323.9	9.5	73.65	304.9	Std.	73	85	145	158	179	192	206	207	207	207
					Alt.	91	106	145	158	179	192	206	223	241	275
$12^3/_4$	323.9	10.3	79.65	303.3	Std.	79	92	157	171	194	207	207	207	207	207
					Alt.	99	115	157	171	194	209	224	242	261	298
$12^3/_4$	323.9	11.1	85.62	301.7	Std.	85	99	169	185	207	207	207	207	207	207
					Alt.	106	124	169	185	209	225	241	261	281	322
$12^3/_4$	323.9	12.7	97.46	298.5	Std.	97	113	193	207	207	207	207	207	207	207
					Alt.	122	142	193	211	239	257	276	299	322	368
$12^3/_4$	323.9	14.3	109.18	295.3	Std.	110	128	207	207	207	207	207	207	207	207
					Alt.	137	160	218	238	269	290	311	336	363	414
$12^3/_4$	323.9	15.9	120.76	292.1	Std.	122	142	207	207	207	207	207	207	207	207
					Alt.	152	177	242	265	300	322	345	374	403	461
$12^3/_4$	323.9	17.5	132.23	288.9	Std.	134	156	207	207	207	207	207	207	207	207
					Alt.	168	193	266	291	330	355	380	411	444	500
$12^3/_4$	323.9	19.1	143.56	285.7	Std.	146	171	207	207	207	207	207	207	207	207
					Alt.	183	193	291	318	360	387	415	449	484	500
$12^3/_4$	323.9	20.6	154.08	282.7	Std.	158	184	207	207	207	207	207	207	207	207
					Alt.	193	193	314	343	388	417	448	484	500	500
$12^3/_4$	323.9	22.2	165.17	279.5	Std.	170	193	207	207	207	207	207	207	207	207
					Alt.	193	193	338	369	418	450	482	500	500	500
$12^3/_4$	323.9	23.8	176.13	276.3	Std.	183	193	207	207	207	207	207	207	207	207
					Alt.	193	193	362	396	448	482	500	500	500	500
$12^3/_4$	323.9	25.4	186.97	273.1	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	387	423	479	500	500	500	500	500
$12^3/_4$	323.9	27.0	197.68	269.9	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	411	449	500	500	500	500	500	500
$12^3/_4$	323.9	28.6	208.27	266.7	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	435	476	500	500	500	500	500	500
$12^3/_4$	323.9	31.8	229.06	260.3	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	484	500	500	500	500	500	500	500
14[d]	355.6	4.8	41.52	346.0	Std.	34	39	67	73	82	89	95	103	111	127
					Alt.	42	49	67	73	82	89	95	103	111	127
14[d]	355.6	5.2	44.93	345.2	Std.	36	42	72	79	89	96	103	111	120	137
					Alt.	45	53	72	79	89	96	103	111	120	137
14[d]	355.6	5.3	45.78	345.0	Std.	37	43	73	80	91	98	105	114	122	140
					Alt.	46	54	73	80	91	98	105	114	122	140
14[d]	355.6	5.6	48.33	344.4	Std.	39	46	78	85	96	103	111	120	129	148
					Alt.	49	57	78	85	96	103	111	120	129	148
14[d]	355.6	6.4	55.11	342.8	Std.	45	52	89	97	110	118	127	137	148	169
					Alt.	56	65	89	97	110	118	127	137	148	169

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
14[d]	355.6	7.1	61.02	341.4	Std.	50	58	98	108	122	131	141	152	164	187
					Alt.	62	72	98	108	122	131	141	152	164	187
14	355.6	7.9	67.74	339.8	Std.	55	64	110	120	136	146	156	169	182	207
					Alt.	69	80	110	120	136	146	156	169	182	208
14	355.6	8.7	74.42	338.2	Std.	61	71	121	132	149	161	172	186	201	207
					Alt.	76	88	121	132	149	161	172	186	201	230
14	355.6	9.5	81.08	336.6	Std.	66	77	132	144	163	175	188	203	207	207
					Alt.	83	97	132	144	163	175	188	203	219	251
14	355.6	10.3	87.71	335.0	Std.	72	84	143	156	177	190	204	207	207	207
					Alt.	90	105	143	156	177	190	204	221	238	272
14	355.6	11.1	94.30	333.4	Std.	78	90	154	168	191	205	207	207	207	207
					Alt.	97	113	154	168	191	205	220	238	256	293
14	355.6	11.9	100.86	331.8	Std.	83	97	165	180	204	207	207	207	207	207
					Alt.	104	121	165	180	204	220	236	255	275	314
14	355.6	12.7	107.39	330.2	Std.	89	103	176	192	207	207	207	207	207	207
					Alt.	111	129	176	192	218	234	251	272	293	335
14	355.6	14.3	120.36	327.0	Std.	100	116	198	207	207	207	207	207	207	207
					Alt.	125	145	198	217	245	264	283	306	330	377
14	355.6	15.9	133.19	323.8	Std.	111	129	207	207	207	207	207	207	207	207
					Alt.	139	162	220	241	273	293	315	341	367	420
14	355.6	17.5	145.91	320.6	Std.	122	142	207	207	207	207	207	207	207	207
					Alt.	153	178	243	265	300	323	346	375	404	462
14	355.6	19.1	158.49	317.4	Std.	133	155	207	207	207	207	207	207	207	207
					Alt.	167	193	265	289	328	352	378	409	441	500
14	355.6	20.6	170.18	314.4	Std.	144	168	207	207	207	207	207	207	207	207
					Alt.	180	193	286	312	354	380	408	441	476	500
14	355.6	22.2	182.52	311.2	Std.	155	181	207	207	207	207	207	207	207	207
					Alt.	193	193	308	336	381	410	439	475	500	500
14	355.6	23.8	194.74	308.0	Std.	166	193	207	207	207	207	207	207	207	207
					Alt.	193	193	330	361	408	439	471	500	500	500
14	355.6	25.4	206.83	304.8	Std.	177	193	207	207	207	207	207	207	207	207
					Alt.	193	193	352	385	436	469	500	500	500	500
14	355.6	27.0	218.79	301.6	Std.	189	193	207	207	207	207	207	207	207	207
					Alt.	193	193	374	409	463	498	500	500	500	500
14	355.6	28.6	230.63	298.4	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	397	433	491	500	500	500	500	500
14	355.6	31.8	253.92	292.0	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	441	482	500	500	500	500	500	500
16[d]	406.4	4.8	47.54	396.8	Std.	29	34	58	64	72	78	83	90	97	111
					Alt.	37	43	58	64	72	78	83	90	97	111
16[d]	406.4	5.2	51.45	396.0	Std.	32	37	63	69	78	84	90	97	105	120
					Alt.	40	46	63	69	78	84	90	97	105	120
16[d]	406.4	5.6	55.35	395.2	Std.	34	40	68	74	84	90	97	105	113	129
					Alt.	43	50	68	74	84	90	97	105	113	129
16[d]	406.4	6.4	63.13	393.6	Std.	39	46	78	85	96	103	111	120	129	148
					Alt.	49	57	78	85	96	103	111	120	129	148
16[d]	406.4	7.1	69.91	392.2	Std.	43	51	86	94	107	115	123	133	143	164
					Alt.	54	63	86	94	107	115	123	133	143	164
16	406.4	7.9	77.63	390.6	Std.	48	56	96	105	119	128	137	148	160	182
					Alt.	60	70	96	105	119	128	137	148	160	182

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
16	406.4	8.7	85.32	389.0	Std.	53	62	106	115	131	140	151	163	176	201
					Alt.	66	77	106	115	131	140	151	163	176	201
16	406.4	9.5	92.98	387.4	Std.	58	68	115	126	143	153	165	178	192	207
					Alt.	73	85	115	126	143	153	165	178	192	219
16	406.4	10.3	100.61	385.8	Std.	63	73	125	137	155	166	178	193	207	207
					Alt.	79	92	125	137	155	166	178	193	208	238
16	406.4	11.1	108.20	384.2	Std.	68	79	135	147	167	179	192	207	207	207
					Alt.	85	99	135	147	167	179	192	208	224	250
16	406.4	11.9	115.77	382.6	Std.	73	85	144	158	179	192	206	207	207	207
					Alt.	91	106	144	158	179	192	206	223	240	250
16	406.4	12.7	123.30	381.0	Std.	78	90	154	168	191	205	207	207	207	207
					Alt.	97	113	154	168	191	205	220	238	250	250
16	406.4	14.3	138.27	377.8	Std.	87	102	173	190	207	207	207	207	207	207
					Alt.	109	127	173	190	215	231	248	250	250	250
16	406.4	15.9	153.11	374.6	Std.	97	113	193	207	207	207	207	207	207	207
					Alt.	121	141	193	211	239	250	250	250	250	250
16	406.4	17.5	167.83	371.4	Std.	107	125	207	207	207	207	207	207	207	207
					Alt.	134	156	212	232	250	250	250	250	250	250
16	406.4	19.1	182.42	368.2	Std.	117	136	207	207	207	207	207	207	207	207
					Alt.	146	170	232	250	250	250	250	250	250	250
16	406.4	20.6	195.98	365.2	Std.	126	147	207	207	207	207	207	207	207	207
					Alt.	157	183	250	250	250	250	250	250	250	250
16	406.4	22.2	210.33	362.0	Std.	136	158	207	207	207	207	207	207	207	207
					Alt.	170	193	250	250	250	250	250	250	250	250
16	406.4	23.8	224.55	358.8	Std.	145	169	207	207	207	207	207	207	207	207
					Alt.	182	193	250	250	250	250	250	250	250	250
16	406.4	25.4	238.64	355.6	Std.	155	181	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
16	406.4	27.0	252.61	352.4	Std.	165	192	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
16	406.4	28.6	266.45	349.2	Std.	175	193	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
16	406.4	30.2	280.17	346.0	Std.	185	193	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
16	406.4	31.8	293.76	342.8	Std.	193	193	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
18[d]	457.0	4.8	53.53	447.4	Std.	26	30	52	57	64	69	74	80	86	99
					Alt.	33	38	52	57	64	69	74	80	86	99
18[d]	457.0	5.6	62.34	445.8	Std.	30	35	60	66	75	80	86	93	101	115
					Alt.	38	44	60	66	75	80	86	93	101	115
18[d]	457.0	6.4	71.12	444.2	Std.	35	41	69	75	85	92	99	107	115	131
					Alt.	43	51	69	75	85	92	99	107	115	131
18[d]	457.0	7.1	78.77	442.8	Std.	39	45	77	84	95	102	109	118	128	146
					Alt.	48	56	77	84	95	102	109	118	128	146
18	457.0	7.9	87.49	441.2	Std.	43	50	85	93	106	113	122	132	142	162
					Alt.	54	62	85	93	106	113	122	132	142	162
18	457.0	8.7	96.18	439.6	Std.	47	55	94	103	116	125	134	145	156	179
					Alt.	59	69	94	103	116	125	134	145	156	179
18	457.0	9.5	104.84	438.0	Std.	52	60	102	112	127	136	146	158	171	195
					Alt.	65	75	102	112	127	136	146	158	171	195

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
18	457.0	10.3	113.46	436.4	Std.	56	65	111	121	138	148	159	172	185	207
					Alt.	70	81	111	121	138	148	159	172	185	211
18	457.0	11.1	122.05	434.8	Std.	60	70	120	131	148	159	171	185	199	207
					Alt.	75	88	120	131	148	159	171	185	199	228
18	457.0	11.9	130.62	433.2	Std.	65	75	128	140	159	171	183	198	207	207
					Alt.	81	94	128	140	159	171	183	198	214	244
18	457.0	12.7	139.15	431.6	Std.	69	80	137	150	170	182	196	207	207	207
					Alt.	86	100	137	150	170	182	196	212	228	250
18	457.0	14.3	156.11	428.4	Std.	78	90	154	169	191	205	207	207	207	207
					Alt.	97	113	154	169	191	205	220	238	250	250
18	457.0	15.9	172.95	425.2	Std.	86	101	172	187	207	207	207	207	207	207
					Alt.	108	126	172	187	212	228	245	250	250	250
18	457.0	17.5	189.67	422.0	Std.	95	111	189	206	207	207	207	207	207	207
					Alt.	119	138	189	206	234	250	250	250	250	250
18	457.0	19.1	206.25	418.8	Std.	104	121	206	207	207	207	207	207	207	207
					Alt.	130	151	206	225	250	250	250	250	250	250
18	457.0	20.6	221.69	415.8	Std.	112	130	207	207	207	207	207	207	207	207
					Alt.	140	163	222	243	250	250	250	250	250	250
18	457.0	22.2	238.03	412.6	Std.	121	140	207	207	207	207	207	207	207	207
					Alt.	151	176	239	250	250	250	250	250	250	250
18	457.0	23.8	254.25	409.4	Std.	129	151	207	207	207	207	207	207	207	207
					Alt.	162	188	250	250	250	250	250	250	250	250
18	457.0	25.4	270.34	406.2	Std.	138	161	207	207	207	207	207	207	207	207
					Alt.	173	193	250	250	250	250	250	250	250	250
18	457.0	27.0	286.30	403.0	Std.	147	171	207	207	207	207	207	207	207	207
					Alt.	183	193	250	250	250	250	250	250	250	250
18	457.0	28.6	302.14	399.8	Std.	155	181	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
18	457.0	30.2	317.85	396.6	Std.	164	191	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
18	457.0	31.8	333.44	393.4	Std.	173	193	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
20[d]	508.0	5.6	69.38	496.8	Std.	27	32	58	63	71	77	82	89	96	110
					Alt.	34	40	58	63	71	77	82	89	96	110
20[d]	508.0	6.4	79.16	495.2	Std.	31	36	66	72	81	88	94	102	110	125
					Alt.	39	46	66	72	81	88	94	102	110	125
20[d]	508.0	7.1	87.70	493.8	Std.	35	40	73	80	90	97	104	113	122	139
					Alt.	43	51	73	80	90	97	104	113	122	139
20	508.0	7.9	97.43	492.2	Std.	39	45	81	89	100	108	116	125	135	155
					Alt.	48	56	81	89	100	108	116	125	135	155
20	508.0	8.7	107.12	490.6	Std.	43	50	89	98	111	119	128	138	149	170
					Alt.	53	62	89	98	111	119	128	138	149	170
20	508.0	9.5	116.78	489.0	Std.	46	54	98	107	121	130	139	151	163	186
					Alt.	58	68	98	107	121	130	139	151	163	186
20	508.0	10.3	126.41	487.4	Std.	50	59	106	116	131	141	151	164	176	201
					Alt.	63	73	106	116	131	141	151	164	176	201
20	508.0	11.1	136.01	485.8	Std.	54	63	114	125	141	152	163	176	190	207
					Alt.	68	79	114	125	141	152	163	176	190	217
20	508.0	11.9	145.58	484.2	Std.	58	68	122	134	151	163	175	189	204	207
					Alt.	73	85	122	134	151	163	175	189	204	233

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure[b] (kPa × 100)[c]									
Size	D (mm)	t (mm)	w_{pe} (kg/m)	d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
20	508.0	12.7	155.12	482.6	Std.	62	72	131	143	162	174	186	202	207	207
					Alt.	78	90	131	143	162	174	186	202	217	248
20	508.0	14.3	174.10	479.4	Std.	70	81	147	161	182	196	207	207	207	207
					Alt.	87	102	147	161	182	196	210	227	245	250
20	508.0	15.9	192.95	476.2	Std.	78	91	163	179	202	207	207	207	207	207
					Alt.	97	113	163	179	202	217	233	250	250	250
20	508.0	17.9	216.34	472.2	Std.	88	102	184	201	207	207	207	207	207	207
					Alt.	109	127	184	201	228	245	250	250	250	250
20	508.0	19.1	230.27	469.8	Std.	93	109	196	207	207	207	207	207	207	207
					Alt.	117	136	196	215	243	250	250	250	250	250
20	508.0	20.6	247.60	466.8	Std.	101	117	207	207	207	207	207	207	207	207
					Alt.	126	147	212	231	250	250	250	250	250	250
20	508.0	22.2	265.95	463.6	Std.	109	126	207	207	207	207	207	207	207	207
					Alt.	136	158	228	249	250	250	250	250	250	250
20	508.0	23.8	284.18	460.4	Std.	116	135	207	207	207	207	207	207	207	207
					Alt.	145	169	245	250	250	250	250	250	250	250
20	508.0	25.4	302.28	457.2	Std.	124	145	207	207	207	207	207	207	207	207
					Alt.	155	181	250	250	250	250	250	250	250	250
20	508.0	27.0	320.26	454.0	Std.	132	154	207	207	207	207	207	207	207	207
					Alt.	165	192	250	250	250	250	250	250	250	250
20	508.0	28.6	338.11	450.8	Std.	140	163	207	207	207	207	207	207	207	207
					Alt.	175	193	250	250	250	250	250	250	250	250
20	508.0	30.2	355.83	447.6	Std.	148	172	207	207	207	207	207	207	207	207
					Alt.	185	193	250	250	250	250	250	250	250	250
20	508.0	31.8	373.43	444.4	Std.	155	181	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
20	508.0	33.3	389.81	441.4	Std.	163	190	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
20	508.0	34.9	407.17	438.2	Std.	171	193	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
22[d]	559.0	5.6	76.42	547.8	Std.	25	29	52	57	65	70	75	81	87	100
					Alt.	31	36	52	57	65	70	75	81	87	100
22[d]	559.0	6.4	87.21	546.2	Std.	28	33	60	65	74	80	85	92	100	114
					Alt.	36	41	60	65	74	80	85	92	100	114
22[d]	559.0	7.1	96.63	544.8	Std.	32	37	66	72	82	88	95	102	110	126
					Alt.	39	46	66	72	82	88	95	102	110	126
22	559.0	7.9	107.36	543.2	Std.	35	41	74	81	91	98	105	114	123	140
					Alt.	44	51	74	81	91	98	105	114	123	140
22	559.0	8.7	118.06	541.6	Std.	39	45	81	89	101	108	116	126	135	155
					Alt.	48	56	81	89	101	108	116	126	135	155
22	559.0	9.5	128.73	540.0	Std.	42	49	89	97	110	118	127	137	148	169
					Alt.	53	61	89	97	110	118	127	137	148	169
22	559.0	10.3	139.37	538.4	Std.	46	53	96	105	119	128	137	149	160	183
					Alt.	57	67	96	105	119	128	137	149	160	183
22	559.0	11.1	149.97	536.8	Std.	49	57	104	113	128	138	148	160	173	197
					Alt.	62	72	104	113	128	138	148	160	173	197
22	559.0	11.9	160.55	535.2	Std.	53	62	111	121	138	148	159	172	185	207
					Alt.	66	77	111	121	138	148	159	172	185	212
22	559.0	12.7	171.09	533.6	Std.	56	66	119	130	147	158	169	183	198	207
					Alt.	71	82	119	130	147	158	169	183	198	226

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
22	559.0	14.3	192.08	530.4	Std.	64	74	134	146	165	178	191	206	207	207
					Alt.	79	92	134	146	165	178	191	206	222	250
22	559.0	15.9	212.95	527.2	Std.	71	82	148	162	184	198	207	207	207	207
					Alt.	88	103	148	162	184	198	212	229	247	250
22	559.0	17.5	233.68	524.0	Std.	78	91	163	179	202	207	207	207	207	207
					Alt.	97	113	163	179	202	218	233	250	250	250
22	559.0	19.1	254.30	520.8	Std.	85	99	178	195	207	207	207	207	207	207
					Alt.	106	124	178	195	221	237	250	250	250	250
22	559.0	20.6	273.51	517.8	Std.	92	107	192	207	207	207	207	207	207	207
					Alt.	114	133	192	210	238	250	250	250	250	250
22	559.0	22.2	293.87	514.6	Std.	99	115	207	207	207	207	207	207	207	207
					Alt.	123	144	207	227	250	250	250	250	250	250
22	559.0	23.8	314.11	511.4	Std.	106	123	207	207	207	207	207	207	207	207
					Alt.	132	154	222	243	250	250	250	250	250	250
22	559.0	25.4	334.23	508.2	Std.	113	131	207	207	207	207	207	207	207	207
					Alt.	141	164	237	250	250	250	250	250	250	250
22	559.0	27.0	354.22	505.0	Std.	120	140	207	207	207	207	207	207	207	207
					Alt.	150	175	250	250	250	250	250	250	250	250
22	559.0	28.6	374.08	501.8	Std.	127	148	207	207	207	207	207	207	207	207
					Alt.	159	185	250	250	250	250	250	250	250	250
22	559.0	30.2	393.81	498.6	Std.	134	156	207	207	207	207	207	207	207	207
					Alt.	168	193	250	250	250	250	250	250	250	250
22	559.0	31.8	413.42	495.4	Std.	141	165	207	207	207	207	207	207	207	207
					Alt.	177	193	250	250	250	250	250	250	250	250
22	559.0	33.3	431.69	492.4	Std.	148	172	207	207	207	207	207	207	207	207
					Alt.	185	193	250	250	250	250	250	250	250	250
22	559.0	34.9	451.06	489.2	Std.	155	181	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
22	559.0	36.5	470.30	486.0	Std.	162	189	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
22	559.0	38.1	489.41	482.8	Std.	169	193	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
24[d]	610.0	6.4	95.26	597.2	Std.	26	30	55	60	68	73	78	85	91	104
					Alt.	33	38	55	60	68	73	78	85	91	104
24[d]	610.0	7.1	105.56	595.8	Std.	29	34	61	66	75	81	87	94	101	116
					Alt.	36	42	61	66	75	81	87	94	101	116
24	610.0	7.9	117.30	594.2	Std.	32	37	68	74	84	90	97	104	113	129
					Alt.	40	47	68	74	84	90	97	104	113	129
24	610.0	8.7	129.00	592.6	Std.	35	41	74	81	92	99	106	115	124	142
					Alt.	44	52	74	81	92	99	106	115	124	142
24	610.0	9.5	140.68	591.0	Std.	39	45	81	89	101	108	116	126	135	155
					Alt.	48	56	81	89	101	108	116	126	135	155
24	610.0	10.3	152.32	589.4	Std.	42	49	88	96	109	117	126	136	147	168
					Alt.	52	61	88	96	109	117	126	136	147	168
24	610.0	11.1	163.93	587.8	Std.	45	53	95	104	118	126	136	147	158	181
					Alt.	57	66	95	104	118	126	136	147	158	181
24	610.0	11.9	175.51	586.2	Std.	48	56	102	111	126	136	145	157	170	194
					Alt.	61	71	102	111	126	136	145	157	170	194
24	610.0	12.7	187.06	584.6	Std.	52	60	109	119	135	145	155	168	181	207
					Alt.	65	75	109	119	135	145	155	168	181	207

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure[b] (kPa × 100)[c]									
Size	D (mm)	t (mm)	w_{pe} (kg/m)	d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
24	610.0	14.3	210.07	581.4	Std.	58	68	122	134	151	163	175	189	204	207
					Alt.	73	85	122	134	151	163	175	189	204	233
24	610.0	15.9	232.94	578.2	Std.	65	75	136	149	168	181	194	207	207	207
					Alt.	81	94	136	149	168	181	194	210	227	250
24	610.0	17.5	255.69	575.0	Std.	71	83	150	164	185	199	207	207	207	207
					Alt.	89	104	150	164	185	199	214	231	249	250
24	610.0	19.1	278.32	571.8	Std.	78	91	163	179	202	207	207	207	207	207
					Alt.	97	113	163	179	202	218	233	250	250	250
24	610.0	20.6	299.41	568.8	Std.	84	98	176	193	207	207	207	207	207	207
					Alt.	105	122	176	193	218	235	250	250	250	250
24	610.0	22.2	321.79	565.6	Std.	90	105	190	207	207	207	207	207	207	207
					Alt.	113	132	190	208	235	250	250	250	250	250
24	610.0	23.8	344.05	562.4	Std.	97	113	204	207	207	207	207	207	207	207
					Alt.	121	141	204	223	250	250	250	250	250	250
24	610.0	25.4	366.17	559.2	Std.	103	120	207	207	207	207	207	207	207	207
					Alt.	129	151	217	238	250	250	250	250	250	250
24	610.0	27.0	388.17	556.0	Std.	110	128	207	207	207	207	207	207	207	207
					Alt.	137	160	231	250	250	250	250	250	250	250
24	610.0	28.6	410.05	552.8	Std.	116	136	207	207	207	207	207	207	207	207
					Alt.	146	169	245	250	250	250	250	250	250	250
24	610.0	30.2	431.80	549.6	Std.	123	143	207	207	207	207	207	207	207	207
					Alt.	154	179	250	250	250	250	250	250	250	250
24	610.0	31.8	453.42	546.4	Std.	129	151	207	207	207	207	207	207	207	207
					Alt.	162	188	250	250	250	250	250	250	250	250
24	610.0	33.3	473.57	543.4	Std.	136	158	207	207	207	207	207	207	207	207
					Alt.	170	193	250	250	250	250	250	250	250	250
24	610.0	34.9	494.95	540.2	Std.	142	165	207	207	207	207	207	207	207	207
					Alt.	178	193	250	250	250	250	250	250	250	250
24	610.0	36.5	516.20	537.0	Std.	149	173	207	207	207	207	207	207	207	207
					Alt.	186	193	250	250	250	250	250	250	250	250
24	610.0	38.1	537.33	533.8	Std.	155	181	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
24	610.0	39.7	558.32	530.6	Std.	162	188	207	207	207	207	207	207	207	207
					Alt.	193	193	250	250	250	250	250	250	250	250
26[d]	660.0	6.4	103.15	647.2	Std.	24	28	51	55	63	67	72	78	84	96
					Alt.	30	35	51	55	63	67	72	78	84	96
26[d]	660.0	7.1	114.31	645.8	Std.	27	31	56	61	70	75	80	87	94	107
					Alt.	33	39	56	61	70	75	80	87	94	107
26	660.0	7.9	127.04	644.2	Std.	30	35	62	68	77	83	89	97	104	119
					Alt.	37	43	62	68	77	83	89	97	104	119
26	660.0	8.7	139.73	642.6	Std.	33	38	69	75	85	92	98	106	115	131
					Alt.	41	48	69	75	85	92	98	106	115	131
26	660.0	9.5	152.39	641.0	Std.	36	42	75	82	93	100	107	116	125	143
					Alt.	45	52	75	82	93	100	107	116	125	143
26	660.0	10.3	165.02	639.4	Std.	39	45	81	89	101	108	116	126	136	155
					Alt.	48	56	81	89	101	108	116	126	136	155
26	660.0	11.1	177.62	637.8	Std.	42	49	88	96	109	117	125	136	146	167
					Alt.	52	61	88	96	109	117	125	136	146	167
26	660.0	11.9	190.19	636.2	Std.	45	52	94	103	117	125	134	145	157	179
					Alt.	56	65	94	103	117	125	134	145	157	179

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
26	660.0	12.7	202.72	634.6	Std.	48	56	100	110	124	134	143	155	167	191
					Alt.	60	70	100	110	124	134	143	155	167	191
26	660.0	14.3	227.70	631.4	Std.	54	63	113	124	140	151	161	175	188	207
					Alt.	67	78	113	124	140	151	161	175	188	215
26	660.0	15.9	252.55	628.2	Std.	60	70	126	137	156	167	180	194	207	207
					Alt.	75	87	126	137	156	167	180	194	209	239
26	660.0	17.5	277.27	625.0	Std.	66	77	138	151	171	184	198	207	207	207
					Alt.	82	96	138	151	171	184	198	214	231	250
26	660.0	19.1	301.87	621.8	Std.	72	84	151	165	187	201	207	207	207	207
					Alt.	90	105	151	165	187	201	216	233	250	250
26	660.0	20.6	324.81	618.8	Std.	78	90	163	178	202	207	207	207	207	207
					Alt.	97	113	163	178	202	217	233	250	250	250
26	660.0	22.2	349.16	615.6	Std.	84	97	176	192	207	207	207	207	207	207
					Alt.	104	122	176	192	217	234	250	250	250	250
26	660.0	23.8	373.39	612.4	Std.	90	104	188	206	207	207	207	207	207	207
					Alt.	112	130	188	206	233	250	250	250	250	250
26	660.0	25.4	397.49	609.2	Std.	96	111	201	207	207	207	207	207	207	207
					Alt.	119	139	201	220	249	250	250	250	250	250
28[d]	711.0	6.4	111.20	698.2	Std.	22	26	47	51	58	63	67	73	78	89
					Alt.	28	33	47	51	58	63	67	73	78	89
28[d]	711.0	7.1	123.24	696.8	Std.	25	29	52	57	65	69	74	81	87	99
					Alt.	31	36	52	57	65	69	74	81	87	99
28	711.0	7.9	136.97	695.2	Std.	28	32	58	63	72	77	83	90	97	110
					Alt.	35	40	58	63	72	77	83	90	97	110
28	711.0	8.7	150.67	693.6	Std.	30	35	64	70	79	85	91	99	106	122
					Alt.	38	44	64	70	79	85	91	99	106	122
28	711.0	9.5	164.34	692.0	Std.	33	39	70	76	86	93	100	108	116	133
					Alt.	41	48	70	76	86	93	100	108	116	133
28	711.0	10.3	177.98	690.4	Std.	36	42	76	83	94	101	108	117	126	144
					Alt.	45	52	76	83	94	101	108	117	126	144
28	711.0	11.1	191.58	688.8	Std.	39	45	81	89	101	108	116	126	136	155
					Alt.	48	56	81	89	101	108	116	126	136	155
28	711.0	11.9	205.15	687.2	Std.	42	48	87	96	108	116	125	135	146	166
					Alt.	52	61	87	96	108	116	125	135	146	166
28	711.0	12.7	218.69	685.6	Std.	44	52	93	102	115	124	133	144	155	177
					Alt.	55	65	93	102	115	124	133	144	155	177
28	711.0	14.3	245.68	682.4	Std.	50	58	105	115	130	140	150	162	175	200
					Alt.	62	73	105	115	130	140	150	162	175	200
28	711.0	15.9	272.54	679.2	Std.	56	65	117	128	145	155	167	180	194	207
					Alt.	69	81	117	128	145	155	167	180	194	222
28	711.0	17.5	299.28	676.0	Std.	61	71	128	140	159	171	183	198	207	207
					Alt.	76	89	128	140	159	171	183	198	214	245
28	711.0	19.1	325.89	672.8	Std.	67	78	140	153	174	187	200	207	207	207
					Alt.	83	97	140	153	174	187	200	217	234	250
28	711.0	20.6	350.72	669.8	Std.	72	84	151	165	187	201	207	207	207	207
					Alt.	90	105	151	165	187	201	216	234	250	250
28	711.0	22.2	377.08	666.6	Std.	78	90	163	178	202	207	207	207	207	207
					Alt.	97	113	163	178	202	217	233	250	250	250
28	711.0	23.8	403.32	663.4	Std.	83	97	175	191	207	207	207	207	207	207
					Alt.	104	121	175	191	216	233	249	250	250	250

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure[b] (kPa × 100)[c]									
Size	D (mm)	t (mm)	w_{pe} (kg/m)	d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
28	711.0	25.4	429.44	660.2	Std.	89	103	186	204	207	207	207	207	207	207
					Alt.	111	129	186	204	231	248	250	250	250	250
30[d]	762.0	6.4	119.25	749.2	Std.	21	24	44	48	54	58	63	68	73	83
					Alt.	26	30	44	48	54	58	63	68	73	83
30[d]	762.0	7.1	132.17	747.8	Std.	23	27	49	53	60	65	69	75	81	93
					Alt.	29	34	49	53	60	65	69	75	81	93
30	762.0	7.9	146.91	746.2	Std.	26	30	54	59	67	72	77	84	90	103
					Alt.	32	37	54	59	67	72	77	84	90	103
30	762.0	8.7	161.61	744.6	Std.	28	33	60	65	74	79	85	92	99	113
					Alt.	35	41	60	65	74	79	85	92	99	113
30	762.0	9.5	176.29	743.0	Std.	31	36	65	71	81	87	93	101	108	124
					Alt.	39	45	65	71	81	87	93	101	108	124
30	762.0	10.3	190.93	741.4	Std.	34	39	71	77	87	94	101	109	118	134
					Alt.	42	49	71	77	87	94	101	109	118	134
30	762.0	11.1	205.54	739.8	Std.	36	42	76	83	94	101	109	117	127	145
					Alt.	45	53	76	83	94	101	109	117	127	145
30	762.0	11.9	220.12	738.2	Std.	39	45	82	89	101	109	116	126	136	155
					Alt.	48	56	82	89	101	109	116	126	136	155
30	762.0	12.7	234.67	736.6	Std.	41	48	87	95	108	116	124	134	145	166
					Alt.	52	60	87	95	108	116	124	134	145	166
30	762.0	14.3	263.67	733.4	Std.	47	54	98	107	121	130	140	151	163	186
					Alt.	58	68	98	107	121	130	140	151	163	186
30	762.0	15.9	292.54	730.2	Std.	52	60	109	119	135	145	155	168	181	207
					Alt.	65	75	109	119	135	145	155	168	181	207
30	762.0	17.5	321.29	727.0	Std.	57	66	120	131	148	160	171	185	200	207
					Alt.	71	83	120	131	148	160	171	185	200	228
30	762.0	19.1	349.91	723.8	Std.	62	72	131	143	162	174	187	202	207	207
					Alt.	78	91	131	143	162	174	187	202	218	249
30	762.0	20.6	376.63	720.8	Std.	67	78	141	154	175	188	201	207	207	207
					Alt.	84	98	141	154	175	188	201	218	235	250
30	762.0	22.2	405.00	717.6	Std.	72	84	152	166	188	202	207	207	207	207
					Alt.	90	105	152	166	188	202	217	235	250	250
30	762.0	23.8	433.26	714.4	Std.	78	90	163	178	202	207	207	207	207	207
					Alt.	97	113	163	178	202	217	233	250	250	250
30	762.0	25.4	461.38	711.2	Std.	83	96	174	190	207	207	207	207	207	207
					Alt.	104	121	174	190	215	232	248	250	250	250
30	762.0	27.0	489.38	708.0	Std.	88	102	185	202	207	207	207	207	207	207
					Alt.	110	128	185	202	229	246	250	250	250	250
30	762.0	28.6	517.25	704.8	Std.	93	109	196	207	207	207	207	207	207	207
					Alt.	117	136	196	214	243	250	250	250	250	250
30	762.0	30.2	544.99	701.6	Std.	98	115	207	207	207	207	207	207	207	207
					Alt.	123	143	207	226	250	250	250	250	250	250
30	762.0	31.8	572.61	698.4	Std.	104	121	207	207	207	207	207	207	207	207
					Alt.	130	151	218	238	250	250	250	250	250	250
32[d]	813.0	6.4	127.30	800.2	Std.	20	23	41	45	51	55	59	63	68	78
					Alt.	24	28	41	45	51	55	59	63	68	78
32[d]	813.0	7.1	141.10	798.8	Std.	22	25	46	50	56	61	65	70	76	87
					Alt.	27	32	46	50	56	61	65	70	76	87
32	813.0	7.9	156.84	797.2	Std.	24	28	51	55	63	68	72	78	84	97
					Alt.	30	35	51	55	63	68	72	78	84	97

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
32	813.0	8.7	172.56	795.6	Std.	27	31	56	61	69	74	80	86	93	106
					Alt.	33	39	56	61	69	74	80	86	93	106
32	813.0	9.5	188.24	794.0	Std.	29	34	61	67	76	81	87	94	102	116
					Alt.	36	42	61	67	76	81	87	94	102	116
32	813.0	10.3	203.88	792.4	Std.	31	37	66	72	82	88	94	102	110	126
					Alt.	39	46	66	72	82	88	94	102	110	126
32	813.0	11.1	219.50	790.8	Std.	34	39	71	78	88	95	102	110	119	136
					Alt.	42	49	71	78	88	95	102	110	119	136
32	813.0	11.9	235.09	789.2	Std.	36	42	76	84	95	102	109	118	127	145
					Alt.	45	53	76	84	95	102	109	118	127	145
32	813.0	12.7	250.64	787.6	Std.	39	45	82	89	101	109	116	126	136	155
					Alt.	49	56	82	89	101	109	116	126	136	155
32	813.0	14.3	281.65	784.4	Std.	44	51	92	100	114	122	131	142	153	175
					Alt.	55	64	92	100	114	122	131	142	153	175
32	813.0	15.9	312.54	781.2	Std.	49	57	102	112	126	136	146	158	170	194
					Alt.	61	71	102	112	126	136	146	158	170	194
32	813.0	17.5	343.30	778.0	Std.	53	62	112	123	139	150	160	174	187	207
					Alt.	67	78	112	123	139	150	160	174	187	214
32	813.0	19.1	373.93	774.8	Std.	58	68	123	134	152	163	175	189	204	207
					Alt.	73	85	123	134	152	163	175	189	204	233
32	813.0	20.6	402.54	771.8	Std.	63	73	132	145	164	176	189	204	207	207
					Alt.	79	92	132	145	164	176	189	204	220	250
32	813.0	22.2	432.93	768.6	Std.	68	79	143	156	176	190	203	207	207	207
					Alt.	85	99	143	156	176	190	203	220	237	250
32	813.0	23.8	463.19	765.4	Std.	73	85	153	167	189	203	207	207	207	207
					Alt.	91	106	153	167	189	203	218	236	250	250
32	813.0	25.4	493.32	762.2	Std.	78	90	163	178	202	207	207	207	207	207
					Alt.	97	113	163	178	202	217	233	250	250	250
32	813.0	27.0	523.33	759.0	Std.	82	96	173	189	207	207	207	207	207	207
					Alt.	103	120	173	189	215	231	247	250	250	250
32	813.0	28.6	553.22	755.8	Std.	87	102	184	201	207	207	207	207	207	207
					Alt.	109	127	184	201	227	244	250	250	250	250
32	813.0	30.2	582.98	752.6	Std.	92	107	194	207	207	207	207	207	207	207
					Alt.	115	134	194	212	240	250	250	250	250	250
32	813.0	31.8	612.61	749.4	Std.	97	113	204	207	207	207	207	207	207	207
					Alt.	121	141	204	223	250	250	250	250	250	250
34[d]	864.0	6.4	135.35	851.2	Std.	18	21	39	42	48	51	55	60	64	74
					Alt.	23	27	39	42	48	51	55	60	64	74
34[d]	864.0	7.1	150.03	849.8	Std.	20	24	43	47	53	57	61	66	71	82
					Alt.	26	30	43	47	53	57	61	66	71	82
34	864.0	7.9	166.78	848.2	Std.	23	26	48	52	59	64	68	74	79	91
					Alt.	28	33	48	52	59	64	68	74	79	91
34	864.0	8.7	183.50	846.6	Std.	25	29	53	57	65	70	75	81	88	100
					Alt.	31	36	53	57	65	70	75	81	88	100
34	864.0	9.5	200.18	845.0	Std.	27	32	57	63	71	76	82	89	96	109
					Alt.	34	40	57	63	71	76	82	89	96	109
34	864.0	10.3	216.84	843.4	Std.	30	34	62	68	77	83	89	96	104	118
					Alt.	37	43	62	68	77	83	89	96	104	118
34	864.0	11.1	233.46	841.8	Std.	32	37	67	73	83	89	96	104	112	128
					Alt.	40	46	67	73	83	89	96	104	112	128

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Minimum Test Pressure[b] (kPa × 100)[c]									
						Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
34	864.0	11.9	250.05	840.2	Std.	34	40	72	79	89	96	103	111	120	137
					Alt.	43	50	72	79	89	96	103	111	120	137
34	864.0	12.7	266.61	838.6	Std.	37	43	77	84	95	102	110	119	128	146
					Alt.	46	53	77	84	95	102	110	119	128	146
34	864.0	14.3	299.64	835.4	Std.	41	48	86	94	107	115	123	133	144	164
					Alt.	51	60	86	94	107	115	123	133	144	164
34	864.0	15.9	332.53	832.2	Std.	46	53	96	105	119	128	137	148	160	183
					Alt.	57	67	96	105	119	128	137	148	160	183
34	864.0	17.5	365.31	829.0	Std.	50	59	106	116	131	141	151	163	176	201
					Alt.	63	73	106	116	131	141	151	163	176	201
34	864.0	19.1	397.95	825.8	Std.	55	64	115	126	143	154	165	178	192	207
					Alt.	69	80	115	126	143	154	165	178	192	220
34	864.0	20.6	428.44	822.8	Std.	59	69	124	136	154	166	178	192	207	207
					Alt.	74	86	124	136	154	166	178	192	207	237
34	864.0	22.2	460.85	819.6	Std.	64	74	134	147	166	179	191	207	207	207
					Alt.	80	93	134	147	166	179	191	207	223	250
34	864.0	23.8	493.12	816.4	Std.	68	80	144	157	178	191	205	207	207	207
					Alt.	86	100	144	157	178	191	205	222	239	250
34	864.0	25.4	525.27	813.2	Std.	73	85	153	168	190	204	207	207	207	207
					Alt.	91	106	153	168	190	204	219	237	250	250
34	864.0	27.0	557.29	810.0	Std.	78	90	163	178	202	207	207	207	207	207
					Alt.	97	113	163	178	202	217	233	250	250	250
34	864.0	28.6	589.19	806.8	Std.	82	96	173	189	207	207	207	207	207	207
					Alt.	103	120	173	189	214	230	247	250	250	250
34	864.0	30.2	620.96	803.6	Std.	87	101	182	199	207	207	207	207	207	207
					Alt.	109	126	182	199	226	243	250	250	250	250
34	864.0	31.8	652.60	800.4	Std.	91	106	192	207	207	207	207	207	207	207
					Alt.	114	133	192	210	238	250	250	250	250	250
36[d]	914.0	6.4	143.24	901.2	Std.	17	20	37	40	45	49	52	56	61	70
					Alt.	22	25	37	40	45	49	52	56	61	70
36[d]	914.0	7.1	158.79	899.8	Std.	19	22	41	44	50	54	58	63	68	77
					Alt.	24	28	41	44	50	54	58	63	68	77
36	914.0	7.9	176.52	898.2	Std.	21	25	45	49	56	60	64	70	75	86
					Alt.	27	31	45	49	56	60	64	70	75	86
36	914.0	8.7	194.22	896.6	Std.	24	28	50	54	62	66	71	77	83	95
					Alt.	30	34	50	54	62	66	71	77	83	95
36	914.0	9.5	211.90	895.0	Std.	26	30	54	59	67	72	77	84	90	103
					Alt.	32	38	54	59	67	72	77	84	90	103
36	914.0	10.3	229.54	893.4	Std.	28	33	59	64	73	78	84	91	98	112
					Alt.	35	41	59	64	73	78	84	91	98	112
36	914.0	11.1	247.15	891.8	Std.	30	35	63	69	78	84	91	98	106	121
					Alt.	38	44	63	69	78	84	91	98	106	121
36	914.0	11.9	264.72	890.2	Std.	32	38	68	74	84	90	97	105	113	129
					Alt.	40	47	68	74	84	90	97	105	113	129
36	914.0	12.7	282.27	888.6	Std.	35	40	73	79	90	97	104	112	121	138
					Alt.	43	50	73	79	90	97	104	112	121	138
36	914.0	14.3	317.27	885.4	Std.	39	45	82	89	101	109	117	126	136	155
					Alt.	49	57	82	89	101	109	117	126	136	155
36	914.0	15.9	352.14	882.2	Std.	43	50	91	99	112	121	130	140	151	173
					Alt.	54	63	91	99	112	121	130	140	151	173

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
36	914.0	17.5	386.88	879.0	Std.	48	55	100	109	124	133	143	154	166	190
					Alt.	59	69	100	109	124	133	143	154	166	190
36	914.0	19.1	421.50	875.8	Std.	52	60	109	119	135	145	156	169	182	207
					Alt.	65	76	109	119	135	145	156	169	182	208
36	914.0	20.6	453.84	872.8	Std.	56	65	118	129	146	157	168	182	196	207
					Alt.	70	81	118	129	146	157	168	182	196	224
36	914.0	22.2	488.22	869.6	Std.	60	70	127	139	157	169	181	196	207	207
					Alt.	75	88	127	139	157	169	181	196	211	241
36	914.0	23.8	522.47	866.4	Std.	65	75	136	149	168	181	194	207	207	207
					Alt.	81	94	136	149	168	181	194	210	226	250
36	914.0	25.4	556.59	863.2	Std.	69	80	145	159	180	193	207	207	207	207
					Alt.	86	100	145	159	180	193	207	224	242	250
36	914.0	27.0	590.58	860.0	Std.	73	85	154	169	191	205	207	207	207	207
					Alt.	92	107	154	169	191	205	220	238	250	250
36	914.0	28.6	624.45	856.8	Std.	78	90	163	179	202	207	207	207	207	207
					Alt.	97	113	163	179	202	217	233	250	250	250
36	914.0	30.2	658.19	853.6	Std.	82	96	172	189	207	207	207	207	207	207
					Alt.	103	119	172	189	214	230	246	250	250	250
36	914.0	31.8	691.81	850.4	Std.	86	101	182	199	207	207	207	207	207	207
					Alt.	108	126	182	199	225	242	250	250	250	250
38	965.0	7.9	186.46	949.2	Std.	20	24	43	47	53	57	61	66	71	81
					Alt.	25	30	43	47	53	57	61	66	71	81
38	965.0	8.7	205.17	947.6	Std.	22	26	47	51	58	63	67	73	78	90
					Alt.	28	33	47	51	58	63	67	73	78	90
38	965.0	9.5	223.84	946.0	Std.	24	28	51	56	64	68	73	79	86	98
					Alt.	31	36	51	56	64	68	73	79	86	98
38	965.0	10.3	242.49	944.4	Std.	27	31	56	61	69	74	80	86	93	106
					Alt.	33	39	56	61	69	74	80	86	93	106
38	965.0	11.1	261.11	942.8	Std.	29	33	60	66	74	80	86	93	100	114
					Alt.	36	42	60	66	74	80	86	93	100	114
38	965.0	11.9	279.69	941.2	Std.	31	36	64	70	80	86	92	99	107	123
					Alt.	38	45	64	70	80	86	92	99	107	123
38	965.0	12.7	298.24	939.6	Std.	33	38	69	75	85	91	98	106	114	131
					Alt.	41	48	69	75	85	91	98	106	114	131
38	965.0	14.3	335.25	936.4	Std.	37	43	77	85	96	103	110	119	129	147
					Alt.	46	54	77	85	96	103	110	119	129	147
38	965.0	15.9	372.14	933.2	Std.	41	48	86	94	106	114	123	133	143	164
					Alt.	51	60	86	94	106	114	123	133	143	164
38	965.0	17.5	408.89	930.0	Std.	45	52	95	103	117	126	135	146	158	180
					Alt.	56	66	95	103	117	126	135	146	158	180
38	965.0	19.1	445.52	926.8	Std.	49	57	103	113	128	138	147	160	172	197
					Alt.	61	72	103	113	128	138	147	160	172	197
38	965.0	20.6	479.75	923.8	Std.	53	62	111	122	138	148	159	172	186	207
					Alt.	66	77	111	122	138	148	159	172	186	212
38	965.0	22.2	516.14	920.6	Std.	57	67	120	131	149	160	171	186	200	207
					Alt.	71	83	120	131	149	160	171	186	200	229
38	965.0	23.8	552.40	917.4	Std.	61	71	129	141	159	171	184	199	207	207
					Alt.	77	89	129	141	159	171	184	199	214	245
38	965.0	25.4	588.53	914.2	Std.	65	76	137	150	170	183	196	207	207	207
					Alt.	82	95	137	150	170	183	196	212	229	250

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure[b] (kPa × 100)[c]									
Size	D (mm)	t (mm)	w_{pe} (kg/m)	d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
38	965.0	27.0	624.54	911.0	Std.	70	81	146	160	181	194	207	207	207	207
					Alt.	87	101	146	160	181	194	209	226	243	250
38	965.0	28.6	660.42	907.8	Std.	74	86	155	169	192	206	207	207	207	207
					Alt.	92	107	155	169	192	206	221	239	250	250
38	965.0	30.2	696.18	904.6	Std.	78	91	163	179	202	207	207	207	207	207
					Alt.	97	113	163	179	202	217	233	250	250	250
38	965.0	31.8	731.80	901.4	Std.	82	95	172	188	207	207	207	207	207	207
					Alt.	102	119	172	188	213	229	246	250	250	250
40	1016.0	7.9	196.39	1000.2	Std.	19	22	41	44	50	54	58	63	68	77
					Alt.	24	28	41	44	50	54	58	63	68	77
40	1016.0	8.7	216.11	998.6	Std.	21	25	45	49	55	59	64	69	74	85
					Alt.	27	31	45	49	55	59	64	69	74	85
40	1016.0	9.5	235.79	997.0	Std.	23	27	49	53	60	65	70	75	81	93
					Alt.	29	34	49	53	60	65	70	75	81	93
40	1016.0	10.3	255.45	995.4	Std.	25	29	53	58	66	70	76	82	88	101
					Alt.	31	37	53	58	66	70	76	82	88	101
40	1016.0	11.1	275.07	993.8	Std.	27	32	57	62	71	76	81	88	95	109
					Alt.	34	39	57	62	71	76	81	88	95	109
40	1016.0	11.9	294.66	992.2	Std.	29	34	61	67	76	81	87	94	102	116
					Alt.	36	42	61	67	76	81	87	94	102	116
40	1016.0	12.7	314.22	990.6	Std.	31	36	65	71	81	87	93	101	109	124
					Alt.	39	45	65	71	81	87	93	101	109	124
40	1016.0	14.3	353.24	987.4	Std.	35	41	73	80	91	98	105	113	122	140
					Alt.	44	51	73	80	91	98	105	113	122	140
40	1016.0	15.9	392.13	984.2	Std.	39	45	82	89	101	109	117	126	136	155
					Alt.	49	57	82	89	101	109	117	126	136	155
40	1016.0	17.5	430.90	981.0	Std.	43	50	90	98	111	120	128	139	150	171
					Alt.	53	62	90	98	111	120	128	139	150	171
40	1016.0	19.1	469.55	977.8	Std.	47	54	98	107	121	131	140	152	163	187
					Alt.	58	68	98	107	121	131	140	152	163	187
40	1016.0	20.6	505.66	974.8	Std.	50	59	106	116	131	141	151	164	176	201
					Alt.	63	73	106	116	131	141	151	164	176	201
40	1016.0	22.2	544.06	971.6	Std.	54	63	114	125	141	152	163	176	190	207
					Alt.	68	79	114	125	141	152	163	176	190	217
40	1016.0	23.8	582.33	968.4	Std.	58	68	122	134	151	163	175	189	204	207
					Alt.	73	85	122	134	151	163	175	189	204	233
40	1016.0	25.4	620.48	965.2	Std.	62	72	131	143	162	174	186	202	207	207
					Alt.	78	90	131	143	162	174	186	202	217	248
40	1016.0	27.0	658.50	962.0	Std.	66	77	139	152	172	185	198	207	207	207
					Alt.	83	96	139	152	172	185	198	214	231	250
40	1016.0	28.6	696.39	958.8	Std.	70	81	147	161	182	196	207	207	207	207
					Alt.	87	102	147	161	182	196	210	227	245	250
40	1016.0	30.2	734.16	955.6	Std.	74	86	155	170	192	207	207	207	207	207
					Alt.	92	107	155	170	192	207	222	240	250	250
40	1016.0	31.8	771.80	952.4	Std.	78	91	163	179	202	207	207	207	207	207
					Alt.	97	113	163	179	202	217	233	250	250	250
42	1067.0	8.7	227.05	1049.6	Std.	20	24	43	47	53	57	61	66	71	81
					Alt.	25	29	43	47	53	57	61	66	71	81
42	1067.0	9.5	247.74	1048.0	Std.	22	26	46	51	58	62	66	72	77	88
					Alt.	28	32	46	51	58	62	66	72	77	88

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
42	1067.0	10.3	268.40	1046.4	Std.	24	28	50	55	62	67	72	78	84	96
					Alt.	30	35	50	55	62	67	72	78	84	96
42	1067.0	11.1	289.03	1044.8	Std.	26	30	54	59	67	72	78	84	90	103
					Alt.	32	38	54	59	67	72	78	84	90	103
42	1067.0	11.9	309.62	1043.2	Std.	28	32	58	64	72	77	83	90	97	111
					Alt.	35	40	58	64	72	77	83	90	97	111
42	1067.0	12.7	330.19	1041.6	Std.	30	34	62	68	77	83	89	96	103	118
					Alt.	37	43	62	68	77	83	89	96	103	118
42	1067.0	14.3	371.22	1038.4	Std.	33	39	70	76	87	93	100	108	117	133
					Alt.	42	48	70	76	87	93	100	108	117	133
42	1067.0	15.9	412.13	1035.2	Std.	37	43	78	85	96	104	111	120	130	148
					Alt.	46	54	78	85	96	104	111	120	130	148
42	1067.0	17.5	452.91	1032.0	Std.	41	47	86	94	106	114	122	132	143	163
					Alt.	51	59	86	94	106	114	122	132	143	163
42	1067.0	19.1	493.57	1028.8	Std.	44	52	93	102	116	124	133	144	156	178
					Alt.	56	65	93	102	116	124	133	144	156	178
42	1067.0	20.6	531.57	1025.8	Std.	48	56	101	110	125	134	144	156	168	192
					Alt.	60	70	101	110	125	134	144	156	168	192
42	1067.0	22.2	571.98	1022.6	Std.	52	60	109	119	134	145	155	168	181	207
					Alt.	65	75	109	119	134	145	155	168	181	207
42	1067.0	23.8	612.26	1019.4	Std.	55	65	116	127	144	155	166	180	194	207
					Alt.	69	81	116	127	144	155	166	180	194	222
42	1067.0	25.4	652.42	1016.2	Std.	59	69	124	136	154	165	177	192	207	207
					Alt.	74	86	124	136	154	165	177	192	207	237
42	1067.0	27.0	692.45	1013.0	Std.	63	73	132	144	164	176	189	204	207	207
					Alt.	79	91	132	144	164	176	189	204	220	250
42	1067.0	28.6	732.36	1009.8	Std.	67	78	140	153	173	186	200	207	207	207
					Alt.	83	97	140	153	173	186	200	216	233	250
42	1067.0	30.2	772.14	1006.6	Std.	70	82	148	162	183	197	207	207	207	207
					Alt.	88	102	148	162	183	197	211	228	246	250
42	1067.0	31.8	811.79	1003.4	Std.	74	86	156	170	193	207	207	207	207	207
					Alt.	93	108	156	170	193	207	222	240	250	250
44	1118.0	8.7	237.99	1100.6	Std.	19	23	41	44	50	54	58	63	68	77
					Alt.	24	28	41	44	50	54	58	63	68	77
44	1118.0	9.5	259.69	1099.0	Std.	21	25	44	48	55	59	63	69	74	84
					Alt.	26	31	44	48	55	59	63	69	74	84
44	1118.0	10.3	281.35	1097.4	Std.	23	27	48	53	60	64	69	74	80	92
					Alt.	29	33	48	53	60	64	69	74	80	92
44	1118.0	11.1	302.99	1095.8	Std.	25	29	52	57	64	69	74	80	86	99
					Alt.	31	36	52	57	64	69	74	80	86	99
44	1118.0	11.9	324.59	1094.2	Std.	26	31	56	61	69	74	79	86	93	106
					Alt.	33	38	56	61	69	74	79	86	93	106
44	1118.0	12.7	346.16	1092.6	Std.	28	33	59	65	73	79	85	92	99	113
					Alt.	35	41	59	65	73	79	85	92	99	113
44	1118.0	14.3	389.21	1089.4	Std.	32	37	67	73	83	89	95	103	111	127
					Alt.	40	46	67	73	83	89	95	103	111	127
44	1118.0	15.9	432.13	1086.2	Std.	35	41	74	81	92	99	106	115	124	141
					Alt.	44	51	74	81	92	99	106	115	124	141
44	1118.0	17.5	474.92	1083.0	Std.	39	45	82	89	101	109	117	126	136	156
					Alt.	49	57	82	89	101	109	117	126	136	156

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Specified Outside Diameter	Specified Wall Thickness	Plain-End Weight per Unit Length	Calculated Inside Diameter[a]		Minimum Test Pressure[b] (kPa × 100)[c]									
Size	D (mm)	t (mm)	w_{pe} (kg/m)	d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
44	1118.0	19.1	517.59	1079.8	Std.	42	49	89	97	110	119	127	138	149	170
					Alt.	53	62	89	97	110	119	127	138	149	170
44	1118.0	20.6	557.47	1076.8	Std.	46	53	96	105	119	128	137	149	160	183
					Alt.	57	67	96	105	119	128	137	149	160	183
44	1118.0	22.2	599.90	1073.6	Std.	49	57	104	113	128	138	148	160	173	197
					Alt.	62	72	104	113	128	138	148	160	173	197
44	1118.0	23.8	642.19	1070.4	Std.	53	62	111	121	138	148	159	172	185	207
					Alt.	66	77	111	121	138	148	159	172	185	212
44	1118.0	25.4	684.37	1067.2	Std.	56	66	119	130	147	158	169	183	198	207
					Alt.	71	82	119	130	147	158	169	183	198	226
44	1118.0	27.0	726.41	1064.0	Std.	60	70	126	138	156	168	180	195	207	207
					Alt.	75	87	126	138	156	168	180	195	210	240
44	1118.0	28.6	768.33	1060.8	Std.	64	74	134	146	165	178	191	206	207	207
					Alt.	79	92	134	146	165	178	191	206	222	250
44	1118.0	30.2	810.12	1057.6	Std.	67	78	141	154	175	188	201	207	207	207
					Alt.	84	98	141	154	175	188	201	218	235	250
44	1118.0	31.8	851.79	1054.4	Std.	71	82	148	162	184	198	207	207	207	207
					Alt.	88	103	148	162	184	198	212	229	247	250
46	1168.0	8.7	248.72	1150.6	Std.	19	22	39	43	48	52	56	60	65	74
					Alt.	23	27	39	43	48	52	56	60	65	74
46	1168.0	9.5	271.40	1149.0	Std.	20	24	42	46	53	57	61	66	71	81
					Alt.	25	29	42	46	53	57	61	66	71	81
46	1168.0	10.3	294.05	1147.4	Std.	22	26	46	50	57	61	66	71	77	88
					Alt.	27	32	46	50	57	61	66	71	77	88
46	1168.0	11.1	316.67	1145.8	Std.	24	27	50	54	61	66	71	77	83	94
					Alt.	30	34	50	54	61	66	71	77	83	94
46	1168.0	11.9	339.26	1144.2	Std.	25	29	53	58	66	71	76	82	89	101
					Alt.	32	37	53	58	66	71	76	82	89	101
46	1168.0	12.7	361.82	1142.6	Std.	27	31	57	62	70	76	81	88	95	108
					Alt.	34	39	57	62	70	76	81	88	95	108
46	1168.0	14.3	406.84	1139.4	Std.	30	35	64	70	79	85	91	99	106	122
					Alt.	38	44	64	70	79	85	91	99	106	122
46	1168.0	15.9	451.73	1136.2	Std.	34	39	71	78	88	95	101	110	118	135
					Alt.	42	49	71	78	88	95	101	110	118	135
46	1168.0	17.5	496.50	1133.0	Std.	37	43	78	85	97	104	112	121	130	149
					Alt.	47	54	78	85	97	104	112	121	130	149
46	1168.0	19.1	541.14	1129.8	Std.	41	47	85	93	106	114	122	132	142	162
					Alt.	51	59	85	93	106	114	122	132	142	162
46	1168.0	20.6	582.87	1126.8	Std.	44	51	92	101	114	123	131	142	153	175
					Alt.	55	64	92	101	114	123	131	142	153	175
46	1168.0	22.2	627.27	1123.6	Std.	47	55	99	108	123	132	142	153	165	189
					Alt.	59	69	99	108	123	132	142	153	165	189
46	1168.0	23.8	671.54	1120.4	Std.	51	59	106	116	132	142	152	164	177	202
					Alt.	63	74	106	116	132	142	152	164	177	202
46	1168.0	25.4	715.68	1117.2	Std.	54	63	114	124	141	151	162	175	189	207
					Alt.	68	79	114	124	141	151	162	175	189	216
46	1168.0	27.0	759.70	1114.0	Std.	57	67	121	132	149	161	172	186	201	207
					Alt.	72	84	121	132	149	161	172	186	201	230
46	1168.0	28.6	803.59	1110.8	Std.	61	71	128	140	158	170	182	197	207	207
					Alt.	76	89	128	140	158	170	182	197	213	243

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
46	1168.0	30.2	847.36	1107.6	Std.	64	75	135	148	167	180	193	207	207	207
					Alt.	80	93	135	148	167	180	193	209	225	250
46	1168.0	31.8	890.99	1104.4	Std.	68	79	142	155	176	189	203	207	207	207
					Alt.	85	98	142	155	176	189	203	220	237	250
48	1219.0	8.7	259.66	1201.6	Std.	18	21	37	41	46	50	53	58	62	71
					Alt.	22	26	37	41	46	50	53	58	62	71
48	1219.0	9.5	283.35	1200.0	Std.	19	23	41	44	50	54	58	63	68	77
					Alt.	24	28	41	44	50	54	58	63	68	77
48	1219.0	10.3	307.01	1198.4	Std.	21	24	44	48	55	59	63	68	73	84
					Alt.	26	31	44	48	55	59	63	68	73	84
48	1219.0	11.1	330.63	1196.8	Std.	23	26	48	52	59	63	68	73	79	90
					Alt.	28	33	48	52	59	63	68	73	79	90
48	1219.0	11.9	354.23	1195.2	Std.	24	28	51	56	63	68	73	79	85	97
					Alt.	30	35	51	56	63	68	73	79	85	97
48	1219.0	12.7	377.79	1193.6	Std.	26	30	54	59	67	72	78	84	91	104
					Alt.	32	38	54	59	67	72	78	84	91	104
48	1219.0	14.3	424.82	1190.4	Std.	29	34	61	67	76	82	87	95	102	117
					Alt.	36	42	61	67	76	82	87	95	102	117
48	1219.0	15.9	471.73	1187.2	Std.	32	38	68	74	84	91	97	105	113	130
					Alt.	41	47	68	74	84	91	97	105	113	130
48	1219.0	17.5	518.51	1184.0	Std.	36	42	75	82	93	100	107	116	125	143
					Alt.	45	52	75	82	93	100	107	116	125	143
48	1219.0	19.1	565.16	1180.8	Std.	39	45	82	89	101	109	117	126	136	156
					Alt.	49	57	82	89	101	109	117	126	136	156
48	1219.0	20.6	608.78	1177.8	Std.	42	49	88	96	109	117	126	136	147	168
					Alt.	52	61	88	96	109	117	126	136	147	168
48	1219.0	22.2	655.19	1174.6	Std.	45	53	95	104	118	127	136	147	158	181
					Alt.	57	66	95	104	118	127	136	147	158	181
48	1219.0	23.8	701.47	1171.4	Std.	48	56	102	111	126	136	145	157	170	194
					Alt.	61	71	102	111	126	136	145	157	170	194
48	1219.0	25.4	747.63	1168.2	Std.	52	60	109	119	135	145	155	168	181	207
					Alt.	65	75	109	119	135	145	155	168	181	207
48	1219.0	27.0	793.66	1165.0	Std.	55	64	116	126	143	154	165	179	193	207
					Alt.	69	80	116	126	143	154	165	179	193	220
48	1219.0	28.6	839.56	1161.8	Std.	58	68	122	134	152	163	175	189	204	207
					Alt.	73	85	122	134	152	163	175	189	204	233
48	1219.0	30.2	885.34	1158.6	Std.	62	72	129	141	160	172	185	200	207	207
					Alt.	77	90	129	141	160	172	185	200	215	246
48	1219.0	31.8	930.99	1155.4	Std.	65	75	136	149	169	181	194	207	207	207
					Alt.	81	94	136	149	169	181	194	210	227	250
52	1321.0	9.5	307.25	1302.0	Std.	18	21	38	41	46	50	54	58	63	71
					Alt.	22	26	38	41	46	50	54	58	63	71
52	1321.0	10.3	332.92	1300.4	Std.	19	23	41	44	50	54	58	63	68	77
					Alt.	24	28	41	44	50	54	58	63	68	77
52	1321.0	11.1	358.55	1298.8	Std.	21	24	44	48	54	58	63	68	73	83
					Alt.	26	30	44	48	54	58	63	68	73	83
52	1321.0	11.9	384.16	1297.2	Std.	22	26	47	51	58	63	67	73	78	90
					Alt.	28	33	47	51	58	63	67	73	78	90
52	1321.0	12.7	409.74	1295.6	Std.	24	28	50	55	62	67	72	78	84	96
					Alt.	30	35	50	55	62	67	72	78	84	96

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
52	1321.0	14.3	460.79	1292.4	Std.	27	31	57	62	70	75	81	87	94	108
					Alt.	34	39	57	62	70	75	81	87	94	108
52	1321.0	15.9	511.72	1289.2	Std.	30	35	63	69	78	84	90	97	105	120
					Alt.	37	44	63	69	78	84	90	97	105	120
52	1321.0	17.5	562.53	1286.0	Std.	33	38	69	76	86	92	99	107	115	132
					Alt.	41	48	69	76	86	92	99	107	115	132
52	1321.0	19.1	613.20	1282.8	Std.	36	42	75	83	93	100	108	117	126	144
					Alt.	45	52	75	83	93	100	108	117	126	144
52	1321.0	20.6	660.60	1279.8	Std.	39	45	81	89	101	108	116	126	136	155
					Alt.	48	56	81	89	101	108	116	126	136	155
52	1321.0	22.2	711.03	1276.6	Std.	42	49	88	96	109	117	125	136	146	167
					Alt.	52	61	88	96	109	117	125	136	146	167
52	1321.0	23.8	761.34	1273.4	Std.	45	52	94	103	116	125	134	145	157	179
					Alt.	56	65	94	103	116	125	134	145	157	179
52	1321.0	25.4	811.52	1270.2	Std.	48	56	100	110	124	134	143	155	167	191
					Alt.	60	70	100	110	124	134	143	155	167	191
52	1321.0	27.0	861.57	1267.0	Std.	51	59	107	117	132	142	152	165	178	203
					Alt.	63	74	107	117	132	142	152	165	178	203
52	1321.0	28.6	911.50	1263.8	Std.	54	63	113	124	140	150	161	175	188	207
					Alt.	67	78	113	124	140	150	161	175	188	215
52	1321.0	30.2	961.30	1260.6	Std.	57	66	119	130	148	159	170	184	199	207
					Alt.	71	83	119	130	148	159	170	184	199	227
52	1321.0	31.8	1010.98	1257.4	Std.	60	70	126	137	156	167	179	194	207	207
					Alt.	75	87	126	137	156	167	179	194	209	239
56	1422.0	9.5	330.91	1403.0	Std.	17	19	35	38	43	46	50	54	58	66
					Alt.	21	24	35	38	43	46	50	54	58	66
56	1422.0	10.3	358.57	1401.4	Std.	18	21	38	41	47	50	54	58	63	72
					Alt.	22	26	38	41	47	50	54	58	63	72
56	1422.0	11.1	386.20	1399.8	Std.	19	23	41	45	50	54	58	63	68	78
					Alt.	24	28	41	45	50	54	58	63	68	78
56	1422.0	11.9	413.80	1398.2	Std.	21	24	44	48	54	58	62	67	73	83
					Alt.	26	30	44	48	54	58	62	67	73	83
56	1422.0	12.7	441.37	1396.6	Std.	22	26	47	51	58	62	67	72	78	89
					Alt.	28	32	47	51	58	62	67	72	78	89
56	1422.0	14.3	496.41	1393.4	Std.	25	29	52	57	65	70	75	81	87	100
					Alt.	31	36	52	57	65	70	75	81	87	100
56	1422.0	15.9	551.32	1390.2	Std.	28	32	58	64	72	78	83	90	97	111
					Alt.	35	40	58	64	72	78	83	90	97	111
56	1422.0	17.5	606.11	1387.0	Std.	31	36	64	70	80	86	92	99	107	122
					Alt.	38	44	64	70	80	86	92	99	107	122
56	1422.0	19.1	660.77	1383.8	Std.	33	39	70	77	87	93	100	108	117	133
					Alt.	42	49	70	77	87	93	100	108	117	133
56	1422.0	20.6	711.91	1380.8	Std.	36	42	76	83	94	101	108	117	126	144
					Alt.	45	52	76	83	94	101	108	117	126	144
56	1422.0	22.2	766.32	1377.6	Std.	39	45	81	89	101	108	116	126	136	155
					Alt.	48	56	81	89	101	108	116	126	136	155
56	1422.0	23.8	820.61	1374.4	Std.	42	48	87	96	108	116	125	135	146	166
					Alt.	52	61	87	96	108	116	125	135	146	166
56	1422.0	25.4	874.78	1371.2	Std.	44	52	93	102	115	124	133	144	155	177
					Alt.	55	65	93	102	115	124	133	144	155	177

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
56	1422.0	27.0	928.82	1368.0	Std.	47	55	99	108	123	132	141	153	165	189
					Alt.	59	69	99	108	123	132	141	153	165	189
56	1422.0	28.6	982.73	1364.8	Std.	50	58	105	115	130	140	150	162	175	200
					Alt.	62	73	105	115	130	140	150	162	175	200
56	1422.0	30.2	1036.52	1361.6	Std.	53	61	111	121	137	148	158	171	185	207
					Alt.	66	77	111	121	137	148	158	171	185	211
56	1422.0	31.8	1090.18	1358.4	Std.	56	65	117	128	145	155	167	180	194	207
					Alt.	69	81	117	128	145	155	167	180	194	222
60	1524.0	9.5	354.80	1505.0	Std.	15	18	33	36	40	43	46	50	54	62
					Alt.	19	23	33	36	40	43	46	50	54	62
60	1524.0	10.3	384.48	1503.4	Std.	17	20	35	39	44	47	50	55	59	67
					Alt.	21	24	35	39	44	47	50	55	59	67
60	1524.0	11.1	414.12	1501.8	Std.	18	21	38	42	47	51	54	59	63	72
					Alt.	23	26	38	42	47	51	54	59	63	72
60	1524.0	11.9	443.73	1500.2	Std.	19	23	41	45	50	54	58	63	68	78
					Alt.	24	28	41	45	50	54	58	63	68	78
60	1524.0	12.7	473.31	1498.6	Std.	21	24	44	48	54	58	62	67	72	83
					Alt.	26	30	44	48	54	58	62	67	72	83
60	1524.0	14.3	532.38	1495.4	Std.	23	27	49	54	61	65	70	76	82	93
					Alt.	29	34	49	54	61	65	70	76	82	93
60	1524.0	15.9	591.32	1492.2	Std.	26	30	54	60	67	72	78	84	91	104
					Alt.	32	38	54	60	67	72	78	84	91	104
60	1524.0	17.5	650.13	1489.0	Std.	29	33	60	66	74	80	86	93	100	114
					Alt.	36	42	60	66	74	80	86	93	100	114
60	1524.0	19.1	708.82	1485.8	Std.	31	36	65	72	81	87	93	101	109	125
					Alt.	39	45	65	72	81	87	93	101	109	125
60	1524.0	20.6	763.72	1482.8	Std.	34	39	71	77	87	94	101	109	118	134
					Alt.	42	49	71	77	87	94	101	109	118	134
60	1524.0	22.2	822.16	1479.6	Std.	36	42	76	83	94	101	109	117	127	145
					Alt.	45	53	76	83	94	101	109	117	127	145
60	1524.0	23.8	880.48	1476.4	Std.	39	45	82	89	101	109	116	126	136	155
					Alt.	48	56	82	89	101	109	116	126	136	155
60	1524.0	25.4	938.67	1473.2	Std.	41	48	87	95	108	116	124	134	145	166
					Alt.	52	60	87	95	108	116	124	134	145	166
60	1524.0	27.0	996.73	1470.0	Std.	44	51	92	101	114	123	132	143	154	176
					Alt.	55	64	92	101	114	123	132	143	154	176
60	1524.0	28.6	1054.67	1466.8	Std.	47	54	98	107	121	130	140	151	163	186
					Alt.	58	68	98	107	121	130	140	151	163	186
60	1524.0	30.2	1112.48	1463.6	Std.	49	57	103	113	128	138	148	160	172	197
					Alt.	62	72	103	113	128	138	148	160	172	197
60	1524.0	31.8	1170.17	1460.4	Std.	52	60	109	119	135	145	155	168	181	207
					Alt.	65	75	109	119	135	145	155	168	181	207
64	1626.0	9.5	378.70	1607.0	Std.	15	17	30	33	38	41	44	47	51	58
					Alt.	18	21	30	33	38	41	44	47	51	58
64	1626.0	10.3	410.38	1605.4	Std.	16	18	33	36	41	44	47	51	55	63
					Alt.	20	23	33	36	41	44	47	51	55	63
64	1626.0	11.1	442.04	1603.8	Std.	17	20	36	39	44	47	51	55	59	68
					Alt.	21	25	36	39	44	47	51	55	59	68
64	1626.0	11.9	473.66	1602.2	Std.	18	21	38	42	47	51	55	59	64	73
					Alt.	23	26	38	42	47	51	55	59	64	73

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
64	1626.0	12.7	505.26	1600.6	Std.	19	23	41	45	50	54	58	63	68	78
					Alt.	24	28	41	45	50	54	58	63	68	78
64	1626.0	14.3	568.35	1597.4	Std.	22	25	46	50	57	61	66	71	76	87
					Alt.	27	32	46	50	57	61	66	71	76	87
64	1626.0	15.9	631.31	1594.2	Std.	24	28	51	56	63	68	73	79	85	97
					Alt.	30	35	51	56	63	68	73	79	85	97
64	1626.0	17.5	694.15	1591.0	Std.	27	31	56	61	70	75	80	87	94	107
					Alt.	33	39	56	61	70	75	80	87	94	107
64	1626.0	19.1	756.86	1587.8	Std.	29	34	61	67	76	82	88	95	102	117
					Alt.	36	42	61	67	76	82	88	95	102	117
64	1626.0	20.6	815.54	1584.8	Std.	31	37	66	72	82	88	94	102	110	126
					Alt.	39	46	66	72	82	88	94	102	110	126
64	1626.0	22.2	878.00	1581.6	Std.	34	39	71	78	88	95	102	110	119	136
					Alt.	42	49	71	78	88	95	102	110	119	136
64	1626.0	23.8	940.34	1578.4	Std.	36	42	76	84	95	102	109	118	127	145
					Alt.	45	53	76	84	95	102	109	118	127	145
64	1626.0	25.4	1002.56	1575.2	Std.	39	45	82	89	101	109	116	126	136	155
					Alt.	49	56	82	89	101	109	116	126	136	155
64	1626.0	27.0	1064.65	1572.0	Std.	41	48	87	95	107	115	124	134	144	165
					Alt.	52	60	87	95	107	115	124	134	144	165
64	1626.0	28.6	1126.61	1568.8	Std.	44	51	92	100	114	122	131	142	153	175
					Alt.	55	64	92	100	114	122	131	142	153	175
64	1626.0	30.2	1188.44	1565.6	Std.	46	54	97	106	120	129	138	150	161	185
					Alt.	58	67	97	106	120	129	138	150	161	185
64	1626.0	31.8	1250.15	1562.4	Std.	49	57	102	112	126	136	146	158	170	194
					Alt.	61	71	102	112	126	136	146	158	170	194
68	1727.0	11.9	503.30	1703.2	Std.	17	20	36	39	45	48	51	56	60	68
					Alt.	21	25	36	39	45	48	51	56	60	68
68	1727.0	12.7	536.89	1701.6	Std.	18	21	38	42	48	51	55	59	64	73
					Alt.	23	27	38	42	48	51	55	59	64	73
68	1727.0	14.3	603.96	1698.4	Std.	21	24	43	47	54	58	62	67	72	82
					Alt.	26	30	43	47	54	58	62	67	72	82
68	1727.0	15.9	670.91	1695.2	Std.	23	27	48	53	59	64	69	74	80	91
					Alt.	29	33	48	53	59	64	69	74	80	91
68	1727.0	17.5	737.73	1692.0	Std.	25	29	53	58	65	70	76	82	88	101
					Alt.	31	37	53	58	65	70	76	82	88	101
68	1727.0	19.1	804.43	1688.8	Std.	27	32	58	63	71	77	82	89	96	110
					Alt.	34	40	58	63	71	77	82	89	96	110
68	1727.0	20.6	866.84	1685.8	Std.	30	34	62	68	77	83	89	96	104	119
					Alt.	37	43	62	68	77	83	89	96	104	119
68	1727.0	22.2	933.30	1682.6	Std.	32	37	67	73	83	89	96	104	112	128
					Alt.	40	46	67	73	83	89	96	104	112	128
68	1727.0	23.8	999.62	1679.4	Std.	34	40	72	79	89	96	103	111	120	137
					Alt.	43	50	72	79	89	96	103	111	120	137
68	1727.0	25.4	1065.82	1676.2	Std.	37	43	77	84	95	102	110	119	128	146
					Alt.	46	53	77	84	95	102	110	119	128	146
68	1727.0	27.0	1131.89	1673.0	Std.	39	45	82	89	101	109	117	126	136	155
					Alt.	49	57	82	89	101	109	117	126	136	155
68	1727.0	28.6	1197.84	1669.8	Std.	41	48	86	94	107	115	123	134	144	165
					Alt.	51	60	86	94	107	115	123	134	144	165

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
68	1727.0	30.2	1263.66	1666.6	Std.	43	51	91	100	113	121	130	141	152	174
					Alt.	54	63	91	100	113	121	130	141	152	174
68	1727.0	31.8	1329.36	1663.4	Std.	46	53	96	105	119	128	137	148	160	183
					Alt.	57	67	96	105	119	128	137	148	160	183
72	1829.0	12.7	568.83	1803.6	Std.	17	20	36	40	45	48	52	56	60	69
					Alt.	22	25	36	40	45	48	52	56	60	69
72	1829.0	14.3	639.93	1800.4	Std.	19	23	41	45	51	54	58	63	68	78
					Alt.	24	28	41	45	51	54	58	63	68	78
72	1829.0	15.9	710.91	1797.2	Std.	22	25	45	50	56	60	65	70	76	86
					Alt.	27	31	45	50	56	60	65	70	76	86
72	1829.0	17.5	781.75	1794.0	Std.	24	28	50	55	62	66	71	77	83	95
					Alt.	30	35	50	55	62	66	71	77	83	95
72	1829.0	19.1	852.47	1790.8	Std.	26	30	55	60	67	73	78	84	91	104
					Alt.	32	38	55	60	67	73	78	84	91	104
72	1829.0	20.6	918.66	1787.8	Std.	28	33	59	64	73	78	84	91	98	112
					Alt.	35	41	59	64	73	78	84	91	98	112
72	1829.0	22.2	989.14	1784.6	Std.	30	35	63	69	78	84	90	98	106	121
					Alt.	38	44	63	69	78	84	90	98	106	121
72	1829.0	23.8	1059.49	1781.4	Std.	32	38	68	74	84	90	97	105	113	129
					Alt.	40	47	68	74	84	90	97	105	113	129
72	1829.0	25.4	1129.71	1778.2	Std.	34	40	72	79	90	96	103	112	121	138
					Alt.	43	50	72	79	90	96	103	112	121	138
72	1829.0	27.0	1199.81	1775.0	Std.	37	43	77	84	95	103	110	119	128	147
					Alt.	46	53	77	84	95	103	110	119	128	147
72	1829.0	28.6	1269.78	1771.8	Std.	39	45	82	89	101	109	117	126	136	155
					Alt.	49	57	82	89	101	109	117	126	136	155
72	1829.0	30.2	1339.62	1768.6	Std.	41	48	86	94	107	115	123	133	144	164
					Alt.	51	60	86	94	107	115	123	133	144	164
72	1829.0	31.8	1409.34	1765.4	Std.	43	50	91	99	112	121	130	140	151	173
					Alt.	54	63	91	99	112	121	130	140	151	173
76	1930.0	12.7	600.46	1904.6	Std.	16	19	34	38	43	46	49	53	57	65
					Alt.	20	24	34	38	43	46	49	53	57	65
76	1930.0	14.3	675.55	1901.4	Std.	18	21	39	42	48	51	55	60	64	74
					Alt.	23	27	39	42	48	51	55	60	64	74
76	1930.0	15.9	750.51	1898.2	Std.	20	24	43	47	53	57	61	66	72	82
					Alt.	26	30	43	47	53	57	61	66	72	82
76	1930.0	17.5	825.34	1895.0	Std.	23	26	47	52	59	63	68	73	79	90
					Alt.	28	33	47	52	59	63	68	73	79	90
76	1930.0	19.1	900.05	1891.8	Std.	25	29	52	56	64	69	74	80	86	98
					Alt.	31	36	52	56	64	69	74	80	86	98
76	1930.0	20.6	969.97	1888.8	Std.	27	31	56	61	69	74	80	86	93	106
					Alt.	33	39	56	61	69	74	80	86	93	106
76	1930.0	22.2	1044.43	1885.6	Std.	29	33	60	66	74	80	86	93	100	114
					Alt.	36	42	60	66	74	80	86	93	100	114
76	1930.0	23.8	1118.76	1882.4	Std.	31	36	64	70	80	86	92	99	107	123
					Alt.	38	45	64	70	80	86	92	99	107	123
76	1930.0	25.4	1192.97	1879.2	Std.	33	38	69	75	85	91	98	106	114	131
					Alt.	41	48	69	75	85	91	98	106	114	131
76	1930.0	27.0	1267.06	1876.0	Std.	35	40	73	80	90	97	104	113	122	139
					Alt.	43	51	73	80	90	97	104	113	122	139

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Table E-6C (Continued)—Plain-End Line Pipe Dimensions, Weights per Unit Length, and Test Pressures for Sizes $6^5/_8$ through 80 (SI Units)

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
						Minimum Test Pressure[b] (kPa × 100)[c]									
Size	Specified Outside Diameter D (mm)	Specified Wall Thickness t (mm)	Plain-End Weight per Unit Length w_{pe} (kg/m)	Calculated Inside Diameter[a] d (mm)		Grade A	Grade B	Grade X42	Grade X46	Grade X52	Grade X56	Grade X60	Grade X65	Grade X70	Grade X80
76	1930.0	28.6	1341.01	1872.8	Std.	37	43	77	85	96	103	110	119	129	147
					Alt.	46	54	77	85	96	103	110	119	129	147
76	1930.0	30.2	1414.84	1869.6	Std.	39	45	82	89	101	109	117	126	136	155
					Alt.	49	57	82	89	101	109	117	126	136	155
76	1930.0	31.8	1488.55	1866.4	Std.	41	48	86	94	106	114	123	133	143	164
					Alt.	51	60	86	94	106	114	123	133	143	164
80	2032.0	14.3	711.52	2003.4	Std.	17	20	37	40	45	49	52	57	61	70
					Alt.	22	25	37	40	45	49	52	57	61	70
80	2032.0	15.9	790.50	2000.2	Std.	19	23	41	45	51	54	58	63	68	78
					Alt.	24	28	41	45	51	54	58	63	68	78
80	2032.0	17.5	869.36	1997.0	Std.	21	25	45	49	56	60	64	69	75	86
					Alt.	27	31	45	49	56	60	64	69	75	86
80	2032.0	19.1	948.09	1993.8	Std.	23	27	49	54	61	65	70	76	82	93
					Alt.	29	34	49	54	61	65	70	76	82	93
80	2032.0	20.6	1021.78	1990.8	Std.	25	29	53	58	66	70	76	82	88	101
					Alt.	31	37	53	58	66	70	76	82	88	101
80	2032.0	22.2	1100.27	1987.6	Std.	27	32	57	62	71	76	81	88	95	109
					Alt.	34	39	57	62	71	76	81	88	95	109
80	2032.0	23.8	1178.63	1984.4	Std.	29	34	61	67	76	81	87	94	102	116
					Alt.	36	42	61	67	76	81	87	94	102	116
80	2032.0	25.4	1256.86	1981.2	Std.	31	36	65	71	81	87	93	101	109	124
					Alt.	39	45	65	71	81	87	93	101	109	124
80	2032.0	27.0	1334.97	1978.0	Std.	33	38	69	76	86	92	99	107	116	132
					Alt.	41	48	69	76	86	92	99	107	116	132
80	2032.0	28.6	1412.95	1974.8	Std.	35	41	73	80	91	98	105	113	122	140
					Alt.	44	51	73	80	91	98	105	113	122	140
80	2032.0	30.2	1490.80	1971.6	Std.	37	43	78	85	96	103	111	120	129	148
					Alt.	46	54	78	85	96	103	111	120	129	148
80	2032.0	31.8	1568.53	1968.4	Std.	39	45	82	89	101	109	117	126	136	155
					Alt.	49	57	82	89	101	109	117	126	136	155

Note: See Table 6C for U.S. Customary unit values corresponding to the SI unit values given in this table.

[a]The calculated inside diameters are given here for information (see 7.2).

[b]The test pressures given in Tables E-6A, E-6B, and E-6C apply to Grades A25, A, B, X42, X46, X52, X56, X60, X65, X70, and X80 only. See 9.4.3 for pressures applicable to other grades.

[c]100 kPa = 1 bar.

[d]Pipe that has this combination of specified outside diameter and specified wall thickness is special plain-end pipe; other combinations given in this table are regular plain-end pipe. Pipe that has a combination of specified outside diameter and specified wall thickness that is intermediate to the tabulated values is considered to be special plain-end pipe if the next lower tabulated value is for special plain-end pipe; other intermediate combinations are considered to be regular plain-end pipe. (See Table 10 for the applicable weight tolerances.)

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APPENDIX F—SUPPLEMENTARY REQUIREMENTS (NORMATIVE)

When specified on the purchase order, the following supplementary requirements (SR) shall apply.

SR3 Color Identification

SR3.1 For Grades X46 and higher of pipe sizes $4^1/_2$ and larger shall be identified by color in accordance with the color code given in SR3.3.

SR3.2 The manufacturer shall apply a 2 in. (50 mm) daub of paint of the appropriate color on the inside surface at one end of each length of pipe.

SR3.3 The grade identification colors are as follows:

Grade	Color
X46	Black
X52	Green
X56	Blue
X60	Red
X65	White
X70	Purple
X80	Yellow

SR4 Nondestructive Inspection of Seamless Line Pipe

SR4.1 SUPPLEMENTARY NONDESTRUCTIVE INSPECTION

Seamless pipe shall be inspected full length for longitudinal defects by either magnetic particle inspection or by ultrasonic or electromagnetic methods. The location of the equipment in the mill shall be at the discretion of the manufacturer; however, the nondestructive inspection shall take place after all heat treating and expansion operations, if performed, but may take place before cropping, beveling, and end sizing.

SR4.2 MAGNETIC PARTICLE INSPECTION

When magnetic particle inspection is employed to inspect for longitudinal defects, the entire outside surface shall be inspected. The depth of all imperfections revealed by magnetic particle inspection shall be determined; and when found to be greater than $12^1/_2$% of the specified wall thickness, the imperfection shall be considered a defect. Pipe containing defects shall be given one of the dispositions specified in 9.7.6.

SR4.3 ULTRASONIC OR ELECTROMAGNETIC INSPECTION

SR4.3.1 Equipment

Any equipment utilizing the ultrasonic or electromagnetic principles and capable of continuous and uninterrupted inspection of the entire outer surface of the pipe may be used. The equipment shall be of sufficient sensitivity to indicate defects and shall be checked as prescribed in SR4.3.2.

SR4.3.2 Reference Standards

At least once per 8 hours per operating shift, a reference standard having the same specified diameter and thickness as the product being inspected shall be used to demonstrate the effectiveness of the inspection equipment and procedures. The reference standard may be of any convenient length as determined by the manufacturer. It shall be scanned by the inspection unit in a manner simulating the inspection of the product. For ultrasonic inspection, the reference standard shall contain a machined notch as specified in Figure F-1. For electromagnetic inspection, the reference standard shall contain either a machined notch as specified in Figure F-1 or a $^1/_8$ in. (3.2 mm) drilled hole (see Note 1). The notch shall be in the outer surface of the reference standard and parallel to the longitudinal axis of the pipe or, at the option of the manufacturer, may be oriented at such an angle as to optimize the detection of anticipated defects (see Note 2). The $^1/_8$ in. (3.2 mm) hole shall be drilled radially through the wall of the reference standard. The inspection equipment shall be adjusted to produce a well-defined indication when the reference standard is scanned by the inspection unit.

Note 1: The reference standards defined above are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.
Note 2: Reference standards other than the specific notch described above may be used by agreement between the purchaser and the manufacturer.

SR4.3.3 Acceptance Limits

Any imperfection that produces a signal greater than the signal received from the reference standard shall be considered a defect unless it can be demonstrated by the manufacturer that the imperfection does not exceed the provisions of 7.8. Pipe containing defects shall be given one of the dispositions specified in 9.7.6.

SR4.4 MARKING

Pipe nondestructively inspected in accordance with this supplementary requirement shall be marked SR4.

SR5 Fracture Toughness Testing (Charpy V-Notch) for Pipe of Size $4^1/_2$ or Larger

SR5.1 The manufacturer is responsible for the performance of Charpy V-notch tests in accordance with ASTM A 370, *Methods and Definitions for Mechanical Testing of*

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Steel Products, as modified herein. Either or both toughness criteria (SR5A—Shear Area or SR5B—Absorbed Energy) may be specified under this supplementary requirement.

SR5.2 The following applies to all specified limits and observed values to be used in connection with this supplementary requirement.

For purposes of determining conformance with these supplementary requirements, an observed value shall be rounded to the nearest whole number in accordance with the rounding-off method of ASTM E 29, *Practice for Using Significant Digits in Test Data to Determine Performance With Specifications*. Further, limiting values as specified or calculated under this supplementary requirement shall be expressed as whole numbers rounded, if necessary.

SR5.3 Except for flattened specimens, the requirements of this supplementary requirement are limited to pipe sizes and wall thicknesses from which a $^1/_2$ size specimen may be secured.

The specimen shall be oriented circumferentially from a location 90° from the weld with the axis of the notch oriented through the pipe wall thickness as shown in Figure F-3.

SR5.4 Except as limited by Item c below, any of the following Charpy V-notch specimens are permissible by agreement between the purchaser and the manufacturer.

a. Full-size specimens. Full-size specimens (10 mm by 10 mm) with or without tapered ends may be used (see note below and Figure F-2).

b. Subsize specimens. The largest possible subsize specimen (see Table F-1) with or without tapered ends may be used. All dimensions other than specimen width are the same as the full-size specimen. Selecting subsize specimens for pipe whose size permits full-size specimens is also permissible by agreement between the purchaser and the manufacturer.

c. Flattened specimens. When because of combinations of diameter and wall thickness the use of $^2/_3$ size tapered end specimens is not practicable (see Table F-1), flattened specimens, $^1/_2$ size conventional specimens, or $^1/_2$ size tapered end specimens shall be used by agreement between the purchaser and the manufacturer. Flattened specimens may be flattened at room temperature in the same manner as transverse tensile strip specimens are prepared. Hot flattening, artificial aging, or heat treatment of flattened specimens is not permitted.

The flattened specimens shall have OD and ID surfaces machined no more than sufficient to make them parallel, or the surfaces shall be wire brushed or cleaned without machining. The specimen width shall essentially represent the full wall thickness of the pipe. All dimensions other than specimen width shall be the same as full-size specimens. The user is cautioned that results of flattened specimens and full-size or subsize specimens may not be correlated or directly compared with one another.

Note: "Tapered end specimens" are designated as "tubular impact specimens containing original OD surface" in ASTM A 370. This terminology is not used here because of possible confusion with the flattened specimens permitted in this SR; flattened specimens may also contain the original OD surface (but not curvature), since machining of flattened specimens is not required by this SR.

SR5.5 If any Charpy V-notch test result for a heat of pipe fails to conform to the applicable requirements of SR5A or SR5B, the manufacturer may elect to heat treat the heat of pipe in accordance with the requirements of 5.4, consider it to be a new heat, test it in accordance with all requirements of 6.2, 9.3, SR5, and SR6 that are applicable to the order item, and proceed in accordance with the applicable requirements of this specification. After one reprocessing heat treatment, any additional reprocessing heat treatment shall be subject to agreement with the purchaser.

For non-heat treated pipe, any reprocessing heat treatment shall be subject to agreement with the purchaser. For heat treated pipe, any reprocessing with a different type of heat treatment (see 5.4) shall be subject to agreement with the purchaser.

SR5A Shear Area

SR5A.1 Three transverse specimens shall be taken from one length of pipe from each heat supplied on the order.

SR5A.2 The specimens shall be tested at 50°F (10°C) or at a lower temperature as specified by the purchaser. The average shear value of the fracture appearance of the three specimens shall not be less than 60%, and the all-heat average for each order per diameter size and grade shall not be less than 80%.

SR5A.3 If the average of the three specimens from one heat does not meet the requirement of 60% shear, the manufacturer may elect to repeat the tests on specimens cut from two additional lengths of pipe from the same heat. If such specimens conform to the specified requirements, all the lengths in the heat shall be accepted except the length initially selected for test. If any of the retest specimens fail to pass this specified retest requirement, the manufacturer may elect to test specimens cut from the individual lengths remaining in the heat.

SR5A.4 The average shear value for a heat shall be the average of the original three specimens if the average is 60% or more; the combined average of the retest specimens, provided the average of each group of three specimens is 60% or more; or, in the event individual lengths are tested, the combined average of all groups of three specimens that meet 60%. The all-heat average value is the combined average of the average shear value for each of the heats supplied for the order item.

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SR5A.5 If the all-heat average of the order does not meet the requirement of 80% shear, the manufacturer shall be responsible for replacement of such heats as may be necessary to bring the average shear area up to 80%.

SR5A.6 Alternatively, the manufacturer may elect to test two or more additional lengths from one or more of the heats. In determining the new heat average, the original test values may be discarded if the pipe length represented is rejected or the three or more individual values are averaged. In any case, the new test values shall be incorporated into the value for the heat.

SR5A.7 Specimens showing material defects or defective preparation, whether observed before or after breaking, may be discarded and replacements shall be considered as original specimens.

SR5A.8 Marking. Pipe tested in accordance with the shear area requirements of this supplementary requirement shall be marked to indicate the type of test, the test temperature, and if flattened specimens are used, the type of specimen. Temperatures below zero shall be preceded by the letter M.

Example at + 32°F:	SR5A-32F
Example of flattened specimen at – 40°C:	SR5AF-M40C

SR5B Absorbed Energy

SR5B.1 The fracture toughness of the pipe shall be determined using Charpy V-notch impact test specimens in accordance with ASTM A 370, as modified herein, and the requirements of SR5A.1, except that test frequency shall be as indicated in SR5B.2. The purchaser shall specify, in whole numbers, both the test temperature and the minimum average absorbed energy for full-size specimens.

Specimens used for shear area determination according to SR5A may be additionally used for the determination of absorbed energy.

SR5B.2 Three transverse specimens representing one test shall be taken from one length of pipe from each inspection lot of 100 lengths per heat produced. An inspection lot shall consist of pipe that is made to the same size and same specified wall thickness by the same process and under the same manufacturing conditions.

SR5B.3 For acceptance, the average absorbed energy of the three individual specimens from a length shall not be less than the full-size value specified by the purchaser. In addition, the lowest individual reading of the three specimens shall not be less than 75% of the specified value. When subsize specimens are used, the individual readings and the average of the three readings are divided by the ratio of the specimen thickness tested to the full-size specimen thickness and compared with the full-size acceptance criteria. When flattened specimens are used, each of the three individual impact energy readings shall be multiplied by 0.3937 (10), and divided by the actual measured specimen width, in inches (millimeters). These results, and the average of the three results, shall meet the specified absorbed energy acceptance criteria for full-size specimens.

SR5B.4 Specimens showing material defects or defective preparations, whether observed before or after breaking, may be discarded and replacements shall be considered original specimens.

In the event a set of test specimens fails to meet the acceptance criteria, the manufacturer may elect to replace the lot of material involved or alternatively to test two more lengths from the same lot. If both of the new tests meet the acceptance criteria, then all pipe in that lot with the exception of the original selected length shall be considered to meet the requirement. Failure of either of the two additional tests shall require testing of each length in the lot for acceptance.

SR5B.5 Pipe complying with the absorbed energy requirements of this supplementary requirement shall be marked to indicate the type of test, the specified [full-size] minimum average absorbed energy, the test temperature, and, if flattened specimens are used, the type of specimen. Temperatures below zero shall be preceded by the letter M, and absorbed energy specified in joules shall be followed by the letter J.

Example for 20 ft-lb at +32°F:	SR5B-20-32F
Example of flattened specimens for 20 ft-lb at – 40°F:	SR5BF-20-M40F
Example of flattened specimens for both SR5A and SR5B for 27 joules at 0°C:	SR5ABF-27J-0C

SR6 Drop-Weight Tear Testing on Welded Pipe of Size 20 or Larger, Grade X52 or Higher

SR6.1 Fracture toughness of pipe sizes 20 and larger, Grade X52 and higher, shall be determined by the manufacturer using drop-weight tear tests in accordance with the following requirements in SR6.2 through SR6.8.

SR6.2 Two transverse specimens shall be taken from one length of pipe from each heat supplied on the order. The specimens shall be oriented circumferentially from a location 90° from the weld with the axis of the notch oriented through the pipe wall thickness as shown in Figure F-3. The specimens shall be tested at 50°F (10°C) or at a lower temperature as specified by the purchaser.

SR6.3 The test specimens, testing procedure, and rating of the specimens shall be in accordance with API Recommended Practice 5L3. The type of notch (pressed or chevron) shall be selected by agreement between the manufacturer and the purchaser.

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SR6.4 At least 80% of the heats shall exhibit a fracture appearance shear area of 40% or more for the specified test temperature (see note).

Note: Due to manufacturing difficulties encountered with thicker materials, pipe manufacturers may not be able to offer pipe in all grades that meet this requirement.

SR6.5 In the event the average value of the two specimens from the length selected to represent the heat is less than 40%, the manufacturer may elect to establish the heat average by testing two specimens from each of two or more additional lengths of pipe in the heat. In establishing the new heat average, the manufacturer may elect (a) to employ the combined average of the three tests or more; or (b) to discard the result of the first test, reject the pipe from which it was taken, and employ the combined average of the two or more additional tests. Alternatively, the manufacturer may elect to test all the pipe in the heat, in which case 80% or more of the lengths tested and applied to the order shall exhibit an average of 40% or more shear.

SR6.6 Specimens showing material defects or defective preparation, whether observed before or after breaking, may be discarded, and replacements shall be considered as original specimens.

SR6.7 The manufacturer shall be responsible for replacement of such heats as may be necessary to meet the above requirements.

SR6.8 Pipe tested in accordance with SR6 shall be marked to indicate the type of test, the type of notch, and the testing temperature. Temperatures below zero shall be preceded by the letter M.

Example for chevron notch at 32°F: SR6C-32F
Example for pressed notch at – 10°C: SR6P-M10C

SR7 Through-the-Flowline (TFL) Pipe

SR7.1 GENERAL

TFL pipe shall comply with all requirements of this specification and the additional requirements specified in SR7.2 through SR7.6.

SR7.2 DIMENSION AND GRADES

TFL pipe shall be seamless or longitudinal seam pipe in the outside diameters, wall thicknesses, and grades listed in Table F-2.

SR7.3 LENGTH

Unless otherwise specified, TFL pipe shall be furnished only in double random lengths with no jointers (girth welds).

SR7.4 DRIFT TESTS

Each length of TFL pipe shall be tested throughout its entire length with a cylindrical drift mandrel conforming to the requirements listed below. The leading edge of the drift mandrel shall be rounded to permit easy entry into the pipe. The drift mandrel shall pass freely through the pipe with a reasonable exerted force equivalent to the weight of the mandrel being used for the test. Pipe shall not be rejected until it has been drift tested when it is free of all foreign matter and properly supported to prevent sagging.

	Drift Mandrel Size			
	Length		Diam., min.	
Size	in.	mm	in.	mm
$< 3^1/_2$	42	1066	d – $^3/_{32}$	d – 2.4
$\geq 3^1/_2$	42	1066	d – $^1/_8$	d – 3.2

SR7.5 HYDROSTATIC TESTS

TFL pipe shall be hydrostatically tested in accordance with the requirements of 9.4, except that the minimum test pressures shall be as shown in Table F-2. These test pressures in Table F-2 represent the lesser of 10,000 psi (68 900 kPa) and the pressure calculated with the equation given in 9.4.3, using a fiber stress (S) equal to 80 percent of the specified minimum yield strength.

SR7.6 MARKING

TFL pipe manufactured in accordance with SR7 shall be marked with the letters TFL in addition to the marking required in Section 10 or Appendix I.

SR15 Test Certificates and Traceability for Line Pipe

SR15.1 The manufacturer shall provide the following data, as applicable, for each order item for which this supplementary requirement is specified on the purchase order. The manufacturer's certificate of compliance shall state the API specification and date of revision to which pipe was manufactured. A Material Test Report, Certificate of Compliance, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the manufacturer's facility. The content of the EDI transmitted document must meet the requirements of this specification and conform to any existing EDI agreement between the purchaser and the manufacturer.

a. Specified outside diameter, specified wall thickness, grade, process of manufacture, and type of heat treatment.

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b. Chemical analyses (heat, product, control, and recheck) showing the weight percent of all elements whose limits or reporting requirements are set in this specification; for PSL 2 pipe, carbon equivalent and applicable maximum allowable value. If order is for by-agreement "high carbon equivalent pipe," that designation shall be included.

c. Test data for all tensile tests required by this specification, including yield strength, ultimate tensile strength, and elongation. The type, size, and orientation of specimens shall be shown.

d. Fracture toughness test results (including test type and criteria and the size, location, and orientation of the specimen) where such testing is required.

e. Minimum hydrostatic test pressure and duration.

f. For welded pipe for which nondestructive inspection of the weld seam is required by this specification, the method of nondestructive inspection employed (radiological, ultrasonic, electromagnetic, and/or magnetic particle), and the type and size of all penetrameters and reference standards used.

g. For seamless pipe for which nondestructive inspection (SR4) is required, the method of inspection employed (ultrasonic, electromagnetic, or magnetic particle) and the type and size of the reference standard used.

h. For electric welded pipe and laser welded pipe, the minimum temperature for heat treatment of the weld seam. Where such heat treatment is not performed, the words "No Seam Heat Treatment" shall be stated on the certificate.

i. Results of any supplemental testing required by the purchaser.

SR15.2 The manufacturer shall establish and follow procedures for maintaining heat and lot identity of all pipe covered by this supplementary requirement. The procedures shall provide means for tracing any length of pipe or coupling to the proper heat and lot and to all applicable chemical and mechanical test results.

SR17 Nondestructive Inspection of Welds in Electric Welded Pipe and Laser Welded Pipe

SR17.1 SUPPLEMENTARY NONDESTRUCTIVE INSPECTION

The weld in electric welded pipe shall be inspected full length for surface and subsurface defects by either ultrasonic or electromagnetic methods. The weld in laser-welded pipe shall be inspected full length for surface and subsurface defects by ultrasonic methods. The location of the equipment in the mill shall be at the discretion of the manufacturer. However, the nondestructive inspection shall take place after all heat treating, hydrostatic testing, expansion, and rotary straightening operations, if performed, but may take place before cropping, beveling, and sizing of pipe.

SR17.2 EQUIPMENT AND REFERENCE STANDARDS

The ultrasonic or electromagnetic inspection equipment requirements are given in 9.7.4.1, and the reference standards are described in 9.7.4.2. Details of the specific techniques (such as method, reference standards, transducer properties, and sensitivity) shall be agreed upon between the purchaser and the manufacturer for the implementation of this supplementary requirement.

SR17.3 ACCEPTANCE LIMITS AND EMI INSPECTIONS

Table 21 gives the height of acceptance limit signals in percent of height of signals produced by reference standards. An imperfection that produced a signal greater than the acceptance limit signal given in Table 21 shall be classified as a defect.

SR17.4 DISPOSITION

Defects shall be disposed of in accordance with 9.7.6, Items a, c, and d. Repair by welding is not permitted. If a defect is removed by grinding, the ground area shall be reinspected by the same method originally used.

SR17.5 MARKING

Pipe nondestructively inspected in accordance with this supplementary requirement shall be marked SR17.

SR18 Carbon Equivalent

SR18.1 For pipe grades up to Grade X70 inclusive, the carbon equivalent, CE, calculated using product analysis and the following equation shall not exceed 0.43%:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

SR18.2 The elements analyzed for product analysis shall include all elements contained in the carbon equivalent equation.

SR19 Additional Fracture Toughness Requirements (Transverse Charpy V-Notch) for PSL 2 Pipe

SR19.1 Except as allowed by SR19.2, fracture toughness testing shall be performed in accordance with the requirements of 9.3.5.1 and 9.3.5.2, with a test temperature of 32°F (0°C) or a lower temperature as specified on the purchase order. The required minimum all-heat average full-size absorbed energy value shall be the greater of

a. 30 ft-lb (40 J) for grades below Grade X80, 60 ft-lb (80 J) for Grade X80 pipe; and

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b. The value obtained from the following equation, using a stress factor (F) of 0.72 or a higher value if specified on the purchase order, and rounding the calculated value to the nearest foot-pound (joule):

U.S. Customary Unit Equation

$$CV = 0.0345(F\sigma_y)^{\frac{3}{2}}\left(\frac{D}{2}\right)^{\frac{1}{2}}$$

SI Unit Equation

$$CV = 0.000512(F\sigma_y)^{\frac{3}{2}}\left(\frac{D}{2}\right)^{\frac{1}{2}}$$

where

CV = minimum all-heat average full-size Charpy V-notch absorbed energy requirement, ft-lb (J),

F = stress factor,

σ_y = specified minimum yield strength, ksi (MPa),

D = specified outside diameter, in. (mm).

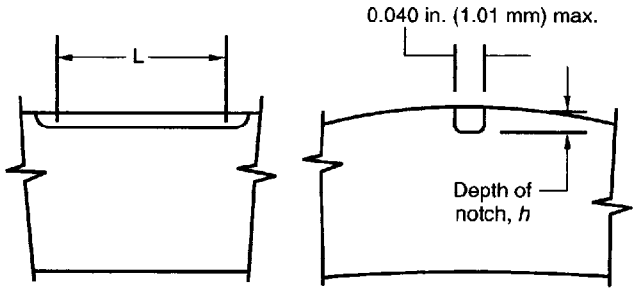
Notes:

1. See Table F-3 for the required minimum all heat-average absorbed energy values for pipe having a standard size and grade, and a stress factor of 0.72.
2. The above equation is one of a number of such relationships derived from full-scale burst test data for a limited number of sizes and grades (see ASME B31.8). It is also judged to be conservative for initiation conditions in pipelines.

SR19.2 Pipe tested at a lower temperature than is required in SR19.1 shall be acceptable if it meets the required absorbed energy values.

SR19.3 Pipe tested in accordance with SR19 shall be marked to indicate the specified (full-size) minimum all-heat average absorbed energy value and the specified test temperature. Temperatures below zero shall be preceded by the letter M, and the absorbed energy specified in joules shall be followed by the letter J.

Example for 30 ft-lb at + 32°F:	SR19-30-32F
Example for 70 J at – 5°C:	SR19-70J-M5C



Depth of notch, h, shall be 12½% of the nominal wall thickness of the pipe being inspected, but not less than 0.012 in. (0.30 mm).

For ultrasonic and eddy current the length of notch at full depth, *L*, shall be at least twice the width of the scanning head.

For diverted flux the length of notch shall be as required by the equipment design to provide a reproducible signal when the reference standard is passed through the equipment at the inspection line speed for the pipe being inspected. Three passes through the equipment shall be required to ensure reproducibility.

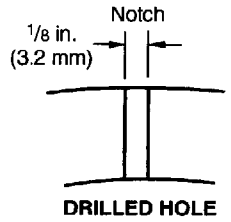


Figure F-1—Reference Standards

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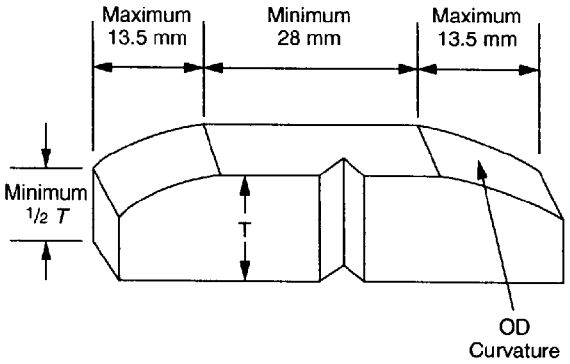

Figure F-2—Impact Test Specimen Tapered End Allowance

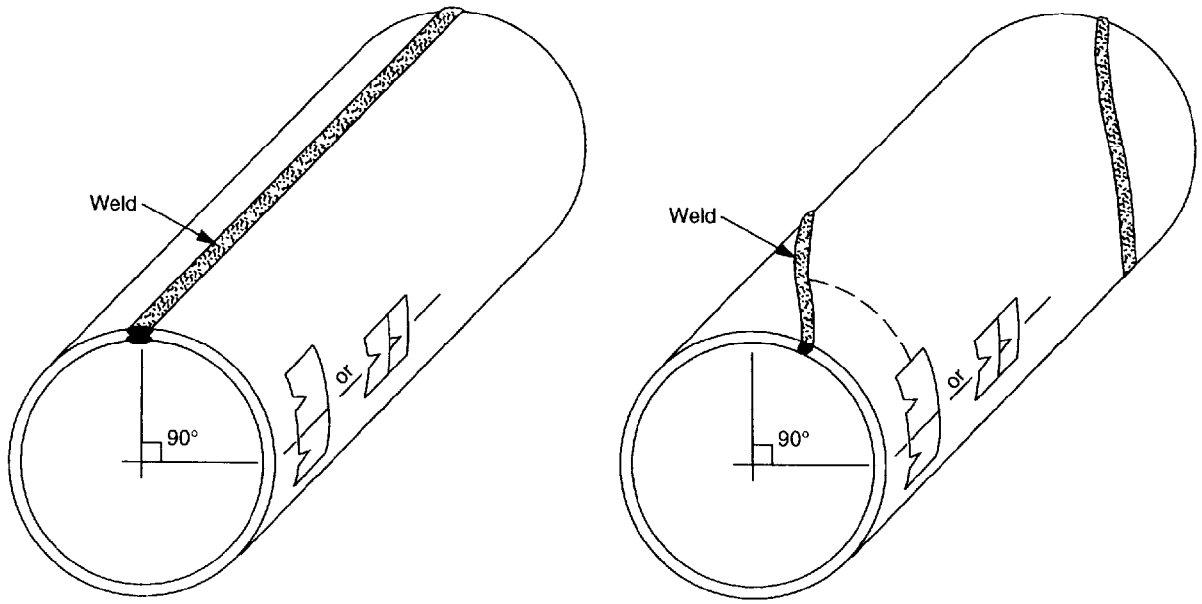

Figure F-3—Charpy V-Notch and Drop-Weight Tear Test Specimen Locations

Table F-1—Minimum Wall Thickness to Obtain Transverse Charpy V-Notch Test Specimens[a]

Size	Minimum Wall Thickness in. (mm)		
	Full Size Specimen	2/3 Size Specimen	1/2 Size Specimen
≥ 4 1/2 and < 5 9/16	0.495 (12.6)	0.429 (10.9)	0.397 (10.1)
≥ 5 9/16 and < 6 5/8	0.469 (11.9)	0.371 (9.4)	0.338 (8.6)
≥ 6 5/8 and < 8 5/8	0.460 (11.7)	0.334 (8.5)	0.301 (7.6)
≥ 8 5/8 and < 10 3/4	0.450 (11.4)	0.318 (8.1)	0.257 (6.5)
≥ 10 3/4 and < 12 3/4	0.443 (11.3)	0.311 (7.9)	0.246 (6.2)
≥ 12 3/4 and < 14	0.438 (11.1)	0.307 (7.8)	0.241 (6.1)
≥ 14 and < 16	0.436 (11.1)	0.305 (7.7)	0.239 (6.1)
≥ 16	0.434 (11.0)	0.304 (7.7)	0.237 (6.0)

[a]This table provides a description of the acceptable specimens and the relationship between pipe dimensions and acceptable specimens. The size limits shown are based upon the use of tapered end transverse specimens (see Figure F-2). These specimen dimension limits include machining tolerances.

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Table F-2—Dimensions, Weights per Unit Length, and Test Pressures for TFL Pipe

(1)	(2)		(3)	(4)		(5)		(6)		(7)	
	Specified Outside Diameter D			Specified Wall Thickness t		Calculated Plain-End Weight per Unit Length w_{pe}		Calculated Inside Diameter[a] d		Minimum Hydrostatic Test Pressure	
Size	in.	mm.	Grade	in.	mm	lb/ft	kg/m	in.	mm	psi	100 kPa[b]
$2^3/_8$	2.375	60.3	X 56	0.188	4.8	4.40	6.57	1.999	50.7	7090	492
$2^7/_8$	2.875	73.0	X 56	0.438	11.1	11.41	16.94	1.999	50.8	10000	689
$2^7/_8$	2.875	73.0	X 56	0.216	5.5	6.14	9.16	2.443	62.0	6730	465
$3^1/_2$	3.500	88.9	X 56	0.530	13.5	16.83	25.10	2.440	61.9	10000	689
4	4.000	101.6	X 60	0.750	19.1	26.06	38.86	2.500	63.4	10000	689
4	4.000	101.6	X 42	0.500	12.7	18.71	27.84	3.000	76.2	8400	579
4	4.000	101.6	X 60	0.500	12.7	18.71	27.84	3.000	76.2	10000	689
4	4.000	101.6	X 70	0.250	6.4	10.02	15.02	3.500	88.8	7000	486
$4^1/_2$	4.500	114.3	X 52	0.750	19.1	30.07	44.84	3.000	76.1	10000	689
$4^1/_2$	4.500	114.3	X 70	0.281	7.1	12.67	18.77	3.938	100.1	6990	480

[a]The calculated inside diameters are given here for information.
[b]100 kPa = 1 bar.

Table F-3 —Minimum All-Heat Average Absorbed Energy Requirements for Stress Factor f of 0.72

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)	
	Minimum All-Heat Average Absorbed Energy, ft-lb (J)																	
	Grade																	
	B		X42		X46		X52		X56		X60		X65		X70		X80	
Size	ft-lb	J	ft-lb	J	ft-lb	J	ft-lb	J	ft-lb	J	ft-lb	J	ft-lb	J	ft-lb	J	ft-lb	J
$4^1/_2$	30	40	30	40	30	40	30	40	30	40	30	40	30	40	30	40	60	80
$5^9/_{16}$	30	40	30	40	30	40	30	40	30	40	30	40	30	40	30	40	60	80
$6^5/_8$	30	40	30	40	30	40	30	40	30	40	30	40	30	40	30	40	60	80
$8^5/_8$	30	40	30	40	30	40	30	40	30	40	30	40	30	40	30	40	60	80
$10^3/_4$	30	40	30	40	30	40	30	40	30	40	30	40	30	40	30	40	60	80
$12^3/_4$	30	40	30	40	30	40	30	40	30	40	30	40	30	40	31	42	60	80
14	30	40	30	40	30	40	30	40	30	40	30	40	30	40	33	44	60	80
16	30	40	30	40	30	40	30	40	30	40	30	40	31	42	35	47	60	80
18	30	40	30	40	30	40	30	40	30	40	30	40	33	45	37	50	60	80
20	30	40	30	40	30	40	30	40	30	40	31	42	35	47	39	53	60	80
22	30	40	30	40	30	40	30	40	30	40	32	44	37	50	41	56	60	80
24	30	40	30	40	30	40	30	40	31	41	34	46	38	52	43	58	60	80
26	30	40	30	40	30	40	30	40	32	43	35	48	40	54	45	60	60	80
28	30	40	30	40	30	40	30	40	33	45	37	50	41	56	46	63	60	80
30	30	40	30	40	30	40	31	42	34	46	38	51	43	58	48	65	60	80
32	30	40	30	40	30	40	32	43	35	48	39	53	44	60	49	67	60	82
34	30	40	30	40	30	40	33	44	36	49	40	55	46	62	51	69	62	84
36	30	40	30	40	30	40	34	45	37	51	42	56	47	63	52	71	64	87
38	30	40	30	40	30	40	34	47	39	52	43	58	48	65	54	73	66	89
40	30	40	30	40	30	40	35	48	40	53	44	59	49	67	55	75	67	91
42	30	40	30	40	30	41	36	49	40	55	45	61	51	69	57	77	69	94
44	30	40	30	40	31	42	37	50	41	56	46	62	52	70	58	79	71	96
46	30	40	30	40	32	43	38	51	42	57	47	64	53	72	59	80	72	98
48	30	40	30	40	32	44	39	53	43	59	48	65	54	73	60	82	74	100
52	30	40	30	40	34	45	40	55	45	61	50	68	56	76	63	85	77	104

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Table F-3 (Continued)—Minimum All-Heat Average Absorbed Energy Requirements for Stress Factor *f* of 0.72

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)	
	Minimum All-Heat Average Absorbed Energy, ft-lb (J)																	
	Grade																	
	B		X42		X46		X52		X56		X60		X65		X70		X80	
Size	ft-lb	J	ft-lb	J	ft-lb	J	ft-lb	J	ft-lb	J	ft-lb	J	ft-lb	J	ft-lb	J	ft-lb	J
56	30	40	30	41	35	47	42	57	47	63	52	70	58	79	65	89	80	108
60	30	40	31	43	36	49	43	59	48	65	54	73	60	82	68	92	83	112
64	30	40	32	44	37	50	45	61	50	68	55	75	62	85	70	95	85	116
68	30	40	33	45	38	52	46	63	52	70	57	77	64	87	72	98	88	119
72	30	40	34	47	39	53	47	64	53	72	59	80	66	90	74	100	90	123
76	30	40	35	48	41	55	49	66	54	74	60	82	68	92	76	103	93	126
80	30	40	36	49	42	56	50	68	56	76	62	84	70	95	78	106	95	129

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APPENDIX G—GUIDED-BEND TEST JIG DIMENSIONS (NORMATIVE)

Table G-1 contains guided-bend test jig dimensions discussed in 9.8.3.

Table G-1 —Guided-Bend Test Jig Dimensions

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)		(11)	
			Dimension A																	
	Specified Wall Thickness		Grade																	
	t		A		B & X42		X46		X52		X56		X60		X65		X70		X80	
Size	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
12 3/4	0.172	4.4	1.0	25.4	1.4	35.6	1.4	35.6	1.6	40.6	1.6	40.6	1.6	40.6	1.6	40.6	1.9	48.3	2.2	55.9
12 3/4	0.188	4.8	1.2	30.5	1.4	35.6	1.6	40.6	1.6	40.6	1.9	48.3	1.9	48.3	1.9	48.3	2.2	55.9	2.6	66.0
12 3/4	0.203	5.2	—	—	1.6	40.6	1.6	40.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0
12 3/4	0.219	5.6	1.4	35.6	1.6	40.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	3.1	78.7
12 3/4	0.250	6.4	1.6	40.6	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.7	94.0
12 3/4	0.281	7.1	1.9	48.3	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
12 3/4	0.312	7.9	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	5.2	132.1
12 3/4	0.330	8.4	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
12 3/4	0.344	8.7	2.2	55.9	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1
12 3/4	0.375	9.5	2.6	66.0	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
12 3/4	0.406	10.3	—	—	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
12 3/4	0.438	11.1	3.1	78.7	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	8.8	223.5
12 3/4	0.500	12.7	—	—	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
12 3/4	0.562	14.3	4.4	111.8	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
12 3/4	0.625	15.9	5.2	132.1	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	18.1	459.7
12 3/4	0.688	17.5	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7	26.0	660.4
12 3/4	0.750	19.1	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2	31.2	792.5
12 3/4	0.812	20.6	8.8	223.5	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5
12 3/4	0.875	22.2	10.5	266.7	15.1	383.5	18.1	459.7	18.1	459.7	21.7	551.2	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5
14	0.188	4.8	1.2	30.5	1.4	35.6	1.6	40.6	1.6	40.6	1.6	40.6	1.9	48.3	1.9	48.3	2.2	55.9	2.6	66.0
14	0.203	5.2	1.2	30.5	1.6	40.6	—	—	—	—	—	—	—	—	—	—	—	—	2.6	66.0
14	0.210	5.3	—	—	1.6	40.6	1.6	40.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0
14	0.219	5.6	—	—	1.6	40.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	3.1	78.7
14	0.250	6.4	1.6	40.6	1.9	48.3	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.7	94.0
14	0.281	7.1	1.9	48.3	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	4.4	111.8
14	0.312	7.9	1.9	48.3	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8
14	0.344	8.7	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
14	0.375	9.5	2.6	66.0	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
14	0.406	10.3	—	—	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	7.4	188.0
14	0.438	11.1	3.1	78.7	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
14	0.469	11.9	—	—	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
14	0.500	12.7	3.7	94.0	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	10.5	266.7
14	0.562	14.3	4.4	111.8	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	12.6	320.0
14	0.625	15.9	5.2	132.1	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
14	0.688	17.5	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
14	0.750	19.1	6.2	157.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	26.0	660.4
14	0.812	20.6	7.4	188.0	10.5	266.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14	0.875	22.2	8.8	223.5	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2	21.7	551.2	31.2	792.5	31.2	792.5
14	0.938	23.8	10.5	266.7	15.1	383.5	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5
16	0.188	4.8	1.2	30.5	1.4	35.6	1.6	40.6	1.6	40.6	1.6	40.6	1.9	48.3	1.9	48.3	2.2	55.9	2.6	66.0
16	0.203	5.2	1.2	30.5	1.6	40.6	1.6	40.6	1.6	40.6	1.9	48.3	1.9	48.3	1.9	48.3	2.2	55.9	2.6	66.0
16	0.219	5.6	1.4	35.6	1.6	40.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.6	55.9	2.6	66.0	3.1	78.7
16	0.250	6.4	1.6	40.6	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7
16	0.281	7.1	1.6	40.6	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0
16	0.312	7.9	1.9	48.3	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
16	0.344	8.7	2.2	55.9	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1

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Table G-1 (Continued)—Guided-Bend Test Jig Dimensions

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)		(11)	
			Dimension A																	
	Specified Wall Thickness t		Grade																	
			A		B & X42		X46		X52		X56		X60		X65		X70		X80	
Size	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
16	0.375	9.5	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	6.2	157.5
16	0.406	10.3	—	—	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5
16	0.438	11.1	3.1	78.7	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
16	0.469	11.9	—	—	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0
16	0.500	12.7	3.7	94.0	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
16	0.562	14.3	4.4	111.8	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
16	0.625	15.9	4.4	111.8	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
16	0.688	17.5	5.2	132.1	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
16	0.750	19.1	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	21.7	551.2
16	0.812	20.6	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	26.0	660.4
16	0.875	22.2	7.4	188.0	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7	18.1	459.7	21.7	551.2	31.2	792.5
16	0.938	23.8	8.8	223.5	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5
16	1.000	25.4	10.5	266.7	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2	26.0	564.2	26.0	564.2	31.2	792.5	31.2	792.5
16	1.062	27.0	10.5	266.7	18.1	459.7	18.1	459.7	21.7	551.2	26.0	564.2	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
16	1.125	28.6	12.6	320.0	21.7	551.2	21.7	551.2	26.0	564.2	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
18	0.188	4.8	1.0	25.4	1.4	35.6	1.4	35.6	1.6	40.6	1.6	40.6	1.9	48.3	1.9	48.3	1.9	48.3	—	—
18	0.219	5.6	1.4	35.6	1.6	40.6	1.6	40.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0
18	0.250	6.4	1.6	40.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7
18	0.281	7.1	1.6	40.6	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0
18	0.312	7.9	1.9	48.3	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
18	0.344	8.7	2.2	55.9	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
18	0.375	9.5	2.2	55.9	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1
18	0.406	10.3	—	—	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
18	0.438	11.1	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	7.4	188.0
18	0.469	11.9	—	—	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
18	0.500	12.7	3.1	78.7	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	8.8	223.5
18	0.562	14.3	3.7	94.0	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	10.5	266.7
18	0.625	15.9	4.4	111.8	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	12.6	320.0
18	0.688	17.5	5.2	132.1	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	15.1	383.5
18	0.750	19.1	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	18.1	459.7
18	0.812	20.6	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	21.7	551.2
18	0.875	22.2	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	26.1	662.9
18	0.938	23.8	8.8	223.5	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	18.1	459.7	21.7	551.2	31.2	792.5
18	1.000	25.4	8.8	223.5	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5
18	1.062	27.0	10.5	266.7	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5	31.2	792.5
18	1.125	28.6	10.5	266.7	18.1	459.7	18.1	459.7	21.7	551.2	26.0	660.4	26.0	660.4	31.2	782.5	31.2	792.5	31.2	792.5
18	1.188	30.2	12.6	320.0	18.1	459.7	21.7	551.2	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
18	1.250	31.8	15.1	383.5	21.7	551.2	26.0	660.4	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
20	0.219	5.6	1.2	30.5	1.6	40.6	1.6	40.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0
20	0.250	6.4	1.6	40.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7
20	0.281	7.1	1.6	40.6	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0
20	0.312	7.9	1.9	48.3	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
20	0.344	8.7	2.2	55.9	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8
20	0.375	9.5	2.2	55.9	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
20	0.406	10.3	—	—	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
20	0.438	11.1	2.6	66.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5
20	0.469	11.9	—	—	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
20	0.500	12.7	3.1	78.7	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0
20	0.562	14.3	3.7	94.0	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5
20	0.625	15.9	4.4	111.8	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
20	0.688	17.5	5.2	132.1	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0

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Table G-1 (Continued)—Guided-Bend Test Jig Dimensions

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)		(11)	
			Dimension A																	
	Specified Wall Thickness		Grade																	
	t		A		B & X42		X46		X52		X56		X60		X65		X70		X80	
Size	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
20	0.750	19.1	5.2	132.1	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
20	0.812	20.6	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
20	0.875	22.2	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	21.7	551.2
20	0.938	23.8	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	18.1	459.7	26.0	660.4
20	1.000	25.4	8.8	223.5	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	18.1	459.7	21.7	551.2	31.2	792.5
20	1.062	27.0	8.8	223.5	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5
20	1.125	28.6	10.5	266.7	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5	31.2	792.5
20	1.188	30.2	10.5	266.7	18.1	459.7	18.1	459.7	21.7	551.2	26.0	660.4	26.0	660.4	26.0	660.4	31.2	792.5	31.2	792.5
20	1.250	31.8	12.6	320.0	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
20	1.312	33.3	12.6	320.0	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
20	1.375	34.9	15.1	383.5	21.7	551.2	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
22	0.219	5.6	1.2	30.5	1.6	40.6	1.6	40.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0
22	0.250	6.4	1.4	35.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7
22	0.281	7.1	1.6	40.6	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.7	94.0
22	0.312	7.9	1.9	48.3	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
22	0.344	8.7	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8
22	0.375	9.5	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
22	0.406	10.3	—	—	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	6.2	157.5
22	0.438	11.1	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5
22	0.469	11.9	—	—	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
22	0.500	12.7	3.1	78.7	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
22	0.562	14.3	3.7	9.0	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
22	0.625	15.9	4.4	111.8	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
22	0.688	17.5	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
22	0.750	19.1	5.2	132.1	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	15.1	383.5
22	0.812	20.6	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
22	0.875	22.2	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
22	0.938	23.8	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2
22	1.000	25.4	7.4	188.0	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	18.1	459.7	26.0	660.4
22	1.062	27.0	8.8	223.5	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	18.1	459.7	21.7	551.2	31.2	792.5
22	1.125	28.6	10.5	266.7	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5
22	1.188	30.2	10.5	266.7	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5	31.2	792.5
22	1.250	31.8	12.6	320.0	18.1	459.7	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	26.0	660.4	31.2	792.5	31.2	792.5
22	1.312	33.3	12.6	30.0	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
22	1.375	34.9	12.6	320.0	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
22	1.438	36.5	15.1	383.5	21.7	551.2	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
22	1.500	38.1	15.1	383.5	26.0	660.4	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
24	0.250	6.4	1.4	35.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7
24	0.281	7.1	1.6	40.6	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.7	94.0
24	0.312	7.9	1.9	48.3	2.2	55.9	2.6	66.0	2.6	66.0	3.1	66.0	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
24	0.344	8.7	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8
24	0.375	9.5	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
24	0.406	10.3	—	—	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1
24	0.438	11.1	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
24	0.469	11.9	—	—	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5
24	0.500	12.7	3.1	78.7	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
24	0.562	14.3	3.7	94.0	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.5	157.5	7.4	188.0	8.8	223.5
24	0.625	15.9	4.4	111.8	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
24	0.688	17.5	4.4	111.8	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	12.6	320.0
24	0.750	19.1	5.2	132.1	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
24	0.812	20.6	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5

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Table G-1 (Continued)—Guided-Bend Test Jig Dimensions

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)		(11)	
			Dimension A																	
	Specified Wall Thickness t		Grade																	
			A		B & X42		X46		X52		X56		X60		X65		X70		X80	
Size	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
24	0.875	22.2	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	18.1	459.7
24	0.938	23.8	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	21.7	551.2
24	1.000	25.4	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2
24	1.062	27.0	8.8	223.5	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	18.1	459.7	26.0	660.4
24	1.125	28.6	8.8	223.5	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7	18.1	459.7	18.1	459.7	21.7	551.2	31.2	792.5
24	1.188	30.2	10.5	266.7	15.1	383.5	15.1	383.5	18.1	459.7	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5
24	1.250	31.8	10.5	266.7	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	26.0	660.4	31.2	792.5
24	1.312	33.3	12.6	320.0	18.1	459.7	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	26.0	660.4	31.2	792.5	31.2	792.5
24	1.375	34.9	12.6	320.0	18.1	459.7	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
24	1.438	36.5	15.1	383.5	21.7	551.2	21.7	551.2	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
24	1.500	38.1	15.1	383.5	21.7	551.2	26.0	660.4	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
24	1.562	39.7	15.1	383.5	26.0	660.4	26.0	660.4	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5	31.2	792.5
26	0.250	6.4	1.4	35.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7
26	0.281	7.1	1.6	40.6	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.7	94.0
26	0.312	7.9	1.9	48.3	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0
26	0.344	8.7	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8
26	0.375	9.5	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
26	0.406	10.3	—	—	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1
26	0.438	11.1	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
26	0.469	11.9	—	—	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5
26	0.500	12.7	3.1	78.7	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
26	0.562	14.3	3.7	94.0	4.4	111.8	5.1	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
26	0.625	15.9	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	10.5	266.7
26	0.688	17.5	4.4	111.8	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7
26	0.750	19.1	5.2	132.1	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
26	0.812	20.6	5.2	132.1	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
26	0.875	22.2	6.2	157.5	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5
26	0.938	23.8	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
26	1.000	25.4	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	21.7	551.2
28	0.250	6.4	1.4	35.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	3.1	78.7
28	0.281	7.1	1.6	40.6	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.7	94.0
28	0.312	7.9	1.9	48.3	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0
28	0.344	8.7	—	—	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8
28	0.375	9.5	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
28	0.406	10.3	—	—	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1
28	0.438	11.1	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
28	0.469	11.9	—	—	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5
28	0.500	12.7	3.1	78.7	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
28	0.562	14.3	3.7	94.0	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	8.8	223.5
28	0.625	15.9	3.7	94.0	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5
28	0.688	17.5	4.4	111.8	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
28	0.750	19.1	5.2	132.1	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
28	0.812	20.6	5.2	132.1	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0
28	0.875	22.2	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
28	0.938	23.8	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
28	1.000	25.4	7.4	188.0	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
30	0.250	6.4	1.4	35.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	3.1	78.7
30	0.281	7.1	1.6	40.6	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.7	94.0
30	0.312	7.9	1.9	48.3	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0
30	0.344	8.7	—	—	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8

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Table G-1 (Continued)—Guided-Bend Test Jig Dimensions

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)		(11)	
			Dimension A																	
	Specified Wall Thickness t		Grade																	
			A		B & X42		X46		X52		X56		X60		X65		X70		X80	
Size	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
30	0.375	9.5	2.2	55.9	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
30	0.406	10.3	-	-	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1
30	0.438	11.1	2.6	66.0	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
30	0.469	11.9	—	—	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5
30	0.500	12.7	3.1	78.7	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
30	0.562	14.3	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0
30	0.625	15.9	3.7	94.0	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5
30	0.688	17.5	4.4	111.8	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
30	0.750	19.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
30	0.812	20.6	5.2	132.1	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0
30	0.875	22.2	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
30	0.938	23.8	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	18.1	459.7
30	1.000	25.4	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
32	0.250	6.4	1.4	35.6	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	3.1	78.7
32	0.281	7.1	1.6	40.6	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.7	94.0
32	0.312	7.9	1.9	48.3	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0
32	0.344	8.7	—	—	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
32	0.375	9.5	2.2	55.9	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	3.7	94.0	5.2	132.1
32	0.406	10.3	—	—	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.7	144.8
32	0.438	11.1	2.6	66.0	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
32	0.469	11.9	—	—	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5
32	0.500	12.7	3.1	78.7	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5
32	0.562	14.3	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0
32	0.625	15.9	3.7	94.0	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
32	0.688	17.5	4.4	111.8	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
32	0.750	19.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7
32	0.812	20.6	5.2	132.1	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
32	0.875	22.2	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0
32	0.938	23.8	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5
32	1.000	25.4	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
32	1.062	27.0	7.4	188.0	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7
32	1.125	28.6	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2
32	1.188	30.2	8.8	223.5	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	18.1	459.7	26.0	660.4
32	1.250	31.8	8.8	223.5	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	18.1	459.7	21.7	551.2	26.0	660.4
34	0.250	6.4	1.4	35.6	1.9	48.3	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	3.1	78.7
34	0.281	7.1	1.6	40.6	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.7	94.0
34	0.312	7.9	1.9	48.3	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0
34	0.344	8.7	—	—	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
34	0.375	9.5	2.2	55.9	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8
34	0.406	10.3	—	—	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
34	0.438	11.1	2.6	66.0	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1
34	0.469	11.9	—	—	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
34	0.500	12.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5
34	0.562	14.3	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0
34	0.625	15.9	3.7	94.0	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
34	0.688	17.5	4.4	111.8	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
34	0.750	19.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7
34	0.812	20.6	5.2	132.1	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	15.0	381.0
34	0.875	22.2	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	15.1	383.5
34	0.938	23.8	6.2	157.5	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
34	1.000	25.4	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7

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Table G-1 (Continued)—Guided-Bend Test Jig Dimensions

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)		(11)	
			Dimension A																	
	Specified Wall Thickness t		Grade																	
			A		B & X42		X46		X52		X56		X60		X65		X70		X80	
Size	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
34	1.062	27.0	7.4	188.0	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
34	1.125	28.6	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2
34	1.188	30.2	8.8	223.5	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2
34	1.250	31.8	8.8	223.5	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	18.1	459.7	18.1	459.7	26.0	660.4
36	0.250	6.4	1.4	35.6	1.9	48.3	1.9	48.3	1.9	48.3	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	3.1	78.7
36	0.281	7.1	1.6	40.6	2.2	55.9	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.7	94.0
36	0.312	7.9	1.9	48.3	2.2	55.	92.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0
36	0.344	8.7	—	—	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
36	0.375	9.5	2.2	55.9	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8
36	0.406	10.3	-	-	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
36	0.438	11.1	2.6	66.0	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1
36	0.469	11.9	—	—	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
36	0.500	12.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5
36	0.562	14.3	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0
36	0.625	15.9	3.7	94.0	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
36	0.688	17.5	4.4	111.8	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
36	0.750	19.1	4.4	111.8	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7
36	0.812	20.6	5.2	132.1	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
36	0.875	22.2	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0
36	0.938	23.8	6.2	157.5	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
36	1.000	25.4	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5
36	1.062	27.0	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
36	1.125	28.6	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	21.7	551.2
36	1.188	30.2	8.8	223.5	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2
36	1.250	31.8	8.8	223.5	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	18.1	459.7	18.1	459.7	26.0	660.4
38	0.312	7.9	1.9	48.3	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0
38	0.344	8.7	1.9	48.3	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
38	0.375	9.5	2.2	55.9	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8
38	0.406	10.3	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
38	0.438	11.1	2.6	66.0	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1
38	0.469	11.9	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
38	0.500	12.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5
38	0.562	14.3	3.1	78.7	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0
38	0.625	15.9	3.7	94.0	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
38	0.688	17.5	4.4	111.8	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5
38	0.750	19.1	4.4	111.8	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7
38	0.812	20.6	5.2	132.1	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
38	0.875	22.2	5.2	132.1	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0
38	0.938	23.8	6.2	157.1	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
38	1.000	25.4	6.2	157.1	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5
38	1.062	27.0	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
38	1.125	28.6	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7
38	1.188	30.2	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2
38	1.250	31.8	8.8	223.5	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2
40	0.312	7.9	1.9	48.3	2.2	55.9	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0
40	0.344	8.7	1.9	48.3	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
40	0.375	9.5	2.2	55.9	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8
40	0.406	10.3	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
40	0.438	11.1	2.6	66.0	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1

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Table G-1 (Continued)—Guided-Bend Test Jig Dimensions

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)		(11)	
			Dimension A																	
	Specified Wall Thickness t		Grade																	
			A		B & X42		X46		X52		X56		X60		X65		X70		X80	
Size	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
40	0.469	11.9	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
40	0.500	12.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5
40	0.562	14.3	3.1	78.7	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0
40	0.625	15.9	3.7	94.0	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.4	7.4	188.0	8.8	223.5
40	0.688	17.5	4.4	111.8	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5
40	0.750	19.1	4.4	111.8	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
40	0.812	20.6	5.2	132.1	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
40	0.875	22.2	5.2	132.1	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0
40	0.938	23.8	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
40	1.000	25.4	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5
40	1.062	27.0	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
40	1.125	28.6	7.4	188.0	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
40	1.188	30.2	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	21.7	551.2
40	1.250	31.8	8.8	223.5	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2
42	0.344	8.7	1.9	48.3	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
42	0.375	9.5	2.2	55.9	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8
42	0.406	10.3	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
42	0.438	11.1	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1
42	0.469	11.9	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
42	0.500	12.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5
42	0.562	14.3	3.1	78.7	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
42	0.625	15.9	3.7	94.0	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
42	0.688	17.5	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5
42	0.750	19.1	4.4	111.8	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
42	0.812	20.6	5.2	132.1	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7
42	0.875	22.2	5.2	132.1	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0
42	0.938	23.8	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	26637	10.5	266.7	12.6	320.0	15.1	383.5
42	1.000	25.4	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
42	1.062	27.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	18.1	459.7
42	1.125	28.6	7.4	188.0	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
42	1.188	30.2	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	18.1	459.7
42	1.250	31.8	8.8	223.5	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2
44	0.344	8.7	1.9	48.3	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
44	0.375	9.5	2.2	55.9	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8
44	0.406	10.3	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
44	0.438	11.1	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1
44	0.469	11.9	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
44	0.500	12.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5
44	0.562	14.3	3.1	78.7	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
44	0.625	15.9	3.7	94.0	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
44	0.688	17.5	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5
44	0.750	19.1	4.4	111.8	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
44	0.812	20.6	5.2	132.1	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7
44	0.875	22.2	5.2	132.1	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
44	0.938	23.8	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0
44	1.000	25.4	6.2	157.5	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	408.9
44	1.062	27.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5
44	1.125	28.6	7.4	188.0	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
44	1.188	30.2	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7
44	1.250	31.8	8.8	223.5	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	18.1	489.7	21.7	551.2

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Table G-1 (Continued)—Guided-Bend Test Jig Dimensions

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)		(11)	
			Dimension A																	
	Specified Wall Thickness t		Grade																	
			A		B & X42		X46		X52		X56		X60		X65		X70		X80	
Size	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
46	0.344	8.7	1.9	48.3	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
46	0.375	9.5	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8
46	0.406	10.3	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
46	0.438	11.1	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1
46	0.469	11.9	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
46	0.500	12.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5
46	0.562	14.3	3.1	78.7	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
46	0.625	15.9	3.7	94.0	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
46	0.688	17.5	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5
46	0.750	19.1	4.4	111.8	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
46	0.812	20.6	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7
46	0.875	22.2	5.2	132.1	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
46	0.938	23.8	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0
46	1.000	25.4	6.2	157.5	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
46	1.062	27.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5
46	1.125	28.6	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
46	1.188	30.2	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7
46	1.250	31.8	8.8	223.5	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7	21.7	551.2
48	0.344	8.7	1.9	48.3	2.6	66.0	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	4.4	111.8
48	0.375	9.5	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8
48	0.406	10.3	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
48	0.438	11.1	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1
48	0.469	11.9	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
48	0.500	12.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.7	170.2
48	0.562	14.3	3.1	78.7	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
48	0.625	15.9	3.7	94.0	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
48	0.688	17.5	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5
48	0.750	19.1	4.4	111.8	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
48	0.812	20.6	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7
48	0.875	22.2	5.2	132.1	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
48	0.938	23.8	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.3	266.7	12.6	320.0
48	1.000	25.4	6.2	157.5	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
48	1.062	27.0	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5
48	1.125	28.6	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
48	1.188	30.2	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
48	1.250	31.8	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	21.7	551.2
52	0.375	9.5	2.2	55.9	2.6	6.0	2.6	66.	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8
52	0.406	10.3	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
52	0.438	11.1	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.4	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1
52	0.469	11.9	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
52	0.500	12.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5
52	0.562	14.3	3.1	78.7	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
52	0.625	15.9	3.7	94.0	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0
52	0.688	17.5	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5
52	0.750	19.1	4.4	111.8	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
52	0.812	20.6	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7
52	0.875	22.2	5.2	132.1	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
52	0.938	23.8	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0
52	1.000	25.4	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
52	1.062	27.0	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5
52	1.125	28.6	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	18.1	459.7

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Table G-1 (Continued)—Guided-Bend Test Jig Dimensions

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)		(11)	
			Dimension A																	
	Specified Wall Thickness t		Grade																	
			A		B & X42		X46		X52		X56		X60		X65		X70		X80	
Size	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
52	1.188	30.2	7.4	188.0	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
52	1.250	31.8	8.8	223.6	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	15.1	383.5	18.1	459.7
56	0.375	9.5	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8
56	0.406	10.3	2.2	55.9	3.1	78.7	3.7	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
56	0.438	11.1	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1
56	0.469	11.9	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
56	0.500	12.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
56	0.562	14.3	3.1	78.7	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
56	0.625	15.9	3.7	94.0	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0
56	0.688	17.5	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5
56	0.750	19.1	4.4	111.8	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
56	0.812	20.6	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7
56	0.875	22.2	5.2	132.1	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
56	0.938	23.8	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0
56	1.000	25.4	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
56	1.062	27.0	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
56	1.125	28.6	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5
56	1.188	30.2	7.4	188.0	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
56	1.250	31.8	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	15.1	383.5	18.1	459.7
60	0.375	9.5	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8
60	0.406	10.3	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
60	0.438	11.1	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1
60	0.469	11.9	2.6	66.0	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1
60	0.500	12.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
60	0.562	14.3	3.1	78.7	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
60	0.625	15.9	3.7	94.0	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0
60	0.688	17.5	3.7	94.0	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
60	0.750	19.1	4.4	111.8	5.2	312.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5
60	0.812	20.6	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7
60	0.875	22.2	5.2	132.1	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7
60	0.938	23.8	5.2	132.1	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0
60	1.000	25.4	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0
60	1.062	27.0	6.2	157.5	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
60	1.125	28.6	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5
60	1.188	30.2	7.4	188.0	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
60	1.250	31.8	7.4	188.0	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
64	0.375	9.5	2.2	55.9	2.6	66.0	2.6	66.0	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8
64	0.406	10.3	2.2	55.9	3.1	78.7	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	5.2	132.1
64	0.438	11.1	2.6	66.0	3.1	78.7	3.1	78.7	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1
64	0.469	11.9	2.6	66.0	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1
64	0.500	12.7	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
64	0.562	14.3	3.1	78.7	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
64	0.625	15.9	3.7	94.0	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0
64	0.688	17.5	3.7	94.0	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
64	0.750	19.1	4.4	111.8	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5
64	0.812	20.6	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7
64	0.875	22.2	5.2	132.1	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7
64	0.938	23.8	5.2	132.1	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
64	1.000	25.4	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0
64	1.062	27.0	6.2	157.5	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5

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Table G-1 (Continued)—Guided-Bend Test Jig Dimensions

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)		(11)	
			Dimension A																	
	Specified Wall Thickness t		Grade																	
			A		B & X42		X46		X52		X56		X60		X65		X70		X80	
Size	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
64	1.125	28.6	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5
64	1.188	30.2	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
64	1.250	31.8	7.4	188.0	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
68	0.469	11.9	2.6	66.0	3.1	78.7	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1
68	0.500	12.7	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
68	0.562	14.3	3.1	78.7	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	7.4	188.0
68	0.625	15.9	3.7	94.0	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0
68	0.688	17.5	3.7	94.0	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
68	0.750	19.1	4.4	111.8	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5
68	0.812	20.6	5.2	132.1	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
68	0.875	22.2	5.2	132.1	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7
68	0.938	23.8	5.2	132.1	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
68	1.000	25.4	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0
68	1.062	27.0	6.2	157.5	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
68	1.125	28.6	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5
68	1.188	30.2	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5
68	1.250	31.8	7.4	188.0	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
72	0.500	12.7	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
72	0.562	14.3	3.1	78.7	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5
72	0.625	15.9	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0
72	0.688	17.5	3.7	94.0	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
72	0.750	19.1	4.4	111.8	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5
72	0.812	20.6	4.4	111.8	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
72	0.875	22.2	5.2	132.1	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7
72	0.938	23.8	5.2	132.1	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
72	1.000	25.4	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0
72	1.062	27.0	6.2	157.7	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
72	1.125	28.6	7.4	188.0	8.8	233.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	15.1	383.5
72	1.188	30.2	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5
72	1.250	31.8	7.4	188.0	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
76	0.500	12.7	2.6	66.0	3.7	94.0	3.7	94.0	3.7	94.0	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	6.2	157.5
76	0.562	14.3	3.1	78.7	4.4	111.8	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5
76	0.625	15.9	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0
76	0.688	17.5	3.7	94.0	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
76	0.750	19.1	4.4	111.8	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5
76	0.812	20.6	4.4	111.8	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
76	0.875	22.2	5.2	132.1	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7
76	0.938	23.8	5.2	132.1	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
76	1.000	25.4	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0
76	1.062	27.0	6.2	157.5	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
76	1.125	28.6	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
76	1.188	30.2	7.4	188.0	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5
76	1.250	31.8	7.4	188.0	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7
80	0.562	14.3	3.1	78.7	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	5.2	132.1	6.2	157.5	6.6	167.6
80	0.625	15.9	3.7	94.0	4.4	111.8	4.4	111.8	5.2	132.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0
80	0.688	17.5	3.7	94.0	5.2	132.1	5.2	312.1	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	8.8	223.5
80	0.750	19.1	4.4	111.8	5.2	132.1	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5
80	0.812	20.6	4.4	111.8	6.2	157.5	6.2	157.5	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	10.5	266.7
80	0.875	22.2	5.2	132.1	6.2	157.5	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7

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Table G-1 (Continued)—Guided-Bend Test Jig Dimensions

(1)	(2)		(3)		(4)		(5)		(6)		(7)		(8)		(9)		(10)		(11)	
			Dimension A																	
	Specified Wall Thickness		Grade																	
	t		A		B & X42		X46		X52		X56		X60		X65		X70		X80	
Size	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
80	0.938	23.8	5.2	132.1	7.4	188.0	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	8.8	223.5	10.5	266.7	12.6	320.0
80	1.000	25.4	6.2	157.5	7.4	188.0	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0
80	1.062	27.0	6.2	157.5	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0
80	1.125	28.6	6.2	157.5	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	15.1	383.5
80	1.188	30.2	7.4	188.0	8.8	223.5	8.8	223.5	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5
80	1.250	31.8	7.4	188.0	10.5	266.7	10.5	266.7	10.5	266.7	12.6	320.0	12.6	320.0	12.6	320.0	15.1	383.5	18.1	459.7

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APPENDIX H—PURCHASER INSPECTION (NORMATIVE)

H.1 Inspection Notice

Where the inspector representing the purchaser desires to inspect pipe or witness tests, reasonable notice shall be given of the time at which the run is to be made.

H.2 Plant Access

The inspector representing the purchaser shall have unrestricted access, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that will concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy the inspector that the pipe is being manufactured in accordance with this specification. All inspections should be made at the place of manufacture prior to shipment, unless otherwise specified on the purchase order, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

H.3 Compliance

The manufacturer is responsible for complying with all of the provisions of this specification. The purchaser may make any investigation necessary to satisfy himself of compliance by the manufacturer and may reject any material that does not comply with this specification.

H.4 Rejection

Unless otherwise provided, material that shows defects on inspection or subsequent to acceptance at the manufacturer's works, or material that proves defective when properly applied in service, may be rejected and the manufacturer so notified. If tests that require the destruction of material are made, any product proven not to have met the requirements of the specification shall be rejected. Disposition of rejected product shall be a matter of agreement between the manufacturer and the purchaser.

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APPENDIX I—MARKING INSTRUCTIONS FOR API LICENSEES (NORMATIVE)

I.1 General

The marking requirements in this appendix apply to licensed manufacturers using the API monogram on products covered by this specification.

Pipe and pipe couplings manufactured in conformance with this specification may be marked by the licensee as specified in Appendix I or Section 10. Products to which the monogram is applied shall be marked as specified in Appendix I.

I.1.1 The required marking on pipe shall be as stipulated hereinafter.

I.1.2 The required marking on couplings shall be die stamped unless otherwise agreed between the purchaser and the manufacturer, in which case they shall be paint stenciled.

I.1.3 Additional markings, including those for compatible standards following the specification marking, are allowed and may be applied as desired by the manufacturer or as requested by the purchaser.

I.2 Location of Markings

The location of identification markings shall be as specified in I2.1 – I2.3.

I.2.1 SIZES 1.900 AND SMALLER

The marking is die stamped on a metal tag fixed to the bundle, or may be printed on the straps or banding clips used to tie the bundle.

I.2.2 SEAMLESS PIPE IN ALL OTHER SIZES AND WELDED PIPE SMALLER THAN SIZE 16

Paint stencil on the outside surface starting at a point between 18 in. and 30 in. (460 and 760 mm) from the end of the pipe, and in the sequence shown in I.3, except when agreed between the purchaser and the manufacturer, some or all of the markings may be placed on the inside surface in a sequence convenient to the manufacturer.

I.2.3 WELDED PIPE SIZES 16 AND LARGER

Paint stencil on the inside surface starting at a point no less than 6 in. from the end of the pipe in a sequence convenient to the manufacturer, unless otherwise specified by the purchaser.

I.3 Sequence of Markings

The sequence of identification markings shall be as specified in I.3.1 – I.3.10.

I.3.1 MANUFACTURER'S API LICENSE NUMBER

The manufacturer's API license number shall be marked. (The manufacturer's name or mark is optional.)

I.3.2 API MONOGRAM ([MONOGRAM]) AND DATE

The API monogram ( ), immediately followed by the date of manufacture (defined as the month and year when the monogram is applied), shall be applied only to products complying with the requirements of the specification and only by authorized manufacturers.

I.3.3 COMPATIBLE STANDARDS

Products in compliance with multiple compatible standards may be marked with the name of each standard.

I.3.4 SPECIFIED DIMENSIONS

The specified outside diameter and the specified wall thickness shall be marked, except that, for the specified outside diameter, any ending zero digits to the right of the decimal need not be included in such markings.

I.3.5 GRADE AND CLASS

The symbols to be used are as follows:

Grade (see Note)	Symbol
Grade A25-Class I	A25
Grade A25-Class II	A25R
Grade A	A
Grade B	B
Grade X42	X42
Grade X46	X46
Grade X52	X52
Grade X56	X56
Grade X60	X60
Grade X65	X65
Grade X70	X70
Grade X80	X80

Note: See 1.3 for limitations on down-grading.

For grades intermediate to X42 and X80, the symbol shall be X followed by the first two digits of the specified minimum yield strength in U.S. Customary units.

By agreement between the purchaser and the manufacturer and when so specified on the purchase order, the grade shall be identified by color in accordance with SR3.

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I.3.6 PRODUCT SPECIFICATION LEVEL

The symbols to be used are as follows:

a. PSL 1	PSL1
b. PSL 2	PSL2

The PSL marking shall be placed immediately after the grade symbol.

I.3.7 PROCESS OF MANUFACTURE

The symbols to be used are as follows:

a. Seamless pipe	S
b. Welded pipe, except continuous welded and laser welded	E
c. Continuous welded pipe	F
d. Laser welded pipe	L

I.3.8 HEAT TREATMENT

The symbols to be used are as follows:

a. Normalized or normalized and tempered	HN
b. Subcritical stress relieved	HS
c. Subcritical age hardened	HA
d. Quench and Tempered	HQ

I.3.9 TEST PRESSURE

When the specified hydrostatic test pressure is higher than the tabulated standard pressure (Tables 4, 5, 6A, 6B, 6C, E-6A, E-6B, or E-6C, whichever is applicable), the word "TESTED" shall be marked, immediately followed by the specified test pressure (in pounds per square inch for pipe ordered in U.S. Customary units, or in hundreds of kilopascals for pipe ordered in SI units).

I.3.10 SUPPLEMENTARY REQUIREMENTS

See Appendix F for supplementary requirements.

I.3.11 EXAMPLES

a. Size 14, 0.375 in. (9.5 mm) specified wall thickness, Grade B, PSL 2, seamless, plain-end pipe should be paint stenciled as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

5LXXXX.X API (MO-YR) 14 0.375 B PSL2 S

or

5LXXXX.X API (MO-YR) 355.6 9.5 B PSL2 S

b. Size $6^5/_8$, 0.280 in. (7.1 mm) specified wall thickness, Grade B, PSL 1, electric welded, plain-end pipe should be paint stenciled as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

5LXXXX.X API (MO-YR) 6.625 0.280 B PSL1 E

or

5LXXXX.X API (MO-YR) 168.3 7.1 B PSL1 E

c. Size $4^1/_2$, 0.237 in. (6.0 mm) specified wall thickness, Grade A25, Class I, continuous welded, threaded-end pipe should be paint stenciled as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

5LXXXX.X API (MO-YR) 4.5 0.237 A25 PSL1 F

or

5LXXXX.X API (MO-YR) 114.3 6.0 A25 PSL1 F

d. Size 14, 0.375 in. (9.5 mm) specified wall thickness, Grade X70, PSL 2, seamless, quenched and tempered, plain-end pipe should be paint stenciled as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

5LXXXX.X API (MO-YR) 14 0.375 X70 PSL2 S HQ

or

5LXXXX.X API (MO-YR) 355.6 9.5 X70 PSL2 S HQ

e. Size $12^3/_4$, 0.330 in. (8.4 mm) specified wall thickness, Grade X42, PSL 1, seamless plain-end pipe should be paint stenciled as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

5LXXXX.X API (MO-YR) 12.75 0.330 X42 PSL1 S

or

5LXXXX.X API (MO-YR) 323.9 8.4 X42 PSL1 S

f. Size $6^5/_8$, 0.216 in. (5.5 mm) specified wall thickness, Grade X42, PSL 1, laser welded, plain-end pipe should be paint stenciled as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

5LXXXX.X API (MO-YR) 6.625 0.216 X42 PSL1 L

or

5LXXXX.X API (MO-YR) 168.3 5.5 X42 PSL1 L

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g. Size 24, 0.406 in. (10.3 mm) specified wall thickness, Grade X42, PSL 2 helical seam submerged-arc welded plain-end pipe should be paint stenciled as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

5LXXXX.X ⟨API⟩ (MO-YR) 24 0.406 X42 PSL2 E

or

5LXXXX.X ⟨API⟩ (MO-YR) 610 10.3 X42 PSL2 E

I.4 Bundle Identification

For pipe of size 1.900 or smaller, the identification markings specified in I.3 shall be placed on the tag, strap, or clip used to tie the bundle. For example, size 1.900, 0.145 in. (3.7 mm) specified wall thickness, Grade B, electric welded, plain-end pipe should be marked as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

5LXXXX.X ⟨API⟩ (MO-YR) 1.9 0.145 B PSL1 E

or

5LXXXX.X ⟨API⟩ (MO-YR) 48.3 3.7 B PSL1 E

I.5 Length

In addition to the identification markings stipulated in I.2, I0.3, and I0.4, the length shall be marked as follows, using feet and tenths of a foot for pipe ordered in U.S. Customary units, or meters to two decimal places for pipe ordered in SI units, unless a different measuring and marking format has been agreed upon by the purchaser and manufacturer:

a. For pipe larger than size 1.900, the length, as measured on the finished pipe, shall be paint stenciled on the outside surface at a location convenient to the manufacturer, or by agreement between the purchaser and the manufacturer, on the inside surface at a convenient location.
b. For pipe of size 1.900 or smaller, the total length of pipe in the bundle shall be marked on the tag, band, or clip.

I.6 Couplings

All couplings in sizes $2^3/_8$ and larger shall be identified with the manufacturer's name or mark and the API monogram (⟨API⟩), immediately followed by the date of manufacture (defined as the month and year when the monogram is applied).

I.7 Die Stamping

Cold die stamping of grades higher than A25 plate or pipe not subsequently heat treated and all pipe with wall thickness of 0.156 in. (4.0 mm) and less is prohibited, except that by agreement between the purchaser and the manufacturer and when so specified on the purchase order, pipe or plate may be cold die stamped. The manufacturer at his option may hot die stamp [200°F (93°C) or higher] plate or pipe, cold die stamp plate or pipe if it is subsequently heat treated, and cold die stamp couplings. Cold die stamping shall be done with rounded or blunt dies. All die stamping shall be at least 1 in. (25 mm) from the weld for all grades except Grade A25.

I.8 Thread Identification

At the manufacturer's option, threaded-end pipe may be identified by stamping or stenciling the pipe adjacent to the threaded ends, with the threader's API license number, the API monogram (⟨API⟩), immediately followed by the date of threading (defined as the month and year the monogram is applied), the specified outside diameter of the pipe, and LP to indicate the type of thread. The thread marking may be applied to products that do or do not bear the API monogram. For example, size $6^5/_8$ threaded-end pipe may be marked as follows, using the value that is appropriate for the pipe outside diameter specified on the purchase order:

5LXXXX.X ⟨API⟩ (MO-YR of threading) 6.625 LP

or

5LXXXX.X ⟨API⟩ (MO-YR of threading) 168.3 LP

If the product is clearly marked elsewhere with the manufacturer's identification, his license number, as above, may be omitted.

I.9 Thread Certification

The use of the monogram (⟨API⟩) as provided in I.8 shall constitute a certification by the manufacturer that the threads so marked comply with the requirements stipulated in the latest edition of API Standard 5B but should not be construed by the purchaser as a representation that the product so marked is, in its entirety, in accordance with any API specification. Manufacturers who use the monogram (⟨API⟩) for thread identification are required to have access to properly certified API reference master pipe gages.

I.10 Pipe Processor Markings

Pipe heat treated by a processor other than the original pipe manufacturer shall be marked as stipulated in I.1 through I.7. The processor shall remove any identification that is not indicative of a new condition of the product as a result of heat treating (such as, prior grade and original pipe manufacturer's name or logo).

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APPENDIX J—SUMMARY OF DIFFERENCES BETWEEN PSL 1 AND PSL 2 (INFORMATIVE)

Parameter	PSL 1	PSL 2	Reference
Grade range	A25 through X70	B through X80	Table 1
Size range	0.405 through 80	$4^1/_2$ through 80	Table 1
Type of Pipe Ends	Plain-end, threaded-end; belled-end; special coupling pipe	Plain-end	Table 1
Seam welding	All methods; continuous welding limited to Grade A25	All methods except continuous and laser welding	Table 1
Electric welds: welder frequency	No minimum	100 kHz minimum	5.1.3.3.2
Heat treatment of electric welds	Required for grades > X42	Required for all grades (B through X80)	5.1.3.3.1; 5.1.3.3.2; 6.2.7
Chemistry: max C for seamless pipe	0.28% for grades ≥ B	0.24%	Tables 2A, 2B
Chemistry: max C for welded pipe	0.26% for grades ≥ B	0.22%	Tables 2A, 2B
Chemistry: max P	0.030% for grades ≥ A	0.025%	Tables 2A, 2B
Chemistry: max S	0.030%	0.015%	Tables 2A, 2B
Carbon Equivalent:	Only when purchaser specifies SR18	Maximum required for each grade	4.2; 4.3; 6.1.3; SR15.1
Yield Strength, Maximum	None	Maximum for each grade	Tables 3A, 3B
UTS, Maximum	None	Maximum for each grade	Tables 3A, 3B
Fracture Toughness	None required	Required for all grades	6.2.6; 9.3.5; 9.8.4; 9.10.7; Table 14
Nondestructive inspection of seamless	Only when purchaser specifies SR4	SR4 mandatory	9.7.2.6
Repair by welding of pipe body, plate, and skelp	Permitted	Prohibited	5.3.2; 9.7.6; B.1; B.2
Repair by welding of weld seams without filler metal	Permitted by agreement	Prohibited	4.3; 9.7.4.4; 9.7.6; B.1.2; B.4
Certification	Certificates when specified per SR15	Certificates (SR15.1) mandatory	12.1
Traceability	Traceable only until all tests are passed, unless SR 15 is specified	Traceable after completion of tests (SR15.2) mandatory	5.6

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APPENDIX K—END LOAD COMPENSATION FOR HYDROSTATIC TEST PRESSURES IN EXCESS OF 90% OF SPECIFIED MINIMUM YIELD STRENGTH (NORMATIVE)

(By agreement between the purchaser and the manufacturer, the following method may be used to determine the hydrostatic test pressure.)

K.1 As a measure to prevent distortion when testing at pressures equivalent to stresses in excess of 90% of specified minimum yield strength, the manufacturer may apply a calculation to compensate for the forces applied to the pipe end that produce a compressive longitudinal stress. The calculation in this appendix is based on Barlow's equation (see 9.4.3) modified by a factor based on the Maximum Shear Theory (see note). The calculation may be applied only when testing in excess of 90% of the specified minimum yield strength. In no case may the gage pressure for testing be less than that calculated using Barlow's equation at 90% of specified minimum yield strength.

Note: The calculation is an approximation of the effective hoop stress (SE), which is practical for application under mill pipe testing conditions. Other calculations provide closer approximations of effective hoop stress but are complex and therefore impractical for application.

K.2 The test pressure calculated shall be rounded to the nearest 10 psi (100 kPa).

K.3 The hydrostatic test pressure compensated for pipe end loading shall be calculated according to the following equation:

U.S. Customary Unit Equation:

$$P_1 = \frac{S_E - \frac{P_R A_R}{A_p}}{\frac{D}{2t} - \frac{A_1}{A_p}}$$

SI Unit Equation:

$$P_1 = 1000\frac{S_E - \frac{P_R A_R}{A_p}}{\frac{D}{2t} - \frac{A_1}{A_p}}$$

where

A_1 = internal cross-sectional area of pipe,

A_P = cross-sectional area of pipe wall,

A_R = cross-sectional area of ram,

P_1 = hydrostatic test pressure in psi (kPa),

P_R = internal pressure on end-sealing ram,

S_E = effective hoop stress in psi (MPa) equal to a percentage of the specified minimum yield strength,

D = specified outside diameter, in. (mm),

t = specified wall thickness, in. (mm).

K.4 The above equation may be manipulated algebraically to provide calculation in other terms appropriate to the manufacturer's testing facility.

K.5 Appropriate techniques for the control of effective hoop stress based on measurements of internal pipe and ram pressures vary according to hydrotester system design. The manufacturer shall provide a control technique appropriate to his installation.

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APPENDIX M—CONVERSION PROCEDURES

The following procedures were used to make the soft metric conversions of U.S. Customary units to SI units in the metric conversion of API Spec 5L.

M.1 Fractions

Fractions and numbers with fractions in U.S. Customary units were converted to the full decimal equivalent in U.S. Customary units without rounding, and the full decimal equivalents in U.S. Customary units were then converted to SI values using the following formula:

$$N_m = 25.4 \bullet N$$

where

N_m = the SI equivalent of dimensions with fractions in U.S. Customary units, mm,

N = the full decimal equivalent of dimensions with fractions without rounding, in.

The SI equivalents of dimensions with fractions in U.S. Customary units were then rounded to the appropriate number of places in mm.

M.2 Outside Diameter

The U.S. Customary values for outside diameters of pipe and couplings were converted to SI values using the following formula:

$$D_m = 25.4 \bullet D$$

where

D_m = SI outside diameter, mm,

D = outside diameter, in.

The SI outside diameters of pipe and couplings smaller than size 18 were rounded to the nearest 0.1 mm. The SI outside diameters of pipe and couplings size 18 and larger were rounded to the nearest 1.0 mm.

M.3 Wall Thickness

The U.S. Customary values for wall thickness were converted to SI values using the following formula:

$$t_m = 25.4 \bullet t$$

where

t_m = SI wall thickness, mm,

t = wall thickness, in.

The SI wall thicknesses were rounded to the nearest 0.1 mm.

M.4 Inside Diameter

The SI inside diameters of pipe were calculated (not converted) using the following formula:

$$d_m = D_m - 2 \bullet t_m$$

where

d_m = SI inside diameter, mm,

D_m = SI outside diameter, mm,

t_m = SI wall thickness, mm.

The SI inside diameters were rounded to the nearest 0.1 mm.

M.5 Plain End Linear Density

The SI plain end linear densities were calculated (not converted) using the following formula:

$$W_{pem} = 0.0246615(D_m - t_m)t_m$$

where

W_{pem} = SI plain end linear density, kg/m,

D_m = SI outside diameter, mm,

t_m = SI wall thickness, mm.

The SI plain end linear densities are rounded to the nearest 0.01 kg/m.

M.6 Yield Strength and Tensile Strength

The U.S. Customary values for yield strength and tensile strength were converted to SI values using the following formula:

$$ys_m = 0.00689476 \bullet ys$$

$$ts_m = 0.00689476 \bullet ts$$

where

ys_m = SI yield strength, MPa,

y_s = yield strength, psi,

ts_m = SI tensile strength, MPa,

t_s = tensile strength, psi.

The converted SI strengths were rounded to the nearest 1 MPa.

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M.7 Hydrostatic Test Pressure

The U.S. Customary values for hydrostatic test pressures for all sizes of threaded pipe, all Grade A25 plain-end pipe smaller than size $5^9/_{16}$, and all Grade A and Grade B plain-end pipe smaller than size $2^3/_8$ were converted to SI values using the following formula:

$$P_m = 0.00689476 \bullet P$$

The converted hydrostatic test pressures were rounded to the nearest 100 kPa.

The SI hydrostatic test pressures for plain-end size $5^9/_{16}$, Grade A25 and for sizes $2^3/_8$ and larger Grades A and higher were calculated (not converted) using the following formula:

$$P_m = 2{,}000 \bullet f \bullet ys_m \bullet t_m / D_m$$

where

P_m = SI hydrostatic test pressure, kPa,

P = hydrostatic test pressure, psi,

f = stress factor, see table below,

ys_m = SI yield strength, MPa,

t_m = SI wall thickness, mm,

D_m = SI outside diameter, mm.

The calculated hydrostatic test pressure were rounded to the nearest 100 kPa, not to exceed 17 200 kPa for sizes $3^1/_2$ and smaller or 19 300 kPa for sizes larger than $3^1/_2$.

The calculated standard hydrostatic test pressures for Grades X42 and higher were rounded to the nearest 100 kPa, not to exceed 20 700 kPa. The calculated alternative hydrostatic test pressure for Grades X42 and higher were rounded to the nearest 100 kPa, not to exceed 50 000 kPa for sizes smaller than 16, or 25 000 kPa for sizes 16 and larger.

		f Factor	
Grade	Size	Standard Test Pressure	Alternative Test Pressure
A25	$5^9/_{16}$	0.60	—
A & B	$\geq 2^3/_8$	0.60	0.75
X42 & higher	$\leq 5^9/_{16}$	0.60	0.75
	$> 5^9/_{16}$ and $\leq 8^5/_8$	0.75	0.75
	$> 8^5/_8$ and < 20	0.85	0.85
	≥ 20	0.90	0.90

M.8 Temperature

The U.S. Customary values for temperatures were converted to SI values using the following formula:

$$°C = {}^5/_9 (°F - 32)$$

where

°C = SI temperature, degrees Celsius,

°F = temperature, degrees Fahrenheit.

The SI temperatures were rounded to the nearest 1°C.

M.9 Charpy Impact Energy

The U.S. Customary values for impact energy were converted to SI values using the following formula:

$$E_m = 1.35582 \bullet E$$

where

E_m = Energy, J,

E = Energy, ft-lb.

The SI energy values were rounded to the nearest 1 J.

M.10 Minimum Length of Couplings

The U.S. Customary values for the minimum lengths of couplings in inches and fractions were converted to full decimal equivalents in U.S. Customary units without rounding, and then the full decimal equivalents were converted to SI values using the following formula:

$$N_{Lm} = 25.4 \bullet N_L$$

where

N_{Lm} = SI minimum length of couplings, mm,

N_L = the full decimal equivalent, without rounding, of the minimum lengths of couplings, in.

The SI minimum lengths of coupling were rounded to the nearest 0.01 mm.

M.11 Diameter of Coupling Recess

The U.S. Customary values for diameters of the coupling recess's were converted to SI values using the following formula:

$$Q_m = 25.4 \bullet Q$$

where

Q_m = SI diameter of the coupling recess, mm,

Q = diameter of the coupling recess, in.

The SI diameter of the couplings recesses were rounded to the nearest 0.01 mm.

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M.12 Width of the Coupling Bearing Face

The U.S. Customary values for widths of the bearing face of couplings were converted to SI values using the following formula:

$$b_m = 25.4 \bullet b$$

where

b_m = SI width of the coupling bearing face, mm,

b = width of the coupling bearing face, in.

The SI width of the coupling bearing face were rounded to the nearest 0.1 mm.

M.13 Coupling Weights

The U.S. Customary values for calculated coupling weights were converted to SI values using the following formula:

$$W_m = 0.4535924 \bullet w$$

where

W_m = SI calculated coupling weight, kg,

w = calculated coupling weight, lb.

The SI calculated coupling weights were rounded to the nearest 0.01 kg.

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Specification for Low Pressure Fiberglass Line Pipe

API SPECIFICATION 15LR (SPEC 15LR)
SIXTH EDITION, SEPTEMBER 1, 1990

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SUGGESTIONS FOR ORDERING API FIBERGLASS LINE PIPE

In placing orders for line pipe to be manufactured in accordance with API Spec 15LR the purchaser may specify the following on the purchase order:

Specification	API Spec 15LR
Quantity	
Pressure Rating	Par. 1.1
Physical Properties	Par. 4.1
Process of Manufacture	Par. 2.1
Resin System	Par. 2.2
Nominal Size or Outside Diameter	Table 6.1
Length	Par. 6.2
Pipe Ends	Par. 7.1
Mill Inspection by Purchaser	Par. 9.1, 9.2
Delivery Date and Shipping Instructions	

Attention is called to the following paragraphs which may require additional discussion or agreement between the purchaser and the manufacturer.

Service Factors	Par. 4.4
Pipe Connection Drawings	Par. 7.2

NOTE: *This specification supersedes the fifth edition of Spec 15LR dated October 1986. This specification was originally adopted in 1967. It was issued as tentative in 1968, and as Spec 5LR in 1972.*

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API SPECIFICATION FOR LOW PRESSURE FIBERGLASS LINE PIPE

FOREWORD

a. This specification is under the jurisdiction of the Committee on Standardization of Plastic Pipe of the American Petroleum Institute.

b. The purpose of this specification is to provide standards for Low Pressure Fiberglass Line Pipe for use in conveying produced fluids including oil, gas, nonportable water and mixtures thereof in the oil and gas producing industries.

c. Nothing in this specification should be interpreted as indicating a preference by the committee for any material or process or as indicating equality between the various materials or processes. In the selection of materials and processes, the purchaser must be guided by his experience and by the service for which the pipe is intended.

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SECTION 1
SCOPE

1.1 Coverage. This specification covers centrifugally cast (CC) and filament wound (FW) fiberglass line pipe and fittings for these pipe in diameters up to and including 16 inches rated for cyclic operating pressures up to and including 1000 psig. It is recommended that the pipe and fittings be purchased by pressure rating. The standard pressure ratings are 150 psig, 200 psig, 250 psig, and 300 psig. Pipe with pressure ratings greater than 300 psig can be purchased in 100 psig increments all based on cyclic pressures. For static pressure conditions higher pressure ratings may be used [refer to Par. 4.5(b)]. Quality control tests, hydrostatic mill tests, dimensions, weights, material properties, physical properties, and minimum performance requirements are included.

1.2 Referenced Standards

a. General. This specification includes by reference, either in total or in part, other API, industry and government standards listed in Appendix F.

b. Requirements. Requirements of other standards included by reference in this specification are essential to the safety and interchangeability of the quipment produced.

c. Equivalent Standards. Other nationally or internationally recognized standards shall be submitted to and approved by API for inclusion in this specification prior to use as equivalent standards.

1.3 Unit Conversion. A decimal/inch system is the standard for the dimensions shown in this specification. Norminal sizes will continue to be shown as fractions. For the purposes of this specification, the fractions and their decimal equivalents are equal and interchangeable. Metric conversions are described in Appendix I.

SECTION 2
PROCESS OF MANUFACTURE AND MATERIALS

2.1 Process of Manufacture. Pipe furnished to this specification shall be produced by the centrifugal casting (CC) or filament winding (FW) methods.

2.2 Material. The reinforced wall of pipe and fittings shall consist of thermosetting polymers reinforced with glass fibers. Acceptable polymers are epoxy resins, polyester resins, and vinyl ester resins. Couplings, connections, fittings, and adhesives shall meet the performance properties listed in Par. 4.6 and Par. 4.7 and shall be manufactured by a process and from materials compatible with the pipe system. They shall at least be equally resistant to the same fluids and environments as the pipe.

NOTES:
(1.) Other resins and reinforcements shall be considered for inclusion in this standard when evidence is presented to show that they are suitable for the applications covered by this standard.

(2.) Vinyl ester resins are defined in ASTM C-582.

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SECTION 3
MATERIAL PROPERTIES AND TESTS

3.1 Pipe and fittings furnished to this specification shall conform to the material requirements listed in Par. 2.2.

3.2 Degree of Cure. Degree of cure shall be determined by differential scanning calorimetry (DSC). The glass transition temperature (T_g) shall be no less than the average production T_g value minus three standard deviations. The average production T_g shall be established by the manufacturer from DSC tests taken from typical API 15LR qualified production product.

Manufacturers shall establish these values for each resin system used.

3.3 Methods of Material Analysis

a. Degree of cure (T_g) shall be determined following the procedure in Appendix B.

b. Glass-resin ratios shall be determined following the procedures of Appendix A.

3.4 Frequency of Tests. The manufacturer shall supply a report showing the degree of cure (T_g) per Par. 3.2 and 3.3 at the frequency required by Par. 5.1(d) for pipe. Samples for material analysis shall be taken from production runs.

SECTION 4
PHYSICAL PROPERTIES AND TESTS

4.1 Physical Properties. Pipe furnished to this specification shall conform to physical property requirements in Par. 4.3. Certain other properties do not have specified requirements but are nevertheless important in piping system design. The manufacturer shall perform the tests shown in Pars. 4.1(a) — 4.1(h) as well as prepare all test reports in compliance with the applicable ASTM standard. Use of the reporting format shown in Appendix G is recommended. These results shall be available upon request.

a. Long-term hydrostatic strength cyclic at 150°F. ASTM D-2992 Procedure A.

b. Thermal Coefficient of Expansion, ASTM D-696.

c. Axial Tensile Modulus of Elasticity, ASTM D-2105.

d. Parallel Plate Crush, SF at 5% deflection, ASTM D-2412.

e. Ultimate Axial Tensile Strength, ASTM D-2105.

f. Hydrostatic Collapse Pressure, ASTM D-2924.

g. Short-time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings, ASTM D-1599.

h. Beam bending modulus to determine pipe support spacing at 73.4°F and 150°F or maximum rated temperature when determined in accordance with ASTM D-2925.

4.2 Frequency of Tests. Pipe furnished to this specification shall be tested by the manufacturer as follows:

a. The short-term test which shall be performed at ambient temperature at the minimum frequency of one per lot as defined in 5.1(b) shall be one of the following:

1. Short-time hydrostatic failure pressure per ASTM D-1599.
2. Cyclic Pressure Strength (short-term) per ASTM D-2143 for 750 cycles minimum.

b. One long-term cyclic hydrostatic regression test to determine the hydrostatic design basis (HDB) shall be performed at 150°F(1) on pipe manufactured by each process which contains no significant product characteristic differences such as listed in Appendix E. The tests shall be conducted as follows:

NOTE (1): *When pipe is to be rated for temperatures higher than 150°F, the tests shall be conducted at the higher temperature.*

1. Initial tests — long-term cyclic hydrostatic pressure tests in compliance with ASTM D-2992 Procedure A.
2. Requalification Tests. The long-term cyclic HDB shall be verified at 150°F after any change as described in Appendix E by conducting abridged tests as follows:

Minimum Number of Samples	Cycles to Failure
2	1,000 to 10,000
2	10,000 to 3×10^6
2	at least 3×10^6

The failure points from these tests shall be combined with the failure points determined during the initial testing. The regression line determined

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on the combined data shall be extrapolated to obtain a requalification Long-Term Hydrostatic Strength (LTHS). If the LTHS for the combined data is greater than or equal to the corresponding lower confidence limit (per ASTM D-2992 Annex A2) of the initial tests, then the initial LTHS may be used. Otherwise, the changed product shall be retested per Section 4 to obtain a new LTHS.

NOTE: *To qualify a changed product at a higher HDB, the product must be retested per Par. 4.2(b)1 to obtain the new HDB.*

c. Impact resistance. The impact resistance of 2″ through 6″ pipe with cyclic pressure ratings of 300 psi and less shall be tested initially following the procedure in Appendix C.

4.3 Minimum Properties. The minimum performance properties for tests specified in Par. 4.2 are:

a. Pipe shall hold for one minute a minimum hydrostatic pressure of 4.0 times its calculated cyclic operating pressure without failure when tested as per Par. 4.2(a)(1).

b. Pipe shall have a minimum short-term cyclic pressure life of 750 cycles when tested at a pressure equal to or greater than the lower confidence limit on the long-term cyclic hydrostatic pressure regression line when back calculated to 750 cycles.

c. The hydrostatic design basis (HDB) extrapolated to 150 million cycles shall equal or exceed the manufacturers published value current at the time of purchase.

d. All 2″ through 6″ pipe with cyclic pressure ratings of 300 psig or less shall have impact resistance which exceeds the requirements of Appendix C. NOTE: *This test is not considered applicable for other pipe.*

4.4 Service Factors. The maximum recommended service factor is 1.0 for the long-term cyclic HDB.

4.5 Pressure Rating.

a. The cyclic pressure rating for a pipe shall be calculated by using the following formula and the hoop stress values determined by the long-term cyclic test listed in Par. 4.2(b)1. The formula is:

$$P_c = \frac{2S_c t}{D}$$

Where:

P_c = internal cyclic pressure rating, psi

S_c = hoop stress = HDB × service factor, psi

t = minimum reinforced wall thickness, inches

D = average diameter inches (OD-t)

HDB_c = Hydrostatic Design Basis, cyclic, psi

b. **Static Pressure.** Additionally, a static pressure rating can be determined by use of one of the following:

$$P_s = 1.5 \times P_c$$

Where P_c is defined in Par. 4.5a and P_s is the internal static pressure rating, psi; or

$$P_s = 0.5 \times \frac{2S_s t}{D}$$

Where HDB_s (S_s) is determined by ASTM D-2992, Procedure B.

NOTE: *Except as indicated above, all references to HDB in this specification refer to the cyclic HDB, and all piping shall be given pressure ratings on the cyclic basis.*

4.6 Qualification Requirements for Fittings. Fittings, couplings, connections and adhesives shall meet the following performance requirements when tested with unrestrained ends in accordance with Par. 4.7.

a. Each component and its field-jointed configuration shall sustain a short-time hydrostatic pressure of at least four (4) times its cyclic rated pressure for one minute without visible weeping or leakage.

b. Each component shall meet or exceed the cycle test requirements of Par. 4.7.b.

4.7 Qualification Tests for Fittings, Couplings, and Connections. Test specimens shall include at least one fitting in each configuration, for example, 45 degree and 90 degree elbow, tee, flange, coupling (includes integral coupling) etc., joined to pipe sections at least 18 inches long or 2 diameters, whichever is longer, using the joining method, design, and adhesive intended for field assembly. Specimen diameters for test in each configuration shall include the maximum product size in each pressure class and each method of manufacture. In addition, smaller sizes in the pressure rating shall be tested as follows:

Product Size Range (inches)	Test Size (inches)
2, 2½, 3	3
4, 6	6
8, 10, 12	12
14, 16	16

In each range of size the manufacturer may elect at its option to test a smaller product size to qualify only the smaller size.

a. Short-time hydrostatic failure pressure tests to determine compliance with Par. 4.6 performed with unrestrained ends at ambient temperature in accordance with ASTM D-1599 using specimens and sizes as described above.

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b. Cyclic Testing.

1. Using the cyclic test data and regression analysis as developed for the pipe under Par. 4.2(b)(1), a regression line is constructed converting the stress vs. cycle data to pressure vs. cycle data for pipe of the intended pressure class.

2. The gauge pressure at the peak pressure of the cycle shall be not less than 1½ nor more than 2 times the pressure rating of the corresponding pipe. The cycle amplitude pressure shall be at least 80% of the selected peak pressure.

3. Test each component specimen as required above with unrestrained ends in accordance with ASTM D-2143 at a test temperature of 150°F. (For components which are to be used at higher temperatures, the higher temperature shall be used.)

4. The number of cycles to failure for the component must be no less than that predicted by the HDB line lower 97.5% confidence limit of the corresponding pipe.

4.8 Requalification Tests for Fittings, Couplings, Connections and Adhesives. The qualification tests of Par. 4.7 shall be repeated after any change as described in Appendix E.

SECTION 5
QUALITY CONTROL TESTS

5.1 Pipe.

a. Mill Pressure Tests. Hydrostatic testing of pipe manufactured to this specification shall be done at a pressure of not less than 1.5 times the calculated cyclic pressure rating. The hydrostatic mill tests shall be conducted randomly with lengths taken during each shift from each production line, unless otherwise agreed upon between manufacturer and purchaser. All mill jointers shall be hydrostatically tested.

b. A lot of pipe shall consist of 5,000 feet or fraction thereof of one size, wall thickness and grade in continuous production.

c. The short-term cyclic pressure test or the short-time hydrostatic failure test per Par. 4.2(a) shall be conducted at a minimum frequency of one test per lot.

d. The test for degree of cure (T_g) per Pars. 3.2 and 3.3 shall be conducted at a mininum frequency of one test per lot.

5.2 Fittings.

a. Mill Pressure Tests — Hydrostatic testing or pneumatic testing of 6" and smaller fittings at a pressure equal to 1.5 times pressure rating shall be conducted at the frequency called for in Par. 5.2(a)(1) or Par. 5.2(a)(2).

1. Fittings shall be randomly tested with fittings taken during each shift from each production line, with at least 20 percent of all 45 degree elbows, 90 degree elbows, and tees tested.

2. Fittings (45 degree elbows, 90 degree elbows, and tees) shall be tested following the sampling plan of Appendix D.

5.3 Retests. If any test specimen of the tests specifically mentioned in Pars. 4.2(a), 5.1 and 5.2(a)(1) fails to conform to the specified requirements, the manufacturer may elect to make retests on two additional lengths or fittings from the same lot. If both of the retest specimens conform to the requirements, all of the lengths or fittings in the lot shall be accepted, except the length or fitting from which the initial specimen was taken. If one or both of the retest specimens fail to conform to the specified requirements, the manufacturer may elect to test individually the remaining lengths or fittings in the lot, in which case determinations are required only for the particular requirements with which the specimens failed to comply in the preceding test.

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SECTION 6
DIMENSIONS AND LENGTHS

6.1 Dimensions. Fiberglass pipe shall be furnished in sizes shown in Table 6.1 as specified on the purchase order.

TABLE 6.1
DIMENSIONS

Nominal Size (inches)	Outside (1) Dia. (inches)	Inside(2) Dia. (inches) Minimum
2	2.375	2.00
2½	2.875	2.40
3	3.500	3.00
4	4.500	4.00
6	6.625	5.80
8	8.625	8.20
10	10.750	10.30
12	12.750	11.90
14	(3)	13.50
16	(3)	15.40

NOTES:

1. The outer diameters are applicable to:
   A. Sizes 2″ through 6″ with 300 psi cyclic pressure ratings.
   B. Sizes 8″ through 12″ with 150 psi cyclic pressure ratings.
   C. All centrifugal cast pipe.
   D. Other outside diameters shall be permitted by agreement between purchaser and manufacturer.
2. The minimum inside diameters are applicable to all filament wound pipe with cyclic pressure ratings greater than pipe covered by Note 1.
3. The minimum inside diameters are applicable to all pressure ratings of 14″ and 16″ diameter pipe.

6.2 Length. Pipe shall be furnished in lengths according to the following schedule.

Length 1	Length 2	Length 3
15 to 21 feet	21 to 34 feet	34 or more feet

Jointers (two pieces coupled to make a standard length) may be furnished to a maximum of 5 percent of the order; but no length used in making a jointer shall be less than 5 feet. Two standard lengths joined to make one long length is not a jointer, but shall be mill hydrotested at a pressure of 1.5 times the cyclic pressure rating.

6.3 Tolerances. Outside diameter of pipe furnished to this specification shall be within the tolerances listed in Table 6.2. The measurements shall be made in accordance with ASTM D-3567.

6.4 Wall Thickness. The pipe's minimum reinforced wall thickness shall not be less than that wall thickness calculated for its pressure class using Par. 4.5(a) and when measured per ASTM D-3567.

TABLE 6.2
DIMENSIONAL TOLERANCES

Nominal Size (Inches)	Outside Diameter (Inches)
2	+0.060,-0.018
2½	+0.060,-0.018
3	+0.060,-0.018
4	+0.066,-0.028
6	+0.086,-0.040
8	+0.108,-0.043
10	+0.128,-0.056
12	+0.145,-0.062
16	+0.165,-0.074

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SECTION 7
PIPE ENDS, CONNECTIONS, END PROTECTION, AND WORKMANSHIP

7.1 Pipe Ends. Pipe shall be furnished threaded, plain end, tapered, special and, or with alternate tapered ends as specified on the purchase order.

a. **Threaded Ends.** Threaded ends shall consist of male and female threads per ASTM D1694 or to API Spec 5B. Threaded joints shall meet the performance requirements of Pars. 4.6 and 4.7.

b. **Plain Ends.** Plain end pipe shall be furnished in lengths specified on the purchase order with square cut ends. Bell and spigot dimensions and tolerances are shown in Table 7.2.

c. **Tapered Ends.** Tapered ends shall consist of tapered spigots with either integral bells or sleeve couplings. Male and female ends shall conform to dimensions shown in Tables 7.1.a & 7.1.b. Tapered joints, when bonded in accordance with manufacturer's recommendation, shall meet the performance requirements of Pars. 4.6 and 4.7.

d. **Special Ends.** When so specified on the purchase order, pipe shall be furnished with ends suitable for use with special couplings. Mechanical joints with elastomeric seals are considered special ends and shall be in accordance with ASTM D4161. These special end connections, when joined in accordance with manufacturer's recommendations, shall meet the performance requirements of Par. 4.6 and 4.7.

e. **Alternate Tapered Ends.** Alternate tapered ends which do not meet the taper angle and spigot end diameter requirements shown in Table 7.1a for nominal sizes 8 inches through 16 inches shall be allowed and shall be identified by the letters "ATE" following the API monogram. Alternate tapered end joints, when bonded in accordance with manufacturer's recommendation, shall meet the performance requirement of Par. 4.6 and 4.7. The angle of alternate taper angle shall be identified in the pipe marking immediately following "ATE" when an alternate taper angle is used.

7.2 Pipe Drawings. The manufacturer shall furnish drawings of the pipe and any special couplings or sealing devices, including dimensions and tolerances, when requested by the purchaser.

7.3 Workmanship. All pipe furnished to this specification shall meet the visual inspection limits listed in Table 7.3.

NOTE: *The dimensions of the spigots for the tapered end adhesive bonded joints are substantially changed from API 5LR dated March 1976; therefore, materials manufactured prior to March 1976 shall be in compliance with 5LR and materials manufactured after October 15, 1986 shall be in compliance with 15LR.*

7.4 Repair of Surface Imperfections. Removal of surface imperfections by methods such as grinding or filing shall be permissible, provided the grinding or filing does not cut into any of the reinforcement, and that all ground or filed areas are coated prior to shipment with the same base resin as was used in the manufacture of the product.

7.5 End Protection. The manufacturer shall provide end protection of such design, material and mechanical strength to protect the ends of the pipe, fittings and end connections from damage under normal handling and transportation. The end protector for female ends shall cover the end to prevent damage by ultra-violet radiation and other weather elements. The end protector's length shall be long enough to cover:

a. All threads of male threaded (pin end) pipe.

b. All machined or ground surfaces of male end (spigot) adhesive bonded joint pipe.

c. All sealing surfaces of elastomeric sealed joints.

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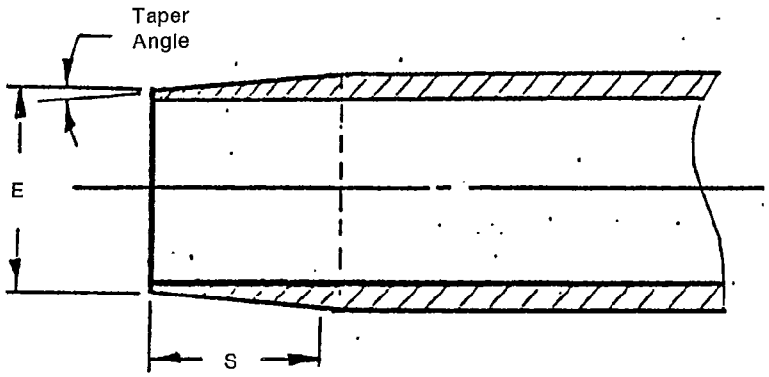
TABLE 7.1a
SPIGOT DIMENSIONS FOR TAPERED ENDS
ADHESIVE BONDED JOINTS



Nominal Pipe Size (in.)	Taper Angle degrees)	Spigot End Dia.[1] E (in.)	Minimum Bond Length[2] S (in.)	Maximum Cyclic Pressure Rating (psi)
2	$1\frac{3}{4}{}^{+0}_{-\frac{1}{4}}$	2.291	.900	300
2½	$1\frac{3}{4}{}^{+0}_{-\frac{1}{4}}$	2.783	1.070	300
3	$1\frac{3}{4}{}^{+0}_{-\frac{1}{4}}$	3.401	1.370	300
4	$1\frac{3}{4}{}^{+0}_{-\frac{1}{4}}$	4.370	1.895	300
6	$1\frac{3}{4}{}^{+0}_{-\frac{1}{4}}$	6.472	2.690	300
8	$1\frac{3}{4}{}^{+0}_{-\frac{1}{4}}$	8.457	2.060	150
10	$1\frac{3}{4}{}^{+0}_{-\frac{1}{4}}$	10.567	2.595	150
12	$1\frac{3}{4}{}^{+0}_{-\frac{1}{4}}$	12.544	2.920	150
14	$1\frac{3}{4}{}^{+0}_{-\frac{1}{4}}$	13.778	3.420	150
16	$1\frac{3}{4}{}^{+0}_{-\frac{1}{4}}$	15.756	3.895	150

[1]Spigot end diameter (E) is a reference dimension; the actual spigot diameter may be smaller.
[2]The minimum bond lengths are based on an adhesive shear stress of approximately 145 psi at the cyclic pressure rating.

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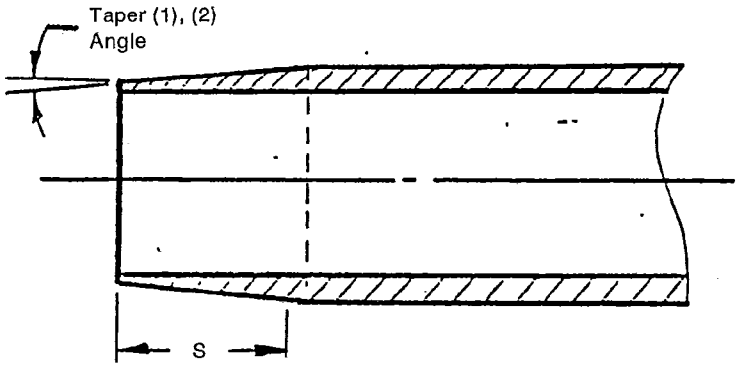
TABLE 7.1b
SPIGOT DIMENSIONS FOR HIGHER PRESSURE RATINGS



Nominal Pipe Size (in.)	Minimum Bond Length[3] S (in.)	Maximum Cyclic Pressure Rating (psi)	Minimum Bond Length S (in.)	Cyclic Pressure Rating (psi)
2	1.505	500	1.810	600
2½	1.785	500	2.140	600
3	2.280	500	2.740	600
4	3.155	500	3.790	600
6	4.480	500	5.375	600
8	2.740	200	4.110	300
10	3.460	200	5.195	300
12	3.895	200	5.840	300
14	4.560	200	6.840	300
16	5.190	200	7.785	300

(1) Taper angle varies according to wall thickness. Standard angles are: 1¾, 3½, 5, and 7 degrees.
(2) Tolerance for taper angle is +0 degrees, –¼ degrees.
(3) The minimum bond lengths are based on an adhesive shear stress of.approximately 145 psi at the cyclic pressure rating.

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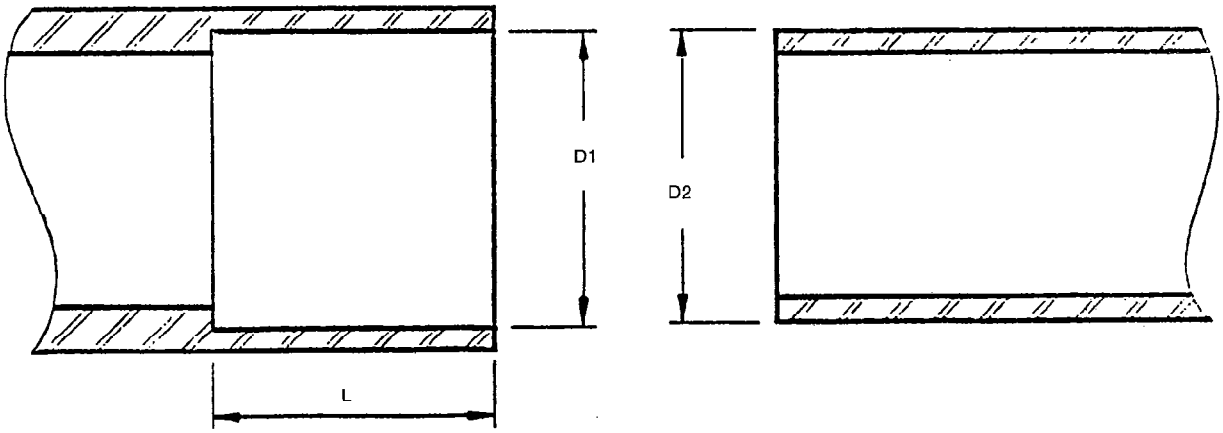
TABLE 7.2
SOCKET DIMENSIONS FOR ADHESIVE BONDED JOINTS USING NON-TAPERED PIPE ENDS
Applies Only to Centrifugally Cast Pipe



Nominal Pipe Size (in.)	SOCKET DIMENSIONS Length Minimum L (in.)	Diameter of Bore D1 (in.) Min.	Max.	PIPE DIMENSIONS Outside Diameter D2 (in.)	Outside Diameter Tolerances (in.)
2	1¾	2.387	2.437	2.375	±0.012
2½	1¾	2.887	2.937	2.875	±0.012
3	1¾	3.512	3.562	3.500	±0.012
4	1¾	4.515	4.562	4.500	±0.015
6	1¾	6.650	6.687	6.625	±0.025
8	1¾	8.650	8.687	8.625	±0.025
10	3¾	10.775	10.812	10.750	±0.025
12	3¾	12.775	12.812	12.750	±0.025
14	3¾	14.025	14.062	14.000	±0.025

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TABLE 7.3
VISUAL STANDARDS

DEFECT	DESCRIPTION	MAXIMUM SIZE
PIPE BODY AND COLLAR		
Burn	thermal decomposition evidenced by distortion or discoloration of the surface	20% area—lightly blemished 5%, area—moderate burn of outer resin layer, structural roving
Chip	small piece broken from edge or surface	permitted if laminate has not been fractured
Crazing	fine cracks at or under the surface as seen by the unaided eye	none permitted
Cut Roving	broken or cut outer rovings due to scraping or scuffing or manufacturing process	maximum 3 per pipe with one square inch maximum size maximum depth of 10% of the nominal wall thickness
Dry Spot	area where reinforcement was not thoroughly wet with resin	maximum 3 streaks per pipe — ½ inch wide, 4 in. long, no dry reinforcement exposed
Fracture	Rupture of laminate without complete penetration. Visible as lighter colored area of interlaminar separation	none permitted
Pits (pinholes)	small craters in the surface	maximum $1/16$" deep, no limit on number
Resin Drip	resin protrusion	maximum ⅛ in. high, no limit on number
Scratch	shallow mark caused by improper handling	no limit on number if reinforcement is not exposed
THREADS		
Air Bubbles	light patch at the root of the thread caused by entrapped air	maximum size ⅛" in any direction and one bubble allowed per connection
Chips	areas where over 10% of thread height is removed	maximum ½" long in one thread per connection

SECTION 8
MARKING

8.1 Pipe manufactured in conformance with this specification shall be marked by the manufacturer as specified in Section 8.2. (Additional markings as desired by the manufacturer or as requested by the purchaser are not prohibited.) Markings shall be permanent, shall not overlap, and shall be applied in such manner as not to damage the pipe.

8.2 Pipe shall be marked with the following:

a. Manufacturer's name or mark

b. Size, nominal, inches

c. Cyclic pressure rating

d. Lot number

e. "Spec 15LR"*

*Users of this specification should note that there is no longer a requirement for marking a product with the API monogram. The American Petroleum Institute continues to license use of the monogram on products covered by this specification but it is administered by the staff of the Institute separately from the specification. The policy describing licensing and use of the monogram is contained in Appendix H, herein. No other use of the monogram is permitted. Licensees should refer to Par. H-13 for marking requirements.

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SECTION 9
INSPECTION AND REJECTION

9.1 Inspection Notice. Where the purchaser or his authorized inspector desires to inspect this pipe, the manufacturer shall give reasonable notice as to when the pipe shall be ready for inspection.

9.2 Plant Access. The inspector representing the purchaser shall have free entry at all times while work on contract of the purchaser is being performed, to all parts of the manufacturer's plant which will concern the inspection of pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe is being furnished in accordance with this specification. All inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified on the purchase order, and shall be so conducted as not to interfere with plant operations.

9.3 Compliance. The manufacturer is responsible for complying with all provisions of this specification. The purchaser may make any investigation necessary to satisfy himself of compliance by the manufacturer and may reject any material that does not comply with this specification. If tests that require the destruction of material are made other than at the place of manufacture, the purchaser shall accept that material which meets the specification but shall reject material which fails to meet the specification.

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APPENDIX A
METHOD OF TEST FOR GLASS-RESIN RATIO OF FIBERGLASS PIPE

Scope

A-1 This appendix covers method of test for the determination of the glass-resin ratio of fiberglass pipe.

Summary of Method

A-2 The Glass-Resin Ratio Test consists of cutting a 1 inch × 1 inch sample from the pipe wall, containing it in a crucible, igniting the material, and allowing it to burn until only ash and carbon remain. The carbonaceous residue is reduced to an ash by heating in a muffle furnace at 1050°F (565°C) cooled in a desiccator and weighed.

A-3 Equipment:

a. Crucible, made of platinum or porcelain, approximately 30 ml capacity.

b. Electric Muffle Furnace, capable of maintaining a temperature of 1050 ±50°F (565 ±28°C).

A-4 Procedure:

a. Heat a crucible at 932 to 1112°F (500 to 600°C) for 10 minutes or more. Cool to room temperature in a desiccator and weigh to the nearest 1.0 mg.

b. Place approximately 5 g. of sample in the crucible and weigh to the nearest 1.0 mg. The maximum size of the sample pieces shall be 1 inch × 1 inch × thickness (25.4 × 25.4 mm). Heat the crucible and sample in a Bunsen flame until the contents ignite. Maintain such a temperature that the sample burns at a uniform and moderate rate until only ash and carbon remain when the burning ceases.

NOTE 1: *It is often convenient to use samples obtained from specimens that have been tested for mechanical properties such as flexural or tensile strength. The samples must be dry and the fractured areas removed, leaving square, unfrayed faces, before these samples are weighed and ignited.*

NOTE 2: *It is not absolutely necessary to ignite the sample in a Bunsen flame. Instead the crucible and contents can be placed in a muffle furnace at a temperature lower than 1050°F (565°C) and ignited. Care must be taken that there will be no mechanical loss of the noncombustible residue.*

NOTE 3: *If the "volatile" content of the sample is desired, determine the weight loss of the crucible and contents after placing in an oven at 212°F (100°C) before ignition. The time crucible and contents must remain in the oven is dependent on the type of "volatiles" present and the specimen geometry.*

c. Heat the crucible and residue in the muffle furnace at 1050 ±50°F (568 ±28°C) until all carbonaceous material has disappeared. Cool the crucible to room temperature in a desiccator and weigh to the nearest 1.0 mg.

NOTE 4: *The time for the carbonaceous residue to disappear is dependent largely on the sample geometry. It can be up to six hours but is usually much less.*

d. Reheat the crucible at 1050°F (565°C) for 10 to 20 minutes, cool in a desiccator and reweigh. Repeat the heating and weighing until consecutive weighings differ by no more than 1.0 mg.

e. Determine the ignition loss on at least two more portions of the same reinforced resin sample.

A-5 Calculations:

a. Calculate the ignition loss of the sample as follows:

$$\text{Ignition loss, \% w} = \frac{(W_1 - W_2) \times 100}{W_1}$$

where:

W_1 = weight of the sample, grams.

W_2 = weight of the residue, grams.

b. Calculate the estimated standard deviation as follows:

$$s = \sqrt{\frac{x^2 - n(\bar{x})^2}{n-1}}$$

s = estimated standard deviation.

x = value of single observation.

n = number of observations.

$\bar{x}$ = arithmetic mean of the set of observations.

A-6 Report: The report shall include the following:

a. The ignition loss, %w and standard deviation. If only glass reinforcement and organic resin were present, the ignition loss can be considered to be the resin content.

b. Observations in regard to any irregularities noted in the physical properties of the residue, such as melting.

c. Pipe identification from number on pipe.

d. Any irregularities noted during the test.

e. Date of test.

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APPENDIX B
METHOD OF TEST FOR THE DETERMINATION OF DEGREE OF CURE BY DIFFERENTIAL SCANNING CALORIMETRY (DSC)

B-1 Scope. This test determines the degree of cure of a fiberglass pipe test specimen relative to statistically significant values obtained from typical production product.

B-2 Definition. Glass transition temperature (T_g) is defined as the midpoint of the inflection temperature at the DSC curve (heat flow vs. temperature).

B-3 Apparatus. Differential scanning calorimeter (DSC).

B-4 Test Specimens.

a. **Size.** The size of the specimen is limited by the size of the DSC sample pan. All specimens *can be a chip* or filed into a fine powder to provide easy weighing and uniform contact with the pan.

b. **Location.** For any given piece of pipe, a sample should be taken 0-10 mils from the outer surface, as well as 0-10 mils from the inner surface. If the pipe sample has a liner, then a specimen should be taken from the liner as well as the inner and outer edges of the over-wrap.

B-5 Procedure.

a. *Maximum* heating rate is *40*°C/minute.

b. Run the scan from room temperature to at least 30°C above the expected glass transition temperature and no more than 250°C.

c. Obtain the T_g (midpoint of the inflection in the DSC curve).

B-6 Report. The report shall include the following items.

a. Complete identification of the specimens, including material, manufacturer's name and lot number (Section 9).

b. Pipe dimensions, including nominal size, minimum reinforced wall thickness, and average outside diameter of reinforced wall. Unreinforced thicknesses (i.e., liner) shall also be reported.

c. Number of specimens tested and where the specimens were taken from the pipe.

d. Heat-up rate for DSC initial temperature and final temperature for both scans.

e. Record glass transition temperature (inflection value) for the first scan as T_g.

f. Date of test.

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APPENDIX C
METHOD OF TEST FOR IMPACT RESISTANCE OF FIBERGLASS PIPE

C-1 Scope. This appendix covers the method of test for the determination of impact resistance of fiberglass pipe.

C-2 Apparatus.

a. A steel ball 2.0 inches in diameter weighing about 1.2 pounds and flat pipe support.

b. Pipe specimen pressurization equipment, soluble fluorescent dye, and ultraviolet lamp.

C-3 Test Specimens and Conditions. One sample each in 2, 3, 4 and 6-inch diameter shall be tested at 73.4F. The pipe shall be fitted with suitable end closures to permit the sample to be pressurized. The specimen length between the end closures shall be not less than five times the outside diameter of the pipe, but in no case less than 12 inches.

C-4 Procedure.

a. A steel ball 2.0 inches in diameter and weighing about 1.2 pounds shall be dropped squarely onto the surface of the pipe with a free fall (which may be guided) for a distance of 12 inches. The ball may be caught or deflected after the hit so that the rebound does not hit the pipe. The pipe shall be full of water containing a soluble fluorescent dye, but not pressurized.

b. The pipe shall be supported on its bottom axis on a solid flat support. Four drops shall be made on randomly selected areas which are a minimum of one pipe diameter and 90 degrees clockwise from each other.

c. The pipe shall then be pressurized to 3.5 times the rated pressure and shall remain at this pressure for five minutes.

d. The pipe shall be examined with an ultraviolet lamp and the unaided eye. Failure in the test specimens shall be leaking or porosity, or any visible shattering, crack, or split from the impact.

C-5 Report. The report shall include the following items:

a. Complete identification of the specimens, including material, manufacturer's name and lot number.

b. Pipe dimensions including nominal size, minimum reinforced wall thickness and average outside diameter of reinforced wall. Unreinforced thicknesses (i.e., liner) shall also be reported.

c. Number of specimens tested and where the specimens were taken from the pipe.

d. Node of failure or other visual indications.

e. Date of test.

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APPENDIX D
SAMPLING PLAN
BASIS: 0.75% AOQL (AVERAGE OUTGOING QUALITY LIMIT)

Lot Size	Sample Size	Allowable No. of Failures To Accept Lot	No. of Failures To Reject Lot
0- 30	ALL	0	1
31- 50	25	0	1
51- 100	33	0	1
101- 200	39	0	1
201- 400	44	0	1
401- 600	45	0	1
	95	1	2
601- 800	46	0	1
	100	1	2
801-1000	47	0	1
	100	1	2

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APPENDIX E
PRODUCT CHARACTERISTICS

Changes in the following characteristics of the system shall require testing in accordance with 4.2(b)2.

E-1 Reinforcement. Significant changes shall be filament diameter, yield, or weight; reinforcement finish (sizing); reinforcement manufacturing process (e.g., single end or multiple end); and reinforcement composition.

E-2 Matrix Material (Resin System). Significant changes shall be resin type, curing agent(s) system, curing temperature, and curing schedule for heat-cured products outside manufacturer's specified tolerances.

E-3 Liner. Significant changes shall be the composition, curing, and thickness outside manufacturer's specified tolerances.

E-4 Geometry. Significant changes shall be the winding angle(s) in excess of ±5 degrees; number of resin reinforcement layers and/or reinforcement layer thickness in excess of 30 percent and/or stacking sequence; percent reinforcement in each direction in excess of ±3 percent; and glass to resin ratio in excess of ±3 percent.

E-5 Report. Use of the following reporting format is recommended.

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REPORTING FORMAT FOR API SPEC 15LR APPENDIX E — PRODUCT CHARACTERISTICS

E-1 Reinforcement:

Reinforcement manufacturer: _____

Reinforcement manufacturer's product code number: _____

Filament Diameter: _____

Nominal Yield: _____

Reinforcement manufacturer's sizing code number: _____

Form (e.g. single end or multiple end): _____

Reinforcement composition: _____

E-2 Matrix material:

Resin type: _____

Resin manufacturer: _____

Resin manufacturer's product code number: _____

Curing agent(s) system: _____

Curing temperature: _____

Curing schedule: _____

E-3 Liner (if any):

Resin type: _____

Resin manufacturer: _____

Resin manufacturer's product code number: _____

Curing agent(s) system: _____

Curing temperature: _____

Curing schedule: _____

Nominal thickness: _____

Minimum thickness: _____

Maximum thickness: _____

E-4 Geometry:

Wind angle(s): _____

Number of reinforcement layers: _____

Nominal reinforcement layer thickness: _____

Stacking sequence: _____

Percent reinforcement in each direction: _____

Glass to resin ratio: _____

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APPENDIX F
REFERENCED STANDARDS

	Designation	Title	Applicable Revision
1.	API Std 5B	Specification for Threading, Gaging, and Thread Inspection of Casing, Tubing, and Line Pipe Threads	Latest Edition
2.	API Spec. Q1	Specification for Quality Programs	Latest Edition
3.	ASTM C-582	Standard Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion Resistant Equipment	1987*
4.	ASTM D-696	Test Method for Coefficient of Linear Thermal Expansion of Plastics	1988*
5.	ASTM D-1599	Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing and Fittings	1988*
6.	ASTM D-1694	Specification for Threads for Reinforced Thermosetting Resin Pipe	1987*
7.	ASTM D-2105	Test Method for Longitudinal Tensile Properties of Reinforced Thermosetting Plastic Pipe and Tube	1985*
8.	ASTM D-2143	Test Method for Cyclic Pressure Strength of Reinforced, Thermosetting Plastic Pipe	1987*
9.	ASTM D-2412	Test Method for External Loading Properties of Plastic Pipe by Parallel — Plate Loading	1987*
10.	ASTM D-2924	Test Method for External Pressure Resistance of Reinforced Thermosetting Resin Pipe	1986*
11.	ASTM D-2925	Test Method for Beam Deflection of Reinforced Thermosetting Plastic Pipe Under Full Bore Flow	1976*
12.	ASTM D-2992	— Procedure A and B; Method for Obtaining Hydrostatic Design Basis for Reinforced Thermosetting Resin Pipe and Fittings	1987*
13.	ASTM D-3567	Method for Determining Dimensions of Reinforced Thermosetting Resin Pipe (RTRP) and Fittings	1985*
14.	ASTM D-4161	Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe Joints Using Flexible Elastomeric Seals	1986*

*This was the latest revision available for review by the API Committee on Standardization of Plastic Pipe at the time this edition was printed. Subsequent revisions are subject to API Committee review prior to acceptance as a referenced standard to this specification.

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APPENDIX G
REPORTING FORMAT FOR API SPEC 15LR PARAGRAPH 4.1-a "LONG TERM HYDROSTATIC STRENGTH CYCLIC AT 150°F, ASTM D-2992 PROCEDURE A"

Identification of test samples:

Material type (a generic resin description): _____

Material source: _____

Manufacturer's name: _____

Product code number: _____

Previous significant history: _____

Pipe Dimensions:

Nominal size: _____

Average wall thickness: _____

Minimum wall thickness: _____

Average outside diameter: _____

Liner material (if lined): _____

Liner thickness (if lined): _____

Fitting Dimensions:

Nominal size: _____

Average wall thickness: _____

Minimum wall thickness: _____

Average outside diameter: _____

Liner material (if lined): _____

Liner thickness (if lined): _____

Type of fitting: _____

Test temperature: _____

Test environment:

Inside of pipe: _____

Outside of pipe: _____

A table containing the following information for all the specimens tested:

Pipe wall stresses in pounds per square inch

Numbers of cycles to failure (Procedure A)

The nature of the failures (e.g. wall fracture, weep, thread leak,: etc.

Failed part (i.e., fitting or pipe)

Identify specimens under stress for more than 1.5×10^7 cycles.

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Estimated long term hydrostatic strength: _____

Stress at log cycles 8.1761 (1.5 x 10^8 cycles) (psi): _____

The hydrostatic design basis (psi): _____

The source of the hydrostatic design basis:

Extrapolated stress value at log cycle 8.1761: _____

Lower confidence value of stress at log cycle 8.1761: _____

The quantity M in Annex A2: _____

The quantity b in equation h = a + bf in Annex A1: _____

The quantity f in equation h = a + bf using values for a and b calculated in Annex A1 and 8.1761 for h: _____

Calculated Hydrostatic Design Basis: _____

Hydrostatic Design Basis category: _____

Any unusual observations:

Dates of tests: _____

Name of laboratory and supervisor: _____

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APPENDIX H
USE OF API MONOGRAM

H-1 Board Resolution. The original resolutions adopted by the Board of Directors of the American Petroleum Institute on October 20, 1924, embodied the purpose and conditions under which such official monogram may be used. A restatement of the resolutions was adopted by the Board of Directors on November 14, 1977, and is reproduced herein as Exhibit A.

H-2 API Monogram. The API monogram — API — is a registered trademark/servicemark of the American Petroleum Institute. Authorization to use the monogram is granted by the Institute to qualified licensees for use as a warranty that they have obtained a valid license to use the monogram and that each individual item which bears the monogram conformed, in every detail, with the API Specification applicable at the date of manufacture. However, the American Petroleum Institute does not represent, warrant or guarantee that products bearing the API monogram do in fact conform to the applicable API specification. Such authorization does not include use of the monogram on letterheads or in advertising without the express statement of fact describing the scope of licensee's authorization and further does not include use of the monogram, the name AMERICAN PETROLEUM INSTITUTE or the description "API" in any advertising or otherwise to indicate API approval or endorsement of products.

The formulation and publication of API Specifications and the API monogram program is not intended in any way to inhibit the purchase of products from companies not licensed to use the API monogram.

H-3 Application for Authority to Use Monogram. Manufacturers desiring to mark their products with the monogram may apply for a license to use the monogram with forms provided in an appendix to each applicable API specification.

Separate applications shall be made for each facility at which the manufacturer desires to apply the monogram and for each API Specification, or part thereof, under which authorization is desired to monogram products at that facility.

The monogram program that involves conformance with API Spec Q1 and surveys, as noted in Par. 3.4, 3.7 and 3.8, will be implemented under each API specification according to a schedule developed by the API staff. Existing licensees and applicants under those specifications which have these requirements will be notified prior to implementation. For specifications not yet under the Spec Q1 and survey program, a decision to award or withhold monogram rights will be made on an objective basis by the Institute from information gained from the "Statement of Manufacturer's Qualifications" form provided in the appendix of that specification.

H-4 Authorization to Use the Monogram. Applicants shall have an approved quality program functioning in conformance with API Spec Q1 and with specific requirements of the applicable API Specification at any particular facility prior to being issued a license to use the API monogram at that facility.

A decision to award or withhold monogram rights will be made by the staff of the Institute subsequent to a survey of the applicant's facilities located at the facility where the monogram is to be applied. The decision will be based upon the extent to which the objective evidence collected during the survey substantiates the manufacturer's conformance to his quality program as described in his Quality Manual which shall meet the requirements of the appropriate API specifications including API Spec Q1.

Each facility where the monogram is to be applied will be judged separately. If approved, a separate license will be granted at that facility. These licenses shall not be assignable or transferable by the Licensee in any manner nor shall Licensee have the right to grant sublicenses. The application of the monogram may not be subcontracted.

Each authorization shall be effective for a period of three years, subject to cancellation for cause.

H-5 Application of the Monogram to the Product.

a. The monogram may be applied at any time appropriate to the manufacturing process.

b. Only an API licensee may apply his monogram.

c. The monogram shall be applied at the licensed facility.

d. A marking procedure specified by the applicable API Specification shall be used to apply the monogram and the date of manufacture.

H-6 Fee for Use of Monogram. The fees assessed are to defray the cost of administering the Monogram Program.

Initial Authorization Fee. The applicant will be assessed an initial authorization fee for the first Specification included in the application, and a separate fee for each additional Specification included in the application.

Annual Renewal Fee. In addition to the initial authorization fee, licensees will be assessed an annual renewal fee for each specification under which he is authorized to use the monogram. First-time applicants issued monogram certificates dated November 1 through December 31 shall not be required to pay a renewal fee for the following year.

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H-7 Surveys.

Initial and Renewal Surveys. First-time applicants and licensees on every third year renewal of license shall be surveyed by qualified surveyors. The parameters of these surveys shall be the appropriate API specifications and the manufacturer's quality manual. The surveys will be performed to gather objective evidence for API's use in verifying that the manufacturer is in conformance with the provisions of the Manufacturers Quality Program as applicable to the API specifications. The manufacturer will be invoiced for the cost of these surveys.

Periodic Surveys. Existing licensees will be periodically surveyed by an approved API surveyor on a nondiscriminatory basis to determine whether or not they continue to qualify for authorization to use the monogram. The frequency of the periodic surveys will be at the discretion of the staff of the Institute. Costs of periodic surveys will be paid by the Institute.

H-8 Cancellation of Monogram Rights. The right to use the monogram is subject to cancellation for the following causes:

a. Applying the monogram on any product that does not meet the Specification.

b. Failure to maintain or have access to properly maintained reference master gages when required by the Specifications.

c. Failure to meet the requirements of a survey.

d. Failure to pay the annual renewal fee for use of the monogram.

e. For any other nondiscriminatory reason satisfactory to the API Staff.

H-9 Reinstatement of Monogram Rights. Manufacturers whose authorization to use the monogram has been cancelled may request reinstatement at any time. If a request for reinstatement is made within sixty (60) days after cancellation, and if the reason for cancellation has been corrected, no new application is necessary. A resurvey of the manufacturer's facilities will be made by an approved Institute surveyor prior to a decision to reinstate monogram rights. The manufacturer will be invoiced for this resurvey regardless of the Institute's decision on reinstatement. If the result of the resurvey indicates to the API staff that the manufacturer is qualified, the license will be reissued.

Request for reinstatement made more than sixty (60) days after cancellation shall be treated as a new application unless circumstances dictate an extension of this time period as agreed upon by the API staff.

H-10 Appeals. An interested party may appeal a decision by the Institute to withhold monogram rights. Appeals shall be directed to the Director, API Production Department and handled by the General Committee of the Production Department with a further right of appeal to the API Management Committee. Competing suppliers or manufacturers of the product or service to which the standard applies or might apply may not be involved in appeals. The General Committee and the Management Committee may convene appeals boards to hear and act on appeals.

H-11 Users Responsibilities. The effectiveness of the API standardization program can be enhanced by users reporting problems encountered with API monogrammed products to the Institute. API solicits information on both new product nonconformance with API requirements and field failures (or malfunctions) which are judged to be caused by either specification deficiencies or nonconformance with API requirements.

H-12 Special API Records. The API staff shall maintain and publish a current list of manufacturers licensed to use the API monogram for each API Specification. The document titled *Composite List of Manufacturers Licensed for Use of the API Monogram* shall be updated twice a year, and a copy shall be mailed to each licensed facility as soon as practical after receipt from the printer. Copies shall be made available to the public at the same time.

The API staff shall also maintain records of reported problems encountered with API monogrammed products. These records will be used internally only by API in evaluation of the quality program and API specifications and will be held in confidence.

H-13 Marking for API Licensees. The following marking requirements apply to licensed manufacturers using the API monogram on products covered by this specification.

a. Pipe manufactured in conformance with this specification shall be marked by the manufacturer as specified in Section 8.2. (Additional markings as desired by the manufacturer or as requested by the purchaser are not prohibited.) Markings shall be permanent, shall not overlap, and shall be applied in such manner as not to damage the pipe.

b. Pipe shall be marked with the following:

1. Manufacturer's name or mark
2. Size, nominal, inches
3. Cyclic pressure rating
4. Lot number
5. API monogram
6. API license number
7. Date of manufacture

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EXHIBIT A
BOARD RESOLUTION

The original resolutions adopted by the Board of Directors of the American Petroleum Institute on Oct. 20, 1924, embodied the purpose and conditions under which such official monogram may be used.

The following restatement of the resolutions was adopted by the Board of Directors on November 14, 1977:

WHEREAS, The Board of Directors of the American Petroleum Institute has caused a review of the Institute's program for licensing the use of the API monogram and

WHEREAS, It now appears desirable to restate and clarify such licensing policy and to confirm and make explicitly clear that it is the licensees, not API, who make the representation and warranty that the equipment or material on which they have affixed the API monogram meets the applicable standards and specifications prescribed by the Institute;

NOW, THEREFORE, BE IT RESOLVED, That the purpose of the voluntary Standardization Program and the Monogram Program of the American Petroleum Institute is to establish a procedure by which purchasers of petroleum equipment and material may identify such equipment and materials as are represented and warranted by the manufacturers thereof to conform to applicable standards and specifications of the American Petroleum Institute; and be it further

RESOLVED, That the previous action under which the following monogram was adopted as the official monogram of the American Petroleum Institute is reaffirmed;

BE IT FURTHER RESOLVED, That the American Petroleum Institute's monogram and standardization programs have been beneficial to the general public as well as the petroleum industry and should be continued and the Secretary is hereby authorized to license the use of the monogram to anyone desiring to do so under such terms and conditions as may be authorized by the Board of Directors of the American Petroleum Institute, provided that the licensee shall agree that the use of the monogram by such licensee shall constitute the licensee's representation and warranty that equipment and materials bearing such monogram complies with the applicable standards and specifications of the American Petroleum Institute; and that licensee shall affix the monogram in the following manner;

BE IT FURTHER RESOLVED, That the words "Official Publication" shall be incorporated with said monogram on all such standards and specifications that may hereafter be adopted and published by the American Petroleum Institute, as follows:

OFFICIAL PUBLICATION

REG. U.S. PATENT OFFICE

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APPENDIX I
METRIC CONVERSIONS

US Customary units are in all cases preferential and shall be the standard in this specification.

LENGTH

1 inch (in.) = 25.4 millimetres (mm) exactly

PRESSURE

1 pound per square inch (psi) = 0.06894757 Bar

NOTE: 1 Bar = 100 kilopascals (kPa)

STRENGTH OR STRESS

1 pound per square inch (psi) = 0.006894757 Megapascals (MPa)

IMPACT ENERGY

1 foot-pound (ft-lb) = 1.3558181 Joules (J)

TORQUE

1foot-pound (ft-lb) = 1.3558181 newton-metres (N m)

TEMPERATURE

The following formula was used to convert degrees Fahrenheit (°F) to degrees Celsius (°C):

$$°C = 5/9 (F-32)$$

MASS

1 pound (lb) = 0.4535924 kilograms (kg)

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PUBLICATIONS LIST

The following related publications are under the jurisdiction of the API Committee on Standardization of Plastic Pipe and are available from the American Petroleum Institute, 1220 L Street, Northwest, Washington, DC 20005; (202) 682-8375.

SPECIFICATIONS

Spec 15HR: **Specification for High Pressure Fiberglass Line Pipe.**
This specification covers high pressure fiberglass line pipe for use in the production of oil and gas.

RECOMMENDED PRACTICES

RP 15A4: **Recommended Practice for Care and Use of Reinforced Thermosetting Resin Casing and Tubing.**
Provides information on transporting, handling and installing reinforced thermosetting resin casing and tubing in oil field usage.

RP 15L4: **Recommended Practice for Care and Use of Reinforced Thermosetting Resin Line Pipe (RTRP).**
Provides information on the transporting, handling, installing, and repairing of reinforced thermosetting resin line pipe (RTRP) in oil field usage.

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NOTICE OF ADOPTION

ADOPTION NOTICE 1
20 August 1991 for
ASME B1.1-1989
29 August 1989
SUPERSEDING
ANSI B1.1-1982
20 April 1984

ASME B1.1-1989 was adopted on 20 August 1991 and is approved for use by the Federal agencies. The American Society of Mechanical Engineers (ASME) prepared this document which was approved by the American National Standards Institute (ANSI) as an American National Standard. Both ASME and ANSI have furnished clearances required by existing regulations. Copies of this document are stocked by the Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, for issue to DoD activities only. All other requestors must obtain documents from:

The American Society of Mechanical Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

or

The American National Standards Institute
11 West 42nd Street
New York, NY 10036

Title of Document: Unified Inch Screw Threads (UN and UNR Thread Form)

Date of Specific Issue Adopted: 29 August 1989

Releasing Non-Government Standards Body: The American Society of Mechanical Engineers

NOTE: Use of this standard is subject to all requirements and limitations of FED-STD-H28/2, Screw-Thread Standards for Federal Services Section 2, Unified Inch Screw Threads - UN and UNR Thread Forms.

Custodians:
Army - AR
Navy - AS
Air Force - 99

Civil Agency Coordinating Activities:
GSA - 7FXE
DOT - ACO
NASA - JFK

Review Activities:
Army - CR, EA, ER, ME
Air Force - 11, 15, 82

Military Coordinating Activity:
DLA - IS
(Project THDS-0083)

User Activity:
Army - AT, MI

AMSC N/A

AREA THDS

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D-90-20

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Unified Inch Screw Threads

(UN and UNR Thread Form)

AN AMERICAN NATIONAL STANDARD

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ASME B1.1 89 ■ 0759670 0039692 4 ■

D-90-20

AN AMERICAN NATIONAL STANDARD

Unified Inch Screw Threads

(UN and UNR Thread Form)

ASME B1.1–1989

(REVISION OF ANSI B1.1–1982)

The American Society of
Mechanical Engineers

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Date of Issuance: May 15, 1990

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FOREWORD

(This Foreword is not part of ASME B1.1-1989.)

This Standard is the outgrowth of and supersedes previous editions that were published as B1-1924, B1.1-1935, B1.1-1949, B1.1-1960, B1.1-1974, and B1.1-1982. Throughout such development, special attention has been given to the practical aspects of thread standardization, and many details of the current Standard result from studies and tests based on user problems. For example, there was disclosed the need for free assembly in high-production industries and the desirability of making some provision for threads that require a coating. The tolerance classes 2A/2B were developed to meet these two major requirements as well as to provide a general standard for externally and internally threaded fasteners.

This issue includes: (a) latest symbols in accordance with latest issue on Nomenclature, ANSI/ASME B1.7M; (b) a clearer definition of acceptability criteria as described in ANSI/ASME B1.3M; (c) sketches and drawings altered to meet the latest legibility requirements. The diameter–pitch combinations remain the same as in previous editions.

The Unified Screw Threads Standard is an integrated system of threads for fastening purposes in mechanisms and structures. Its outstanding characteristic is general interchangeability of threads, achieved through the standardization of thread form, diameter–pitch combinations, and limits of size.

The Standard has as its original basis the work done more than a century ago by William Sellers in the United States and Sir Joseph Whitworth in Great Britain. Throughout the intervening years there have been many further developments and revisions, culminating in the system of Unified Threads approved and adopted for use by all inch-using countries.

The achievements represented by ASME B1.1 in development, standardization, and unification are the result of cooperation and coordination of many organizations, including The American Society of Mechanical Engineers, Society of Automotive Engineers, National Institute of Science and Technology (formerly National Bureau of Standards), Committee B1, the former National Screw Thread Commission, the former Interdepartmental Screw Thread Committee, British Standards Institution, Canadian Standards Association, and American National Standards Institute.

Unification of screw thread standards received its impetus from the need for interchangeability among the billions of fasteners used in the complex equipment of modern technology and made in different countries. Equally important, however, are international trade in mechanisms of all kinds and the servicing of transportation equipment which moves from country to country. These have made unification not only highly advantageous, but practically essential. In sizes $\frac{1}{4}$ in. and larger, complete unification of certain thread series and six tolerance classes was signaled by the signing of an accord on November 18, 1948. Since that time, further unification has been extended into smaller sizes. Working through Technical Committee No. 1 of the International Organization for Standardization (ISO), the unified standard was adopted as an ISO inch screw thread standard, ISO 5864, parallel to the ISO metric screw thread system. Both systems have a common basic profile. The standard was subject to Quadripartite Standardization Agree-

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ment (QSTAG) 247, in the ABCA Army Standardization Program of America, Britain, Canada, and Australia.

Suggestions for improvement of this Standard will be welcomed. They should be sent to the American National Standards Institute, 1430 Broadway, New York, New York, 10018.

ASME B1.1-1989 was approved by the American National Standards Institute (ANSI) on August 29, 1989.

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Standardization and Unification of Screw Threads

(The following is the roster of the Committee at the time of approval of this Standard.)

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UNIFIED INCH SCREW THREADS (UN AND UNR THREAD FORM)

1 GENERAL

1.1 Scope

This Standard specifies the thread form, series, class, allowance, tolerance, and designation for unified screw threads. (In order to emphasize that unified screw threads are based on inch modules, they may be denoted unified inch screw threads.) Several variations in thread form have been developed for unified threads; however, this Standard covers only UN and UNR thread forms.

For easy reference, a metric translation of this Standard has been incorporated as Appendix C. Appendices A through C contain useful information that is supplementary to the sections of this Standard.

1.2 Unified Screw Thread Standards

The standards for unified screw threads published in this Standard are in agreement with formal standards of the International Organization for Standardization for diameter–pitch combinations, designations, and tolerances for 60 deg. triangular form inch screw threads. Unified screw threads had their origin in an accord signed in Washington, D.C., on November 18, 1948, by representatives of standardizing bodies of Canada, the United Kingdom, and the United States, and have subsequently superseded American National screw threads.

1.3 UN and UNR Screw Threads

UNR applies only to external threads; the difference between UN and UNR threads, in addition to designation, is that a flat or optional rounded root contour is specified for UN threads, while only a rounded root contour is specified for UNR threads.

1.4 Interchangeability

Unified (UN/UNR) and its predecessor, American National screw threads, have substantially the same thread form, and threads of both standards having the same diameter and pitch are mechanically interchangeable. The principal differences between these standards relate to the application of allowances, the variation of tolerances with size, differences in the amounts of pitch diameter tolerances for external and internal threads, and differences in thread designations. Unified inch and ISO metric screw threads are not mechanically interchangeable.

1.5 Designations

Unified thread sizes (specific combinations of diameter and pitch) are identified by the letter combination "UN" in the thread symbol. In the unified standards, the pitch diameter tolerances for external threads differ from those for internal threads; for this reason the letter "A" is used in the thread symbol to denote an external thread and the letter "B," an internal thread. Where the letters "U," "A," or "B" do not appear in the thread designation, the threads conform to the outdated American National screw threads. Details regarding thread designations are given in Section 6.

1.6 Reference Documents

The latest issues of the following documents form a part of this Standard to the extent specified herein.

American National Standards

When the following American National Standards referred to in this Standard are superseded by a revision approved by the American National Standards Institute, Inc., the revision shall apply.

ANSI/ASME B1.2
Gages and Gaging for Unified Inch Screw Threads

ANSI/ASME B1.3M
Screw Thread Gaging Systems for Dimensional Acceptability — Inch and Metric Screw Threads

ANSI/ASME B1.7M
Nomenclature, Definitions, and Letter Symbols for Screw Threads

ANSI B94.11M
Twist Drills

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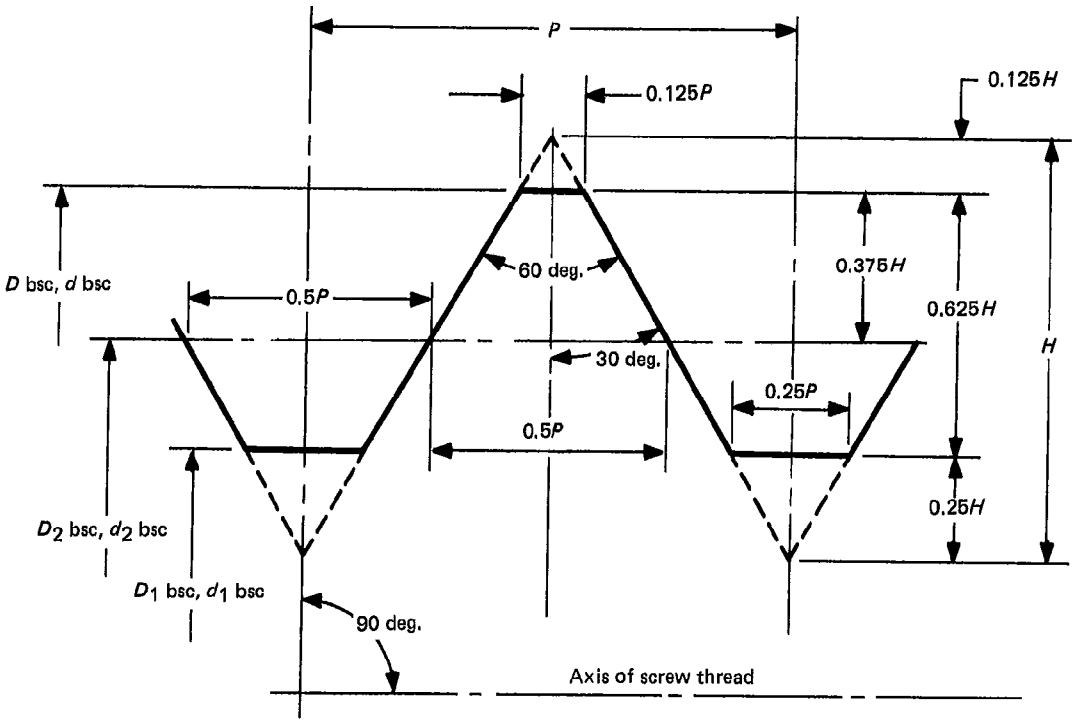

FIG. 1 BASIC PROFILE FOR UN AND UNR SCREW THREADS

International Organization for Standardization
ISO 68
ISO General Purpose Screw Threads—Basic Profile

1.7 Acceptability

Acceptability of product threads shall be in accordance with ANSI/ASME B1.3M. Gages and gaging shall be in accordance with ANSI/ASME B1.2.

1.8 Reference Temperature

The reference temperature is 68°F for dimensions defined by this system.

1.9 Units of Measure

All dimensions in this Standard, including all tables, are in inches unless otherwise specified.

1.10 Federal Government Use

When this Standard is approved by the Department of Defense and federal agencies and is incorporated into FED-STD-H28/2, Screw-Thread Standards for Federal Services, Section 2, the use of this Standard by the federal government will be subject to all the requirements and limitations of FED-STD-H28/2.

2 SCREW THREAD PROFILE

2.1 Scope

The basic profile and design profiles are defined in this Section and are the basis of all thread dimensions given in this Standard.

2.2 Basic Profile

The basic profile for UN screw threads is identical to that for UNR screw threads and is shown in Fig. 1. Profile applies to an axial plane.

For reference, the basic profile for UN and UNR screw threads is identical to that for ISO metric screw threads shown in ISO 68.

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2.3 Design Profiles

The design profiles define the maximum-material conditions for external and internal threads with no allowance and are derived from the basic profile. The design profiles of both external and internal screw threads vary from the basic profile.

2.3.1 Design Profiles of External Threads. The design profiles of external UN and UNR screw threads are included in Figs. 2 and 3. A flat root contour is specified for UN threads; however, it is permissible to provide for some threading tool crest wear. Therefore, a rounded root contour cleared beyond the 0.25*P* flat width of the basic profile is optional. The rounded root also reduces the rate of threading tool crest wear and improves fatigue strength over that of a flat root thread.

(a) The root contour of external UNR screw threads shown in Figs. 2 and 3 shall have a smooth, continuous, nonreversing contour with a radius of curvature not less than 0.108*P* at any point and shall blend tangentially into the flanks and any straight segment. At the maximum-material condition, the point of tangency shall be at a distance not less than 0.625*H* below the basic major diameter.

(b) The design profiles of external UN and UNR screw threads have flat crests. However, in practice, product thread crests may be flat, or partially or corner rounded. A rounded crest tangent at a 0.125*P* flat is shown as an option in Figs. 2 and 3.

2.3.2 Design Profile of Internal Threads. The design profile of the internal UN screw thread is included in Figs. 2 and 3 (*there is no internal UNR screw thread*). In practice it is necessary to provide for some threading tool crest wear; therefore, the root of the design profile is rounded and cleared beyond the 0.125*P* flat width of the basic profile.

2.4 Formulas and Symbols

The formulas and symbols pertaining to the basic profile and the design profiles are given in Section 10.

3 SCREW THREAD SERIES

3.1 Thread Series Definition

Thread series are groups of diameter–pitch combinations distinguished from each other by the number of threads per inch applied to a series of specific diameters. There are two general series classifications: standard and special.

3.1.1 Standard Series. The standard series consists of three series with graded pitches (coarse, fine, and extra fine) and eight series with constant pitches (4, 6, 8, 12, 16, 20, 28, and 32 threads per inch). The standard series is shown in Table 2. Limits of size are shown in Table 3A. See Section 8 for limits of size.

3.1.2 Special Series. The special series consists of all threads with diameter–pitch combinations that are not included in the standard series. When allowances and tolerances of special series threads are derived from unified formulation as shown in Section 5, the threads are designated UNS or UNRS. Limits of size for selected combinations of UNS/UNRS threads are shown in Table 3B. If allowance and tolerance are not derived from unified formulation, the threads are designated special. See Section 6 for details of designation.

3.2 Order of Selection

Wherever possible, selection should be made from Table 3A, Standard Series—Unified Screw Threads, preference being given to the coarse and fine thread series. If threads in the standard series do not meet the requirements of design, reference should be made to the selected combinations in Table 3B. The third expedient is to design UNS/UNRS threads using tables of allowance and tolerance in Sections 12 and 13. The last resort is to design special threads and use the formulas for limits of size in Section 8.

3.3 Coarse Thread Series Applications

The coarse thread series (UNC/UNRC) is generally used for the bulk production of screws, bolts, and nuts. It is commonly used in relatively low strength materials such as cast iron, aluminum, magnesium, brass, bronze, and plastic, because the coarse series threads provide more resistance to internal thread stripping than the fine or extra-fine series. Coarse series threads are advantageous where rapid assembly or disassembly is required, or if corrosion or damage from nicks due to handling or use is likely.

3.4 Fine Thread Series Applications

The fine thread series (UNF/UNRF) is commonly used for bolts and nuts in high strength applications. This series has less thread depth and a larger minor diameter than coarse series threads. Consequently, thinner walls are permitted for internal threads and

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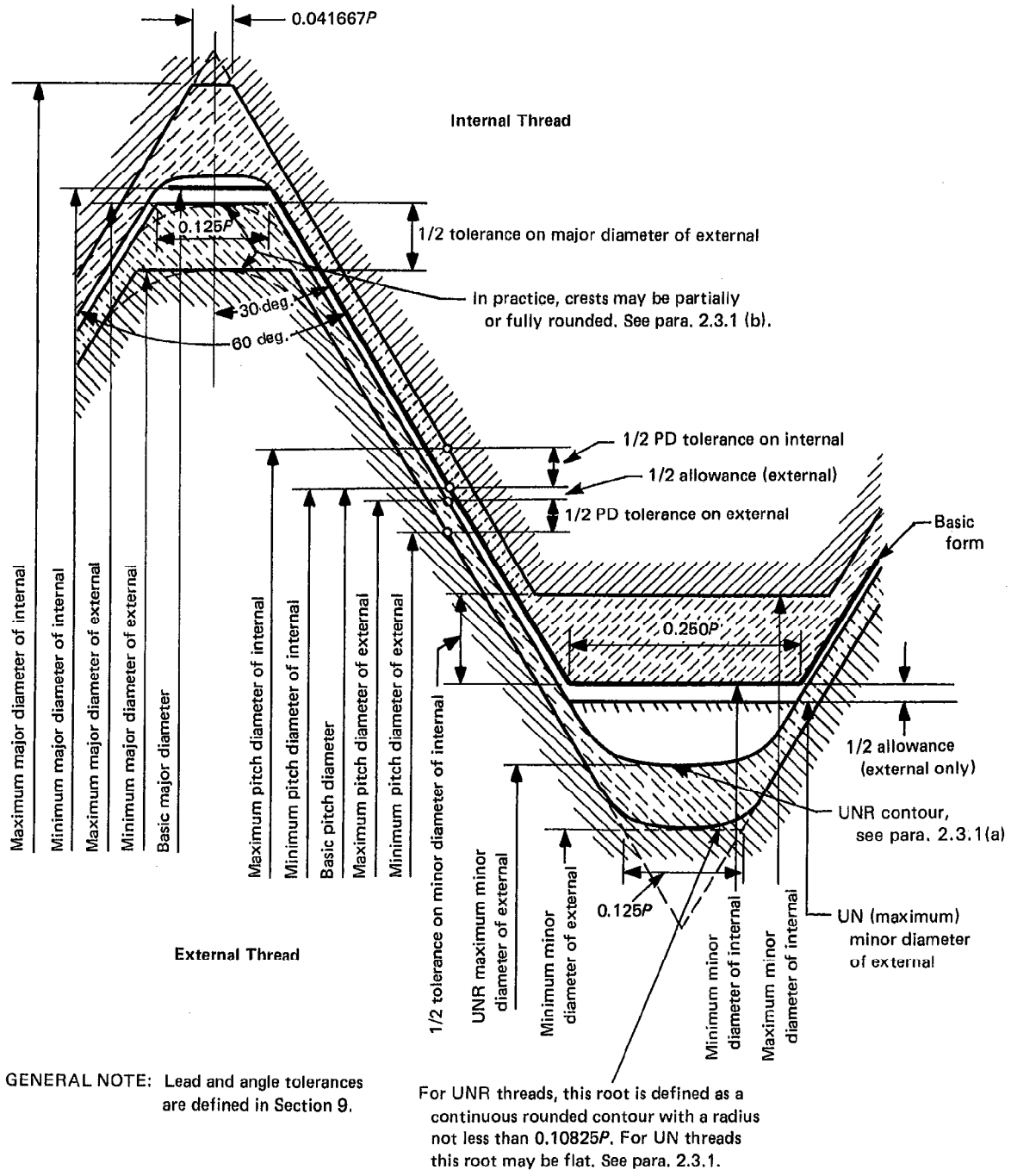

GENERAL NOTE: Lead and angle tolerances are defined in Section 9.

For UNR threads, this root is defined as a continuous rounded contour with a radius not less than 0.10825*P*. For UN threads this root may be flat. See para. 2.3.1.

FIG. 2 DISPOSITION OF DIAMETRAL TOLERANCES, ALLOWANCE, AND CREST CLEARANCE FOR UNIFIED INCH SCREW THREAD CLASSES 1A, 2A, 1B, AND 2B

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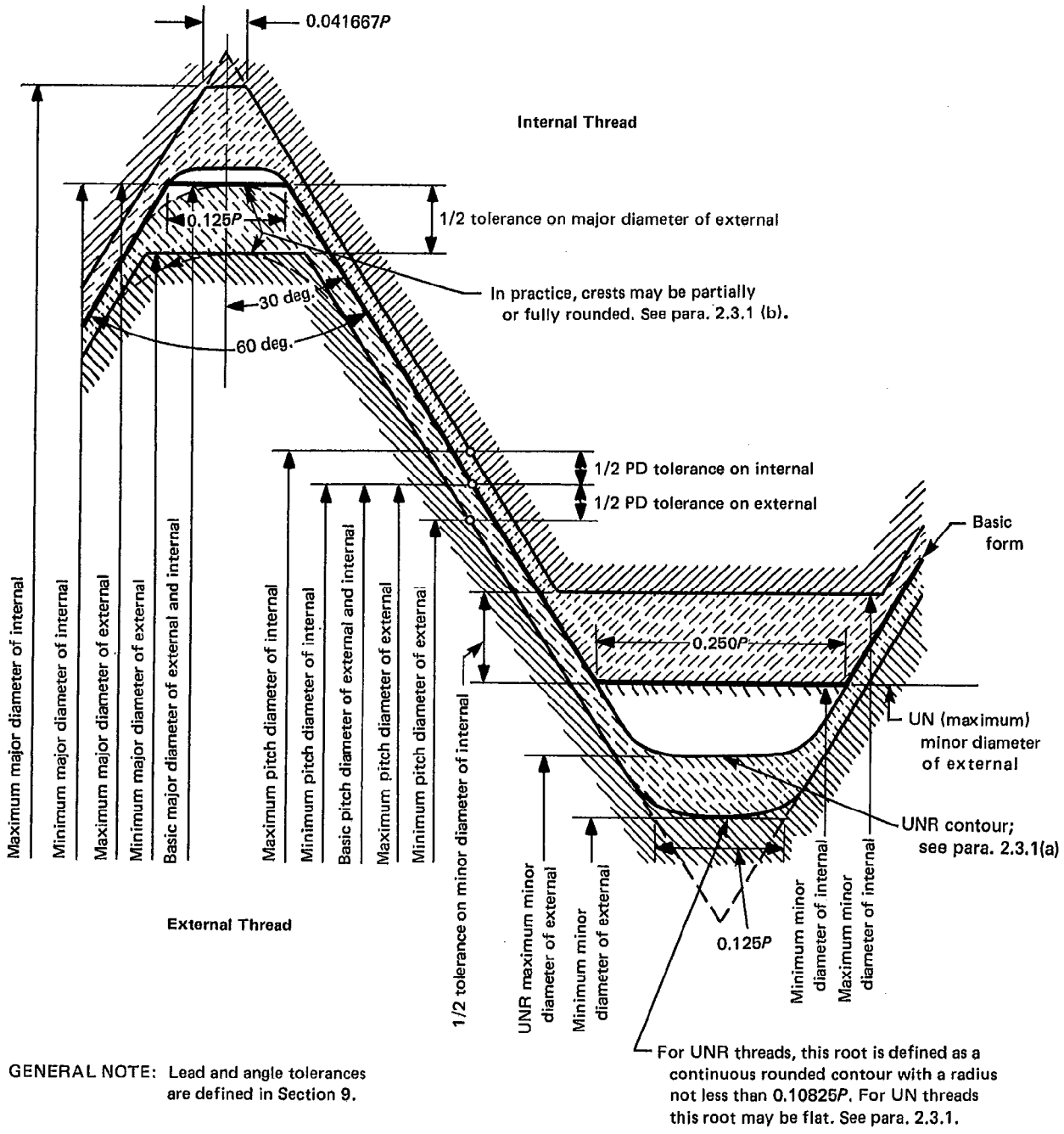

GENERAL NOTE: Lead and angle tolerances are defined in Section 9.

FIG. 3 DISPOSITION OF DIAMETRAL TOLERANCES AND CREST CLEARANCES FOR UNIFIED INCH SCREW THREAD CLASSES 3A AND 3B

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more strength is available to external threads than for coarse series threads of the same nominal size. In order to prevent internal thread stripping, a longer length of engagement is required for fine series than for coarse series threads for thread materials of the same strength levels. However, for both fine and coarse series threads, length of engagement in tapped holes must be selected to meet strength requirements. Fine series threads have less tendency to loosen under vibration than coarse series threads, because of the smaller lead angle. This also allows for finer adjustment in cases such as a slotted nut and cotter pin assembly.

3.5 Extra-Fine Thread Series Applications

The extra-fine series (UNEF/UNREF) is used particularly for equipment and threaded parts that require fine adjustment, such as bearing retaining nuts, adjusting screws, etc., and for thin-wall tubing and thin nuts.

3.6 Constant-Pitch Thread Series Applications

The various constant-pitch series (UN/UNR) with 4, 6, 8, 12, 16, 20, 28, and 32 threads per inch, given in Table 2, offer a comprehensive range of diameter–pitch combinations for those purposes where the threads in the coarse, fine, and extra-fine series do not meet the particular requirements of the design. The primary sizes of the 8-UN, 12-UN, and 16-UN series shown in Table 2 are the most commonly used.

Whenever a thread in a constant-pitch series also appears in the UNC, UNF, or UNEF series, the symbols and tolerances for limits of size of those standard series are applicable.

3.6.1 8-Thread Series. The 8-thread series (8-UN) is a uniform-pitch series for large diameters or as a compromise between coarse and fine thread series. Although originally intended for high-pressure-joint bolts and nuts, it is now widely used as a substitute for the coarse thread series for diameters larger than 1 in.

3.6.2 12-Thread Series. The 12-thread series (12-UN) is a uniform-pitch series for large diameters requiring threads of medium-fine pitch. Although originally intended for boiler practice, it is now used as a continuation of the fine thread series for diameters larger than 1½ in.

3.6.3 16-Thread Series. The 16-thread series (16-UN) is a uniform-pitch series for large diameters requiring fine-pitch threads. It is suitable for adjusting collars and retaining nuts and also serves as a continuation of the extra-fine thread series for diameters larger than $1\frac{11}{16}$ in.

3.7 Fine Threads for Thin-Wall Tubing

The limits of size for a 27-thread series, ranging from ¼ to 1 in. nominal size, are included in Table 3B. These threads are recommended for general use on thin-wall tubing. The minimum length of complete thread shall be one-third of the basic major diameter plus five threads ($D/3 + 0.185$).

4 SCREW THREAD CLASSES

4.1 Thread Classes

Thread classes are distinguished from each other by the amounts of tolerance and allowance. Classes 1A, 2A, and 3A apply to external threads only, and Classes 1B, 2B, and 3B apply to internal threads only. Allowance is specified only for Classes 1A and 2A and the allowance is identical for both classes. Tolerance decreases as class number increases (e.g., tolerance for Class 3A is less than that for Class 2A, which is less than that for Class 1A).

4.1.1 Class 2A and 2B Threads. Class 2A (external) and Class 2B (internal) threads are the most commonly used thread classes for general applications, including production of bolts, screws, nuts, and similar threaded fasteners.

The maximum diameters of Class 2A uncoated threads are less than basic by the amount of the allowance. The allowance minimizes galling and seizing in high-cycle wrench assembly, or it can be used to accommodate plated finishes or other coating. However, for threads with additive finish, the maximum diameters of Class 2A may be exceeded by the amount of the allowance; i.e., the 2A maximum diameters apply to an unplated part or to a part before plating, whereas the basic diameters (the 2A maximum diameter plus allowance) apply to a part after plating. The minimum diameters of Class 2B threads, whether or not plated or coated, are basic, affording no allowance or clearance in assembly at maximum-material limits.

4.1.2 Class 3A and 3B Threads. Class 3A (external) and Class 3B (internal) threads provide for applications where closeness of fit and/or accuracy of thread elements are important. The maximum diameters of Class 3A threads and the minimum di-

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ameters of Class 3B threads, whether or not plated or coated, are basic, affording no allowance or clearance for assembly at maximum-material limits.

4.1.3 Class 1A and 1B Threads. Class 1A (external) and Class 1B (internal) threads replaced American National Class 1 screw threads. These classes provide for applications where a liberal tolerance and an allowance are required to permit easy assembly even with slightly nicked threads. These classes are intended for ordnance and other special uses. Maximum diameters of Class 1A threads are less than basic by the amount of the allowance (the allowance is identical to that for Class 2A). The allowance is not available for plating or coating and, consequently, in some cases it may be necessary to make special provisions in thread manufacturing for accommodation of plating or coating. The minimum diameters of Class 1B threads, whether or not plated or coated, are basic and consequently afford no allowance or clearance for assembly at maximum-material limits.

4.1.4 Class 2AG Threads. Certain applications require an allowance for rapid assembly to permit application of the proper lubricant or for residual growth due to high-temperature expansion. In these applications, when the thread is coated and the 2A allowance is not permitted to be consumed by such coating, the thread class symbol is qualified by the addition of the letter G (old symbol for allowance) following the class symbol. Refer to paras. 6.2.1, 7.1, and 7.3 for more detailed information.

4.2 Combinations of Classes

The requirements for screw thread fits for specific applications are predicated on end use and can be met by specifying the proper combinations of thread classes for the components. For example, a Class 2A external thread may be used with a Class 1B, 2B, or 3B internal thread.

5 SCREW THREAD ALLOWANCE AND TOLERANCE

5.1 Allowance

Allowance is specified only for Class 1A and 2A external threads. For Class 1A threads, its purpose is to preclude the possibility of surface-to-surface fit between mating parts and it cannot be used to accommodate plating or coating. For Class 2A threads, the allowance may be used to accommodate plating or coating. Allowance for Classes 1A and 2A is identical and is based on Class 2A pitch diameter tolerance for the respective series standard length of engagement and is applicable for all lengths of engagement.

Formulas for allowance are given in para. 5.8.1(a) and values are given in Sections 12 and 13.

Applications of allowances to the basic thread form are shown in Fig. 2.

EXAMPLE: 2.0625-12UNS-2A
From para. 5.8.1(a): Allowance $es = 0.300\ Td_2(2A)$.
From para. 5.2, example (1): $Td_2(2A) = 0.0061$.
Therefore, $es = 0.300 \times 0.0061 = 0.00183$, or 0.0018 in. when rounded.

5.2 Pitch Diameter Tolerance, All Classes

NOTE: Refer to Table 2 for the standard series of diameter–pitch combinations. Allowances and tolerances for standard series threads are applied in Table 3A. All other diameter–pitch combinations are considered nonstandard. Allowances and tolerances for a selection of nonstandard threads are applied in Table 3B.

The pitch diameter tolerances specified in Table 3A for all classes of the UNC and UNF series are based on a length of engagement equal to the basic major (nominal) diameter and are applicable for lengths of engagement from five pitches to up to 1½ diameters. For the 4-UN, 6-UN, and 8-UN series, the pitch diameter tolerances specified for Classes 2A, 2B, 3A, and 3B are based on a length of engagement equal to the basic major (nominal) diameter and are applicable for lengths of engagement up to 1½ diameters.

The pitch diameter tolerances specified in Table 3A for all classes of the UNEF, 12-UN, 16-UN, 20-UN, 28-UN, and 32-UN series are based on a length of engagement of 9 pitches and are applicable for lengths of engagement from 5 to 15 pitches.

The pitch diameter tolerances specified in Table 3B for all classes of the UNS series are based on a length of engagement of 9 pitches and are applicable for lengths of engagement from 5 to 15 pitches.

Formulas for pitch diameter tolerance are given in paras. 5.8.1(c) and 5.8.2(b), and values are given in Sections 12 and 13.

Applications of tolerances to the thread form are shown in Figs. 2 and 3.

For special threads not included in Table 3B, the tolerances and allowances should be obtained from the tabulated tolerances or increments for special threads, if applicable, or computed from the formula values for standard lengths of engagement. For lengths of engagement over 15 to and including 30

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pitches, the pitch diameter tolerances are 1.25 times the formula values; and for lengths of engagement over 30 pitches, the tolerances are 1.50 times the formula values.

EXAMPLES:
(1) 2.0625-12UNS-2A; LE = 1 in. (12 pitches).
Use Table 34 column for major diameter of 1.875 through 2.25. Read pitch diameter tolerance Td_2(2A) in 12 threads per inch row for length of engagement LE equal to 0.42 to 1.25 in. (5 to 15 pitches). Td_2 = 0.0061 in.
(2) 6.500-5UNS-SE2B; LE = 4 in. (20 pitches).
From para. 5.8.2(b): TD_2(2B) = 1.300 Td_2(2A). Use Table 19 for Td_2(2A), since 5 TPI is not tabulated in Table 37.

Increment D (not tabulated) = 0.0015 $\sqrt[3]{D}$	= 0.002799
Increment LE (9 pitches)	= 0.002012
Increment P	= 0.005130
Td_2(2A) for $LE = 9P$	= 0.009941
TD_2(2B) for $LE = 9P$ = 1.300 Td_2(2A)	= 0.012923
TD_2(2B) for $LE = 20P$ = 1.25 TD_2(2B)	= 0.016154

or 0.0162 in. when rounded.

5.3 Special Lengths of Engagement *LE*

For special applications, the required length of engagement might be the determining factor in the proper selection of thread tolerances. When design considerations require nonstandard pitches or extreme conditions of engagement not covered by the tables, the tolerances may be modified as explained below or calculated using the formulas.

It is particularly important that this increase in tolerance be noted by the user for external threads (Class 3A) callout. At times it is impossible for the producer to know the length of engagement with an internally threaded member. It may be necessary for the producer to lower the maximum values of pitch diameter when making such externally threaded components. Hence the increased tolerance noted.

5.3.1 Long *LE* Using Gage Length *LG* Equal to *LE*

(a) For engagement lengths exceeding 1.5 diameters, for UNC, UNF, 4-UN, 6-UN, and 8-UN series, the pitch diameter tolerances shown in Table 3A should be increased as follows.

(1) For lengths of engagement over 1.5 to and including 3 diameters, the pitch diameter tolerances are 1.25 times the values for the standard lengths of engagement shown in Table 3A.

(2) For lengths of engagement over 3 diameters, the tolerances are 1.50 times the values shown in Table 3A.

EXAMPLE:
0.500-13UNC-SE2B; LE = 1 in. (2 diameters).
From Table 3A or Table 20: TD_2 = 0.0065.
TD_2 for LE of 2 diameters = 1.25 Td_2 standard
= 1.25 × 0.0065
= 0.0081 in.

(b) For engagement lengths exceeding 15 pitches, for UNEF, 12-UN, 16-UN, 20-UN, 28-UN, and 32-UN series, and for UNS threads in Table 3B, the pitch diameter tolerances shown in Tables 3A and 3B, as applicable, should be increased as follows.

(1) For lengths of engagement over 15 to and including 30 pitches, the pitch diameter tolerances are 1.25 times the values for the standard lengths of engagement shown in Tables 3A and 3B, as applicable.

(2) For lengths of engagement over 30 pitches, the tolerances are 1.50 times the values shown in Tables 3A and 3B, as applicable.

EXAMPLE:
1.5000-28UN-SE2A; LE = 2 in. (56 pitches).
From Table 3A or Table 29: Td_2 = 0.0042 for standard length of engagement.
Td_2 for LE = 56 pitches = 1.50 Td_2 standard
= 1.50 × 0.0042
= 0.0063 in.

NOTE: See example in para. 5.3.1(c).

(c) Major Diameter Tolerance and Length of Engagement for External Threads, All Classes. External thread major diameter tolerances are based on pitch only and are applicable for all lengths of engagement, with this exception: where the external thread pitch diameter tolerance for long lengths of engagement exceeds 0.9 times the major diameter tolerance, the latter should be increased to 1.10 times the adjusted pitch diameter tolerance.

Formulas for the major diameter tolerance for external threads are given in para. 5.8.1(b) and values are given in Sections 12 and 13.

EXAMPLE:
1.5000-28UN-SE2A; LE = 2 in. (56 pitches).
From the example in para. 5.3.1(b), Td_2 = 0.0063.
From Table 29, Td = 0.0065, so Td_2 = 0.969 Td. Therefore, Td must be adjusted to 1.10 Td_2.
Adjusted Td = 1.10 × 0.0063 = 0.0069 in.

(d) High Strength Materials Using Standard Pitch Diameter Tolerances. For applications of long length of engagement of mating parts involving very high strength materials, increases in tolerances based on standard length of engagement may be detrimental. In these cases, the tolerances based on the standard

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length of engagement may be applied to increased length of engagement threads. This requires the GO thread gages to have a special length equal to the length of engagement.

(e) Standard Bolt, Added Allowance in Tapped Hole, EI Increases. In some cases where greater than standard length of engagement is required, it is desirable to use standard externally threaded parts with tolerances based on standard length of engagement. For example, in the case of a standard bolt assembled into a tapped hole in aluminum, the designation of the bolt thread will conform to that of a thread for a standard length of engagement.

To assure proper assembly, the tapped hole thread into which the bolt is assembled must not interfere with the bolt thread. This could happen if no special provision were made in the tapped hole thread due to the cumulative effect of lead variation on the bolt thread, inasmuch as the increased length of engagement exceeds the thickness of the GO thread gage used for acceptance of the bolt thread. To avoid this condition, an allowance should be provided in the tapped hole, the amount of which should be the diameter equivalent of the cumulative lead variation for the increased length of engagement, which is one-half the pitch diameter tolerance of the bolt thread allowed for the standard length of engagement. This requires the GO thread and GO plain gages to have a special length equal to the length of engagement.

EXAMPLE:
0.5000-13UNC-SE2B; LE = 1 in. (2 diameters); assembled with standard bolt thread.
Add allowance $EI = {}^1/_2Td_2$ for standard bolt thread. From Table 4, column 5, ${}^1/_2Td_2$ (standard) = 0.0025. Therefore, the thread is redesignated to indicate a nonstandard internal thread with the allowance of 0.0025 added to the basic size of 0.5000. New designation is 0.5025-13UNS-SE2B. Allowance is also added to the standard minor diameter size limits and to the adjusted pitch diameter size limits. See paras. 5.3.1(a) and 6.6.1.

(f) Standard Internal Thread, Added Allowance on External Thread, es Increases. In some cases where greater than standard length of engagement is required, it is desirable to use standard internally threaded parts with tolerances based on standard length of engagement.

The threaded rod onto which a standard clevis yoke is assembled must not interfere with the clevis yoke thread, since standard clevis yokes have extra internal threads. An allowance should be provided on the rod thread, the amount of which should be the diameter equivalent of the cumulative lead variation for the increased length of engagement, which is one-half the pitch diameter tolerance of clevis yoke thread allowed for the standard length of engagement. The major diameter tolerance is not increased. This requires the GO thread and GO plain gages to have a special length equal to the length of engagement.

EXAMPLE:
0.3750-24UNF-SE2A; LE = 0.88 in. (2.35 diameters); assembled with standard internal thread.
Add allowance, equal to ${}^1/_2TD_2$ for standard internal thread. From Table 4, column 8, ${}^1/_2TD_2$ (standard) = 0.00245, which is rounded to 0.0025. Therefore, the thread is redesignated to indicate a nonstandard external thread with the allowance of 0.0025 subtracted from the basic size of 0.3750. New designation is 0.3725-24UNS-SE2A. The added allowance is also subtracted from the standard major diameter size limits and from the adjusted pitch diameter size limits. See paras. 5.3.1(a) and 6.6.1.

5.3.2 Long Length of Engagement Using Standard Thread Gage Limits. ANSI/ASME B1.2 recommends that the length of the GO gage should approximate the length of engagement. However, it is sometimes more economical to accept these threads with GO thread gages made from standard gage blanks which have length approximating the standard lengths of engagement.

NOTE: When this is done, additional precautions are necessary to determine the effect of cumulative variation of lead and straightness of thread axis due to a long length of engagement.

If applicable, an additional allowance should be provided, preferably on the external thread, the amount of which should be the diameter equivalent of the cumulative lead variation for the increased length of engagement, equal to the sum of one-half the pitch diameter tolerances of the external and internal threads allowed for the standard length of engagement.

EXAMPLE:
0.3750-24UNF-2A; LE = 0.88 in. (2.35 diameters); with external and internal thread gages of standard length.
Add allowance equal to ${}^1/_2Td_2 + {}^1/_2TD_2$ for standard mating threads. From Table 4, column 5, ${}^1/_2Td_2$ (standard) = 0.0019.
From Table 4, column 8, ${}^1/_2TD_2$ (standard) = 0.00245.
The sum of these, after rounding, is equal to 0.0044, which is the added allowance. Therefore, the thread is redesignated to indicate a nonstandard external thread, with the allowance of 0.0044 subtracted from the basic size of 0.3750. New designation is 0.3706-24UNS-2A. The added allowance is also subtracted from the standard major diameter and pitch diameter size limits. See para. 6.6.2.

5.4 Minor Diameter Tolerance and Allowance for External Threads

The tolerance for minor diameter is for reference only. In dimensioning external threads, the minimum minor diameter is not specified, being established by the crest of an unworn tool. In practice, the minor diameter of an external thread is satisfactory when

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accepted by a gage or gaging method that represents the maximum-material condition of the internal thread less the allowance *es*, if any. A formula for the minor diameter tolerance of external threads is given in para. 5.8.1(d).

5.5 Major Diameter Tolerance for Internal Threads

The tolerance for major diameter is for reference only. In dimensioning internal threads, the maximum major diameter is not specified, being established by the crest of an unworn tool. In practice, the major diameter of an internal thread is satisfactory when accepted by a gage or gaging method that represents the maximum-material condition of an external thread which has no allowance. A formula for the major diameter tolerance of internal threads is given in para. 5.8.2(a).

5.6 Minor Diameter Tolerance and Length of Engagement for Internal Threads

Formulas for the minor diameter tolerance for internal threads are given in para. 5.8.2(c) and values are given in Sections 12 and 13.

Internal thread minor diameter tolerances are suitable for lengths of engagement up to 1.5 diameters. For applications having shorter or longer lengths of engagement, it may be advantageous to decrease or increase the tolerance as explained below.

5.6.1 The principal practical factors which govern minor diameter tolerance are ease of tapping, standard drill sizes, and height of engagement.

NOTE: Height of engagement is measured in a radial direction, while length of engagement is measured in an axial direction.

Height of engagement correlates with the stripping strength of the thread assembly and, therefore, also with the length of engagement. It also correlates with the tendency toward disengagement of the threads on one side when assembly is eccentric. The amount of possible eccentricity is one-half of the sum of the allowance and pitch diameter tolerances on both mating threads. For a given pitch, or height of thread, this sum increases with the diameter, and accordingly, this factor would require a decrease in minor diameter tolerance with an increase in thread diameter. However, such a decrease in tolerance often is not feasible without requiring special drill sizes; therefore, to be able to use as many as possible of the available standard drill sizes listed in ANSI B94.11M, the minor diameter tolerance for Classes 1B and 2B of a given pitch for ¼ in. diameter and larger is constant.

There may be applications where the lengths of engagement of the mating threads or the combination of materials used for mating threads are such that the maximum tolerance may not provide the desired strength of the fastening. Experience has shown that for lengths of engagement less than 0.67*D* (the minimum thickness of standard nuts), the minor diameter tolerance may be reduced without causing tapping difficulties.

In other applications, the length of engagement of mating threads may be long because of design considerations or the combination of materials used for mating threads. As the threads engaged increase in number, their height of engagement may be shallower and still develop stripping strength greater than the external thread breaking strength. In these cases, the maximum tolerance should be increased to reduce the possibility of tapping difficulties.

It is particularly important to reduce the number of minor diameter tolerances to a practical minimum. This reduction is usually obvious to the producer of longer internally threaded components, but sometimes is not understood by the user. Tolerances for all recommended diameters, lengths of engagement, and selected pitches are given in Table 39 for Classes 1B and 2B, and in Table 40 for Class 3B.

In these Tables, the tolerances for lengths of engagement less than 0.33*D* are 0.50 times the formula values. For lengths of engagement from 0.33*D* to 0.67*D*, the tolerances are 0.75 times the formula values; for lengths of engagement from 0.67*D* to 1.5*D*, the tolerances are equal to the formula values; and for lengths of engagement over 1.5*D*, the tolerances are 1.25 times the formula values. Where the tolerance value so computed is more than 0.394*P*, which corresponds to a resulting minimum thread height of 53%, the value is adjusted to equal 0.394*P*.

5.7 Disposition of Allowance and Tolerance

The disposition of allowance, tolerance, and crest clearances for the various thread classes is shown in Figs. 2 and 3.

5.8 Formulas for Allowance and Tolerance

The following formulas for allowance and tolerance are used for unified formulation and apply to standard and special series screw threads.

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The following symbols are used in the equations.

D = basic major (nominal) diameter
LE = length of engagement, in.
P = pitch, in. = $1/n$
H = height of fundamental triangle = $0.866025P$
n = threads per inch

5.8.1 External Thread

(a) Allowance (External Threads)

(1) Classes 1A and 2A = 0.300 Class 2A pitch diameter tolerance

(2) Class 3A = no allowance

(b) Major Diameter Tolerance (External Threads)

(1) Class 1A = $0.090\sqrt[3]{P^2}$

(2) Classes 2A and 3A = $0.060\sqrt[3]{P^2}$

The tolerance for Class 2A coarse and the 8-thread series threads of unfinished, hot-rolled material is $0.090\sqrt[3]{P^2}$. This does not apply to standard fasteners with rolled threads.

(c) Pitch Diameter Tolerance (External Threads)

(1) Class 1A = 1.500 Class 2A pitch diameter tolerance

(2) Class 2A[1] = $0.0015\sqrt[3]{D} + 0.0015\sqrt{LE} + 0.015\sqrt[3]{P^2}$

(3) Class 3A = 0.750 Class 2A pitch diameter tolerance

(d) Minor Diameter Tolerance (External Threads)

(1) UNR Classes. To intersection of rounded root with its centerline (see Figs. 2 and 3), equals pitch diameter tolerance for class of thread specified, plus $H/8$ (see Table 6).

(2) UN Classes 1A, 2A, and 3A. To intersection of flat root with flanks of threads (see Figs. 2 and 3), equals pitch diameter tolerance for class of thread specified, plus $H/4$ (see Table 6).

5.8.2 Internal Thread

(a) Major Diameter Tolerance (Internal Threads). For Classes 1B, 2B, and 3B, equals $H/6$ plus the pitch diameter tolerance of the class of thread under consideration.

(b) Pitch Diameter Tolerance (Internal Threads)

(1) Class 1B = 1.950 Class 2A pitch diameter tolerance (1.5 Class 2B)

(2) Class 2B = 1.300 Class 2A pitch diameter tolerance

(3) Class 3B = 0.975 Class 2A pitch diameter tolerance (0.750 Class 2B)

(c) Minor Diameter Tolerance (Internal Threads)

(1) Classes 1B and 2B. For all thread series and special threads in sizes less than ¼ in., equals $[0.05\sqrt[3]{P^2} + 0.03P/D] - 0.002$ in., within the following limitations.

(a) Tolerances shall not be greater than $0.394P$. (This corresponds to 53% of the thread[2] and applies in the range of the smallest number sizes of the UNC and UNF thread series.)

(b) Tolerances shall not be less than $0.25P - 0.4P^2$. (This corresponds to a thread[2] of 65% for 80 to 24 threads per inch.)

The formulas are suitable for general applications having lengths of engagement up to 1.5 diameters.

For all thread series and special threads ¼ in. and larger, 80 to 4 threads per inch, inclusive, equals $0.25P - 0.4P^2$. (This corresponds to a thread[2] of 64.5% for 80 threads per inch graduating to 71.8% for 4 threads per inch.) For all thread series and special threads ¼ in. and larger with less than 4 threads per inch, equals $0.15P$.

(2) Class 3B. For all thread series, equals $[0.05\sqrt[3]{P^2} + 0.03P/D] - 0.002$ in., within the following limitations.

(a) Tolerance shall not be greater than $0.394P$. (This corresponds to 53% of the thread[2] and applies in the range of the smallest numbered sizes of the UNC and UNF thread series.)

(b) Tolerance shall not be less than:

(1) for 80 to 13 threads per inch, inclusive, $0.23P - 1.5P^2$. (This corresponds to a thread[2] of 67% for 80 threads per inch, graduating to 74% for 13 threads per inch.)

(2) for 12 threads per inch and coarser, $0.120P$. (This corresponds to a thread[2] of 74% and is the tolerance for all sizes 12 threads and coarser and 1 in. and larger.)

The formulas are suitable for general applications having lengths of engagement up to 1.5 diameters.

5.9 Circular Runout

Circular runout is the full indicator movement (see ANSI Y14.5M).

5.9.1 Internal Thread. When measurement is specified, the runout of the minor diameter cylinder with the pitch diameter cylinder on the internal thread shall not exceed its pitch diameter tolerance.

[1]See Table 19 for values of these terms corresponding to given values of diameter, length of engagement, and pitch.

[2]The percent of thread is based on the "old symmetrical" thread height of $0.64952P$. See Table 6, column 13.

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5.9.2 External Thread. When measurement is specified, the runout of the major diameter cylinder with the pitch diameter cylinder on the external thread shall not exceed its pitch diameter tolerance.

5.10 Lead and Flank Angle Tolerances

See Section 9.

5.11 Coated or Plated Threads

See Section 7 for dimensional accommodation and limits for coated threads.

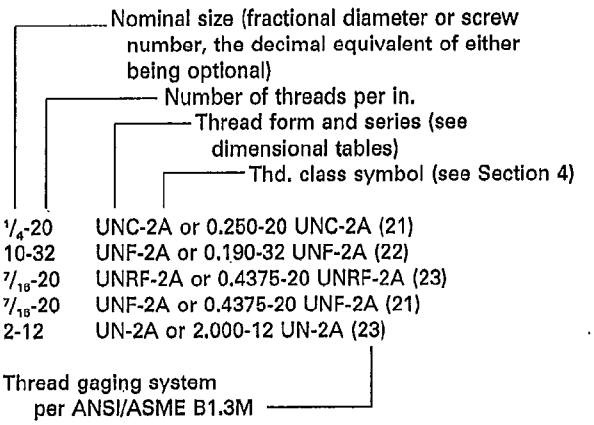
6 SCREW THREAD DESIGNATION

6.1 Basic Method of Designating

The basic method of designating a screw thread is used where the standard tolerances or limits of size based on the standard length of engagement are applicable, as indicated in Section 5.

The designation specifies in sequence the nominal size, number of threads per inch, thread series symbol, thread class symbol, and gaging system per ANSI/ASME B1.3M (see Fig. 4). The nominal size is the basic major diameter and is specified as the fractional diameter, screw number, or their decimal equivalent. Where decimal equivalents are used for size callout, they shall be shown in four place decimals (omitting the cipher in the fourth place) for fractional sizes, and in three place decimals for number sizes. They shall be interpreted as being nominal size designations only and shall have no dimensional significance beyond the fractional size or number designation. The thread series symbol indicates the thread form (refer to Section 2), series, and tolerance formulation (refer to Section 3). The thread series symbols for the UN thread form are UNC, UNF, UNEF, or UN for only those sizes of the various series shown in Table 2 and UNS for any other intermediate and larger size diameter–pitch combination having tolerances to unified formulation. The corresponding thread series symbols for the UNR thread form are UNRC, UNRF, UNREF, or UNR. The symbol UNRS corresponds to UNS. The thread class symbols are 1A, 1B, 2A, 2B, 3A, or 3B, where the suffixes A and B relate to external and internal threads, respectively.

UNS threads and threads having special length of engagement require certain additional information as shown in paras. 6.4 and 6.6.



GENERAL NOTE:
Thread acceptability gaging system requirement of ANSI/ASME B1.3M may be added to the thread size designation as noted above or as specified in pertinent documentation, such as drawing or procurement document.

FIG. 4 SCREW THREAD DESIGNATIONS

6.2 Method of Designating Coated Threads

Specification on drawings of the before and after coating dimensions for screw threads is sometimes dictated by an engineering or production consideration that the size before and after coating be controlled. This results from coated screw threads having two stages of design — the before coating stage and the after coating stage. The threaded product may be produced by a supplier and coated by a user. In this case, it is necessary that a clear understanding of the coating requirements and the allowance for coating buildup be agreed upon by both supplier and user (see Section 7).

The before coating (plating) dimensions have a definite bearing on the strength of the screw threads. The before coating stage is, therefore, decidedly an engineering consideration; it is also a production consideration in requiring that proper allowance be made for the specified coating thickness. The finished parts should be of a size after coating that will allow them to be assembled with their coating components as intended.

Recommended methods for designating coated thread under various conditions are described in the following paragraph.

6.2.1 For coated (or plated) Class 2A external threads, the basic (max.) major and basic (max.) pitch diameters shall be given, followed by the words

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AFTER COATING. The major and pitch diameter limits of size before coating shall also be given, followed by the words BEFORE COATING.

EXAMPLE:
$^3/_4$-10 UNC-2A (21)
Major diam. 0.7500 max. } AFTER
PD 0.6850 max.[3] } COATING

Major diam. 0.7482–0.7353 } BEFORE
PD 0.6832–0.6773[4] } COATING

Certain applications require an allowance for rapid assembly to permit application of the proper lubricant or for residual growth due to high-temperature expansion. In these applications, when the thread is coated and 2A allowance is not permitted to be consumed by such coating, the thread class symbol is qualified by the addition of the letter G (old symbol for allowance) following the class symbol; the maximum major and maximum pitch diameters are reduced below basic size by the amount of the 2A allowance and followed by the words AFTER COATING, thereby insuring that the allowance is maintained. The thread before coating must have special provisions to allow for coating thickness. The major and pitch diameter limits of size before coating (calculated in accordance with Section 7) shall also be given, followed by the letters SPL (special) and by the words BEFORE COATING.

EXAMPLE:
$^3/_4$-10 UNC-2AG (22)
Major diam. 0.7482 max. } AFTER
PD 0.6832 max.[4] } COATING

Major diam. 0.7464–0.7335 SPL } BEFORE
PD 0.6814–0.6755 SPL[5] } COATING

Threads accepted to Class 2A limits before coating are accepted after coating by basic size Class 3A GO thread gages. The allowance given in the dimensional tables for Class 2A thread is sufficient to allow for a limited amount of coating as described in Section 7. However, if a greater coating thickness is required, it will be necessary to calculate the before coating limits in accordance with Section 7.

6.2.2 For coated (or plated) Class 3A external threads, the maximum major and maximum pitch diameters may optionally be given, followed by the words AFTER COATING, thereby indicating that the thread before coating must have special provisions to allow for coating thickness. The major and pitch diameter limits of size before coating (calculated in accordance with para. 7.5) shall be given, followed by the letters SPL (special) and by the words BEFORE COATING.

EXAMPLE: Thickness of coating 0.0002 in. to 0.0003 in.
$^1/_4$-28 UNF-3A (21)
Major diam. 0.2500 max. } AFTER COATING
PD 0.2268 max.[6] } (Optional)

Major diam. 0.2494–0.2431 SPL } BEFORE
PD 0.2256–0.2235 SPL } COATING

6.2.3 For coated (or plated) Class 1A external threads, the maximum major and maximum pitch diameters may optionally be given, followed by the words AFTER COATING, thereby indicating that the thread before coating must have special provisions to allow for coating thickness. The major and pitch diameter limits of size before coating (calculated in accordance with para. 7.5) shall be given, followed by the letters SPL (special) and by the words BEFORE COATING.

EXAMPLE: Thickness of coating 0.0002 in. to 0.0003 in.
$^1/_4$-20 UNC-1A (21)
Major diam. 0.2489 max. } AFTER COATING
PD 0.2164 max.[7] } (Optional)

Major diam. 0.2483–0.2363 SPL } BEFORE
PD 0.2152–0.2100 SPL[8] } COATING

6.2.4 Where an allowance is required to accommodate coating (or plating) on Class 1B, 2B, or 3B internal threads, the minimum minor and minimum pitch diameters may optionally be given, followed by the words AFTER COATING. The minor and pitch diameter limits of size before coating (calculated in accordance with para. 7.6) shall be given, followed by the letters SPL (special) and by the words BEFORE COATING.

EXAMPLES: Thickness of coating 0.0002 in. to 0.0003 in.
$^1/_4$-20 UNC-1B (21)
Minor diam. 0.196 min. } AFTER COATING
PD 0.2175 min. } (Optional)

Minor diam. 0.197–0.207 SPL } BEFORE
PD 0.2187–0.2256 SPL } COATING

[3]Major and PD values are equal to basic and correspond to those in Table 3A for Class 3A.

[4]Major and PD limits are those in Table 3A for Class 2A.

[5]Major and PD limits correspond to those in Table 3A for Class 2A minus the coating allowance.

[6]Major and PD limits are those in Table 3A for Class 3A.

[7]Major and PD limits are those in Table 3A for Class 1A.

[8]Major and PD limits correspond to those in Table 3A for Class 1A minus the coating allowance.

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$^{3}/_{4}$-10 UNC-2B (22)
Minor diam. 0.642 min. } AFTER COATING
PD 0.6850 min. } (Optional)

Minor diam. 0.643–0.663 SPL } BEFORE
PD 0.6862–0.6935 SPL } COATING

$^{1}/_{4}$-28 UNF-3B (23)
Minor diam. 0.2110 min. } AFTER COATING
PD 0.2268 min. } (Optional)

Minor diam. 0.2116–0.2194 SPL } BEFORE
PD 0.2280–0.2308 SPL } COATING

NOTE: The after coating limits for all of the examples above are the minor and PD values in Table 3A for the respective class of thread.

6.3 Method of Designating Left-Hand Threads

Unless otherwise specified, threads are right hand; a left-hand thread shall be designated LH as follows.

EXAMPLE:
$^{1}/_{4}$-20 UNC-3A-LH (21)

6.4 Method of Designating UNS Threads

UNS threads are special combinations of diameter and pitch with tolerance to unified formulation.

UNS threads have the basic form of designation set out above, supplemented always by the limits of size.

EXAMPLES:
$^{1}/_{4}$-24 UNS-3A (21)
Major diam. 0.2500–0.2428
PD 0.2229–0.2201
Minor diam. 0.205 max.

0.495-20 UNS-3A (21)
Major diam. 0.4950–0.4869
PD 0.4625–0.4593
Minor diam. 0.441 max.

1.200-10 UNS-2B (21)
Minor diam. 1.092–1.113
PD 1.1350–1.1432
Major diam. 1.200 min.

6.5 Designations for Other Threads

Threads having tolerances that do not conform to unified formulation and threads having multiple start or lead, or special form, also require additional considerations in the thread designation. The recommended methods of designating these threads are described in the following paragraphs.

6.5.1 Method of Designating Threads Having Tolerances Not to Unified Formulation. If a standard series thread is altered in any respect other than revised pitch diameter limits for a special length of engagement, the modification of crests, or the adjustment of the limits of size to accommodate coating, as shown above, it is designated in accordance with the following.

EXAMPLES:
$^{7}/_{16}$-24 Unified Form SPL-EXT[9] (22)
Major diam. 0.4340–0.4280 SPL
PD 0.4065–0.4025 SPL
Minor diam. 0.3889 max.
LE 0.38

$^{1}/_{2}$-13 Unified Form SPL-INT[9] (22)
Minor diam. 0.424–0.434 SPL
PD 0.4500–0.4580 SPL
Major diam. 0.5000 min.
LE 0.50

6.5.2 Method of Designating Multiple Start Threads. If a thread is required with a multiple start or lead, it is designated by specifying in sequence the nominal size, pitch (in decimals or threads per inch), and lead (in decimals or fractions) as follows.

EXAMPLE:
$^{3}/_{4}$-0.0625*P*-0.1875*L* Unified Form SPL-EXT[9] (23)
Major diam. 0.7485–0.7391
PD 0.7079–0.7003 SPL
Minor diam. 0.6808 max.
LE 0.75

6.5.3 Method of Designating Special Form Threads. If a thread for design consideration requires a variation from unified standard thread contour and is not covered by another recognized standard, such as when the detail of the root differs from that for the standard thread form, the designation shall not include either the letters "UN" or the word "UNIFIED," but shall be as follows.

EXAMPLE:
$^{7}/_{8}$-18 SPL 60 deg. Form-EXT[9] (22)
Major diam. 0.8750–0.8668
PD 0.8384–0.8343
Minor diam. 0.8068 max.
LE 0.69

[9]Where the thread designation is used in text or is shown on a drawing and a leader line does not indicate the specific position, then add EXT or INT to the designation.

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6.6 Method of Designating Threads Having Special Length of Engagement

In the assembly of threads in mating parts, the length of engagement varies according to the design requirements. It should be noted that the length of engagement is not necessarily the same as the full thread length provided on the part, but is the length of assembled thread in the mating parts.

Where a standard series thread has a special length of engagement differing from that for which the standard pitch diameter tolerances are applicable as indicated in Section 5, the thread class symbol is qualified by the addition of the letters SE (special engagement) preceding the class symbol. The specification of the special pitch diameter limits of size and the length of engagement *LE*, rounded to a two place decimal, are a requirement.

EXAMPLES:
1/2-13 UNC-SE2A (23)
PD 0.4485–0.4423
LE 1.00

1/4-24 UNS-SE3A (23)
Major diam. 0.2500–0.2428
PD 0.2229–0.2194
LE 0.88

6.6.1 In some cases where greater than standard length of engagement is required, it is desirable to use standard externally threaded parts with tolerances based on standard length of engagement. For example, in the case of a standard bolt assembled into a tapped hole in aluminum, the designation of the bolt thread will conform to that of a thread for a standard length of engagement.

The designation for the tapped hole thread should include the allowance in the basic size, the pitch diameter limits of size, and the length of gage, in addition to the information normally given. See para. 5.3.1(e).

EXAMPLE: Requiring use of 1.00 long GO thread and GO plain gages
0.5025-13 UNS-SE2B (21)
Minor diam. 0.420–0.437
PD 0.4525–0.4606
LG 1.00

Similarly, where greater than standard length of engagement is required, it is desirable to use standard internally threaded parts with tolerances based on standard length of engagement. Therefore, the external thread is provided with an added allowance. See para. 5.3.1(f).

The designation for the external thread should include the added allowance in the basic size, the pitch diameter limits of size, and the length of gage, in addition to the information normally given.

EXAMPLE: Requiring use of 0.88 long GO thread and GO plain gages
0.3725-24 UNS-SE2A (21)
Major diam. 0.3714–0.3642
PD 0.3443–0.3396
LG 0.88

6.6.2 When a long length of engagement is required and standard length GO thread and GO plain gages are to be used, the thread designation should indicate the thread modifications and a standard gage length, *LG* Std. (see para. 5.3.2).

EXAMPLES: With additional allowance indicating use of standard length GO thread and GO plain gages
0.5058-13 UNS-2B (22)
Minor diam. 0.423–0.440
PD 0.4558–0.4623
LG Std.

0.3706-24 UNS-2A (22)
Major diam. 0.3695–0.3623
PD 0.3424–0.3386
LG Std.

6.6.3 For applications of long length of engagement of mating parts involving very high strength materials, increases in tolerances based on standard length of engagement may be detrimental. In these cases, the tolerances based on the standard length of engagement may be applied to increased length of engagement threads. This requires the GO thread gages to have a special length equal to the length of engagement as specified.

The designations for restricted applications should be qualified with the abbreviation SPL (special) as shown in the examples below. See para. 5.3.1(d).

EXAMPLES: Requiring use of 1.00 long GO thread and GO plain gages
0.500-20 UNF-3A SPL (21)
LG 1.00 SPL

0.500-20 UNF-3B SPL (21)
LG 1.00 SPL

NOTE: In drawings, tolerances tabulated for the standard length of engagement in ASME B1.1 shall apply over the full length of engagement.

6.7 Method of Designating Threads Having Modified Crests

It is occasionally necessary to modify the limits of size of the major diameter of an external thread or the minor diameter of an internal thread within the maximum-material limits established for standard series and special threads in order to fit a specific pur-

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pose, but without change in class of thread or pitch diameter limits. (It should be noted that standard pitch diameter gages may be used to accept such threads.) Such threads shall be specified with the established thread designation, followed by a statement of the modified diameter limits and the designation MOD. This practice also applies to modifications of internal thread minor diameters described in para. 5.6.1.

EXAMPLES:
$^3/_8$-24 UNF-3A MOD (21)
Major diam. 0.3720–0.3648 MOD

$1^1/_2$-10 UNS-3B MOD (21)
Minor diam. 1.398–1.409 MOD
PD 1.4350–1.4412
Major diam. 1.500 min.

7 DIMENSIONAL ACCOMMODATION OF COATING OR PLATING FOR 60 DEG. THREADS

7.1 Introduction

It is not within the scope of this Standard to make recommendations for thickness of, or to specify limits for, coatings. However, it will aid mechanical interchangeability if certain principles are followed wherever conditions permit. The following guides should be helpful in determining the amount and direction of the alterations to establish applicable limits of size before coating. Some commonly used and firmly established processes for heavy coatings, such as hot dip galvanizing, do not fall within the scope of this Section.

NOTE: The term *coating* refers to one or more applications of additive material to threads, including dry film lubricants, but excluding soft or liquid lubricants that are readily displaced in assembly and gaging. Plating is therefore included as coating in the text.

This Standard specifies limits of size that pertain whether threads are coated or uncoated. Only in Class 2A threads is the allowance available to accommodate coatings. Thus, in all classes of internal threads and in all Class 1A, 2AG, and 3A external threads, limits of size must be adjusted before plating to provide suitable provision for the desired coating.

7.2 Material Limits for Coated Threads

Unless otherwise specified, size limits for standard external thread Class 2A apply prior to coating. The external thread allowance may thus be used to accommodate the coating thickness on coated parts, provided that the maximum coating thickness is no more than one-fourth of the allowance (see Fig. 5). Thus, the thread after coating is subject to acceptance using a basic Class 3A size GO thread gage and a Class 2A thread gage for either minimum material or NOT GO. Where external thread has no allowance, or allowance must be maintained after coating, and for standard internal threads, sufficient allowance must be provided prior to coating to assure that finished product threads do not exceed the maximum-material limits specified. For thread Class 3A, Class 2A allowances in accordance with Tables 20 to 30 or Table 32 should be applied whenever possible (see paras. 7.4, 7.5, and 7.6).

7.3 Dimensional Effects of Coating

On a cylindrical surface, the effect of coating is to change the diameter by twice the coating thickness, one coating thickness on each side of the cylinder. Because the coating thickness is measured perpendicular to the coated surface, while the pitch diameter is measured perpendicular to the thread axis, the effect of a uniformly coated thread flank on the pitch diameter is a change of four times the thickness of coating on the flank (see Fig. 5). The diameters of external threads before coating will be smaller, while the diameters of internal threads before coating will be larger, than the coated diameters.

7.4 External Thread With Allowance Available for Coating

7.4.1 Maximum and Minimum Coating Thickness Specified. The amount of the allowance on the pitch diameter is sufficient for uniform coating if four times the maximum coating thickness is equal to or less than the allowance tabulated in Tables 3A, 3B, 20 to 30, or 32.

7.4.2 Only Nominal or Minimum Coating Thickness Specified. If no coating thickness tolerance is given, it is recommended that a tolerance of plus 50% of the nominal or minimum thickness be assumed. Then the amount of the allowance on the pitch diameter is sufficient for uniform coating if six times the specified coating thickness is equal to or less than the allowance tabulated in Tables 3A, 3B, 20 to 30, or 32.

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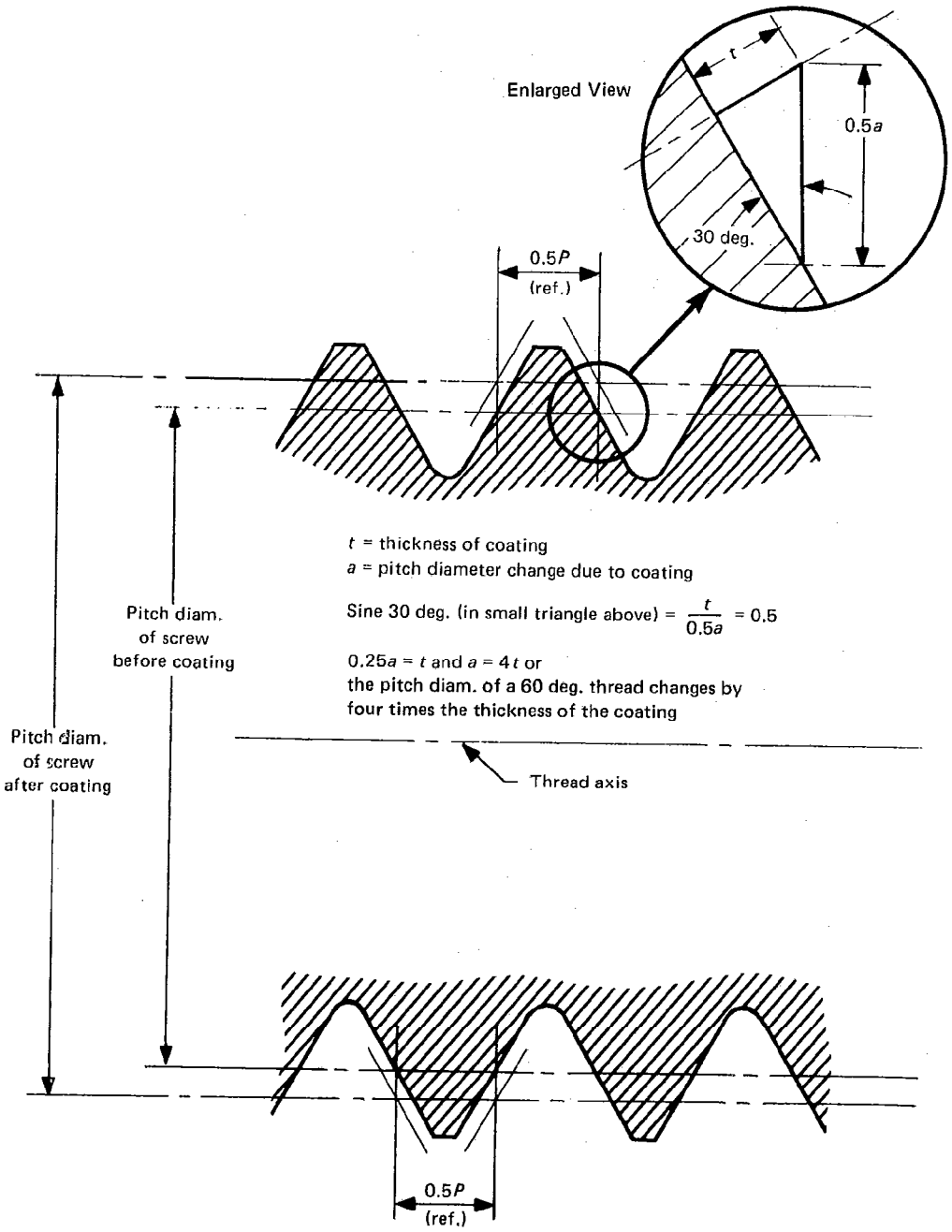

FIG. 5 RATIO OF PITCH DIAMETER CHANGE TO THICKNESS OF COATING ON 60 DEG. THREADS

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7.5 External Thread With No Allowance for Coating

7.5.1 Maximum and Minimum Coating Thickness Specified. To determine before coating gaging limits for a uniformly coated thread, decrease:

(a) the maximum pitch diameter by four times the maximum coating thickness;

(b) the minimum pitch diameter by four times the minimum coating thickness;

(c) the maximum major diameter by two times the maximum coating thickness;

(d) the minimum major diameter by two times the minimum coating thickness.

EXAMPLE:
⅜-16 UNC-2A (21) AFTER COATING
Coating thickness 0.0002–0.0003 in.

To determine the before coating maximum-material sizes, decrease the maximum pitch diameter of 0.3331 in. by 0.0012 in. (4 × 0.0003) to 0.3319 in., and the maximum major diameter of 0.3737 in. by 0.0006 in. (2 × 0.0003) to 0.3731 in. For the before coating minimum sizes, decrease the minimum pitch diameter of 0.3287 in. by 0.0008 in. (4 × 0.0002) to 0.3279 in., and the minimum major diameter of 0.3643 in. by 0.0004 in. (2 × 0.0002) to 0.3639 in. The before coating sizes should be included in the thread designation (see para. 6.2.1).

7.5.2 Only Nominal or Minimum Coating Thickness Specified. If no coating thickness tolerance is given, it is recommended that a tolerance of plus 50% of the nominal or minimum thickness be assumed. Then, to determine before coating gaging limits for a uniformly coated thread, decrease:

(a) the maximum pitch diameter by six times the coating thickness;

(b) the minimum pitch diameter by four times the coating thickness;

(c) the maximum major diameter by three times the coating thickness;

(d) the minimum major diameter by two times the coating thickness.

EXAMPLE:
½-13 UNC-3A (22)
Coating thickness 0.0004 in.

Since the allowance for Class 2A thread is 0.0015 in., the nominal or minimum coating thickness that may be applied is equal to 0.0015 in. divided by six, or 0.00025 in. (the maximum thickness of coating that may be applied is equal to 0.0015 divided by four or 0.00038 in.). This is not sufficient for the required nominal or minimum coating of 0.0004 in. specified, so additional adjustments to the before coating pitch and major diameters must be made.

To determine the before coating maximum-material sizes, decrease the maximum pitch diameter of 0.4500 in. by 0.0024 in. (6 × 0.0004) to 0.4476 in., and the maximum major diameter of 0.5000 in. by 0.0012 in. (3 × 0.0004) to 0.4988 in. For the before coating minimum sizes, decrease the minimum pitch diameter of 0.4463 in. by 0.0016 in. (4 × 0.0004) to 0.4447 in., and the minimum major diameter of 0.4891 in. by 0.0008 in. (2 × 0.0004) to 0.4883 in. The before coating sizes should be included in the thread designation (see para. 6.2.1).

7.5.3 Adjusted Size Limits. It should be noted in the preceding examples that the before coating material limit tolerances are less than the tolerances after coating. This is because the coating tolerance consumes some of the product tolerance. In some instances, there may be insufficient pitch diameter tolerance available in the before coating condition, so that additional adjustments and controls will be necessary.

7.5.4 Strength. On small thread sizes (0.190 in. and smaller), there is a possibility that coating thickness adjustments will cause base material (minimum) conditions that may significantly affect the strength of externally threaded parts. Limitations on coating thickness, or part redesign, may be necessary.

7.6 Internal Threads

Standard internal threads provide no allowance for coating thickness. To determine before coating gaging limits for a uniformly coated thread, increase:

(a) the minimum pitch diameter by four times the maximum coating thickness, if specified, or by six times the minimum or nominal coating thickness, if not specified;

(b) the maximum pitch diameter by four times the minimum or nominal coating thickness;

(c) the minimum minor diameter by two times the maximum coating thickness, if specified, or by three times the minimum or nominal coating thickness, if not specified;

(d) the maximum minor diameter by two times the minimum or nominal coating thickness.

7.7 Other Considerations

It is essential to adequately review all possibilities and consider limitations in the threading and coating production processes before finalizing the coating

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process and the allowance required to accommodate the coating. A no allowance thread after coating shall not transgress the basic profile, and is therefore subject to acceptance using a basic Class 3A, 1B, 2B, or 3B size GO thread gage.

8 STANDARD SERIES THREADS (UN/UNR) AND LIMITS OF SIZE FOR STANDARD SERIES AND UNS/UNRS SERIES THREADS

8.1 Standard Series

The standard series for unified inch screw threads is listed in Table 2. Although the designations shown are for the UN thread form, UNR designations may be used in all cases.

8.2 Limits of Size

The limits of size are defined by the design profile at its maximum-material condition and the minimum profile at the minimum-material condition. The limits are specified as diameters (major diameter, minor diameter, pitch diameter), and the practical interpretation of these limits on a three-dimensional threaded product depends on the method of inspection. These dimensions serve as a basis for measurement and gaging of the thread, but the methods, techniques, and equipment used for thread evaluation establish the degree of thread conformance to the tabulated dimensions. Current techniques for measuring and gaging do not verify exact conformance of a thread to its specified maximum and minimum envelope. See ANSI/ASME B1.3M for gaging systems for dimensional acceptability.

8.2.1 Limits of size for the majority of the standard series are shown in Table 3A. Omissions are the secondary size range in the 4-UN series, all sizes over 6 in. in the 6-UN series, and all sizes over 6 in. in the 8-UN series. Refer to Table 2 for a list of secondary sizes.

8.2.2 The limits of size for selected combinations of diameter and pitch with tolerances and allowances to unified formulation (designated UNS) are shown in Table 3B.

8.2.3 Limits of size not given may be calculated from the formulas given in the following paragraphs. Formulas and symbols for thread form are given in Section 10.

8.3 Formulas for Limits of Size

These formulas were used to calculate the values shown in Tables 3A and 3B for standard series and selected combinations, respectively. The following symbols are used in the equations.

D bsc = basic major (nominal) diameter
h_s = height of external thread (see Table 6)
h_n = height of internal thread (see Table 6)
h_{as} = screw addendum height (see Table 6)
h_b = $2h_{as}$ (see Table 6)
D_2 bsc = basic pitch diameter ($D - h_b$) (see Tables 8 through 18)
d_3 = UNR series design minor diameter [$d_1 - (H/8)$] (see Tables 8 through 18)
D_1 bsc = basic minor diameter ($D - 2h_n$) (see Tables 8 through 18)
P = pitch, in.

To obtain limits of size using the formulas, see Table 6 for basic thread form data, Section 11 for basic dimensions, Sections 12 and 13 for allowances and tolerances, or Section 5 for formulas of allowance and tolerance. For easy reference, outline guides for determining limits of size of external and internal threads are given in Tables 1A and 1B.

Section 8 continues on page 53.

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TABLE 1A OUTLINE GUIDE FOR DETERMINING LIMITS OF SIZE OF EXTERNAL THREADS

Thread Class	Major Diameter d		Pitch Diameter d_2		Minor Diameter d_1
	Maximum	Minimum	Maximum	Minimum	
1A	Nominal size minus allowance	Maximum, minus tolerance	Maximum major diameter minus h_b (Table 6, col. 13)	Maximum, minus tolerance	See paras. 8.3.1(e) and (f). Established by crest of new tool and minimum minor diameter of GO thread gage.
2A	Nominal size minus allowance	Maximum, minus tolerance	Maximum major diameter minus h_b (Table 6, col. 13)	Maximum, minus tolerance	See paras. 8.3.1(e) and (f). Established by crest of new tool and minimum minor diameter of GO thread gage.
3A	Nominal size	Maximum, minus tolerance	Maximum major diameter minus h_b (Table 6, col. 13)	Maximum, minus tolerance	See paras. 8.3.1(e) and (f). Established by crest of new tool and minimum minor diameter of GO thread gage.

TABLE 1B OUTLINE GUIDE FOR DETERMINING LIMITS OF SIZE OF INTERNAL THREADS

Thread Class	Minor Diameter D_1		Pitch Diameter D_2		Major Diameter D
	Minimum	Maximum	Minimum	Maximum	
1B	Nominal size minus $2h_n$ (Table 6, col. 15)	Minimum, plus tolerance	Nominal size minus h_b (Table 6, col. 13)	Minimum, plus tolerance	See paras. 8.3.2(a) and (b). Established by crest of new tool and maximum major diameter of GO thread gage.
2B	Nominal size minus $2h_n$ (Table 6, col. 15)	Minimum, plus tolerance	Nominal size minus h_b (Table 6, col. 13)	Minimum, plus tolerance	See paras. 8.3.2(a) and (b). Established by crest of new tool and maximum major diameter of GO thread gage.
3B	Nominal size minus $2h_n$ (Table 6, col. 15)	Minimum, plus tolerance	Nominal size minus h_b (Table 6, col. 13)	Minimum, plus tolerance	See paras. 8.3.2(a) and (b). Established by crest of new tool and maximum major diameter of GO thread gage.

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TABLE 2 STANDARD SERIES THREADS (UN/UNR)

Nominal Size			Threads/in.											
			Series With Graded Pitches			Series With Constant Pitches								
Primary	Secondary	Basic Major Diameter	Coarse UNC	Fine UNF	Extra-Fine UNEF	4-UN	6-UN	8-UN	12-UN	16-UN	20-UN	28-UN	32-UN	Nominal Size
0	...	0.0600	...	80	...	...	...	...	...	...	...	...	...	0
...	1	0.0730	64	72	...	...	...	...	...	...	...	...	...	1
2	...	0.0860	56	64	...	...	...	...	...	...	...	...	...	2
...	3	0.0990	48	56	...	...	...	...	...	...	...	...	...	3
4	...	0.1120	40	48	...	...	...	...	...	...	...	...	...	4
5	...	0.1250	40	44	...	...	...	...	...	...	...	...	...	5
6	...	0.1380	32	40	...	...	...	...	...	...	...	...	UNC	6
8	...	0.1640	32	36	...	...	...	...	...	...	...	...	UNC	8
10	...	0.1900	24	32	...	...	...	...	...	...	...	...	UNF	10
...	12	0.2160	24	28	32	...	...	...	...	...	...	UNF	UNEF	12
1/4	...	0.2500	20	28	32	...	...	...	...	...	UNC	UNF	UNEF	1/4
5/16	...	0.3125	18	24	32	...	...	...	...	...	20	28	UNEF	5/16
3/8	...	0.3750	16	24	32	...	...	...	...	UNC	20	28	UNEF	3/8
7/16	...	0.4375	14	20	28	...	...	...	...	16	UNF	UNEF	32	7/16
1/2	...	0.5000	13	20	28	...	...	...	...	16	UNF	UNEF	32	1/2
9/16	...	0.5625	12	18	24	...	...	...	UNC	16	20	28	32	9/16
5/8	...	0.6250	11	18	24	...	...	...	12	16	20	28	32	5/8
...	11/16	0.6875	...	...	24	...	...	...	12	16	20	28	32	11/16
3/4	...	0.7500	10	16	20	...	...	...	12	UNF	UNEF	28	32	3/4
...	13/16	0.8125	...	...	20	...	...	...	12	16	UNEF	28	32	13/16
7/8	...	0.8750	9	14	20	...	...	...	12	16	UNEF	28	32	7/8
...	15/16	0.9375	...	...	20	...	...	...	12	16	UNEF	28	32	15/16
1	...	1.0000	8	12	20	...	...	UNC	UNF	16	UNEF	28	32	1
...	1 1/16	1.0625	...	...	18	...	...	8	12	16	20	28	...	1 1/16
1 1/8	...	1.1250	7	12	18	...	...	8	UNF	16	20	28	...	1 1/8
...	1 3/16	1.1875	...	...	18	...	...	8	12	16	20	28	...	1 3/16
1 1/4	...	1.2500	7	12	18	...	...	8	UNF	16	20	28	...	1 1/4
...	1 5/16	1.3125	...	...	18	...	...	8	12	16	20	28	...	1 5/16
1 3/8	...	1.3750	6	12	18	...	UNC	8	UNF	16	20	28	...	1 3/8
...	1 7/16	1.4375	...	...	18	...	6	8	12	16	20	28	...	1 7/16
1 1/2	...	1.5000	6	12	18	...	UNC	8	UNF	16	20	28	...	1 1/2
...	1 9/16	1.5625	...	...	18	...	6	8	12	16	20	...	...	1 9/16
1 5/8	...	1.6250	...	...	18	...	6	8	12	16	20	...	...	1 5/8
...	1 11/16	1.6875	...	...	18	...	6	8	12	16	20	...	...	1 11/16
1 3/4	...	1.7500	5	...	...	...	6	8	12	16	20	...	...	1 3/4
...	1 13/16	1.8125	...	...	...	...	6	8	12	16	20	...	...	1 13/16
1 7/8	...	1.8750	...	...	...	...	6	8	12	16	20	...	...	1 7/8
...	1 15/16	1.9375	...	...	...	...	6	8	12	16	20	...	...	1 15/16
2	...	2.0000	4 1/2	...	...	...	6	8	12	16	20	...	...	2
...	2 1/8	2.1250	...	...	...	...	6	8	12	16	20	...	...	2 1/8
2 1/4	...	2.2500	4 1/2	...	...	...	6	8	12	16	20	...	...	2 1/4
...	2 3/8	2.3750	...	...	...	...	6	8	12	16	20	...	...	2 3/8
2 1/2	...	2.5000	4	...	...	UNC	6	8	12	16	20	...	...	2 1/2
...	2 5/8	2.6250	...	...	...	4	6	8	12	16	20	...	...	2 5/8
2 3/4	...	2.7500	4	...	...	UNC	6	8	12	16	20	...	...	2 3/4
...	2 7/8	2.8750	...	...	...	4	6	8	12	16	20	...	...	2 7/8

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TABLE 2 STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size			Threads/in.											
			Series With Graded Pitches			Series With Constant Pitches								
Primary	Secondary	Basic Major Diameter	Coarse UNC	Fine UNF	Extra-Fine UNEF	4-UN	6-UN	8-UN	12-UN	16-UN	20-UN	28-UN	32-UN	Nominal Size
3	...	3.0000	4	...	...	UNC	6	8	12	16	20	...	...	3
...	3 1/8	3.1250	...	...	...	4	6	8	12	16	...	...	...	3 1/8
3 1/4	...	3.2500	4	...	...	UNC	6	8	12	16	...	...	...	3 1/4
...	3 3/8	3.3750	...	...	...	4	6	8	12	16	...	...	...	3 3/8
3 1/2	...	3.5000	4	...	...	UNC	6	8	12	16	...	...	...	3 1/2
...	3 5/8	3.6250	...	...	...	4	6	8	12	16	...	...	...	3 5/8
3 3/4	...	3.7500	4	...	...	UNC	6	8	12	16	...	...	...	3 3/4
...	3 7/8	3.8750	...	...	...	4	6	8	12	16	...	...	...	3 7/8
4	...	4.0000	4	...	...	UNC	6	8	12	16	...	...	...	4
...	4 1/8	4.1250	...	...	...	4	6	8	12	16	...	...	...	4 1/8
4 1/4	...	4.2500	...	...	...	4	6	8	12	16	...	...	...	4 1/4
...	4 3/8	4.3750	...	...	...	4	6	8	12	16	...	...	...	4 3/8
4 1/2	...	4.5000	...	...	...	4	6	8	12	16	...	...	...	4 1/2
...	4 5/8	4.6250	...	...	...	4	6	8	12	16	...	...	...	4 5/8
4 3/4	...	4.7500	...	...	...	4	6	8	12	16	...	...	...	4 3/4
...	4 7/8	4.8750	...	...	...	4	6	8	12	16	...	...	...	4 7/8
5	...	5.0000	...	...	...	4	6	8	12	16	...	...	...	5
...	5 1/8	5.1250	...	...	...	4	6	8	12	16	...	...	...	5 1/8
5 1/4	...	5.2500	...	...	...	4	6	8	12	16	...	...	...	5 1/4
...	5 3/8	5.3750	...	...	...	4	6	8	12	16	...	...	...	5 3/8
5 1/2	...	5.5000	...	...	...	4	6	8	12	16	...	...	...	5 1/2
...	5 5/8	5.6250	...	...	...	4	6	8	12	16	...	...	...	5 5/8
5 3/4	...	5.7500	...	...	...	4	6	8	12	16	...	...	...	5 3/4
...	5 7/8	5.8750	...	...	...	4	6	8	12	16	...	...	...	5 7/8
6	...	6.0000	...	...	...	4	6	8	12	16	...	...	...	6

GENERAL NOTE:
Series designation shown indicates the UN thread form; however, the UNR thread form may be specified by substituting UNR in place of UN in all designations for external use only.

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
0-80 or 0.060-80	UNF	2A	0.0005	0.0595	0.0563	...	0.0514	0.0496	0.0018	0.0446	2B	0.0465	0.0514	0.0519	0.0542	0.0023	0.0600
		3A	0.0000	0.0600	0.0568	...	0.0519	0.0506	0.0013	0.0451	3B	0.0465	0.0514	0.0519	0.0536	0.0017	0.0600
1-64 or 0.073-64	UNC	2A	0.0006	0.0724	0.0686	...	0.0623	0.0603	0.0020	0.0538	2B	0.0561	0.0623	0.0629	0.0655	0.0026	0.0730
		3A	0.0000	0.0730	0.0692	...	0.0629	0.0614	0.0015	0.0544	3B	0.0561	0.0623	0.0629	0.0648	0.0019	0.0730
1-72 or 0.073-72	UNF	2A	0.0006	0.0724	0.0689	...	0.0634	0.0615	0.0019	0.0559	2B	0.0580	0.0635	0.0640	0.0665	0.0025	0.0730
		3A	0.0000	0.0730	0.0695	...	0.0640	0.0626	0.0014	0.0565	3B	0.0580	0.0635	0.0640	0.0659	0.0019	0.0730
2-56 or 0.086-56	UNC	2A	0.0006	0.0854	0.0813	...	0.0738	0.0717	0.0021	0.0642	2B	0.0667	0.0737	0.0744	0.0772	0.0028	0.0860
		3A	0.0000	0.0860	0.0819	...	0.0744	0.0728	0.0016	0.0648	3B	0.0667	0.0737	0.0744	0.0765	0.0021	0.0860
2-64 or 0.086-64	UNF	2A	0.0006	0.0854	0.0816	...	0.0753	0.0733	0.0020	0.0668	2B	0.0691	0.0753	0.0759	0.0786	0.0027	0.0860
		3A	0.0000	0.0860	0.0822	...	0.0759	0.0744	0.0015	0.0674	3B	0.0691	0.0753	0.0759	0.0779	0.0020	0.0860
3-48 or 0.099-48	UNC	2A	0.0007	0.0983	0.0938	...	0.0848	0.0825	0.0023	0.0734	2B	0.0764	0.0845	0.0855	0.0885	0.0030	0.0990
		3A	0.0000	0.0990	0.0945	...	0.0855	0.0838	0.0017	0.0741	3B	0.0764	0.0845	0.0855	0.0877	0.0022	0.0990
3-56 or 0.099-56	UNF	2A	0.0007	0.0983	0.0942	...	0.0867	0.0845	0.0022	0.0771	2B	0.0797	0.0865	0.0874	0.0902	0.0028	0.0990
		3A	0.0000	0.0990	0.0949	...	0.0874	0.0858	0.0016	0.0778	3B	0.0797	0.0865	0.0874	0.0895	0.0021	0.0990
4-40 or 0.112-40	UNC	2A	0.0008	0.1112	0.1061	...	0.0950	0.0925	0.0025	0.0814	2B	0.0849	0.0939	0.0958	0.0991	0.0033	0.1120
		3A	0.0000	0.1120	0.1069	...	0.0958	0.0939	0.0019	0.0822	3B	0.0849	0.0939	0.0958	0.0982	0.0024	0.1120
4-48 or 0.112-48	UNF	2A	0.0007	0.1113	0.1068	...	0.0978	0.0954	0.0024	0.0864	2B	0.0894	0.0968	0.0985	0.1016	0.0031	0.1120
		3A	0.0000	0.1120	0.1075	...	0.0985	0.0967	0.0018	0.0871	3B	0.0894	0.0968	0.0985	0.1008	0.0023	0.1120
5-40 or 0.125-40	UNC	2A	0.0008	0.1242	0.1191	...	0.1080	0.1054	0.0026	0.0944	2B	0.0979	0.1062	0.1088	0.1121	0.0033	0.1250
		3A	0.0000	0.1250	0.1199	...	0.1088	0.1069	0.0019	0.0952	3B	0.0979	0.1062	0.1088	0.1113	0.0025	0.1250
5-44 or 0.125-44	UNF	2A	0.0007	0.1243	0.1195	...	0.1095	0.1070	0.0025	0.0972	2B	0.1004	0.1079	0.1102	0.1134	0.0032	0.1250
		3A	0.0000	0.1250	0.1202	...	0.1102	0.1083	0.0019	0.0979	3B	0.1004	0.1079	0.1102	0.1126	0.0024	0.1250
6-32 or 0.138-32	UNC	2A	0.0008	0.1372	0.1312	...	0.1169	0.1141	0.0028	0.1000	2B	0.104	0.114	0.1177	0.1214	0.0037	0.1380
		3A	0.0000	0.1380	0.1320	...	0.1177	0.1156	0.0021	0.1008	3B	0.1040	0.1140	0.1177	0.1204	0.0027	0.1380
6-40 or 0.138-40	UNF	2A	0.0008	0.1372	0.1321	...	0.1210	0.1184	0.0026	0.1074	2B	0.111	0.119	0.1218	0.1252	0.0034	0.1380
		3A	0.0000	0.1380	0.1329	...	0.1218	0.1198	0.0020	0.1082	3B	0.1110	0.1186	0.1218	0.1243	0.0025	0.1380
8-32 or 0.164-32	UNC	2A	0.0009	0.1631	0.1571	...	0.1428	0.1399	0.0029	0.1259	2B	0.130	0.139	0.1437	0.1475	0.0038	0.1640
		3A	0.0000	0.1640	0.1580	...	0.1437	0.1415	0.0022	0.1268	3B	0.1300	0.1389	0.1437	0.1465	0.0028	0.1640
8-36 or 0.164-36	UNF	2A	0.0008	0.1632	0.1577	...	0.1452	0.1424	0.0028	0.1301	2B	0.134	0.142	0.1460	0.1496	0.0036	0.1640
		3A	0.0000	0.1640	0.1585	...	0.1460	0.1439	0.0021	0.1309	3B	0.1340	0.1416	0.1460	0.1487	0.0027	0.1640

(Notes follow at end of table)

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
10-24 or 0.190-24	UNC	2A	0.0010	0.1890	0.1818	. . .	0.1619	0.1586	0.0033	0.1394	2B	0.145	0.156	0.1629	0.1672	0.0043	0.1900
		3A	0.0000	0.1900	0.1828	. . .	0.1629	0.1604	0.0025	0.1404	3B	0.1450	0.1555	0.1629	0.1661	0.0032	0.1900
10-32 or 0.190-32	UNF	2A	0.0009	0.1891	0.1831	. . .	0.1688	0.1658	0.0030	0.1519	2B	0.156	0.164	0.1697	0.1736	0.0039	0.1900
		3A	0.0000	0.1900	0.1840	. . .	0.1697	0.1674	0.0023	0.1528	3B	0.1560	0.1641	0.1697	0.1726	0.0029	0.1900
12-24 or 0.216-24	UNC	2A	0.0010	0.2150	0.2078	. . .	0.1879	0.1845	0.0034	0.1654	2B	0.171	0.181	0.1889	0.1933	0.0044	0.2160
		3A	0.0000	0.2160	0.2088	. . .	0.1889	0.1863	0.0026	0.1664	3B	0.1710	0.1807	0.1889	0.1922	0.0033	0.2160
12-28 or 0.216-28	UNF	2A	0.0010	0.2150	0.2085	. . .	0.1918	0.1886	0.0032	0.1724	2B	0.177	0.186	0.1928	0.1970	0.0042	0.2160
		3A	0.0000	0.2160	0.2095	. . .	0.1928	0.1904	0.0024	0.1734	3B	0.1770	0.1857	0.1928	0.1959	0.0031	0.2160
12-32 or 0.216-32	UNEF	2A	0.0009	0.2151	0.2091	. . .	0.1948	0.1917	0.0031	0.1779	2B	0.182	0.190	0.1957	0.1998	0.0041	0.2160
		3A	0.0000	0.2160	0.2100	. . .	0.1957	0.1933	0.0024	0.1788	3B	0.1820	0.1895	0.1957	0.1988	0.0031	0.2160
1/4-20 or 0.250-20	UNC	1A	0.0011	0.2489	0.2367	. . .	0.2164	0.2108	0.0056	0.1894	1B	0.196	0.207	0.2175	0.2248	0.0073	0.2500
		2A	0.0011	0.2489	0.2408	0.2367	0.2164	0.2127	0.0037	0.1894	2B	0.196	0.207	0.2175	0.2224	0.0049	0.2500
		3A	0.0000	0.2500	0.2419	. . .	0.2175	0.2147	0.0028	0.1905	3B	0.1960	0.2067	0.2175	0.2211	0.0036	0.2500
1/4-28 or 0.250-28	UNF	1A	0.0010	0.2490	0.2392	. . .	0.2258	0.2208	0.0050	0.2064	1B	0.211	0.220	0.2268	0.2333	0.0065	0.2500
		2A	0.0010	0.2490	0.2425	. . .	0.2258	0.2225	0.0033	0.2064	2B	0.211	0.220	0.2268	0.2311	0.0043	0.2500
		3A	0.0000	0.2500	0.2435	. . .	0.2268	0.2243	0.0025	0.2074	3B	0.2110	0.2190	0.2268	0.2300	0.0032	0.2500
1/4-32 or 0.250-32	UNEF	2A	0.0010	0.2490	0.2430	. . .	0.2287	0.2255	0.0032	0.2118	2B	0.216	0.224	0.2297	0.2339	0.0042	0.2500
		3A	0.0000	0.2500	0.2440	. . .	0.2297	0.2273	0.0024	0.2128	3B	0.2160	0.2229	0.2297	0.2328	0.0031	0.2500
5/16-18 or 0.3125-18	UNC	1A	0.0012	0.3113	0.2982	. . .	0.2752	0.2691	0.0061	0.2452	1B	0.252	0.265	0.2764	0.2843	0.0079	0.3125
		2A	0.0012	0.3113	0.3026	0.2982	0.2752	0.2712	0.0040	0.2452	2B	0.252	0.265	0.2764	0.2817	0.0053	0.3125
		3A	0.0000	0.3125	0.3038	. . .	0.2764	0.2734	0.0030	0.2464	3B	0.2520	0.2630	0.2764	0.2803	0.0039	0.3125
5/16-20 or 0.3125-20	UN	2A	0.0012	0.3113	0.3032	. . .	0.2788	0.2748	0.0040	0.2518	2B	0.258	0.270	0.2800	0.2852	0.0052	0.3125
		3A	0.0000	0.3125	0.3044	. . .	0.2800	0.2770	0.0030	0.2530	3B	0.2580	0.2680	0.2800	0.2839	0.0039	0.3125
5/16-24 or 0.3125-24	UNF	1A	0.0011	0.3114	0.3006	. . .	0.2843	0.2788	0.0055	0.2618	1B	0.267	0.277	0.2854	0.2925	0.0071	0.3125
		2A	0.0011	0.3114	0.3042	. . .	0.2843	0.2806	0.0037	0.2618	2B	0.267	0.277	0.2854	0.2902	0.0048	0.3125
		3A	0.0000	0.3125	0.3053	. . .	0.2854	0.2827	0.0027	0.2629	3B	0.2670	0.2754	0.2854	0.2890	0.0036	0.3125
5/16-28 or 0.3125-28	UN	2A	0.0010	0.3115	0.3050	. . .	0.2883	0.2849	0.0034	0.2689	2B	0.274	0.282	0.2893	0.2937	0.0044	0.3125
		3A	0.0000	0.3125	0.3060	. . .	0.2893	0.2867	0.0026	0.2699	3B	0.2740	0.2807	0.2893	0.2926	0.0033	0.3125
5/16-32 or 0.3125-32	UNEF	2A	0.0010	0.3115	0.3055	. . .	0.2912	0.2880	0.0032	0.2743	2B	0.279	0.286	0.2922	0.2964	0.0042	0.3125
		3A	0.0000	0.3125	0.3065	. . .	0.2922	0.2898	0.0024	0.2753	3B	0.2790	0.2847	0.2922	0.2953	0.0031	0.3125

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
3/8-16 or 0.375-16	UNC	1A	0.0013	0.3737	0.3595	. . .	0.3331	0.3266	0.0065	0.2992	1B	0.307	0.321	0.3344	0.3429	0.0085	0.3750
		2A	0.0013	0.3737	0.3643	0.3595	0.3331	0.3287	0.0044	0.2992	2B	0.307	0.321	0.3344	0.3401	0.0057	0.3750
		3A	0.0000	0.3750	0.3656	. . .	0.3344	0.3311	0.0033	0.3005	3B	0.3070	0.3182	0.3344	0.3387	0.0043	0.3750
3/8-20 or 0.375-20	UN	2A	0.0012	0.3738	0.3657	. . .	0.3413	0.3372	0.0041	0.3143	2B	0.321	0.332	0.3425	0.3479	0.0054	0.3750
		3A	0.0000	0.3750	0.3669	. . .	0.3425	0.3394	0.0031	0.3155	3B	0.3210	0.3297	0.3425	0.3465	0.0040	0.3750
3/8-24 or 0.375-24	UNF	1A	0.0011	0.3739	0.3631	. . .	0.3468	0.3411	0.0057	0.3243	1B	0.330	0.340	0.3479	0.3553	0.0074	0.3750
		2A	0.0011	0.3739	0.3667	. . .	0.3468	0.3430	0.0038	0.3243	2B	0.330	0.340	0.3479	0.3528	0.0049	0.3750
		3A	0.0000	0.3750	0.3678	. . .	0.3479	0.3450	0.0029	0.3254	3B	0.3300	0.3372	0.3479	0.3516	0.0037	0.3750
3/8-28 or 0.375-28	UN	2A	0.0011	0.3739	0.3674	. . .	0.3507	0.3471	0.0036	0.3313	2B	0.336	0.345	0.3518	0.3564	0.0046	0.3750
		3A	0.0000	0.3750	0.3685	. . .	0.3518	0.3491	0.0027	0.3324	3B	0.3360	0.3426	0.3518	0.3553	0.0035	0.3750
3/8-32 or 0.375-32	UNEF	2A	0.0010	0.3740	0.3680	. . .	0.3537	0.3503	0.0034	0.3368	2B	0.341	0.349	0.3547	0.3591	0.0044	0.3750
		3A	0.0000	0.3750	0.3690	. . .	0.3547	0.3522	0.0025	0.3378	3B	0.3410	0.3469	0.3547	0.3580	0.0033	0.3750
7/16-14 or 0.4375-14	UNC	1A	0.0014	0.4361	0.4206	. . .	0.3897	0.3826	0.0071	0.3511	1B	0.360	0.376	0.3911	0.4003	0.0092	0.4375
		2A	0.0014	0.4361	0.4258	0.4206	0.3897	0.3850	0.0047	0.3511	2B	0.360	0.376	0.3911	0.3972	0.0061	0.4375
		3A	0.0000	0.4375	0.4272	. . .	0.3911	0.3876	0.0035	0.3525	3B	0.3600	0.3717	0.3911	0.3957	0.0046	0.4375
7/16-16 or 0.4375-16	UN	2A	0.0014	0.4361	0.4267	. . .	0.3955	0.3909	0.0046	0.3616	2B	0.370	0.384	0.3969	0.4028	0.0059	0.4375
		3A	0.0000	0.4375	0.4281	. . .	0.3969	0.3935	0.0034	0.3630	3B	0.3700	0.3800	0.3969	0.4014	0.0045	0.4375
7/16-20 or 0.4375-20	UNF	1A	0.0013	0.4362	0.4240	. . .	0.4037	0.3975	0.0062	0.3767	1B	0.383	0.395	0.4050	0.4131	0.0081	0.4375
		2A	0.0013	0.4362	0.4281	. . .	0.4037	0.3995	0.0042	0.3767	2B	0.383	0.395	0.4050	0.4104	0.0054	0.4375
		3A	0.0000	0.4375	0.4294	. . .	0.4050	0.4019	0.0031	0.3780	3B	0.3830	0.3916	0.4050	0.4091	0.0041	0.4375
7/16-28 or 0.4375-28	UNEF	2A	0.0011	0.4364	0.4299	. . .	0.4132	0.4096	0.0036	0.3938	2B	0.399	0.407	0.4143	0.4189	0.0046	0.4375
		3A	0.0000	0.4375	0.4310	. . .	0.4143	0.4116	0.0027	0.3949	3B	0.3990	0.4051	0.4143	0.4178	0.0035	0.4375
7/16-32 or 0.4375-32	UN	2A	0.0010	0.4365	0.4305	. . .	0.4162	0.4128	0.0034	0.3993	2B	0.404	0.411	0.4172	0.4216	0.0044	0.4375
		3A	0.0000	0.4375	0.4315	. . .	0.4172	0.4147	0.0025	0.4003	3B	0.4040	0.4094	0.4172	0.4205	0.0033	0.4375
1/2-13 or 0.500-13	UNC	1A	0.0015	0.4985	0.4822	. . .	0.4485	0.4411	0.0074	0.4069	1B	0.417	0.434	0.4500	0.4597	0.0097	0.5000
		2A	0.0015	0.4985	0.4876	0.4822	0.4485	0.4435	0.0050	0.4069	2B	0.417	0.434	0.4500	0.4565	0.0065	0.5000
		3A	0.0000	0.5000	0.4891	. . .	0.4500	0.4463	0.0037	0.4084	3B	0.4170	0.4284	0.4500	0.4548	0.0048	0.5000
1/2-16 or 0.500-16	UN	2A	0.0014	0.4986	0.4892	. . .	0.4580	0.4533	0.0047	0.4241	2B	0.432	0.446	0.4594	0.4655	0.0061	0.5000
		3A	0.0000	0.5000	0.4906	. . .	0.4594	0.4559	0.0035	0.4255	3B	0.4320	0.4419	0.4594	0.4640	0.0046	0.5000
1/2-20 or 0.500-20	UNF	1A	0.0013	0.4987	0.4865	. . .	0.4662	0.4598	0.0064	0.4392	1B	0.446	0.457	0.4675	0.4759	0.0084	0.5000
		2A	0.0013	0.4987	0.4906	. . .	0.4662	0.4619	0.0043	0.4392	2B	0.446	0.457	0.4675	0.4731	0.0056	0.5000
		3A	0.0000	0.5000	0.4919	. . .	0.4675	0.4643	0.0032	0.4405	3B	0.4460	0.4537	0.4675	0.4717	0.0042	0.5000

(Notes follow at end of table)

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
1/2-28 or 0.500-28	UNEF	2A	0.0011	0.4989	0.4924	...	0.4757	0.4720	0.0037	0.4563	2B	0.461	0.470	0.4768	0.4816	0.0048	0.5000
		3A	0.0000	0.5000	0.4935	...	0.4768	0.4740	0.0028	0.4574	3B	0.4610	0.4676	0.4768	0.4804	0.0036	0.5000
1/2-32 or 0.500-32	UN	2A	0.0010	0.4990	0.4930	...	0.4787	0.4752	0.0035	0.4618	2B	0.466	0.474	0.4797	0.4842	0.0045	0.5000
		3A	0.0000	0.5000	0.4940	...	0.4797	0.4771	0.0026	0.4628	3B	0.4660	0.4719	0.4797	0.4831	0.0034	0.5000
9/16-12 or 0.5625-12	UNC	1A	0.0016	0.5609	0.5437	...	0.5068	0.4990	0.0078	0.4617	1B	0.472	0.490	0.5084	0.5186	0.0102	0.5625
		2A	0.0016	0.5609	0.5495	0.5437	0.5068	0.5016	0.0052	0.4617	2B	0.472	0.490	0.5084	0.5152	0.0068	0.5625
		3A	0.0000	0.5625	0.5511	...	0.5084	0.5045	0.0039	0.4633	3B	0.4720	0.4843	0.5084	0.5135	0.0051	0.5625
9/16-16 or 0.5625-16	UN	2A	0.0014	0.5611	0.5517	...	0.5205	0.5158	0.0047	0.4866	2B	0.495	0.509	0.5219	0.5280	0.0061	0.5625
		3A	0.0000	0.5625	0.5531	...	0.5219	0.5184	0.0035	0.4880	3B	0.4950	0.5040	0.5219	0.5265	0.0046	0.5625
9/16-18 or 0.5625-18	UNF	1A	0.0014	0.5611	0.5480	...	0.5250	0.5182	0.0068	0.4950	1B	0.502	0.515	0.5264	0.5353	0.0089	0.5625
		2A	0.0014	0.5611	0.5524	...	0.5250	0.5205	0.0045	0.4950	2B	0.502	0.515	0.5264	0.5323	0.0059	0.5625
		3A	0.0000	0.5625	0.5538	...	0.5264	0.5230	0.0034	0.4964	3B	0.5020	0.5106	0.5264	0.5308	0.0044	0.5625
9/16-20 or 0.5625-20	UN	2A	0.0013	0.5612	0.5531	...	0.5287	0.5245	0.0042	0.5017	2B	0.508	0.520	0.5300	0.5355	0.0055	0.5625
		3A	0.0000	0.5625	0.5544	...	0.5300	0.5268	0.0032	0.5030	3B	0.5080	0.5162	0.5300	0.5341	0.0041	0.5625
9/16-24 or 0.5625-24	UNEF	2A	0.0012	0.5613	0.5541	...	0.5342	0.5303	0.0039	0.5117	2B	0.517	0.527	0.5354	0.5405	0.0051	0.5625
		3A	0.0000	0.5625	0.5553	...	0.5354	0.5325	0.0029	0.5129	3B	0.5170	0.5244	0.5354	0.5392	0.0038	0.5625
9/16-28 or 0.5625-28	UN	2A	0.0011	0.5614	0.5549	...	0.5382	0.5345	0.0037	0.5188	2B	0.524	0.532	0.5393	0.5441	0.0048	0.5625
		3A	0.0000	0.5625	0.5560	...	0.5393	0.5365	0.0028	0.5199	3B	0.5240	0.5301	0.5393	0.5429	0.0036	0.5625
9/16-32 or 0.5625-32	UN	2A	0.0010	0.5615	0.5555	...	0.5412	0.5377	0.0035	0.5243	2B	0.529	0.536	0.5422	0.5467	0.0045	0.5625
		3A	0.0000	0.5625	0.5565	...	0.5422	0.5396	0.0026	0.5253	3B	0.5290	0.5344	0.5422	0.5456	0.0034	0.5625
5/8-11 or 0.625-11	UNC	1A	0.0016	0.6234	0.6052	...	0.5644	0.5561	0.0083	0.5152	1B	0.527	0.546	0.5660	0.5767	0.0107	0.6250
		2A	0.0016	0.6234	0.6113	0.6052	0.5644	0.5589	0.0055	0.5152	2B	0.527	0.546	0.5660	0.5732	0.0072	0.6250
		3A	0.0000	0.6250	0.6129	...	0.5660	0.5619	0.0041	0.5168	3B	0.5270	0.5391	0.5660	0.5714	0.0054	0.6250
5/8-12 or 0.625-12	UN	2A	0.0016	0.6234	0.6120	...	0.5693	0.5639	0.0054	0.5242	2B	0.535	0.553	0.5709	0.5780	0.0071	0.6250
		3A	0.0000	0.6250	0.6136	...	0.5709	0.5668	0.0041	0.5258	3B	0.5350	0.5463	0.5709	0.5762	0.0053	0.6250
5/8-16 or 0.625-16	UN	2A	0.0014	0.6236	0.6142	...	0.5830	0.5782	0.0048	0.5491	2B	0.557	0.571	0.5844	0.5906	0.0062	0.6250
		3A	0.0000	0.6250	0.6156	...	0.5844	0.5808	0.0036	0.5505	3B	0.5570	0.5662	0.5844	0.5890	0.0046	0.6250
5/8-18 or 0.625-18	UNF	1A	0.0014	0.6236	0.6105	...	0.5875	0.5805	0.0070	0.5575	1B	0.565	0.578	0.5889	0.5980	0.0091	0.6250
		2A	0.0014	0.6236	0.6149	...	0.5875	0.5828	0.0047	0.5575	2B	0.565	0.578	0.5889	0.5949	0.0060	0.6250
		3A	0.0000	0.6250	0.6163	...	0.5889	0.5854	0.0035	0.5589	3B	0.5650	0.5730	0.5889	0.5934	0.0045	0.6250

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
5/8-20 or 0.625-20	UN	2A	0.0013	0.6237	0.6156	...	0.5912	0.5869	0.0043	0.5642	2B	0.571	0.582	0.5925	0.5981	0.0056	0.6250
		3A	0.0000	0.6250	0.6169	...	0.5925	0.5893	0.0032	0.5655	3B	0.5710	0.5787	0.5925	0.5967	0.0042	0.6250
5/8-24 or 0.625-24	UNEF	2A	0.0012	0.6238	0.6166	...	0.5967	0.5927	0.0040	0.5742	2B	0.580	0.590	0.5979	0.6031	0.0052	0.6250
		3A	0.0000	0.6250	0.6178	...	0.5979	0.5949	0.0030	0.5754	3B	0.5800	0.5869	0.5979	0.6018	0.0039	0.6250
5/8-28 or 0.625-28	UN	2A	0.0011	0.6239	0.6174	...	0.6007	0.5969	0.0038	0.5813	2B	0.586	0.595	0.6018	0.6067	0.0049	0.6250
		3A	0.0000	0.6250	0.6185	...	0.6018	0.5990	0.0028	0.5824	3B	0.5860	0.5926	0.6018	0.6055	0.0037	0.6250
5/8-32 or 0.625-32	UN	2A	0.0011	0.6239	0.6179	...	0.6036	0.6000	0.0036	0.5867	2B	0.591	0.590	0.6047	0.6093	0.0046	0.6250
		3A	0.0000	0.6250	0.6190	...	0.6047	0.6020	0.0027	0.5878	3B	0.5910	0.5969	0.6047	0.6082	0.0035	0.6250
11/16-12 or 0.6875-12	UN	2A	0.0016	0.6859	0.6745	...	0.6318	0.6264	0.0054	0.5867	2B	0.597	0.615	0.6334	0.6405	0.0071	0.6875
		3A	0.0000	0.6875	0.6761	...	0.6334	0.6293	0.0041	0.5883	3B	0.5970	0.6085	0.6334	0.6387	0.0053	0.6875
11/16-16 or 0.6875-16	UN	2A	0.0014	0.6861	0.6767	...	0.6455	0.6407	0.0048	0.6116	2B	0.620	0.634	0.6469	0.6531	0.0062	0.6875
		3A	0.0000	0.6875	0.6781	...	0.6469	0.6433	0.0036	0.6130	3B	0.6200	0.6284	0.6469	0.6515	0.0046	0.6875
11/16-20 or 0.6875-20	UN	2A	0.0013	0.6862	0.6781	...	0.6537	0.6494	0.0043	0.6267	2B	0.633	0.645	0.6550	0.6606	0.0056	0.6875
		3A	0.0000	0.6875	0.6794	...	0.6550	0.6518	0.0032	0.6280	3B	0.6330	0.6412	0.6550	0.6592	0.0042	0.6875
11/16-24 or 0.6875-24	UNEF	2A	0.0012	0.6863	0.6791	...	0.6592	0.6552	0.0040	0.6367	2B	0.642	0.652	0.6604	0.6656	0.0052	0.6875
		3A	0.0000	0.6875	0.6803	...	0.6604	0.6574	0.0030	0.6379	3B	0.6420	0.6494	0.6604	0.6643	0.0039	0.6875
11/16-28 or 0.6875-28	UN	2A	0.0011	0.6864	0.6799	...	0.6632	0.6594	0.0038	0.6438	2B	0.649	0.657	0.6643	0.6692	0.0049	0.6875
		3A	0.0000	0.6875	0.6810	...	0.6643	0.6615	0.0028	0.6449	3B	0.6490	0.6551	0.6643	0.6680	0.0037	0.6875
11/16-32 or 0.6875-32	UN	2A	0.0011	0.6864	0.6804	...	0.6661	0.6625	0.0036	0.6492	2B	0.654	0.661	0.6672	0.6718	0.0046	0.6875
		3A	0.0000	0.6875	0.6815	...	0.6672	0.6645	0.0027	0.6503	3B	0.6540	0.6594	0.6672	0.6707	0.0035	0.6875
3/4-10 or 0.750-10	UNC	1A	0.0018	0.7482	0.7288	...	0.6832	0.6744	0.0088	0.6291	1B	0.642	0.663	0.6850	0.6965	0.0115	0.7500
		2A	0.0018	0.7482	0.7353	0.7288	0.6832	0.6773	0.0059	0.6291	2B	0.642	0.663	0.6850	0.6927	0.0077	0.7500
		3A	0.0000	0.7500	0.7371	...	0.6850	0.6806	0.0044	0.6309	3B	0.6420	0.6545	0.6850	0.6907	0.0057	0.7500
3/4-12 or 0.750-12	UN	2A	0.0017	0.7483	0.7369	...	0.6942	0.6887	0.0055	0.6491	2B	0.660	0.678	0.6959	0.7031	0.0072	0.7500
		3A	0.0000	0.7500	0.7386	...	0.6959	0.6918	0.0041	0.6508	3B	0.6600	0.6707	0.6959	0.7013	0.0054	0.7500
3/4-16 or 0.750-16	UNF	1A	0.0015	0.7485	0.7343	...	0.7079	0.7004	0.0075	0.6740	1B	0.682	0.696	0.7094	0.7192	0.0098	0.7500
		2A	0.0015	0.7485	0.7391	...	0.7079	0.7029	0.0050	0.6740	2B	0.682	0.696	0.7094	0.7159	0.0065	0.7500
		3A	0.0000	0.7500	0.7406	...	0.7094	0.7056	0.0038	0.6755	3B	0.6820	0.6908	0.7094	0.7143	0.0049	0.7500
3/4-20 or 0.750-20	UNEF	2A	0.0013	0.7487	0.7406	...	0.7162	0.7118	0.0044	0.6892	2B	0.696	0.707	0.7175	0.7232	0.0057	0.7500
		3A	0.0000	0.7500	0.7419	...	0.7175	0.7142	0.0033	0.6905	3B	0.6960	0.7037	0.7175	0.7218	0.0043	0.7500

(Notes follow at end of table)

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
3/4-28 or 0.750-28	UN	2A	0.0012	0.7488	0.7423	...	0.7256	0.7218	0.0038	0.7062	2B	0.711	0.720	0.7268	0.7318	0.0050	0.7500
		3A	0.0000	0.7500	0.7435	...	0.7268	0.7239	0.0029	0.7074	3B	0.7110	0.7176	0.7268	0.7305	0.0037	0.7500
3/4-32 or 0.750-32	UN	2A	0.0011	0.7489	0.7429	...	0.7286	0.7250	0.0036	0.7117	2B	0.716	0.724	0.7297	0.7344	0.0047	0.7500
		3A	0.0000	0.7500	0.7440	...	0.7297	0.7270	0.0027	0.7128	3B	0.7160	0.7219	0.7297	0.7333	0.0036	0.7500
13/16-12 or 0.8125-12	UN	2A	0.0017	0.8108	0.7994	...	0.7567	0.7512	0.0055	0.7116	2B	0.722	0.740	0.7584	0.7656	0.0072	0.8125
		3A	0.0000	0.8125	0.8011	...	0.7584	0.7543	0.0041	0.7133	3B	0.7220	0.7329	0.7584	0.7638	0.0054	0.8125
13/16-16 or 0.8125-16	UN	2A	0.0015	0.8110	0.8016	...	0.7704	0.7655	0.0049	0.7365	2B	0.745	0.759	0.7719	0.7782	0.0063	0.8125
		3A	0.0000	0.8125	0.8031	...	0.7719	0.7683	0.0036	0.7380	3B	0.7450	0.7533	0.7719	0.7766	0.0047	0.8125
13/16-20 or 0.8125-20	UNEF	2A	0.0013	0.8112	0.8031	...	0.7787	0.7743	0.0044	0.7517	2B	0.758	0.770	0.7800	0.7857	0.0057	0.8125
		3A	0.0000	0.8125	0.8044	...	0.7800	0.7767	0.0033	0.7530	3B	0.7580	0.7662	0.7800	0.7843	0.0043	0.8125
13/16-28 or 0.8125-28	UN	2A	0.0012	0.8113	0.8048	...	0.7881	0.7843	0.0038	0.7687	2B	0.774	0.782	0.7893	0.7943	0.0050	0.8125
		3A	0.0000	0.8125	0.8060	...	0.7893	0.7864	0.0029	0.7699	3B	0.7740	0.7801	0.7893	0.7930	0.0037	0.8125
13/16-32 or 0.8125-32	UN	2A	0.0011	0.8114	0.8054	...	0.7911	0.7875	0.0036	0.7742	2B	0.779	0.786	0.7922	0.7969	0.0047	0.8125
		3A	0.0000	0.8125	0.8065	...	0.7922	0.7895	0.0027	0.7753	3B	0.7790	0.7844	0.7922	0.7958	0.0036	0.8125
7/8-9 or 0.875-9	UNC	1A	0.0019	0.8731	0.8523	...	0.8009	0.7914	0.0095	0.7408	1B	0.755	0.778	0.8028	0.8151	0.0123	0.8750
		2A	0.0019	0.8731	0.8592	0.8523	0.8009	0.7946	0.0063	0.7408	2B	0.755	0.778	0.8028	0.8110	0.0082	0.8750
		3A	0.0000	0.8750	0.8611	...	0.8028	0.7981	0.0047	0.7427	3B	0.7550	0.7681	0.8028	0.8089	0.0061	0.8750
7/8-12 or 0.875-12	UN	2A	0.0017	0.8733	0.8619	...	0.8192	0.8137	0.0055	0.7741	2B	0.785	0.803	0.8209	0.8281	0.0072	0.8750
		3A	0.0000	0.8750	0.8636	...	0.8209	0.8168	0.0041	0.7758	3B	0.7850	0.7948	0.8209	0.8263	0.0054	0.8750
7/8-14 or 0.875-14	UNF	1A	0.0016	0.8734	0.8579	...	0.8270	0.8189	0.0081	0.7884	1B	0.798	0.814	0.8286	0.8392	0.0106	0.8750
		2A	0.0016	0.8734	0.8631	...	0.8270	0.8216	0.0054	0.7884	2B	0.798	0.814	0.8286	0.8356	0.0070	0.8750
		3A	0.0000	0.8750	0.8647	...	0.8286	0.8245	0.0041	0.7900	3B	0.7980	0.8068	0.8286	0.8339	0.0053	0.8750
7/8-16 or 0.875-16	UN	2A	0.0015	0.8735	0.8641	...	0.8329	0.8280	0.0049	0.7900	2B	0.807	0.821	0.8344	0.8407	0.0063	0.8750
		3A	0.0000	0.8750	0.8656	...	0.8344	0.8308	0.0036	0.8005	3B	0.8070	0.8158	0.8344	0.8391	0.0047	0.8750
7/8-20 or 0.875-20	UNEF	2A	0.0013	0.8737	0.8656	...	0.8412	0.8368	0.0044	0.8142	2B	0.821	0.832	0.8425	0.8482	0.0057	0.8750
		3A	0.0000	0.8750	0.8669	...	0.8425	0.8392	0.0033	0.8155	3B	0.8210	0.8287	0.8425	0.8468	0.0043	0.8750
7/8-28 or 0.875-28	UN	2A	0.0012	0.8738	0.8673	...	0.8506	0.8468	0.0038	0.8312	2B	0.836	0.845	0.8518	0.8568	0.0050	0.8750
		3A	0.0000	0.8750	0.8685	...	0.8518	0.8489	0.0029	0.8324	3B	0.8360	0.8426	0.8518	0.8555	0.0037	0.8750
7/8-32 or 0.875-32	UN	2A	0.0011	0.8739	0.8679	...	0.8536	0.8500	0.0036	0.8367	2B	0.841	0.849	0.8547	0.8594	0.0047	0.8750
		3A	0.0000	0.8750	0.8690	...	0.8547	0.8520	0.0027	0.8378	3B	0.8410	0.8469	0.8547	0.8583	0.0036	0.8750

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
15/16-12 or 0.9375-12	UN	2A	0.0017	0.9358	0.9244	...	0.8817	0.8760	0.0057	0.8366	2B	0.847	0.865	0.8834	0.8908	0.0074	0.9375
		3A	0.0000	0.9375	0.9261	...	0.8834	0.8793	0.0041	0.8383	3B	0.8470	0.8575	0.8834	0.8889	0.0055	0.9375
15/16-16 or 0.9375-16	UN	2A	0.0015	0.9360	0.9266	...	0.8954	0.8904	0.0050	0.8615	2B	0.870	0.884	0.8969	0.9034	0.0065	0.9375
		3A	0.0000	0.9375	0.9281	...	0.8969	0.8932	0.0037	0.8630	3B	0.8700	0.8783	0.8969	0.9018	0.0049	0.9375
15/16-20 or 0.9375-20	UNEF	2A	0.0014	0.9361	0.9280	...	0.9036	0.8991	0.0045	0.8766	2B	0.883	0.895	0.9050	0.9109	0.0059	0.9375
		3A	0.0000	0.9375	0.9294	...	0.9050	0.9016	0.0034	0.8780	3B	0.8830	0.8912	0.9050	0.9094	0.0044	0.9375
15/16-28 or 0.9375-28	UN	2A	0.0012	0.9363	0.9298	...	0.9131	0.9091	0.0040	0.8937	2B	0.899	0.907	0.9143	0.9195	0.0052	0.9375
		3A	0.0000	0.9375	0.9310	...	0.9143	0.9113	0.0030	0.8949	3B	0.8990	0.9051	0.9143	0.9182	0.0039	0.9375
15/16-32 or 0.9375-32	UN	2A	0.0011	0.9364	0.9304	...	0.9161	0.9123	0.0038	0.8992	2B	0.904	0.911	0.9172	0.9221	0.0049	0.9375
		3A	0.0000	0.9375	0.9315	...	0.9172	0.9144	0.0028	0.9003	3B	0.9040	0.9094	0.9172	0.9209	0.0037	0.9375
1-8 or 1.000-8	UNC	1A	0.0020	0.9980	0.9755	...	0.9168	0.9067	0.0101	0.8492	1B	0.865	0.890	0.9188	0.9320	0.0132	1.0000
		2A	0.0020	0.9980	0.9830	0.9755	0.9168	0.9100	0.0068	0.8492	2B	0.865	0.890	0.9188	0.9276	0.0088	1.0000
		3A	0.0000	1.0000	0.9850	...	0.9188	0.9137	0.0051	0.8512	3B	0.8650	0.8797	0.9188	0.9254	0.0066	1.0000
1-12 or 1.000-12	UNF	1A	0.0018	0.9982	0.9810	...	0.9441	0.9353	0.0088	0.8990	1B	0.910	0.928	0.9459	0.9573	0.0114	1.0000
		2A	0.0018	0.9982	0.9868	...	0.9441	0.9382	0.0059	0.8990	2B	0.910	0.928	0.9459	0.9535	0.0076	1.0000
		3A	0.0000	1.0000	0.9886	...	0.9459	0.9415	0.0044	0.9008	3B	0.9100	0.9198	0.9459	0.9516	0.0057	1.0000
1-14 or 1.000-14	UNS (5)	1A	0.0017	0.9983	0.9828	...	0.9519	0.9435	0.0084	0.9132	1B	0.923	0.938	0.9536	0.9645	0.0109	1.0000
		2A	0.0017	0.9983	0.9880	...	0.9519	0.9463	0.0056	0.9132	2B	0.923	0.938	0.9536	0.9609	0.0073	1.0000
		3A	0.0000	1.0000	0.9897	...	0.9536	0.9494	0.0042	0.9149	3B	0.9230	0.9315	0.9536	0.9590	0.0054	1.0000
1-16 or 1.000-16	UN	2A	0.0015	0.9985	0.9891	...	0.9579	0.9529	0.0050	0.9240	2B	0.932	0.946	0.9594	0.9659	0.0065	1.0000
		3A	0.0000	1.0000	0.9906	...	0.9594	0.9557	0.0037	0.9255	3B	0.9320	0.9408	0.9594	0.9643	0.0049	1.0000
1-20 or 1.000-20	UNEF	2A	0.0014	0.9986	0.9905	...	0.9661	0.9616	0.0045	0.9391	2B	0.946	0.957	0.9675	0.9734	0.0059	1.0000
		3A	0.0000	1.0000	0.9919	...	0.9675	0.9641	0.0034	0.9405	3B	0.9460	0.9537	0.9675	0.9719	0.0044	1.0000
1-28 or 1.000-28	UN	2A	0.0012	0.9988	0.9923	...	0.9756	0.9716	0.0040	0.9562	2B	0.961	0.970	0.9768	0.9820	0.0052	1.0000
		3A	0.0000	1.0000	0.9935	...	0.9768	0.9738	0.0030	0.9574	3B	0.9610	0.9676	0.9768	0.9807	0.0039	1.0000
1-32 or 1.000-32	UN	2A	0.0011	0.9989	0.9929	...	0.9786	0.9748	0.0038	0.9617	2B	0.966	0.974	0.9797	0.9846	0.0049	1.0000
		3A	0.0000	1.0000	0.9940	...	0.9797	0.9769	0.0028	0.9628	3B	0.9660	0.9719	0.9797	0.9834	0.0037	1.0000
1 1/16-8 or 1.0625-8	UN	2A	0.0020	1.0605	1.0455	...	0.9793	0.9725	0.0068	0.9117	2B	0.927	0.952	0.9813	0.9902	0.0089	1.0625
		3A	0.0000	1.0625	1.0475	...	0.9813	0.9762	0.0051	0.9137	3B	0.9270	0.9422	0.9813	0.9880	0.0067	1.0625

(Notes follow at end of table)

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
1 1/16-12 or 1.0625-12	UN	2A	0.0017	1.0608	1.0494	...	1.0067	1.0010	0.0057	0.9616	2B	0.972	0.990	1.0084	1.0158	0.0074	1.0625
		3A	0.0000	1.0625	1.0511	...	1.0084	1.0042	0.0042	0.9633	3B	0.9720	0.9823	1.0084	1.0139	0.0055	1.0625
1 1/16-16 or 1.0625-16	UN	2A	0.0015	1.0610	1.0516	...	1.0204	1.0154	0.0050	0.9865	2B	0.995	1.009	1.0219	1.0284	0.0065	1.0625
		3A	0.0000	1.0625	1.0531	...	1.0219	1.0182	0.0037	0.9880	3B	0.9950	1.0033	1.0219	1.0268	0.0049	1.0625
1 1/16-18 or 1.0625-18	UNEF	2A	0.0014	1.0611	1.0524	...	1.0250	1.0203	0.0047	0.9950	2B	1.002	1.015	1.0264	1.0326	0.0062	1.0625
		3A	0.0000	1.0625	1.0538	...	1.0264	1.0228	0.0036	0.9964	3B	1.0020	1.0105	1.0264	1.0310	0.0046	1.0625
1 1/16-20 or 1.0625-20	UN	2A	0.0014	1.0611	1.0530	...	1.0286	1.0241	0.0045	1.0016	2B	1.008	1.020	1.0300	1.0359	0.0059	1.0625
		3A	0.0000	1.0625	1.0544	...	1.0300	1.0266	0.0034	1.0030	3B	1.0080	1.0162	1.0300	1.0344	0.0044	1.0625
1 1/16-28 or 1.0625-28	UN	2A	0.0012	1.0613	1.0548	...	1.0381	1.0341	0.0040	1.0187	2B	1.024	1.032	1.0393	1.0445	0.0052	1.0625
		3A	0.0000	1.0625	1.0560	...	1.0393	1.0363	0.0030	1.0199	3B	1.0240	1.0301	1.0393	1.0432	0.0039	1.0625
1 1/8-7 or 1.125-7	UNC	1A	0.0022	1.1228	1.0982	...	1.0300	1.0191	0.0109	0.9527	1B	0.970	0.998	1.0322	1.0463	0.0141	1.1250
		2A	0.0022	1.1228	1.1064	1.0982	1.0300	1.0228	0.0072	0.9527	2B	0.970	0.998	1.0322	1.0416	0.0094	1.1250
		3A	0.0000	1.1250	1.1086	...	1.0322	1.0268	0.0054	0.9549	3B	0.9700	0.9875	1.0322	1.0393	0.0071	1.1250
1 1/8-8 or 1.125-8	UN	2A	0.0021	1.1229	1.1079	1.1004	1.0417	1.0348	0.0069	0.9741	2B	0.990	1.015	1.0438	1.0528	0.0090	1.1250
		3A	0.0000	1.1250	1.1100	...	1.0438	1.0386	0.0052	0.9762	3B	0.9900	1.0047	1.0438	1.0505	0.0067	1.1250
1 1/8-12 or 1.125-12	UNF	1A	0.0018	1.1232	1.1060	...	1.0691	1.0601	0.0090	1.0240	1B	1.035	1.053	1.0709	1.0826	0.0117	1.1250
		2A	0.0018	1.1232	1.1118	...	1.0691	1.0631	0.0060	1.0240	2B	1.035	1.053	1.0709	1.0787	0.0078	1.1250
		3A	0.0000	1.1250	1.1136	...	1.0709	1.0664	0.0045	1.0258	3B	1.0350	1.0448	1.0709	1.0768	0.0059	1.1250
1 1/8-16 or 1.125-16	UN	2A	0.0015	1.1235	1.1141	...	1.0829	1.0779	0.0050	1.0490	2B	1.057	1.071	1.0844	1.0909	0.0065	1.1250
		3A	0.0000	1.1250	1.1156	...	1.0844	1.0807	0.0037	1.0505	3B	1.0570	1.0658	1.0844	1.0893	0.0049	1.1250
1 1/8-18 or 1.125-18	UNEF	2A	0.0014	1.1236	1.1149	...	1.0875	1.0828	0.0047	1.0575	2B	1.065	1.078	1.0889	1.0951	0.0062	1.1250
		3A	0.0000	1.1250	1.1163	...	1.0889	1.0853	0.0036	1.0589	3B	1.0650	1.0730	1.0889	1.0935	0.0046	1.1250
1 1/8-20 or 1.125-20	UN	2A	0.0014	1.1236	1.1155	...	1.0911	1.0866	0.0045	1.0641	2B	1.071	1.082	1.0925	1.0984	0.0059	1.1250
		3A	0.0000	1.1250	1.1169	...	1.0925	1.0891	0.0034	1.0655	3B	1.0710	1.0787	1.0925	1.0969	0.0044	1.1250
1 1/8-28 or 1.125-28	UN	2A	0.0012	1.1238	1.1173	...	1.1006	1.0966	0.0040	1.0812	2B	1.086	1.095	1.1018	1.1070	0.0052	1.1250
		3A	0.0000	1.1250	1.1185	...	1.1018	1.0988	0.0030	1.0824	3B	1.0860	1.0926	1.1018	1.1057	0.0039	1.1250
1 3/16-8 or 1.1875-8	UN	2A	0.0021	1.1854	1.1704	...	1.1042	1.0972	0.0070	1.0366	2B	1.052	1.077	1.1063	1.1154	0.0091	1.1875
		3A	0.0000	1.1875	1.1725	...	1.1063	1.1011	0.0052	1.0387	3B	1.0520	1.0672	1.1063	1.1131	0.0068	1.1875
1 3/16-12 or 1.1875-12	UN	2A	0.0017	1.1858	1.1744	...	1.1317	1.1259	0.0058	1.0866	2B	1.097	1.115	1.1334	1.1409	0.0075	1.1875
		3A	0.0000	1.1875	1.1761	...	1.1334	1.1291	0.0043	1.0883	3B	1.0970	1.1073	1.1334	1.1390	0.0056	1.1875

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
1 3/16-16 or 1.1875-16	UN	2A	0.0015	1.1860	1.1766	...	1.1454	1.1403	0.0051	1.1115	2B	1.120	1.134	1.1469	1.1535	0.0066	1.1875
		3A	0.0000	1.1875	1.1781	...	1.1469	1.1431	0.0038	1.1130	3B	1.1200	1.1283	1.1469	1.1519	0.0050	1.1875
1 3/16-18 or 1.1875-18	UNEF	2A	0.0015	1.1860	1.1773	...	1.1499	1.1450	0.0049	1.1199	2B	1.127	1.140	1.1514	1.1577	0.0063	1.1875
		3A	0.0000	1.1875	1.1788	...	1.1514	1.1478	0.0036	1.1214	3B	1.1270	1.1355	1.1514	1.1561	0.0047	1.1875
1 3/16-20 or 1.1875-20	UN	2A	0.0014	1.1861	1.1780	...	1.1536	1.1489	0.0047	1.1266	2B	1.133	1.145	1.1550	1.1611	0.0061	1.1875
		3A	0.0000	1.1875	1.1794	...	1.1550	1.1515	0.0035	1.1280	3B	1.1330	1.1412	1.1550	1.1595	0.0045	1.1875
1 3/16-28 or 1.1875-28	UN	2A	0.0012	1.1863	1.1798	...	1.1631	1.1590	0.0041	1.1437	2B	1.149	1.157	1.1643	1.1696	0.0053	1.1875
		3A	0.0000	1.1875	1.1810	...	1.1643	1.1612	0.0031	1.1449	3B	1.1490	1.1551	1.1643	1.1683	0.0040	1.1875
1 1/4-7 or 1.250-7	UNC	1A	0.0022	1.2478	1.2232	...	1.1550	1.1439	0.0111	1.0777	1B	1.095	1.123	1.1572	1.1716	0.0144	1.2500
		2A	0.0022	1.2478	1.2314	1.2232	1.1550	1.1476	0.0074	1.0777	2B	1.095	1.123	1.1572	1.1668	0.0096	1.2500
		3A	0.0000	1.2500	1.2336	...	1.1572	1.1517	0.0055	1.0799	3B	1.0950	1.1125	1.1572	1.1644	0.0072	1.2500
1 1/4-8 or 1.250-8	UN	2A	0.0021	1.2479	1.2329	1.2254	1.1667	1.1597	0.0070	1.0991	2B	1.115	1.140	1.1688	1.1780	0.0092	1.2500
		3A	0.0000	1.2500	1.2350	...	1.1688	1.1635	0.0053	1.1012	3B	1.1150	1.1297	1.1688	1.1757	0.0069	1.2500
1 1/4-12 or 1.250-12	UNF	1A	0.0018	1.2482	1.2310	...	1.1941	1.1849	0.0092	1.1490	1B	1.160	1.178	1.1959	1.2079	0.0120	1.2500
		2A	0.0018	1.2482	1.2368	...	1.1941	1.1879	0.0062	1.1490	2B	1.160	1.178	1.1959	1.2039	0.0080	1.2500
		3A	0.0000	1.2500	1.2386	...	1.1959	1.1913	0.0046	1.1508	3B	1.1600	1.1698	1.1959	1.2019	0.0060	1.2500
1 1/4-16 or 1.250-16	UN	2A	0.0015	1.2485	1.2391	...	1.2079	1.2028	0.0051	1.1740	2B	1.182	1.196	1.2094	1.2160	0.0066	1.2500
		3A	0.0000	1.2500	1.2406	...	1.2094	1.2056	0.0038	1.1755	3B	1.1820	1.1908	1.2094	1.2144	0.0050	1.2500
1 1/4-18 or 1.250-18	UNEF	2A	0.0015	1.2485	1.2398	...	1.2124	1.2075	0.0049	1.1824	2B	1.190	1.203	1.2139	1.2202	0.0063	1.2500
		3A	0.0000	1.2500	1.2413	...	1.2139	1.2103	0.0036	1.1839	3B	1.1900	1.1980	1.2139	1.2186	0.0047	1.2500
1 1/4-20 or 1.250-20	UN	2A	0.0014	1.2486	1.2405	...	1.2161	1.2114	0.0047	1.1891	2B	1.196	1.207	1.2175	1.2236	0.0061	1.2500
		3A	0.0000	1.2500	1.2419	...	1.2175	1.2140	0.0035	1.1905	3B	1.1960	1.2037	1.2175	1.2220	0.0045	1.2500
1 1/4-28 or 1.250-28	UN	2A	0.0012	1.2488	1.2423	...	1.2256	1.2215	0.0041	1.2062	2B	1.211	1.220	1.2268	1.2321	0.0053	1.2500
		3A	0.0000	1.2500	1.2435	...	1.2268	1.2237	0.0031	1.2074	3B	1.2110	1.2176	1.2268	1.2308	0.0040	1.2500
1 5/16-8 or 1.3125-8	UN	2A	0.0021	1.3104	1.2954	...	1.2292	1.2221	0.0071	1.1616	2B	1.177	1.202	1.2313	1.2405	0.0092	1.3125
		3A	0.0000	1.3125	1.2975	...	1.2313	1.2260	0.0053	1.1637	3B	1.1770	1.1922	1.2313	1.2382	0.0069	1.3125
1 5/16-12 or 1.3125-12	UN	2A	0.0017	1.3108	1.2994	...	1.2567	1.2509	0.0058	1.2116	2B	1.222	1.240	1.2584	1.2659	0.0075	1.3125
		3A	0.0000	1.3125	1.3011	...	1.2584	1.2541	0.0043	1.2133	3B	1.2220	1.2323	1.2584	1.2640	0.0056	1.3125
1 5/16-16 or 1.3125-16	UN	2A	0.0015	1.3110	1.3016	...	1.2704	1.2653	0.0051	1.2365	2B	1.245	1.259	1.2719	1.2785	0.0066	1.3125
		3A	0.0000	1.3125	1.3031	...	1.2719	1.2681	0.0038	1.2380	3B	1.2450	1.2533	1.2719	1.2769	0.0050	1.3125

(Notes follow at end of table)

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
1 5/16-18 or 1.3125-18	UNEF	2A	0.0015	1.3110	1.3023	...	1.2749	1.2700	0.0049	1.2449	2B	1.252	1.265	1.2764	1.2827	0.0063	1.3125
		3A	0.0000	1.3125	1.3038	...	1.2764	1.2728	0.0036	1.2464	3B	1.2520	1.2605	1.2764	1.2811	0.0047	1.3125
1 5/16-20 or 1.3125-20	UN	2A	0.0014	1.3111	1.3030	...	1.2786	1.2739	0.0047	1.2516	2B	1.258	1.270	1.2800	1.2861	0.0061	1.3125
		3A	0.0000	1.3125	1.3044	...	1.2800	1.2765	0.0035	1.2530	3B	1.2580	1.2662	1.2800	1.2845	0.0045	1.3125
1 5/16-28 or 1.3125-28	UN	2A	0.0012	1.3113	1.3048	...	1.2881	1.2840	0.0041	1.2687	2B	1.274	1.282	1.2893	1.2946	0.0053	1.3125
		3A	0.0000	1.3125	1.3060	...	1.2893	1.2862	0.0031	1.2699	3B	1.2740	1.2801	1.2893	1.2933	0.0040	1.3125
1 3/8-6 or 1.375-6	UNC	1A	0.0024	1.3726	1.3453	...	1.2643	1.2523	0.0120	1.1742	1B	1.195	1.225	1.2667	1.2822	0.0155	1.3750
		2A	0.0024	1.3726	1.3544	1.3453	1.2643	1.2563	0.0080	1.1742	2B	1.195	1.225	1.2667	1.2771	0.0104	1.3750
		3A	0.0000	1.3750	1.3568	...	1.2667	1.2607	0.0060	1.1766	3B	1.1950	1.2146	1.2667	1.2745	0.0078	1.3750
1 3/8-8 or 1.375-8	UN	2A	0.0022	1.3728	1.3578	1.3503	1.2916	1.2844	0.0072	1.2240	2B	1.240	1.265	1.2938	1.3031	0.0093	1.3750
		3A	0.0000	1.3750	1.3600	...	1.2938	1.2884	0.0054	1.2262	3B	1.2400	1.2547	1.2938	1.3008	0.0070	1.3750
1 3/8-12 or 1.375-12	UNF	1A	0.0019	1.3731	1.3559	...	1.3190	1.3096	0.0094	1.2739	1B	1.285	1.303	1.3209	1.3332	0.0123	1.3750
		2A	0.0019	1.3731	1.3617	...	1.3190	1.3127	0.0063	1.2739	2B	1.285	1.303	1.3209	1.3291	0.0082	1.3750
		3A	0.0000	1.3750	1.3636	...	1.3209	1.3162	0.0047	1.2758	3B	1.2850	1.2948	1.3209	1.3270	0.0061	1.3750
1 3/8-16 or 1.375-16	UN	2A	0.0015	1.3735	1.3641	...	1.3329	1.3278	0.0051	1.2990	2B	1.307	1.321	1.3344	1.3410	0.0066	1.3750
		3A	0.0000	1.3750	1.3656	...	1.3344	1.3306	0.0038	1.3005	3B	1.3070	1.3158	1.3344	1.3394	0.0050	1.3750
1 3/8-18 or 1.375-18	UNEF	2A	0.0015	1.3735	1.3648	...	1.3374	1.3325	0.0049	1.3074	2B	1.315	1.328	1.3389	1.3452	0.0063	1.3750
		3A	0.0000	1.3750	1.3663	...	1.3389	1.3353	0.0036	1.3089	3B	1.3150	1.3230	1.3389	1.3436	0.0047	1.3750
1 3/8-20 or 1.375-20	UN	2A	0.0014	1.3736	1.3655	...	1.3411	1.3364	0.0047	1.3141	2B	1.321	1.332	1.3425	1.3486	0.0061	1.3750
		3A	0.0000	1.3750	1.3669	...	1.3425	1.3390	0.0035	1.3155	3B	1.3210	1.3287	1.3425	1.3470	0.0045	1.3750
1 3/8-28 or 1.375-28	UN	2A	0.0012	1.3738	1.3673	...	1.3506	1.3465	0.0041	1.3312	2B	1.336	1.345	1.3518	1.3571	0.0053	1.3750
		3A	0.0000	1.3750	1.3685	...	1.3518	1.3487	0.0031	1.3324	3B	1.3360	1.3426	1.3518	1.3558	0.0040	1.3750
1 7/16-6 or 1.4375-6	UN	2A	0.0024	1.4351	1.4169	...	1.3268	1.3188	0.0080	1.2367	2B	1.257	1.288	1.3292	1.3396	0.0104	1.4375
		3A	0.0000	1.4375	1.4193	...	1.3292	1.3232	0.0060	1.2391	3B	1.2570	1.2771	1.3292	1.3370	0.0078	1.4375
1 7/16-8 or 1.4375-8	UN	2A	0.0022	1.4353	1.4203	...	1.3541	1.3469	0.0072	1.2865	2B	1.302	1.327	1.3563	1.3657	0.0094	1.4375
		3A	0.0000	1.4375	1.4225	...	1.3563	1.3509	0.0054	1.2887	3B	1.3020	1.3172	1.3563	1.3634	0.0071	1.4375
1 7/16-12 or 1.4375-12	UN	2A	0.0018	1.4357	1.4243	...	1.3816	1.3757	0.0059	1.3365	2B	1.347	1.365	1.3834	1.3910	0.0076	1.4375
		3A	0.0000	1.4375	1.4261	...	1.3834	1.3790	0.0044	1.3383	3B	1.3470	1.3573	1.3834	1.3891	0.0057	1.4375
1 7/16-16 or 1.4375-16	UN	2A	0.0016	1.4359	1.4265	...	1.3953	1.3901	0.0052	1.3614	2B	1.370	1.384	1.3969	1.4037	0.0068	1.4375
		3A	0.0000	1.4375	1.4281	...	1.3969	1.3930	0.0039	1.3630	3B	1.3700	1.3783	1.3969	1.4020	0.0051	1.4375

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
1 7/16-18 or 1.4375-18	UNEF	2A	0.0015	1.4360	1.4273	...	1.3999	1.3949	0.0050	1.3699	2B	1.377	1.390	1.4014	1.4079	0.0065	1.4375
		3A	0.0000	1.4375	1.4288	...	1.4014	1.3977	0.0037	1.3714	3B	1.3770	1.3855	1.4014	1.4062	0.0048	1.4375
1 7/16-20 or 1.4375-20	UN	2A	0.0014	1.4361	1.4280	...	1.4036	1.3988	0.0048	1.3766	2B	1.383	1.395	1.4050	1.4112	0.0062	1.4375
		3A	0.0000	1.4375	1.4294	...	1.4050	1.4014	0.0036	1.3780	3B	1.3830	1.3912	1.4050	1.4096	0.0046	1.4375
1 7/16-28 or 1.4375-28	UN	2A	0.0013	1.4362	1.4297	...	1.4130	1.4088	0.0042	1.3936	2B	1.399	1.407	1.4143	1.4198	0.0055	1.4375
		3A	0.0000	1.4375	1.4310	...	1.4143	1.4112	0.0031	1.3949	3B	1.3990	1.4051	1.4143	1.4184	0.0041	1.4375
1 1/2-6 or 1.500-6	UNC	1A	0.0024	1.4976	1.4703	...	1.3893	1.3772	0.0121	1.2992	1B	1.320	1.350	1.3917	1.4075	0.0158	1.5000
		2A	0.0024	1.4976	1.4794	1.4703	1.3893	1.3812	0.0081	1.2992	2B	1.320	1.350	1.3917	1.4022	0.0105	1.5000
		3A	0.0000	1.5000	1.4818	...	1.3917	1.3856	0.0061	1.3016	3B	1.3200	1.3396	1.3917	1.3996	0.0079	1.5000
1 1/2-8 or 1.500-8	UN	2A	0.0022	1.4978	1.4828	1.4753	1.4166	1.4093	0.0073	1.3490	2B	1.365	1.390	1.4188	1.4283	0.0095	1.5000
		3A	0.0000	1.5000	1.4850	...	1.4188	1.4133	0.0055	1.3512	3B	1.3650	1.3797	1.4188	1.4259	0.0071	1.5000
1 1/2-12 or 1.500-12	UNF	1A	0.0019	1.4981	1.4809	...	1.4440	1.4344	0.0096	1.3989	1B	1.410	1.428	1.4459	1.4584	0.0125	1.5000
		2A	0.0019	1.4981	1.4867	...	1.4440	1.4376	0.0064	1.3989	2B	1.410	1.428	1.4459	1.4542	0.0083	1.5000
		3A	0.0000	1.5000	1.4886	...	1.4459	1.4411	0.0048	1.4008	3B	1.4100	1.4198	1.4459	1.4522	0.0063	1.5000
1 1/2-16 or 1.500-16	UN	2A	0.0016	1.4984	1.4890	...	1.4578	1.4526	0.0052	1.4239	2B	1.432	1.446	1.4594	1.4662	0.0068	1.5000
		3A	0.0000	1.5000	1.4906	...	1.4594	1.4555	0.0039	1.4255	3B	1.4320	1.4408	1.4594	1.4645	0.0051	1.5000
1 1/2-18 or 1.500-18	UNEF	2A	0.0015	1.4985	1.4898	...	1.4624	1.4574	0.0050	1.4324	2B	1.440	1.452	1.4639	1.4704	0.0065	1.5000
		3A	0.0000	1.5000	1.4913	...	1.4639	1.4602	0.0037	1.4339	3B	1.4400	1.4480	1.4639	1.4687	0.0048	1.5000
1 1/2-20 or 1.500-20	UN	2A	0.0014	1.4986	1.4905	...	1.4661	1.4613	0.0048	1.4391	2B	1.446	1.457	1.4675	1.4737	0.0062	1.5000
		3A	0.0000	1.5000	1.4919	...	1.4675	1.4639	0.0036	1.4405	3B	1.4460	1.4537	1.4675	1.4721	0.0046	1.5000
1 1/2-28 or 1.500-28	UN	2A	0.0013	1.4987	1.4922	...	1.4755	1.4713	0.0042	1.4561	2B	1.461	1.470	1.4768	1.4823	0.0055	1.5000
		3A	0.0000	1.5000	1.4935	...	1.4768	1.4737	0.0031	1.4574	3B	1.4610	1.4676	1.4768	1.4809	0.0041	1.5000
1 9/16-6 or 1.5625-6	UN	2A	0.0024	1.5601	1.5419	...	1.4518	1.4436	0.0082	1.3617	2B	1.382	1.413	1.4542	1.4648	0.0106	1.5625
		3A	0.0000	1.5625	1.5443	...	1.4542	1.4481	0.0061	1.3641	3B	1.3820	1.4021	1.4542	1.4622	0.0080	1.5625
1 9/16-8 or 1.5625-8	UN	2A	0.0022	1.5603	1.5453	...	1.4791	1.4717	0.0074	1.4115	2B	1.427	1.452	1.4813	1.4909	0.0096	1.5625
		3A	0.0000	1.5625	1.5475	...	1.4813	1.4758	0.0055	1.4137	3B	1.4270	1.4422	1.4813	1.4885	0.0072	1.5625
1 9/16-12 or 1.5625-12	UN	2A	0.0018	1.5607	1.5493	...	1.5066	1.5007	0.0059	1.4615	2B	1.472	1.490	1.5084	1.5160	0.0076	1.5625
		3A	0.0000	1.5625	1.5511	...	1.5084	1.5040	0.0044	1.4633	3B	1.4720	1.4823	1.5084	1.5141	0.0057	1.5625
1 9/16-16 or 1.5625-16	UN	2A	0.0016	1.5609	1.5515	...	1.5203	1.5151	0.0052	1.4864	2B	1.495	1.509	1.5219	1.5287	0.0068	1.5625
		3A	0.0000	1.5625	1.5531	...	1.5219	1.5180	0.0039	1.4880	3B	1.4950	1.5033	1.5219	1.5270	0.0051	1.5625

(Notes follow at end of table)

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
1 9/16-18 or 1.5625-18	UNEF	2A	0.0015	1.5610	1.5523	...	1.5249	1.5199	0.0050	1.4949	2B	1.502	1.515	1.5264	1.5329	0.0065	1.5625
		3A	0.0000	1.5625	1.5538	...	1.5264	1.5227	0.0037	1.4964	3B	1.5020	1.5105	1.5264	1.5312	0.0048	1.5625
1 9/16-20 or 1.5625-20	UN	2A	0.0014	1.5611	1.5530	...	1.5286	1.5238	0.0048	1.5016	2B	1.508	1.520	1.5300	1.5362	0.0062	1.5625
		3A	0.0000	1.5625	1.5544	...	1.5300	1.5264	0.0036	1.5030	3B	1.5080	1.5162	1.5300	1.5346	0.0046	1.5625
1 5/8-6 or 1.625-6	UN	2A	0.0025	1.6225	1.6043	...	1.5142	1.5060	0.0082	1.4246	2B	1.445	1.475	1.5167	1.5274	0.0107	1.6250
		3A	0.0000	1.6250	1.6068	...	1.5167	1.5105	0.0062	1.4271	3B	1.4450	1.4646	1.5167	1.5247	0.0080	1.6250
1 5/8-8 or 1.625-8	UN	2A	0.0022	1.6228	1.6078	1.6003	1.5416	1.5342	0.0074	1.4784	2B	1.490	1.515	1.5438	1.5535	0.0097	1.6250
		3A	0.0000	1.6250	1.6100	...	1.5438	1.5382	0.0056	1.4806	3B	1.4900	1.5047	1.5438	1.5510	0.0072	1.6250
1 5/8-12 or 1.625-12	UN	2A	0.0018	1.6232	1.6118	...	1.5691	1.5632	0.0059	1.5240	2B	1.535	1.553	1.5709	1.5785	0.0076	1.6250
		3A	0.0000	1.6250	1.6136	...	1.5709	1.5665	0.0044	1.5258	3B	1.5350	1.5448	1.5709	1.5766	0.0057	1.6250
1 5/8-16 or 1.625-16	UN	2A	0.0016	1.6234	1.6140	...	1.5828	1.5776	0.0052	1.5489	2B	1.557	1.571	1.5844	1.5912	0.0068	1.6250
		3A	0.0000	1.6250	1.6156	...	1.5844	1.5805	0.0039	1.5505	3B	1.5570	1.5658	1.5844	1.5895	0.0051	1.6250
1 5/8-18 or 1.625-18	UNEF	2A	0.0015	1.6235	1.6148	...	1.5874	1.5824	0.0050	1.5574	2B	1.565	1.578	1.5889	1.5954	0.0065	1.6250
		3A	0.0000	1.6250	1.6163	...	1.5889	1.5852	0.0037	1.5589	3B	1.5650	1.5730	1.5889	1.5937	0.0048	1.6250
1 5/8-20 or 1.625-20	UN	2A	0.0014	1.6236	1.6155	...	1.5911	1.5863	0.0048	1.5641	2B	1.571	1.582	1.5925	1.5987	0.0062	1.6250
		3A	0.0000	1.6250	1.6169	...	1.5925	1.5889	0.0036	1.5655	3B	1.5710	1.5787	1.5925	1.5971	0.0046	1.6250
1 11/16-6 or 1.6875-6	UN	2A	0.0025	1.6850	1.6668	...	1.5767	1.5684	0.0083	1.4866	2B	1.507	1.538	1.5792	1.5900	0.0108	1.6875
		3A	0.0000	1.6875	1.6693	...	1.5792	1.5730	0.0062	1.4891	3B	1.5070	1.5271	1.5792	1.5873	0.0081	1.6875
1 11/16-8 or 1.6875-8	UN	2A	0.0022	1.6853	1.6703	...	1.6041	1.5966	0.0075	1.5365	2B	1.552	1.577	1.6063	1.6160	0.0097	1.6875
		3A	0.0000	1.6875	1.6725	...	1.6063	1.6007	0.0056	1.5387	3B	1.5520	1.5672	1.6063	1.6136	0.0073	1.6875
1 11/16-12 or 1.6875-12	UN	2A	0.0018	1.6857	1.6743	...	1.6316	1.6256	0.0060	1.5865	2B	1.597	1.615	1.6334	1.6412	0.0078	1.6875
		3A	0.0000	1.6875	1.6761	...	1.6334	1.6289	0.0045	1.5883	3B	1.5970	1.6073	1.6334	1.6392	0.0058	1.6875
1 11/16-16 or 1.6875-16	UN	2A	0.0016	1.6859	1.6765	...	1.6453	1.6400	0.0053	1.6114	2B	1.620	1.634	1.6469	1.6538	0.0069	1.6875
		3A	0.0000	1.6875	1.6781	...	1.6469	1.6429	0.0040	1.6130	3B	1.6200	1.6283	1.6469	1.6521	0.0052	1.6875
1 11/16-18 or 1.6875-18	UNEF	2A	0.0015	1.6860	1.6773	...	1.6499	1.6448	0.0051	1.6199	2B	1.627	1.640	1.6514	1.6580	0.0066	1.6875
		3A	0.0000	1.6875	1.6788	...	1.6514	1.6476	0.0038	1.6214	3B	1.6270	1.6355	1.6514	1.6563	0.0049	1.6875
1 11/16-20 or 1.6875-20	UN	2A	0.0015	1.6860	1.6779	...	1.6535	1.6487	0.0048	1.6265	2B	1.633	1.645	1.6550	1.6613	0.0063	1.6875
		3A	0.0000	1.6875	1.6794	...	1.6550	1.6514	0.0036	1.6280	3B	1.6330	1.6412	1.6550	1.6597	0.0047	1.6875

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
1¾-5 or 1.750-5	UNC	1A	0.0027	1.7473	1.7165	...	1.6174	1.6040	0.0134	1.5092	1B	1.534	1.568	1.6201	1.6375	0.0174	1.7500
		2A	0.0027	1.7473	1.7268	1.7165	1.6174	1.6085	0.0089	1.5092	2B	1.534	1.568	1.6201	1.6317	0.0116	1.7500
		3A	0.0000	1.7500	1.7295	...	1.6201	1.6134	0.0067	1.5119	3B	1.5340	1.5575	1.6201	1.6288	0.0087	1.7500
1¾-6 or 1.750-6	UN	2A	0.0025	1.7475	1.7293	...	1.6392	1.6309	0.0083	1.5491	2B	1.570	1.600	1.6417	1.6525	0.0108	1.7500
		3A	0.0000	1.7500	1.7318	...	1.6417	1.6354	0.0063	1.5516	3B	1.5700	1.5896	1.6417	1.6498	0.0081	1.7500
1¾-8 or 1.750-8	UN	2A	0.0023	1.7477	1.7327	1.7252	1.6665	1.6590	0.0075	1.5989	2B	1.615	1.640	1.6688	1.6786	0.0098	1.7500
		3A	0.0000	1.7500	1.7350	...	1.6688	1.6632	0.0056	1.6012	3B	1.6150	1.6297	1.6688	1.6762	0.0074	1.7500
1¾-12 or 1.750-12	UN	2A	0.0018	1.7482	1.7368	...	1.6941	1.6881	0.0060	1.6490	2B	1.660	1.678	1.6959	1.7037	0.0078	1.7500
		3A	0.0000	1.7500	1.7386	...	1.6959	1.6914	0.0045	1.6508	3B	1.6600	1.6698	1.6959	1.7017	0.0058	1.7500
1¾-16 or 1.750-16	UN	2A	0.0016	1.7484	1.7390	...	1.7078	1.7025	0.0053	1.6739	2B	1.682	1.696	1.7094	1.7163	0.0069	1.7500
		3A	0.0000	1.7500	1.7406	...	1.7094	1.7054	0.0040	1.6755	3B	1.6820	1.6908	1.7094	1.7146	0.0052	1.7500
1¾-20 or 1.750-20	UN	2A	0.0015	1.7485	1.7404	...	1.7160	1.7112	0.0048	1.6890	2B	1.696	1.707	1.7175	1.7238	0.0063	1.7500
		3A	0.0000	1.7500	1.7419	...	1.7175	1.7139	0.0036	1.6905	3B	1.6960	1.7037	1.7175	1.7222	0.0047	1.7500
1 13/16-6 or 1.8125-6	UN	2A	0.0025	1.8100	1.7918	...	1.7017	1.6933	0.0084	1.6116	2B	1.632	1.663	1.7042	1.7151	0.0109	1.8125
		3A	0.0000	1.8125	1.7943	...	1.7042	1.6979	0.0063	1.6141	3B	1.6320	1.6521	1.7042	1.7124	0.0082	1.8125
1 13/16-8 or 1.8125-8	UN	2A	0.0023	1.8102	1.7952	...	1.7290	1.7214	0.0076	1.6614	2B	1.677	1.702	1.7313	1.7412	0.0099	1.8125
		3A	0.0000	1.8125	1.7975	...	1.7313	1.7256	0.0057	1.6637	3B	1.6770	1.6922	1.7313	1.7387	0.0074	1.8125
1 13/16-12 or 1.8125-12	UN	2A	0.0018	1.8107	1.7993	...	1.7566	1.7506	0.0060	1.7115	2B	1.722	1.740	1.7584	1.7662	0.0078	1.8125
		3A	0.0000	1.8125	1.8011	...	1.7584	1.7539	0.0045	1.7133	3B	1.7220	1.7323	1.7584	1.7642	0.0058	1.8125
1 13/16-16 or 1.8125-16	UN	2A	0.0016	1.8109	1.8015	...	1.7703	1.7650	0.0053	1.7364	2B	1.745	1.759	1.7719	1.7788	0.0069	1.8125
		3A	0.0000	1.8125	1.8031	...	1.7719	1.7679	0.0040	1.7380	3B	1.7450	1.7533	1.7719	1.7771	0.0052	1.8125
1 13/16-20 or 1.8125-20	UN	2A	0.0015	1.8110	1.8029	...	1.7785	1.7737	0.0048	1.7515	2B	1.758	1.770	1.7800	1.7863	0.0063	1.8125
		3A	0.0000	1.8125	1.8044	...	1.7800	1.7764	0.0036	1.7530	3B	1.7580	1.7662	1.7800	1.7847	0.0047	1.8125
1⅞-6 or 1.875-6	UN	2A	0.0025	1.8725	1.8543	...	1.7642	1.7558	0.0084	1.6741	2B	1.695	1.725	1.7667	1.7777	0.0110	1.8750
		3A	0.0000	1.8750	1.8568	...	1.7667	1.7604	0.0063	1.6766	3B	1.6950	1.7146	1.7667	1.7749	0.0082	1.8750
1⅞-8 or 1.875-8	UN	2A	0.0023	1.8727	1.8577	1.8502	1.7915	1.7838	0.0077	1.7239	2B	1.740	1.765	1.7938	1.8038	0.0100	1.8750
		3A	0.0000	1.8750	1.8600	...	1.7938	1.7881	0.0057	1.7262	3B	1.7400	1.7547	1.7938	1.8013	0.0075	1.8750
1⅞-12 or 1.875-12	UN	2A	0.0018	1.8732	1.8618	...	1.8191	1.8131	0.0060	1.7740	2B	1.785	1.803	1.8209	1.8287	0.0078	1.8750
		3A	0.0000	1.8750	1.8636	...	1.8209	1.8164	0.0045	1.7758	3B	1.7850	1.7948	1.8209	1.8267	0.0058	1.8750

(Notes follow at end of table)

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allow-ance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Toler-ance		Class	Min.	Max.	Min.	Max.	Toler-ance	Min.
1⅞-16 or 1.875-16	UN	2A	0.0016	1.8734	1.8640	. . .	1.8328	1.8275	0.0053	1.7989	2B	1.807	1.821	1.8344	1.8413	0.0069	1.8750
		3A	0.0000	1.8750	1.8656	. . .	1.8344	1.8304	0.0040	1.8005	3B	1.8070	1.8158	1.8344	1.8396	0.0052	1.8750
1⅞-20 or 1.875-20	UN	2A	0.0015	1.8735	1.8654	. . .	1.8410	1.8362	0.0048	1.8140	2B	1.821	1.832	1.8425	1.8488	0.0063	1.8750
		3A	0.0000	1.8750	1.8669	. . .	1.8425	1.8389	0.0036	1.8155	3B	1.8210	1.8287	1.8425	1.8472	0.0047	1.8750
1 15/16-6 or 1.9375-6	UN	2A	0.0026	1.9349	1.9167	. . .	1.8266	1.8181	0.0085	1.7365	2B	1.757	1.788	1.8292	1.8403	0.0111	1.9375
		3A	0.0000	1.9375	1.9193	. . .	1.8292	1.8228	0.0064	1.7391	3B	1.7570	1.7771	1.8292	1.8375	0.0083	1.9375
1 15/16-8 or 1.9375-8	UN	2A	0.0023	1.9352	1.9202	. . .	1.8540	1.8463	0.0077	1.7864	2B	1.802	1.827	1.8563	1.8663	0.0100	1.9375
		3A	0.0000	1.9375	1.9225	. . .	1.8563	1.8505	0.0058	1.7887	3B	1.8020	1.8172	1.8563	1.8638	0.0075	1.9375
1 15/16-12 or 1.9375-12	UN	2A	0.0018	1.9357	1.9243	. . .	1.8816	1.8755	0.0061	1.8365	2B	1.847	1.865	1.8834	1.8913	0.0079	1.9375
		3A	0.0000	1.9375	1.9261	. . .	1.8834	1.8789	0.0045	1.8383	3B	1.8470	1.8573	1.8834	1.8893	0.0059	1.9375
1 15/16-16 or 1.9375-16	UN	2A	0.0016	1.9359	1.9265	. . .	1.8953	1.8899	0.0054	1.8614	2B	1.870	1.884	1.8969	1.9039	0.0070	1.9375
		3A	0.0000	1.9375	1.9281	. . .	1.8969	1.8929	0.0040	1.8630	3B	1.8700	1.8783	1.8969	1.9021	0.0052	1.9375
1 15/16-20 or 1.9375-20	UN	2A	0.0015	1.9360	1.9279	. . .	1.9035	1.8986	0.0049	1.8765	2B	1.883	1.895	1.9050	1.9114	0.0064	1.9375
		3A	0.0000	1.9375	1.9294	. . .	1.9050	1.9013	0.0037	1.8780	3B	1.8830	1.8912	1.9050	1.9098	0.0048	1.9375
2-4½ or 2.000-4.5	UNC	1A	0.0029	1.9971	1.9641	. . .	1.8528	1.8385	0.0143	1.7324	1B	1.759	1.795	1.8557	1.8743	0.0186	2.0000
		2A	0.0029	1.9971	1.9751	1.9641	1.8528	1.8433	0.0095	1.7324	2B	1.759	1.795	1.8557	1.8681	0.0124	2.0000
		3A	0.0000	2.0000	1.9780	. . .	1.8557	1.8486	0.0071	1.7353	3B	1.7590	1.7861	1.8557	1.8650	0.0093	2.0000
2-6 or 2.000-6	UN	2A	0.0026	1.9974	1.9792	. . .	1.8891	1.8805	0.0086	1.7990	2B	1.820	1.850	1.8917	1.9028	0.0111	2.0000
		3A	0.0000	2.0000	1.9818	. . .	1.8917	1.8853	0.0064	1.8016	3B	1.8200	1.8396	1.8917	1.9000	0.0083	2.0000
2-8 or 2.000-8	UN	2A	0.0023	1.9977	1.9827	1.9752	1.9165	1.9087	0.0078	1.8489	2B	1.865	1.890	1.9188	1.9289	0.0101	2.0000
		3A	0.0000	2.0000	1.9850	. . .	1.9188	1.9130	0.0058	1.8512	3B	1.8650	1.8797	1.9188	1.9264	0.0076	2.0000
2-12 or 2.000-12	UN	2A	0.0018	1.9982	1.9868	. . .	1.9441	1.9380	0.0061	1.8990	2B	1.910	1.928	1.9459	1.9538	0.0079	2.0000
		3A	0.0000	2.0000	1.9886	. . .	1.9459	1.9414	0.0045	1.9008	3B	1.9100	1.9198	1.9459	1.9518	0.0059	2.0000
2-16 or 2.000-16	UN	2A	0.0016	1.9984	1.9890	. . .	1.9578	1.9524	0.0054	1.9239	2B	1.932	1.946	1.9594	1.9664	0.0070	2.0000
		3A	0.0000	2.0000	1.9906	. . .	1.9594	1.9554	0.0040	1.9255	3B	1.9320	1.9408	1.9594	1.9646	0.0052	2.0000
2-20 or 2.000-20	UN	2A	0.0015	1.9985	1.9904	. . .	1.9660	1.9611	0.0049	1.9390	2B	1.946	1.957	1.9675	1.9739	0.0064	2.0000
		3A	0.0000	2.0000	1.9919	. . .	1.9675	1.9638	0.0037	1.9405	3B	1.9460	1.9537	1.9675	1.9723	0.0048	2.0000
2⅛-6 or 2.125-6	UN	2A	0.0026	2.1224	2.1042	. . .	2.0141	2.0054	0.0087	1.9240	2B	1.945	1.975	2.0167	2.0280	0.0113	2.1250
		3A	0.0000	2.1250	2.1068	. . .	2.0167	2.0102	0.0065	1.9266	3B	1.9450	1.9646	2.0167	2.0251	0.0084	2.1250

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
2⅛-8 or 2.125-8	UN	2A	0.0024	2.1226	2.1076	2.1001	2.0414	2.0335	0.0079	1.9738	2B	1.990	2.015	2.0438	2.0540	0.0102	2.1250
		3A	0.0000	2.1250	2.1100	...	2.0438	2.0379	0.0059	1.9762	3B	1.9900	2.0047	2.0438	2.0515	0.0077	2.1250
2⅛-12 or 2.125-12	UN	2A	0.0018	2.1232	2.1118	...	2.0691	2.0630	0.0061	2.0240	2B	2.035	2.053	2.0709	2.0788	0.0079	2.1250
		3A	0.0000	2.1250	2.1136	...	2.0709	2.0664	0.0045	2.0258	3B	2.0350	2.0448	2.0709	2.0768	0.0059	2.1250
2⅛-16 or 2.125-16	UN	2A	0.0016	2.1234	2.1140	...	2.0828	2.0774	0.0054	2.0489	2B	2.057	2.071	2.0844	2.0914	0.0070	2.1250
		3A	0.0000	2.1250	2.1156	...	2.0844	2.0803	0.0041	2.0505	3B	2.0570	2.0658	2.0844	2.0896	0.0052	2.1250
2⅛-20 or 2.125-20	UN	2A	0.0015	2.1235	2.1154	...	2.0910	2.0861	0.0049	2.0640	2B	2.071	2.082	2.0925	2.0989	0.0064	2.1250
		3A	0.0000	2.1250	2.1169	...	2.0925	2.0888	0.0037	2.0655	3B	2.0710	2.0787	2.0925	2.0973	0.0048	2.1250
2¼-4½ or 2.250-4.5	UNC	1A	0.0029	2.2471	2.2141	...	2.1028	2.0882	0.0146	1.9824	1B	2.009	2.045	2.1057	2.1247	0.0190	2.2500
		2A	0.0029	2.2471	2.2251	2.2141	2.1028	2.0931	0.0097	1.9824	2B	2.009	2.045	2.1057	2.1183	0.0126	2.2500
		3A	0.0000	2.2500	2.2280	...	2.1057	2.0984	0.0073	1.9853	3B	2.0090	2.0361	2.1057	2.1152	0.0095	2.2500
2¼-6 or 2.250-6	UN	2A	0.0026	2.2474	2.2292	...	2.1391	2.1303	0.0088	2.0490	2B	2.070	2.100	2.1417	2.1531	0.0114	2.2500
		3A	0.0000	2.2500	2.2318	...	2.1417	2.1351	0.0066	2.0516	3B	2.0700	2.0896	2.1417	2.1502	0.0085	2.2500
2¼-8 or 2.250-8	UN	2A	0.0024	2.2476	2.2326	2.2251	2.1664	2.1584	0.0080	2.0988	2B	2.115	2.140	2.1688	2.1792	0.0104	2.2500
		3A	0.0000	2.2500	2.2350	...	2.1688	2.1628	0.0060	2.1012	3B	2.1150	2.1297	2.1688	2.1766	0.0078	2.2500
2¼-12 or 2.250-12	UN	2A	0.0018	2.2482	2.2368	...	2.1941	2.1880	0.0061	2.1490	2B	2.160	2.178	2.1959	2.2038	0.0079	2.2500
		3A	0.0000	2.2500	2.2386	...	2.1959	2.1914	0.0045	2.1508	3B	2.1600	2.1698	2.1959	2.2018	0.0059	2.2500
2¼-16 or 2.250-16	UN	2A	0.0016	2.2484	2.2390	...	2.2078	2.2024	0.0054	2.1739	2B	2.182	2.196	2.2094	2.2164	0.0070	2.2500
		3A	0.0000	2.2500	2.2406	...	2.2094	2.2053	0.0041	2.1755	3B	2.1820	2.1908	2.2094	2.2146	0.0052	2.2500
2¼-20 or 2.250-20	UN	2A	0.0015	2.2485	2.2404	...	2.2160	2.2111	0.0049	2.1890	2B	2.196	2.207	2.2175	2.2239	0.0064	2.2500
		3A	0.0000	2.2500	2.2419	...	2.2175	2.2137	0.0038	2.1905	3B	2.1960	2.2037	2.2175	2.2223	0.0048	2.2500
2⅜-6 or 2.375-6	UN	2A	0.0027	2.3723	2.3541	...	2.2640	2.2551	0.0089	2.1739	2B	2.195	2.226	2.2667	2.2782	0.0115	2.3750
		3A	0.0000	2.3750	2.3568	...	2.2667	2.2601	0.0066	2.1766	3B	2.1950	2.2146	2.2667	2.2753	0.0086	2.3750
2⅜-8 or 2.375-8	UN	2A	0.0024	2.3726	2.3576	...	2.2914	2.2833	0.0081	2.2238	2B	2.240	2.265	2.2938	2.3043	0.0105	2.3750
		3A	0.0000	2.3750	2.3600	...	2.2938	2.2878	0.0060	2.2262	3B	2.2400	2.2547	2.2938	2.3017	0.0079	2.3750
2⅜-12 or 2.375-12	UN	2A	0.0019	2.3731	2.3617	...	2.3190	2.3128	0.0062	2.2739	2B	2.285	2.303	2.3209	2.3290	0.0081	2.3750
		3A	0.0000	2.3750	2.3636	...	2.3209	2.3163	0.0046	2.2758	3B	2.2850	2.2948	2.3209	2.3269	0.0060	2.3750
2⅜-16 or 2.375-16	UN	2A	0.0017	2.3733	2.3639	...	2.3327	2.3272	0.0055	2.2988	2B	2.307	2.321	2.3344	2.3416	0.0072	2.3750
		3A	0.0000	2.3750	2.3656	...	2.3344	2.3303	0.0041	2.3005	3B	2.3070	2.3158	2.3344	2.3398	0.0054	2.3750

(Notes follow at end of table)

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
2⅜-20 or 2.375-20	UN	2A	0.0015	2.3735	2.3654	...	2.3410	2.3359	0.0051	2.3140	2B	2.321	2.332	2.3425	2.3491	0.0066	2.3750
		3A	0.0000	2.3750	2.3669	...	2.3425	2.3387	0.0038	2.3155	3B	2.3210	2.3287	2.3425	2.3475	0.0050	2.3750
2½-4 or 2.500-4	UNC	1A	0.0031	2.4969	2.4612	...	2.3345	2.3190	0.0155	2.1992	1B	2.229	2.267	2.3376	2.3578	0.0202	2.5000
		2A	0.0031	2.4969	2.4731	2.4612	2.3345	2.3241	0.0104	2.1992	2B	2.229	2.267	2.3376	2.3511	0.0135	2.5000
		3A	0.0000	2.5000	2.4762	...	2.3376	2.3298	0.0078	2.2023	3B	2.2290	2.2594	2.3376	2.3477	0.0101	2.5000
2½-6 or 2.500-6	UN	2A	0.0027	2.4973	2.4791	...	2.3890	2.3800	0.0090	2.2989	2B	2.320	2.350	2.3917	2.4033	0.0116	2.5000
		3A	0.0000	2.5000	2.4818	...	2.3917	2.3850	0.0067	2.3016	3B	2.3200	2.3396	2.3917	2.4004	0.0087	2.5000
2½-8 or 2.500-8	UN	2A	0.0024	2.4976	2.4826	2.4751	2.4164	2.4082	0.0082	2.3488	2B	2.365	2.390	2.4188	2.4294	0.0106	2.5000
		3A	0.0000	2.5000	2.4850	...	2.4188	2.4127	0.0061	2.3512	3B	2.3650	2.3797	2.4188	2.4268	0.0080	2.5000
2½-12 or 2.500-12	UN	2A	0.0019	2.4981	2.4867	...	2.4440	2.4378	0.0062	2.3989	2B	2.410	2.428	2.4459	2.4540	0.0081	2.5000
		3A	0.0000	2.5000	2.4886	...	2.4459	2.4413	0.0046	2.4008	3B	2.4100	2.4198	2.4459	2.4519	0.0060	2.5000
2½-16 or 2.500-16	UN	2A	0.0017	2.4983	2.4889	...	2.4577	2.4522	0.0055	2.4238	2B	2.432	2.446	2.4594	2.4666	0.0072	2.5000
		3A	0.0000	2.5000	2.4906	...	2.4594	2.4553	0.0041	2.4255	3B	2.4320	2.4408	2.4594	2.4648	0.0054	2.5000
2½-20 or 2.500-20	UN	2A	0.0015	2.4985	2.4904	...	2.4660	2.4609	0.0051	2.4390	2B	2.446	2.457	2.4675	2.4741	0.0066	2.5000
		3A	0.0000	2.5000	2.4919	...	2.4675	2.4637	0.0038	2.4405	3B	2.4460	2.4537	2.4675	2.4725	0.0050	2.5000
2⅝-6 or 2.625-6	UN	2A	0.0027	2.6223	2.6041	...	2.5140	2.5050	0.0090	2.4239	2B	2.445	2.475	2.5167	2.5285	0.0118	2.6250
		3A	0.0000	2.6250	2.6068	...	2.5167	2.5099	0.0068	2.4266	3B	2.4450	2.4646	2.5167	2.5255	0.0088	2.6250
2⅝-8 or 2.625-8	UN	2A	0.0025	2.6225	2.6075	...	2.5413	2.5331	0.0082	2.4737	2B	2.490	2.515	2.5438	2.5545	0.0107	2.6250
		3A	0.0000	2.6250	2.6100	...	2.5438	2.5376	0.0062	2.4762	3B	2.4900	2.5047	2.5438	2.5518	0.0080	2.6250
2⅝-12 or 2.625-12	UN	2A	0.0019	2.6231	2.6117	...	2.5690	2.5628	0.0062	2.5239	2B	2.535	2.553	2.5709	2.5790	0.0081	2.6250
		3A	0.0000	2.6250	2.6136	...	2.5709	2.5663	0.0046	2.5258	3B	2.5350	2.5448	2.5709	2.5769	0.0060	2.6250
2⅝-16 or 2.625-16	UN	2A	0.0017	2.6233	2.6139	...	2.5827	2.5772	0.0055	2.5488	2B	2.557	2.571	2.5844	2.5916	0.0072	2.6250
		3A	0.0000	2.6250	2.6156	...	2.5844	2.5803	0.0041	2.5505	3B	2.5570	2.5658	2.5844	2.5898	0.0054	2.6250
2⅝-20 or 2.625-20	UN	2A	0.0015	2.6235	2.6154	...	2.5910	2.5859	0.0051	2.5640	2B	2.571	2.582	2.5925	2.5991	0.0066	2.6250
		3A	0.0000	2.6250	2.6169	...	2.5925	2.5887	0.0038	2.5655	3B	2.5710	2.5787	2.5925	2.5975	0.0050	2.6250
2¾-4 or 2.750-4	UNC	1A	0.0032	2.7468	2.7111	...	2.5844	2.5686	0.0158	2.4491	1B	2.479	2.517	2.5876	2.6082	0.0206	2.7500
		2A	0.0032	2.7468	2.7230	2.7111	2.5844	2.5739	0.0105	2.4491	2B	2.479	2.517	2.5876	2.6013	0.0137	2.7500
		3A	0.0000	2.7500	2.7262	...	2.5876	2.5797	0.0079	2.4523	3B	2.4790	2.5094	2.5876	2.5979	0.0103	2.7500
2¾-6 or 2.750-6	UN	2A	0.0027	2.7473	2.7291	...	2.6390	2.6299	0.0091	2.5489	2B	2.570	2.600	2.6417	2.6536	0.0119	2.7500
		3A	0.0000	2.7500	2.7318	...	2.6417	2.6349	0.0068	2.5516	3B	2.5700	2.5896	2.6417	2.6506	0.0089	2.7500

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
2¾-8 or 2.750-8	UN	2A	0.0025	2.7475	2.7325	2.7250	2.6663	2.6580	0.0083	2.5987	2B	2.615	2.640	2.6688	2.6796	0.0108	2.7500
		3A	0.0000	2.7500	2.7350	...	2.6688	2.6625	0.0063	2.6012	3B	2.6150	2.6297	2.6688	2.6769	0.0081	2.7500
2¾-12 or 2.750-12	UN	2A	0.0019	2.7481	2.7367	...	2.6940	2.6878	0.0062	2.6489	2B	2.660	2.678	2.6959	2.7040	0.0081	2.7500
		3A	0.0000	2.7500	2.7386	...	2.6959	2.6913	0.0046	2.6508	3B	2.6600	2.6698	2.6959	2.7019	0.0060	2.7500
2¾-16 or 2.750-16	UN	2A	0.0017	2.7483	2.7389	...	2.7077	2.7022	0.0055	2.6738	2B	2.682	2.696	2.7094	2.7166	0.0072	2.7500
		3A	0.0000	2.7500	2.7406	...	2.7094	2.7053	0.0041	2.6755	3B	2.6820	2.6908	2.7094	2.7148	0.0054	2.7500
2¾-20 or 2.750-20	UN	2A	0.0015	2.7485	2.7404	...	2.7160	2.7109	0.0051	2.6890	2B	2.696	2.707	2.7175	2.7241	0.0066	2.7500
		3A	0.0000	2.7500	2.7419	...	2.7175	2.7137	0.0038	2.6905	3B	2.6960	2.7037	2.7175	2.7225	0.0050	2.7500
2⅞-6 or 2.875-6	UN	2A	0.0028	2.8722	2.8540	...	2.7639	2.7547	0.0092	2.6738	2B	2.695	2.725	2.7667	2.7787	0.0120	2.8750
		3A	0.0000	2.8750	2.8568	...	2.7667	2.7598	0.0069	2.6766	3B	2.6950	2.7146	2.7667	2.7757	0.0090	2.8750
2⅞-8 or 2.875-8	UN	2A	0.0025	2.8725	2.8575	...	2.7913	2.7829	0.0084	2.7237	2B	2.740	2.765	2.7938	2.8048	0.0110	2.8750
		3A	0.0000	2.8750	2.8600	...	2.7938	2.7875	0.0063	2.7262	3B	2.7400	2.7547	2.7938	2.8020	0.0082	2.8750
2⅞-12 or 2.875-12	UN	2A	0.0019	2.8731	2.8617	...	2.8190	2.8127	0.0063	2.7739	2B	2.785	2.803	2.8209	2.8291	0.0082	2.8750
		3A	0.0000	2.8750	2.8636	...	2.8209	2.8162	0.0047	2.7758	3B	2.7850	2.7948	2.8209	2.8271	0.0062	2.8750
2⅞-16 or 2.875-16	UN	2A	0.0017	2.8733	2.8639	...	2.8327	2.8271	0.0056	2.7988	2B	2.807	2.821	2.8344	2.8417	0.0073	2.8750
		3A	0.0000	2.8750	2.8656	...	2.8344	2.8302	0.0042	2.8005	3B	2.8070	2.8158	2.8344	2.8399	0.0055	2.8750
2⅞-20 or 2.875-20	UN	2A	0.0016	2.8734	2.8653	...	2.8409	2.8357	0.0052	2.8139	2B	2.821	2.832	2.8425	2.8493	0.0068	2.8750
		3A	0.0000	2.8750	2.8669	...	2.8425	2.8386	0.0039	2.8155	3B	2.8210	2.8287	2.8425	2.8476	0.0051	2.8750
3-4 or 3.000-4	UNC	1A	0.0032	2.9968	2.9611	...	2.8344	2.8183	0.0161	2.6991	1B	2.729	2.767	2.8376	2.8585	0.0209	3.0000
		2A	0.0032	2.9968	2.9730	2.9611	2.8344	2.8237	0.0107	2.6991	2B	2.729	2.767	2.8376	2.8515	0.0139	3.0000
		3A	0.0000	3.0000	2.9762	...	2.8376	2.8296	0.0080	2.7023	3B	2.7290	2.7594	2.8376	2.8480	0.0104	3.0000
3-6 or 3.000-6	UN	2A	0.0028	2.9972	2.9790	...	2.8889	2.8796	0.0093	2.7988	2B	2.820	2.850	2.8917	2.9038	0.0121	3.0000
		3A	0.0000	3.0000	2.9818	...	2.8917	2.8847	0.0070	2.8016	3B	2.8200	2.8396	2.8917	2.9008	0.0091	3.0000
3-8 or 3.000-8	UN	2A	0.0026	2.9974	2.9824	2.9749	2.9162	2.9077	0.0085	2.8486	2B	2.865	2.890	2.9188	2.9299	0.0111	3.0000
		3A	0.0000	3.0000	2.9850	...	2.9188	2.9124	0.0064	2.8512	3B	2.8650	2.8797	2.9188	2.9271	0.0083	3.0000
3-12 or 3.000-12	UN	2A	0.0019	2.9981	2.9867	...	2.9440	2.9377	0.0063	2.8989	2B	2.910	2.928	2.9459	2.9541	0.0082	3.0000
		3A	0.0000	3.0000	2.9886	...	2.9459	2.9412	0.0047	2.9008	3B	2.9100	2.9198	2.9459	2.9521	0.0062	3.0000
3-16 or 3.000-16	UN	2A	0.0017	2.9983	2.9889	...	2.9577	2.9521	0.0056	2.9238	2B	2.932	2.946	2.9594	2.9667	0.0073	3.0000
		3A	0.0000	3.0000	2.9906	...	2.9594	2.9552	0.0042	2.9255	3B	2.9320	2.9408	2.9594	2.9649	0.0055	3.0000

(Notes follow at end of table)

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
3-20 or 3.000-20	UN	2A	0.0016	2.9984	2.9903	...	2.9659	2.9607	0.0052	2.9389	2B	2.946	2.957	2.9675	2.9743	0.0068	3.0000
		3A	0.0000	3.0000	2.9919	...	2.9675	2.9636	0.0039	2.9405	3B	2.9460	2.9537	2.9675	2.9726	0.0051	3.0000
3⅛-6 or 3.125-6	UN	2A	0.0028	3.1222	3.1040	...	3.0139	3.0045	0.0094	2.9238	2B	2.945	2.975	3.0167	3.0289	0.0122	3.1250
		3A	0.0000	3.1250	3.1068	...	3.0167	3.0097	0.0070	2.9266	3B	2.9450	2.9646	3.0167	3.0259	0.0092	3.1250
3⅛-8 or 3.125-8	UN	2A	0.0026	3.1224	3.1074	...	3.0412	3.0326	0.0086	2.9736	2B	2.990	3.015	3.0438	3.0550	0.0112	3.1250
		3A	0.0000	3.1250	3.1100	...	3.0438	3.0374	0.0064	2.9762	3B	2.9900	3.0047	3.0438	3.0522	0.0084	3.1250
3⅛-12 or 3.125-12	UN	2A	0.0019	3.1231	3.1117	...	3.0690	3.0627	0.0063	3.0239	2B	3.035	3.053	3.0709	3.0791	0.0082	3.1250
		3A	0.0000	3.1250	3.1136	...	3.0709	3.0662	0.0047	3.0258	3B	3.0350	3.0448	3.0709	3.0771	0.0062	3.1250
3⅛-16 or 3.125-16	UN	2A	0.0017	3.1233	3.1139	...	3.0827	3.0771	0.0056	3.0488	2B	3.057	3.071	3.0844	3.0917	0.0073	3.1250
		3A	0.0000	3.1250	3.1156	...	3.0844	3.0802	0.0042	3.0505	3B	3.0570	3.0658	3.0844	3.0899	0.0055	3.1250
3¼-4 or 3.250-4	UNC	1A	0.0033	3.2467	3.2110	...	3.0843	3.0680	0.0163	2.9490	1B	2.979	3.017	3.0876	3.1088	0.0212	3.2500
		2A	0.0033	3.2467	3.2229	3.2110	3.0843	3.0734	0.0109	2.9490	2B	2.979	3.017	3.0876	3.1017	0.0141	3.2500
		3A	0.0000	3.2500	3.2262	...	3.0876	3.0794	0.0082	2.9523	3B	2.9790	3.0094	3.0876	3.0982	0.0106	3.2500
3¼-6 or 3.250-6	UN	2A	0.0028	3.2472	3.2290	...	3.1389	3.1294	0.0095	3.0488	2B	3.070	3.100	3.1417	3.1540	0.0123	3.2500
		3A	0.0000	3.2500	3.2318	...	3.1417	3.1346	0.0071	3.0516	3B	3.0700	3.0896	3.1417	3.1509	0.0092	3.2500
3¼-8 or 3.250-8	UN	2A	0.0026	3.2474	3.2324	3.2249	3.1662	3.1575	0.0087	3.0986	2B	3.115	3.140	3.1688	3.1801	0.0113	3.2500
		3A	0.0000	3.2500	3.2350	...	3.1688	3.1623	0.0065	3.1012	3B	3.1150	3.1297	3.1688	3.1773	0.0085	3.2500
3¼-12 or 3.250-12	UN	2A	0.0019	3.2481	3.2367	...	3.1940	3.1877	0.0063	3.1489	2B	3.160	3.178	3.1959	3.2041	0.0082	3.2500
		3A	0.0000	3.2500	3.2386	...	3.1959	3.1912	0.0047	3.1508	3B	3.1600	3.1698	3.1959	3.2021	0.0062	3.2500
3¼-16 or 3.250-16	UN	2A	0.0017	3.2483	3.2389	...	3.2077	3.2021	0.0056	3.1738	2B	3.182	3.196	3.2094	3.2167	0.0073	3.2500
		3A	0.0000	3.2500	3.2406	...	3.2094	3.2052	0.0042	3.1755	3B	3.1820	3.1908	3.2094	3.2149	0.0055	3.2500
3⅜-6 or 3.375-6	UN	2A	0.0029	3.3721	3.3539	...	3.2638	3.2543	0.0095	3.1737	2B	3.195	3.225	3.2667	3.2791	0.0124	3.3750
		3A	0.0000	3.3750	3.3568	...	3.2667	3.2595	0.0072	3.1766	3B	3.1950	3.2146	3.2667	3.2760	0.0093	3.3750
3⅜-8 or 3.375-8	UN	2A	0.0026	3.3724	3.3574	...	3.2912	3.2824	0.0088	3.2236	2B	3.240	3.265	3.2938	3.3052	0.0114	3.3750
		3A	0.0000	3.3750	3.3600	...	3.2938	3.2872	0.0066	3.2262	3B	3.2400	3.2547	3.2938	3.3023	0.0085	3.3750
3⅜-12 or 3.375-12	UN	2A	0.0019	3.3731	3.3617	...	3.3190	3.3126	0.0064	3.2739	2B	3.285	3.303	3.3209	3.3293	0.0084	3.3750
		3A	0.0000	3.3750	3.3636	...	3.3209	3.3161	0.0048	3.2758	3B	3.2850	3.2948	3.3209	3.3272	0.0063	3.3750
3⅜-16 or 3.375-16	UN	2A	0.0017	3.3733	3.3639	...	3.3327	3.3269	0.0058	3.2988	2B	3.307	3.321	3.3344	3.3419	0.0075	3.3750
		3A	0.0000	3.3750	3.3656	...	3.3344	3.3301	0.0043	3.3005	3B	3.3070	3.3158	3.3344	3.3400	0.0056	3.3750

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
3½-4 or 3.500-4	UNC	1A	0.0033	3.4967	3.4610	...	3.3343	3.3177	0.0166	3.1990	1B	3.229	3.267	3.3376	3.3591	0.0215	3.5000
		2A	0.0033	3.4967	3.4729	3.4610	3.3343	3.3233	0.0110	3.1990	2B	3.229	3.267	3.3376	3.3519	0.0143	3.5000
		3A	0.0000	3.5000	3.4762	...	3.3376	3.3293	0.0083	3.2023	3B	3.2290	3.2594	3.3376	3.3484	0.0108	3.5000
3½-6 or 3.500-6	UN	2A	0.0029	3.4971	3.4789	...	3.3888	3.3792	0.0096	3.2987	2B	3.320	3.350	3.3917	3.4042	0.0125	3.5000
		3A	0.0000	3.5000	3.4818	...	3.3917	3.3845	0.0072	3.3016	3B	3.3200	3.3396	3.3917	3.4011	0.0094	3.5000
3½-8 or 3.500-8	UN	2A	0.0026	3.4974	3.4824	3.4749	3.4162	3.4074	0.0088	3.3486	2B	3.365	3.390	3.4188	3.4303	0.0115	3.5000
		3A	0.0000	3.5000	3.4850	...	3.4188	3.4122	0.0066	3.3512	3B	3.3650	3.3797	3.4188	3.4274	0.0086	3.5000
3½-12 or 3.500-12	UN	2A	0.0019	3.4981	3.4867	...	3.4440	3.4376	0.0064	3.3989	2B	3.410	3.428	3.4459	3.4543	0.0084	3.5000
		3A	0.0000	3.5000	3.4886	...	3.4459	3.4411	0.0048	3.4008	3B	3.4100	3.4198	3.4459	3.4522	0.0063	3.5000
3½-16 or 3.500-16	UN	2A	0.0017	3.4983	3.4889	...	3.4577	3.4519	0.0058	3.4238	2B	3.432	3.446	3.4594	3.4669	0.0075	3.5000
		3A	0.0000	3.5000	3.4906	...	3.4594	3.4551	0.0043	3.4255	3B	3.4320	3.4408	3.4594	3.4650	0.0056	3.5000
3⅝-6 or 3.625-6	UN	2A	0.0029	3.6221	3.6039	...	3.5138	3.5041	0.0097	3.4237	2B	3.445	3.475	3.5167	3.5293	0.0126	3.6250
		3A	0.0000	3.6250	3.6068	...	3.5167	3.5094	0.0073	3.4266	3B	3.4450	3.4646	3.5167	3.5262	0.0095	3.6250
3⅝-8 or 3.625-8	UN	2A	0.0027	3.6223	3.6073	...	3.5411	3.5322	0.0089	3.4735	2B	3.490	3.515	3.5438	3.5554	0.0116	3.6250
		3A	0.0000	3.6250	3.6100	...	3.5438	3.5371	0.0067	3.4762	3B	3.4900	3.5047	3.5438	3.5525	0.0087	3.6250
3⅝-12 or 3.625-12	UN	2A	0.0019	3.6231	3.6117	...	3.5690	3.5626	0.0064	3.5239	2B	3.535	3.553	3.5709	3.5793	0.0084	3.6250
		3A	0.0000	3.6250	3.6136	...	3.5709	3.5661	0.0048	3.5258	3B	3.5350	3.5448	3.5709	3.5772	0.0063	3.6250
3⅝-16 or 3.625-16	UN	2A	0.0017	3.6233	3.6139	...	3.5827	3.5769	0.0058	3.5488	2B	3.557	3.571	3.5844	3.5919	0.0075	3.6250
		3A	0.0000	3.6250	3.6156	...	3.5844	3.5801	0.0043	3.5505	3B	3.5570	3.5658	3.5844	3.5900	0.0056	3.6250
3¾-4 or 3.750-4	UNC	1A	0.0034	3.7466	3.7109	...	3.5842	3.5674	0.0168	3.4489	1B	3.479	3.517	3.5876	3.6094	0.0218	3.7500
		2A	0.0034	3.7466	3.7228	3.7109	3.5842	3.5730	0.0112	3.4489	2B	3.479	3.517	3.5876	3.6021	0.0145	3.7500
		3A	0.0000	3.7500	3.7262	...	3.5876	3.5792	0.0084	3.4523	3B	3.4790	3.5094	3.5876	3.5985	0.0109	3.7500
3¾-6 or 3.750-6	UN	2A	0.0029	3.7471	3.7289	...	3.6388	3.6290	0.0098	3.5487	2B	3.570	3.600	3.6417	3.6544	0.0127	3.7500
		3A	0.0000	3.7500	3.7318	...	3.6417	3.6344	0.0073	3.5516	3B	3.5700	3.5896	3.6417	3.6512	0.0095	3.7500
3¾-8 or 3.750-8	UN	2A	0.0027	3.7473	3.7323	3.7248	3.6661	3.6571	0.0090	3.5985	2B	3.615	3.640	3.6688	3.6805	0.0117	3.7500
		3A	0.0000	3.7500	3.7350	...	3.6688	3.6621	0.0067	3.6012	3B	3.6150	3.6297	3.6688	3.6776	0.0088	3.7500
3¾-12 or 3.750-12	UN	2A	0.0019	3.7481	3.7367	...	3.6940	3.6876	0.0064	3.6489	2B	3.660	3.678	3.6959	3.7043	0.0084	3.7500
		3A	0.0000	3.7500	3.7386	...	3.6959	3.6911	0.0048	3.6508	3B	3.6600	3.6698	3.6959	3.7022	0.0063	3.7500
3¾-16 or 3.750-16	UN	2A	0.0017	3.7483	3.7389	...	3.7077	3.7019	0.0058	3.6738	2B	3.682	3.696	3.7094	3.7169	0.0075	3.7500
		3A	0.0000	3.7500	3.7406	...	3.7094	3.7051	0.0043	3.6755	3B	3.6820	3.6908	3.7094	3.7150	0.0056	3.7500

(Notes follow at end of table)

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
3⅞-6 or 3.875-6	UN	2A	0.0030	3.8720	3.8538	...	3.7637	3.7538	0.0099	3.6736	2B	3.695	3.725	3.7667	3.7795	0.0128	3.8750
		3A	0.0000	3.8750	3.8568	...	3.7667	3.7593	0.0074	3.6766	3B	3.6950	3.7146	3.7667	3.7763	0.0096	3.8750
3⅞-8 or 3.875-8	UN	2A	0.0027	3.8723	3.8573	...	3.7911	3.7820	0.0091	3.7235	2B	3.740	3.765	3.7938	3.8056	0.0118	3.8750
		3A	0.0000	3.8750	3.8600	...	3.7938	3.7870	0.0068	3.7262	3B	3.7400	3.7547	3.7938	3.8026	0.0088	3.8750
3⅞-12 or 3.875-12	UN	2A	0.0020	3.8730	3.8616	...	3.8189	3.8124	0.0065	3.7738	2B	3.785	3.803	3.8209	3.8294	0.0085	3.8750
		3A	0.0000	3.8750	3.8636	...	3.8209	3.8160	0.0049	3.7758	3B	3.7850	3.7948	3.8209	3.8273	0.0064	3.8750
3⅞-16 or 3.875-16	UN	2A	0.0018	3.8732	3.8638	...	3.8326	3.8267	0.0059	3.7987	2B	3.807	3.821	3.8344	3.8420	0.0076	3.8750
		3A	0.0000	3.8750	3.8656	...	3.8344	3.8300	0.0044	3.8005	3B	3.8070	3.8158	3.8344	3.8401	0.0057	3.8750
4-4 or 4.000-4	UNC	1A	0.0034	3.9966	3.9609	...	3.8342	3.8172	0.0170	3.6989	1B	3.729	3.767	3.8376	3.8597	0.0221	4.0000
		2A	0.0034	3.9966	3.9728	3.9609	3.8342	3.8229	0.0113	3.6989	2B	3.729	3.767	3.8376	3.8523	0.0147	4.0000
		3A	0.0000	4.0000	3.9762	...	3.8376	3.8291	0.0085	3.7023	3B	3.7290	3.7594	3.8376	3.8487	0.0111	4.0000
4-6 or 4.000-6	UN	2A	0.0030	3.9970	3.9788	...	3.8887	3.8788	0.0099	3.7986	2B	3.820	3.850	3.8917	3.9046	0.0129	4.0000
		3A	0.0000	4.0000	3.9818	...	3.8917	3.8843	0.0074	3.8016	3B	3.8200	3.8396	3.8917	3.9014	0.0097	4.0000
4-8 or 4.000-8	UN	2A	0.0027	3.9973	3.9823	3.9748	3.9161	3.9070	0.0091	3.8485	2B	3.865	3.890	3.9188	3.9307	0.0119	4.0000
		3A	0.0000	4.0000	3.9850	...	3.9188	3.9120	0.0068	3.8512	3B	3.8650	3.8797	3.9188	3.9277	0.0089	4.0000
4-12 or 4.000-12	UN	2A	0.0020	3.9980	3.9866	...	3.9439	3.9374	0.0065	3.8988	2B	3.910	3.928	3.9459	3.9544	0.0085	4.0000
		3A	0.0000	4.0000	3.9886	...	3.9459	3.9410	0.0049	3.9008	3B	3.9100	3.9198	3.9459	3.9523	0.0064	4.0000
4-16 or 4.000-16	UN	2A	0.0018	3.9982	3.9888	...	3.9576	3.9517	0.0059	3.9237	2B	3.932	3.946	3.9594	3.9670	0.0076	4.0000
		3A	0.0000	4.0000	3.9906	...	3.9594	3.9550	0.0044	3.9255	3B	3.9320	3.9408	3.9594	3.9651	0.0057	4.0000
4⅛-6 or 4.125-6	UN	2A	0.0030	4.1220	4.1038	...	4.0137	4.0037	0.0100	3.9236	2B	3.945	3.975	4.0167	4.0297	0.0130	4.1250
		3A	0.0000	4.1250	4.1068	...	4.0167	4.0092	0.0075	3.9266	3B	3.9450	3.9646	4.0167	4.0264	0.0097	4.1250
4⅛-8 or 4.125-8	UN	2A	0.0028	4.1222	4.1072	...	4.0410	4.0318	0.0092	3.9734	2B	3.990	4.015	4.0438	4.0558	0.0120	4.1250
		3A	0.0000	4.1250	4.1100	...	4.0438	4.0369	0.0069	3.9762	3B	3.9900	4.0047	4.0438	4.0528	0.0090	4.1250
4⅛-12 or 4.125-12	UN	2A	0.0020	4.1230	4.1116	...	4.0689	4.0624	0.0065	4.0238	2B	4.035	4.053	4.0709	4.0794	0.0085	4.1250
		3A	0.0000	4.1250	4.1136	...	4.0709	4.0660	0.0049	4.0258	3B	4.0350	4.0448	4.0709	4.0773	0.0064	4.1250
4⅛-16 or 4.125-16	UN	2A	0.0018	4.1232	4.1138	...	4.0826	4.0767	0.0059	4.0487	2B	4.057	4.071	4.0844	4.0920	0.0076	4.1250
		3A	0.0000	4.1250	4.1156	...	4.0844	4.0800	0.0044	4.0505	3B	4.0570	4.0658	4.0844	4.0901	0.0057	4.1250
4¼-4 or 4.250-4	UN	2A	0.0034	4.2466	4.2228	...	4.0842	4.0727	0.0115	3.9489	2B	3.979	4.017	4.0876	4.1025	0.0149	4.2500
		3A	0.0000	4.2500	4.2262	...	4.0876	4.0790	0.0086	3.9523	3B	3.9790	4.0094	4.0876	4.0988	0.0112	4.2500

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
4¼-6 or 4.250-6	UN	2A	0.0030	4.2470	4.2288	...	4.1387	4.1286	0.0101	4.0486	2B	4.070	4.100	4.1417	4.1548	0.0131	4.2500
		3A	0.0000	4.2500	4.2318	...	4.1417	4.1342	0.0075	4.0516	3B	4.0700	4.0896	4.1417	4.1515	0.0098	4.2500
4¼-8 or 4.250-8	UN	2A	0.0028	4.2472	4.2322	...	4.1660	4.1567	0.0093	4.0984	2B	4.115	4.140	4.1688	4.1808	0.0120	4.2500
		3A	0.0000	4.2500	4.2350	...	4.1688	4.1618	0.0070	4.1012	3B	4.1150	4.1297	4.1688	4.1779	0.0091	4.2500
4¼-12 or 4.250-12	UN	2A	0.0020	4.2480	4.2366	...	4.1939	4.1874	0.0065	4.1488	2B	4.160	4.178	4.1959	4.2044	0.0085	4.2500
		3A	0.0000	4.2500	4.2386	...	4.1959	4.1910	0.0049	4.1508	3B	4.1600	4.1698	4.1959	4.2023	0.0064	4.2500
4¼-16 or 4.250-16	UN	2A	0.0018	4.2482	4.2388	...	4.2076	4.2017	0.0059	4.1737	2B	4.182	4.196	4.2094	4.2170	0.0076	4.2500
		3A	0.0000	4.2500	4.2406	...	4.2094	4.2050	0.0044	4.1755	3B	4.1820	4.1908	4.2094	4.2151	0.0057	4.2500
4⅜-6 or 4.375-6	UN	2A	0.0030	4.3720	4.3538	...	4.2637	4.2536	0.0101	4.1736	2B	4.195	4.225	4.2667	4.2799	0.0132	4.3750
		3A	0.0000	4.3750	4.3568	...	4.2667	4.2591	0.0076	4.1766	3B	4.1950	4.2146	4.2667	4.2766	0.0099	4.3750
4⅜-8 or 4.375-8	UN	2A	0.0028	4.3722	4.3572	...	4.2910	4.2817	0.0093	4.2234	2B	4.240	4.265	4.2938	4.3058	0.0120	4.3750
		3A	0.0000	4.3750	4.3600	...	4.2938	4.2868	0.0070	4.2262	3B	4.2400	4.2547	4.2938	4.3029	0.0091	4.3750
4⅜-12 or 4.375-12	UN	2A	0.0020	4.3730	4.3616	...	4.3189	4.3124	0.0065	4.2738	2B	4.285	4.303	4.3209	4.3294	0.0085	4.3750
		3A	0.0000	4.3750	4.3636	...	4.3209	4.3160	0.0049	4.2758	3B	4.2850	4.2948	4.3209	4.3273	0.0064	4.3750
4⅜-16 or 4.375-16	UN	2A	0.0018	4.3732	4.3638	...	4.3326	4.3267	0.0059	4.2987	2B	4.307	4.321	4.3344	4.3420	0.0076	4.3750
		3A	0.0000	4.3750	4.3656	...	4.3344	4.3300	0.0044	4.3005	3B	4.3070	4.3158	4.3344	4.3401	0.0057	4.3750
4½-4 or 4.500-4	UN	2A	0.0035	4.4965	4.4727	...	4.3341	4.3225	0.0116	4.1988	2B	4.229	4.267	4.3376	4.3527	0.0151	4.5000
		3A	0.0000	4.5000	4.4762	...	4.3376	4.3289	0.0087	4.2023	3B	4.2290	4.2594	4.3376	4.3489	0.0113	4.5000
4½-6 or 4.500-6	UN	2A	0.0031	4.4969	4.4787	...	4.3886	4.3784	0.0102	4.2985	2B	4.320	4.350	4.3917	4.4050	0.0133	4.5000
		3A	0.0000	4.5000	4.4818	...	4.3917	4.3840	0.0077	4.3016	3B	4.3200	4.3396	4.3917	4.4016	0.0099	4.5000
4½-8 or 4.500-8	UN	2A	0.0028	4.4972	4.4822	...	4.4160	4.4066	0.0094	4.3484	2B	4.365	4.390	4.4188	4.4310	0.0122	4.5000
		3A	0.0000	4.5000	4.4850	...	4.4188	4.4117	0.0071	4.3512	3B	4.3650	4.3797	4.4188	4.4280	0.0092	4.5000
4½-12 or 4.500-12	UN	2A	0.0020	4.4980	4.4866	...	4.4439	4.4374	0.0065	4.3988	2B	4.410	4.428	4.4459	4.4544	0.0085	4.5000
		3A	0.0000	4.5000	4.4886	...	4.4459	4.4410	0.0049	4.4008	3B	4.4100	4.4198	4.4459	4.4523	0.0064	4.5000
4½-16 or 4.500-16	UN	2A	0.0018	4.4982	4.4888	...	4.4576	4.4517	0.0059	4.4237	2B	4.432	4.446	4.4594	4.4670	0.0076	4.5000
		3A	0.0000	4.5000	4.4906	...	4.4594	4.4550	0.0044	4.4255	3B	4.4320	4.4408	4.4594	4.4651	0.0057	4.5000
4⅝-6 or 4.625-6	UN	2A	0.0031	4.6219	4.6037	...	4.5136	4.5033	0.0103	4.4235	2B	4.445	4.475	4.5167	4.5300	0.0133	4.6250
		3A	0.0000	4.6250	4.6068	...	4.5167	4.5090	0.0077	4.4266	3B	4.4450	4.4646	4.5167	4.5267	0.0100	4.6250
4⅝-8 or 4.625-8	UN	2A	0.0029	4.6221	4.6071	...	4.5409	4.5314	0.0095	4.4733	2B	4.490	4.515	4.5438	4.5562	0.0124	4.6250
		3A	0.0000	4.6250	4.6100	...	4.5438	4.5367	0.0071	4.4762	3B	4.4900	4.5047	4.5438	4.5531	0.0093	4.6250

(Notes follow at end of table)

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
4⅝-12 or 4.625-12	UN	2A	0.0020	4.6230	4.6116	...	4.5689	4.5622	0.0067	4.5238	2B	4.535	4.553	4.5709	4.5796	0.0087	4.6250
		3A	0.0000	4.6250	4.6136	...	4.5709	4.5659	0.0050	4.5258	3B	4.5350	4.5448	4.5709	4.5775	0.0066	4.6250
4⅝-16 or 4.625-16	UN	2A	0.0018	4.6232	4.6138	...	4.5826	4.5765	0.0061	4.5487	2B	4.557	4.571	4.5844	4.5923	0.0079	4.6250
		3A	0.0000	4.6250	4.6156	...	4.5844	4.5799	0.0045	4.5505	3B	4.5570	4.5658	4.5844	4.5903	0.0059	4.6250
4¾-4 or 4.750-4	UN	2A	0.0035	4.7465	4.7227	...	4.5841	4.5724	0.0117	4.4488	2B	4.479	4.517	4.5876	4.6029	0.0153	4.7500
		3A	0.0000	4.7500	4.7262	...	4.5876	4.5788	0.0088	4.4523	3B	4.4790	4.5094	4.5876	4.5990	0.0114	4.7500
4¾-6 or 4.750-6	UN	2A	0.0031	4.7469	4.7287	...	4.6386	4.6283	0.0103	4.5485	2B	4.570	4.600	4.6417	4.6551	0.0134	4.7500
		3A	0.0000	4.7500	4.7318	...	4.6417	4.6340	0.0077	4.5516	3B	4.5700	4.5896	4.6417	4.6518	0.0101	4.7500
4¾-8 or 4.750-8	UN	2A	0.0029	4.7471	4.7321	...	4.6659	4.6564	0.0095	4.5983	2B	4.615	4.640	4.6688	4.6812	0.0124	4.7500
		3A	0.0000	4.7500	4.7350	...	4.6688	4.6617	0.0071	4.6012	3B	4.6150	4.6297	4.6688	4.6781	0.0093	4.7500
4¾-12 or 4.750-12	UN	2A	0.0020	4.7480	4.7366	...	4.6939	4.6872	0.0067	4.6488	2B	4.660	4.678	4.6959	4.7046	0.0087	4.7500
		3A	0.0000	4.7500	4.7386	...	4.6959	4.6909	0.0050	4.6508	3B	4.6600	4.6698	4.6959	4.7025	0.0066	4.7500
4¾-16 or 4.750-16	UN	2A	0.0018	4.7482	4.7388	...	4.7076	4.7015	0.0061	4.6737	2B	4.682	4.696	4.7094	4.7173	0.0079	4.7500
		3A	0.0000	4.7500	4.7406	...	4.7094	4.7049	0.0045	4.6755	3B	4.6820	4.6908	4.7094	4.7153	0.0059	4.7500
4⅞-6 or 4.875-6	UN	2A	0.0031	4.8719	4.8537	...	4.7636	4.7532	0.0104	4.7635	2B	4.695	4.725	4.7667	4.7802	0.0135	4.8750
		3A	0.0000	4.8750	4.8568	...	4.7667	4.7589	0.0078	4.6766	3B	4.6950	4.7146	4.7667	4.7768	0.0101	4.8750
4⅞-8 or 4.875-8	UN	2A	0.0029	4.8721	4.8571	...	4.7909	4.7813	0.0096	4.7233	2B	4.740	4.765	4.7938	4.8063	0.0125	4.8750
		3A	0.0000	4.8750	4.8600	...	4.7938	4.7866	0.0072	4.7262	3B	4.7400	4.7547	4.7938	4.8032	0.0094	4.8750
4⅞-12 or 4.875-12	UN	2A	0.0020	4.8730	4.8616	...	4.8189	4.8122	0.0067	4.7738	2B	4.785	4.803	4.8209	4.8296	0.0087	4.8750
		3A	0.0000	4.8750	4.8636	...	4.8209	4.8159	0.0050	4.7758	3B	4.7850	4.7948	4.8209	4.8275	0.0066	4.8750
4⅞-16 or 4.875-16	UN	2A	0.0018	4.8732	4.8638	...	4.8326	4.8265	0.0061	4.7987	2B	4.807	4.821	4.8344	4.8423	0.0079	4.8750
		3A	0.0000	4.8750	4.8656	...	4.8344	4.8299	0.0045	4.8005	3B	4.8070	4.8158	4.8344	4.8403	0.0059	4.8750
5-4 or 5.000-4	UN	2A	0.0036	4.9964	4.9726	...	4.8340	4.8221	0.0119	4.6987	2B	4.729	4.767	4.8376	4.8530	0.0154	5.0000
		3A	0.0000	5.0000	4.9762	...	4.8376	4.8287	0.0089	4.7023	3B	4.7290	4.7594	4.8376	4.8492	0.0116	5.0000
5-6 or 5.000-6	UN	2A	0.0031	4.9969	4.9787	...	4.8886	4.8781	0.0105	4.7985	2B	4.820	4.850	4.8917	4.9053	0.0136	5.0000
		3A	0.0000	5.0000	4.9818	...	4.8917	4.8839	0.0078	4.8016	3B	4.8200	4.8396	4.8917	4.9019	0.0102	5.0000
5-8 or 5.000-8	UN	2A	0.0029	4.9971	4.9821	...	4.9159	4.9062	0.0097	4.8483	2B	4.865	4.890	4.9188	4.9314	0.0126	5.0000
		3A	0.0000	5.0000	4.9850	...	4.9188	4.9115	0.0073	4.8512	3B	4.8650	4.8797	4.9188	4.9283	0.0095	5.0000
5-12 or 5.000-12	UN	2A	0.0020	4.9980	4.9866	...	4.9439	4.9372	0.0067	4.8988	2B	4.910	4.928	4.9459	4.9546	0.0087	5.0000
		3A	0.0000	5.0000	4.9886	...	4.9459	4.9409	0.0050	4.9008	3B	4.9100	4.9198	4.9459	4.9525	0.0066	5.0000

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
5-16 or 5.000-16	UN	2A	0.0018	4.9982	4.9888	...	4.9576	4.9515	0.0061	4.9237	2B	4.932	4.946	4.9594	4.9673	0.0079	5.0000
		3A	0.0000	5.0000	4.9906	...	4.9594	4.9549	0.0045	4.9255	3B	4.9320	4.9408	4.9594	4.9653	0.0059	5.0000
5⅛-6 or 5.125-6	UN	2A	0.0032	5.1218	5.1036	...	5.0135	5.0030	0.0105	4.9234	2B	4.945	4.975	5.0167	5.0304	0.0137	5.1250
		3A	0.0000	5.1250	5.1068	...	5.0167	5.0088	0.0079	4.9266	3B	4.9450	4.9646	5.0167	5.0270	0.0103	5.1250
5⅛-8 or 5.125-8	UN	2A	0.0029	5.1221	5.1071	...	5.0409	5.0312	0.0097	4.9733	2B	4.990	5.015	5.0438	5.0564	0.0126	5.1250
		3A	0.0000	5.1250	5.1100	...	5.0438	5.0365	0.0073	4.9762	3B	4.9900	5.0047	5.0438	5.0533	0.0095	5.1250
5⅛-12 or 5.125-12	UN	2A	0.0020	5.1230	5.1116	...	5.0689	5.0622	0.0067	5.0238	2B	5.035	5.053	5.0709	5.0796	0.0087	5.1250
		3A	0.0000	5.1250	5.1136	...	5.0709	5.0659	0.0050	5.0258	3B	5.0350	5.0448	5.0709	5.0775	0.0066	5.1250
5⅛-16 or 5.125-16	UN	2A	0.0018	5.1232	5.1138	...	5.0826	5.0765	0.0061	5.0487	2B	5.057	5.071	5.0844	5.0923	0.0079	5.1250
		3A	0.0000	5.1250	5.1156	...	5.0844	5.0799	0.0045	5.0505	3B	5.0570	5.0658	5.0844	5.0903	0.0059	5.1250
5¼-4 or 5.250-4	UN	2A	0.0036	5.2464	5.2226	...	5.0840	5.0720	0.0120	4.9487	2B	4.979	5.017	5.0876	5.1032	0.0156	5.2500
		3A	0.0000	5.2500	5.2262	...	5.0876	5.0786	0.0090	4.9523	3B	4.9790	5.0094	5.0876	5.0993	0.0117	5.2500
5¼-6 or 5.250-6	UN	2A	0.0032	5.2468	5.2286	...	5.1385	5.1279	0.0106	5.0464	2B	5.070	5.100	5.1417	5.1555	0.0138	5.2500
		3A	0.0000	5.2500	5.2318	...	5.1417	5.1338	0.0079	5.0516	3B	5.0700	5.0896	5.1417	5.1520	0.0103	5.2500
5¼-8 or 5.250-8	UN	2A	0.0029	5.2471	5.2321	...	5.1659	5.1561	0.0098	5.0983	2B	5.115	5.140	5.1688	5.1815	0.0127	5.2500
		3A	0.0000	5.2500	5.2350	...	5.1688	5.1614	0.0074	5.1012	3B	5.1150	5.1297	5.1688	5.1784	0.0096	5.2500
5¼-12 or 5.250-12	UN	2A	0.0020	5.2480	5.2366	...	5.1939	5.1872	0.0067	5.1488	2B	5.160	5.178	5.1959	5.2046	0.0087	5.2500
		3A	0.0000	5.2500	5.2386	...	5.1959	5.1909	0.0050	5.1508	3B	5.1600	5.1698	5.1959	5.2025	0.0066	5.2500
5¼-16 or 5.250-16	UN	2A	0.0018	5.2482	5.2388	...	5.2076	5.2015	0.0061	5.1737	2B	5.182	5.196	5.2094	5.2173	0.0079	5.2500
		3A	0.0000	5.2500	5.2406	...	5.2094	5.2049	0.0045	5.1755	3B	5.1820	5.1908	5.2094	5.2153	0.0059	5.2500
5⅜-6 or 5.375-6	UN	2A	0.0032	5.3718	5.3536	...	5.2635	5.2529	0.0106	5.1734	2B	5.195	5.225	5.2667	5.2805	0.0138	5.3750
		3A	0.0000	5.3750	5.3568	...	5.2667	5.2587	0.0080	5.1766	3B	5.1950	5.2146	5.2667	5.2771	0.0104	5.3750
5⅜-8 or 5.375-8	UN	2A	0.0030	5.3720	5.3570	...	5.2908	5.2809	0.0099	5.2232	2B	5.240	5.265	5.2938	5.3067	0.0129	5.3750
		3A	0.0000	5.3750	5.3600	...	5.2938	5.2864	0.0074	5.2262	3B	5.2400	5.2547	5.2938	5.3035	0.0097	5.3750
5⅜-12 or 5.375-12	UN	2A	0.0020	5.3730	5.3616	...	5.3189	5.3122	0.0067	5.2738	2B	5.285	5.303	5.3209	5.3296	0.0087	5.3750
		3A	0.0000	5.3750	5.3636	...	5.3209	5.3159	0.0050	5.2758	3B	5.2850	5.2948	5.3209	5.3275	0.0066	5.3750
5⅜-16 or 5.375-16	UN	2A	0.0018	5.3732	5.3638	...	5.3326	5.3265	0.0061	5.2987	2B	5.307	5.321	5.3344	5.3423	0.0079	5.3750
		3A	0.0000	5.3750	5.3656	...	5.3344	5.3299	0.0045	5.3005	3B	5.3070	5.3158	5.3344	5.3403	0.0059	5.3750
5½-4 or 5.500-4	UN	2A	0.0036	5.4964	5.4726	...	5.3340	5.3219	0.0121	5.1987	2B	5.229	5.267	5.3376	5.3534	0.0158	5.5000
		3A	0.0000	5.5000	5.4762	...	5.3376	5.3285	0.0091	5.2023	3B	5.2290	5.2594	5.3376	5.3494	0.0118	5.5000

(Notes follow at end of table)

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
5½-6 or 5.500-6	UN	2A	0.0032	5.4968	5.4786	...	5.3885	5.3778	0.0107	5.2984	2B	5.320	5.350	5.3917	5.4056	0.0139	5.5000
		3A	0.0000	5.5000	5.4818	...	5.3917	5.3837	0.0080	5.3016	3B	5.3200	5.3396	5.3917	5.4021	0.0104	5.5000
5½-8 or 5.500-8	UN	2A	0.0030	5.4970	5.4820	...	5.4158	5.4059	0.0099	5.3482	2B	5.365	5.390	5.4188	5.4317	0.0129	5.5000
		3A	0.0000	5.5000	5.4850	...	5.4188	5.4114	0.0074	5.3512	3B	5.3650	5.3797	5.4188	5.4285	0.0097	5.5000
5½-12 or 5.500-12	UN	2A	0.0020	5.4980	5.4866	...	5.4439	5.4372	0.0067	5.3988	2B	5.410	5.428	5.4459	5.4546	0.0087	5.5000
		3A	0.0000	5.5000	5.4886	...	5.4459	5.4409	0.0050	5.4008	3B	5.4100	5.4198	5.4459	5.4525	0.0066	5.5000
5½-16 or 5.500-16	UN	2A	0.0018	5.4982	5.4888	...	5.4576	5.4515	0.0061	5.4237	2B	5.432	5.446	5.4594	5.4673	0.0079	5.5000
		3A	0.0000	5.5000	5.4906	...	5.4594	5.4549	0.0045	5.4255	3B	5.4320	5.4408	5.4594	5.4653	0.0059	5.5000
5⅝-6 or 5.625-6	UN	2A	0.0032	5.6218	5.6036	...	5.5135	5.5027	0.0108	5.4234	2B	5.445	5.475	5.5167	5.5307	0.0140	5.6250
		3A	0.0000	5.6250	5.6068	...	5.5167	5.5086	0.0081	5.4266	3B	5.4450	5.4646	5.5167	5.5272	0.0105	5.6250
5⅝-8 or 5.625-8	UN	2A	0.0030	5.6220	5.6070	...	5.5408	5.5308	0.0100	5.4732	2B	5.490	5.515	5.5438	5.5568	0.0130	5.6250
		3A	0.0000	5.6250	5.6100	...	5.5438	5.5363	0.0075	5.4762	3B	5.4900	5.5047	5.5438	5.5536	0.0098	5.6250
5⅝-12 or 5.625-12	UN	2A	0.0021	5.6229	5.6115	...	5.5688	5.5619	0.0069	5.5237	2B	5.535	5.553	5.5709	5.5799	0.0090	5.6250
		3A	0.0000	5.6250	5.6136	...	5.5709	5.5657	0.0052	5.5258	3B	5.5350	5.5448	5.5709	5.5776	0.0067	5.6250
5⅝-16 or 5.625-16	UN	2A	0.0019	5.6231	5.6137	...	5.5825	5.5763	0.0062	5.5486	2B	5.557	5.571	5.5844	5.5925	0.0081	5.6250
		3A	0.0000	5.6250	5.6156	...	5.5844	5.5797	0.0047	5.5505	3B	5.5570	5.5658	5.5844	5.5905	0.0061	5.6250
5¾-4 or 5.750-4	UN	2A	0.0037	5.7463	5.7225	...	5.5839	5.5717	0.0122	5.4486	2B	5.479	5.517	5.5876	5.6035	0.0159	5.7500
		3A	0.0000	5.7500	5.7262	...	5.5876	5.5784	0.0092	5.4523	3B	5.4790	5.5094	5.5876	5.5995	0.0119	5.7500
5¾-6 or 5.750-6	UN	2A	0.0032	5.7468	5.7286	...	5.6385	5.6277	0.0108	5.5484	2B	5.570	5.600	5.6417	5.6558	0.0141	5.7500
		3A	0.0000	5.7500	5.7318	...	5.6417	5.6336	0.0081	5.5516	3B	5.5700	5.5896	5.6417	5.6523	0.0106	5.7500
5¾-8 or 5.750-8	UN	2A	0.0030	5.7470	5.7250	...	5.6658	5.6558	0.0100	5.5982	2B	5.615	5.640	5.6688	5.6818	0.0130	5.7500
		3A	0.0000	5.7500	5.7350	...	5.6688	5.6613	0.0075	5.6012	3B	5.6150	5.6297	5.6688	5.6786	0.0098	5.7500
5¾-12 or 5.750-12	UN	2A	0.0021	5.7479	5.7365	...	5.6938	5.6869	0.0069	5.6487	2B	5.660	5.678	5.6959	5.7049	0.0090	5.7500
		3A	0.0000	5.7500	5.7386	...	5.6959	5.6907	0.0052	5.6508	3B	5.6600	5.6698	5.6959	5.7026	0.0067	5.7500
5¾-16 or 5.750-16	UN	2A	0.0019	5.7481	5.7387	...	5.7075	5.7013	0.0062	5.6736	2B	5.682	5.696	5.7094	5.7175	0.0081	5.7500
		3A	0.0000	5.7500	5.7406	...	5.7094	5.7047	0.0047	5.6755	3B	5.6820	5.6908	5.7094	5.7155	0.0061	5.7500
5⅞-6 or 5.875-6	UN	2A	0.0033	5.8717	5.8535	...	5.7634	5.7525	0.0109	5.6733	2B	5.695	5.725	5.7667	5.7809	0.0142	5.8750
		3A	0.0000	5.8750	5.8568	...	5.7667	5.7585	0.0082	5.6766	3B	5.6950	5.7146	5.7667	5.7773	0.0106	5.8750
5⅞-8 or 5.875-8	UN	2A	0.0031	5.8719	5.8569	...	5.7907	5.7806	0.0101	5.7231	2B	5.740	5.765	5.7938	5.8069	0.0131	5.8750
		3A	0.0000	5.8750	5.8600	...	5.7938	5.7862	0.0076	5.7262	3B	5.7400	5.7547	5.7938	5.8036	0.0098	5.8750

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TABLE 3A LIMITS OF SIZE FOR STANDARD SERIES THREADS (UN/UNR) (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)									Internal (1)						
				Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
5⅞-12 or 5.875-12	UN	2A	0.0021	5.8729	5.8615	...	5.8188	5.8119	0.0069	5.7737	2B	5.785	5.803	5.8209	5.8299	0.0090	5.8750
		3A	0.0000	5.8750	5.8636	...	5.8209	5.8157	0.0052	5.7758	3B	5.7850	5.7948	5.8209	5.8276	0.0067	5.8750
5⅞-16 or 5.875-16	UN	2A	0.0019	5.8731	5.8637	...	5.8325	5.8263	0.0062	5.7986	2B	5.807	5.821	5.8344	5.8425	0.0081	5.8750
		3A	0.0000	5.8750	5.8656	...	5.8344	5.8297	0.0047	5.8005	3B	5.8070	5.8158	5.8344	5.8405	0.0061	5.8750
6-4 or 6.000-4	UN	2A	0.0037	5.9963	5.9725	...	5.8339	5.8215	0.0124	5.6986	2B	5.729	5.767	5.8376	5.8537	0.0161	6.0000
		3A	0.0000	6.0000	5.9762	...	5.8376	5.8283	0.0093	5.7023	3B	5.7290	5.7594	5.8376	5.8496	0.0120	6.0000
6-6 or 6.000-6	UN	2A	0.0033	5.9967	5.9785	...	5.8884	5.8775	0.0109	5.7983	2B	5.820	5.850	5.8917	5.9059	0.0142	6.0000
		3A	0.0000	6.0000	5.9818	...	5.8917	5.8835	0.0082	5.8016	3B	5.8200	5.8396	5.8917	5.9024	0.0107	6.0000
6-8 or 6.000-8	UN	2A	0.0031	5.9969	5.9819	...	5.9157	5.9055	0.0102	5.8481	2B	5.865	5.890	5.9188	5.9321	0.0133	6.0000
		3A	0.0000	6.0000	5.9850	...	5.9188	5.9111	0.0077	5.8512	3B	5.8650	5.8797	5.9188	5.9287	0.0099	6.0000
6-12 or 6.000-12	UN	2A	0.0021	5.9979	5.9865	...	5.9438	5.9369	0.0069	5.8987	2B	5.910	5.928	5.9459	5.9549	0.0090	6.0000
		3A	0.0000	6.0000	5.9886	...	5.9459	5.9407	0.0052	5.9008	3B	5.9100	5.9198	5.9459	5.9526	0.0067	6.0000
6-16 or 6.000-16	UN	2A	0.0019	5.9981	5.9887	...	5.9575	5.9513	0.0062	5.9236	2B	5.932	5.946	5.9594	5.9675	0.0081	6.0000
		3A	0.0000	6.0000	5.9906	...	5.9594	5.9547	0.0047	5.9255	3B	5.9320	5.9408	5.9594	5.9655	0.0061	6.0000

GENERAL NOTES:

(a) Series designation shown indicates the UN thread form; however, the UNR thread form may be specified by substituting UNR in place of UN in all designations for external use only.

(b) The minimum material pitch diameters in a number of cases do not agree with the pitch diameter increment total as given in Table 19. Tabulated pitch diameters shown have been in effect since ANSI B1.1-1949 edition. ASME B1 Committee agrees that no changes should be made.

NOTES:

(1) Thread classes may be combined. See para. 4.2.

(2) For Class 2A threads having an additive finish, the maximum major and pitch diameters, after coating, may equal the basic sizes, whose values are the same as the maximum values shown for Class 3A in these columns. See paras. 4.1.1 and 4.1.3.

(3) For unfinished hot material, not including standard fasteners with rolled threads.

(4) UN series external thread maximum minor diameter is basic (D_1 in Section 11) for Class 3A and basic minus allowance for Classes 1A and 2A.

(5) Formerly NF. Not a recommended standard size. Tolerances and allowances are based on one diameter length of engagement.

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TABLE 3B LIMITS OF SIZE FOR SELECTED COMBINATIONS OF UNS/UNRS SERIES THREADS

Nominal Size and Threads/in.	Series Designation	External (1)								Internal (1)						
				Major Diameter		Pitch Diameter			UNR Minor Diam. Max. (3) (Ref.)		Minor Diameter		Pitch Diameter			Major Diam.
		Class	Allow-ance	Max. (2)	Min.	Max. (2)	Min.	Toler-ance		Class	Min.	Max.	Min.	Max.	Toler-ance	Min.
10-28 or 0.190-28	UNS	2A	0.0010	0.1890	0.1825	0.1658	0.1625	0.0033	0.1464	2B	0.151	0.160	0.1668	0.1711	0.0043	0.1900
10-36 or 0.190-36	UNS	2A	0.0009	0.1891	0.1836	0.1711	0.1681	0.0030	0.1560	2B	0.160	0.166	0.1720	0.1759	0.0039	0.1900
10-40 or 0.190-40	UNS	2A	0.0009	0.1891	0.1840	0.1729	0.1700	0.0029	0.1592	2B	0.163	0.169	0.1738	0.1775	0.0037	0.1900
10-48 or 0.190-48	UNS	2A	0.0008	0.1892	0.1847	0.1757	0.1731	0.0026	0.1644	2B	0.167	0.172	0.1765	0.1799	0.0034	0.1900
10-56 or 0.190-56	UNS	2A	0.0007	0.1893	0.1852	0.1777	0.1752	0.0025	0.1681	2B	0.171	0.175	0.1784	0.1816	0.0032	0.1900
12-36 or 0.216-36	UNS	2A	0.0009	0.2151	0.2096	0.1971	0.1941	0.0030	0.1821	2B	0.186	0.192	0.1980	0.2019	0.0039	0.2160
12-40 or 0.216-40	UNS	2A	0.0009	0.2151	0.2100	0.1989	0.1960	0.0029	0.1835	2B	0.189	0.195	0.1998	0.2035	0.0037	0.2160
12-48 or 0.216-48	UNS	2A	0.0008	0.2152	0.2107	0.2017	0.1991	0.0026	0.1904	2B	0.193	0.198	0.2025	0.2059	0.0034	0.2160
12-56 or 0.216-56	UNS	2A	0.0007	0.2153	0.2112	0.2037	0.2012	0.0025	0.1941	2B	0.197	0.201	0.2044	0.2076	0.0032	0.2160
1/4-24 or 0.250-24	UNS	2A	0.0011	0.2489	0.2417	0.2218	0.2181	0.0037	0.1993	2B	0.205	0.215	0.2229	0.2277	0.0048	0.2500
1/4-27 or 0.250-27	UNS	2A	0.0010	0.2490	0.2423	0.2249	0.2214	0.0035	0.2049	2B	0.210	0.219	0.2259	0.2304	0.0045	0.2500
1/4-36 or 0.250-36	UNS	2A	0.0009	0.2491	0.2436	0.2311	0.2280	0.0031	0.2161	2B	0.220	0.226	0.2320	0.2360	0.0040	0.2500
1/4-40 or 0.250-40	UNS	2A	0.0009	0.2491	0.2440	0.2329	0.2300	0.0029	0.2193	2B	0.223	0.229	0.2338	0.2376	0.0038	0.2500
1/4-48 or 0.250-48	UNS	2A	0.0008	0.2492	0.2447	0.2357	0.2330	0.0027	0.2243	2B	0.227	0.232	0.2365	0.2401	0.0036	0.2500
1/4-56 or 0.250-56	UNS	2A	0.0008	0.2492	0.2451	0.2376	0.2350	0.0026	0.2280	2B	0.231	0.235	0.2384	0.2417	0.0033	0.2500
5/16-27 or 0.3125-27	UNS	2A	0.0010	0.3115	0.3048	0.2874	0.2839	0.0035	0.2674	2B	0.272	0.281	0.2884	0.2929	0.0045	0.3125
5/16-36 or 0.3125-36	UNS	2A	0.0009	0.3116	0.3061	0.2936	0.2905	0.0031	0.2785	2B	0.282	0.289	0.2945	0.2985	0.0040	0.3125
5/16-40 or 0.3125-40	UNS	2A	0.0009	0.3116	0.3065	0.2954	0.2925	0.0029	0.2818	2B	0.285	0.291	0.2963	0.3001	0.0038	0.3125
5/16-48 or 0.3125-48	UNS	2A	0.0008	0.3117	0.3072	0.2982	0.2955	0.0027	0.2869	2B	0.290	0.295	0.2990	0.3026	0.0036	0.3125
3/8-18 or 0.375-18	UNS	2A	0.0013	0.3737	0.3650	0.3376	0.3333	0.0043	0.3076	2B	0.315	0.328	0.3389	0.3445	0.0056	0.3750
3/8-27 or 0.375-27	UNS	2A	0.0011	0.3739	0.3672	0.3498	0.3462	0.0036	0.3298	2B	0.335	0.344	0.3509	0.3556	0.0047	0.3750
3/8-36 or 0.375-36	UNS	2A	0.0010	0.3740	0.3685	0.3560	0.3528	0.0032	0.3409	2B	0.345	0.352	0.3570	0.3612	0.0042	0.3750
3/8-40 or 0.375-40	UNS	2A	0.0009	0.3741	0.3690	0.3579	0.3548	0.0031	0.3443	2B	0.348	0.354	0.3588	0.3628	0.0040	0.3750
0.390-27	UNS	2A	0.0011	0.3889	0.3822	0.3648	0.3612	0.0036	0.3448	2B	0.350	0.359	0.3659	0.3706	0.0047	0.3900
7/16-18 or 0.4375-18	UNS	2A	0.0013	0.4362	0.4275	0.4001	0.3958	0.0043	0.3701	2B	0.377	0.390	0.4014	0.4070	0.0056	0.4375
7/16-24 or 0.4375-24	UNS	2A	0.0011	0.4364	0.4292	0.4093	0.4055	0.0038	0.3868	2B	0.392	0.402	0.4104	0.4153	0.0049	0.4375
7/16-27 or 0.4375-27	UNS	2A	0.0011	0.4364	0.4297	0.4123	0.4087	0.0036	0.3923	2B	0.397	0.406	0.4134	0.4181	0.0047	0.4375

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TABLE 3B LIMITS OF SIZE FOR SELECTED COMBINATIONS OF UNS/UNRS SERIES THREADS (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)								Internal (1)						
				Major Diameter		Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diam.
		Class	Allow-ance	Max. (2)	Min.	Max. (2)	Min.	Toler-ance	Max. (3) (Ref.)	Class	Min.	Max.	Min.	Max.	Toler-ance	Min.
½-12 or 0.500-12	UNS	2A	0.0016	0.4984	0.4870	0.4443	0.4389	0.0054	0.3992	2B	0.410	0.428	0.4459	0.4529	0.0070	0.5000
	UNS	3A	0.0000	0.5000	0.4886	0.4459	0.4419	0.0040	0.4008	3B	0.4100	0.4223	0.4459	0.4511	0.0052	0.5000
½-14 or 0.500-14	UNS	2A	0.0015	0.4985	0.4882	0.4521	0.4471	0.0050	0.4135	2B	0.423	0.438	0.4536	0.4601	0.0065	0.5000
½-18 or 0.500-18	UNS	2A	0.0013	0.4987	0.4900	0.4626	0.4582	0.0044	0.4326	2B	0.440	0.453	0.4639	0.4697	0.0058	0.5000
½-24 or 0.500-24	UNS	2A	0.0012	0.4988	0.4916	0.4717	0.4678	0.0039	0.4492	2B	0.455	0.465	0.4729	0.4780	0.0051	0.5000
½-27 or 0.500-27	UNS	2A	0.0011	0.4989	0.4922	0.4748	0.4711	0.0037	0.4548	2B	0.460	0.469	0.4759	0.4807	0.0048	0.5000
9/16-14 or 0.5625-14	UNS	2A	0.0015	0.5610	0.5507	0.5146	0.5096	0.0050	0.4760	2B	0.485	0.501	0.5161	0.5226	0.0065	0.5625
9/16-27 or 0.5625-27	UNS	2A	0.0011	0.5614	0.5547	0.5373	0.5336	0.0037	0.5173	2B	0.522	0.531	0.5384	0.5432	0.0048	0.5625
⅝-14 or 0.625-14	UNS	2A	0.0015	0.6235	0.6132	0.5771	0.5720	0.0051	0.5385	2B	0.548	0.564	0.5786	0.5852	0.0066	0.6250
⅝-27 or 0.625-27	UNS	2A	0.0011	0.6239	0.6172	0.5998	0.5960	0.0038	0.5798	2B	0.585	0.594	0.6009	0.6059	0.0050	0.6250
¾-14 or 0.750-14	UNS	2A	0.0015	0.7485	0.7382	0.7021	0.6970	0.0051	0.6635	2B	0.673	0.688	0.7036	0.7103	0.0067	0.7500
¾-18 or 0.750-18	UNS	2A	0.0014	0.7486	0.7399	0.7125	0.7079	0.0046	0.6825	2B	0.690	0.703	0.7139	0.7199	0.0060	0.7500
¾-24 or 0.750-24	UNS	2A	0.0012	0.7488	0.7416	0.7217	0.7176	0.0041	0.6992	2B	0.705	0.715	0.7229	0.7282	0.0053	0.7500
¾-27 or 0.750-27	UNS	2A	0.0012	0.7488	0.7421	0.7247	0.7208	0.0039	0.7047	2B	0.710	0.719	0.7259	0.7310	0.0051	0.7500
⅞-10 or 0.875-10	UNS	2A	0.0018	0.8732	0.8603	0.8082	0.8022	0.0060	0.7542	2B	0.767	0.788	0.8100	0.8178	0.0078	0.8750
⅞-18 or 0.875-18	UNS	2A	0.0014	0.8736	0.8649	0.8375	0.8329	0.0046	0.8075	2B	0.815	0.828	0.8389	0.8449	0.0060	0.8750
⅞-24 or 0.875-24	UNS	2A	0.0012	0.8738	0.8666	0.8467	0.8426	0.0041	0.8242	2B	0.830	0.840	0.8479	0.8532	0.0053	0.8750
⅞-27 or 0.875-27	UNS	2A	0.0012	0.8738	0.8671	0.8497	0.8458	0.0039	0.8297	2B	0.835	0.844	0.8509	0.8560	0.0051	0.8750
1-10 or 1.000-10	UNS	2A	0.0018	0.9982	0.9853	0.9332	0.9270	0.0062	0.8792	2B	0.892	0.913	0.9350	0.9430	0.0080	1.0000
1-18 or 1.000-18	UNS	2A	0.0014	0.9986	0.9899	0.9625	0.9578	0.0047	0.9325	2B	0.940	0.953	0.9639	0.9701	0.0062	1.0000
1-24 or 1.000-24	UNS	2A	0.0013	0.9987	0.9915	0.9716	0.9674	0.0042	0.9491	2B	0.955	0.965	0.9729	0.9784	0.0055	1.0000
1-27 or 1.000-27	UNS	2A	0.0012	0.9988	0.9921	0.9747	0.9707	0.0040	0.9547	2B	0.960	0.969	0.9759	0.9811	0.0052	1.0000
1⅛-10 or 1.125-10	UNS	2A	0.0018	1.1232	1.1103	1.0582	1.0520	0.0062	1.0042	2B	1.017	1.038	1.0600	1.0680	0.0080	1.1250
1⅛-14 or 1.125-14	UNS	2A	0.0016	1.1234	1.1131	1.0770	1.0717	0.0053	1.0384	2B	1.048	1.064	1.0786	1.0855	0.0069	1.1250
1⅛-24 or 1.125-24	UNS	2A	0.0013	1.1237	1.1165	1.0966	1.0924	0.0042	1.0742	2B	1.080	1.090	1.0979	1.1034	0.0055	1.1250
1¼-10 or 1.250-10	UNS	2A	0.0019	1.2481	1.2352	1.1831	1.1768	0.0063	1.1291	2B	1.142	1.163	1.1850	1.1932	0.0082	1.2500
1¼-14 or 1.250-14	UNS	2A	0.0016	1.2484	1.2381	1.2020	1.1966	0.0054	1.1634	2B	1.173	1.188	1.2036	1.2106	0.0070	1.2500
1¼-24 or 1.250-24	UNS	2A	0.0013	1.2487	1.2415	1.2216	1.2173	0.0043	1.1991	2B	1.205	1.215	1.2229	1.2285	0.0056	1.2500

(Notes follow at end of table)

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TABLE 3B LIMITS OF SIZE FOR SELECTED COMBINATIONS OF UNS/UNRS SERIES THREADS (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)								Internal (1)						
				Major Diameter		Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diam.
		Class	Allowance	Max. (2)	Min.	Max. (2)	Min.	Tolerance	Max. (3) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
1⅜-10 or 1.375-10	UNS	2A	0.0019	1.3731	1.3602	1.3081	1.3018	0.0063	1.2541	2B	1.267	1.288	1.3100	1.3182	0.0082	1.3750
1⅜-14 or 1.375-14	UNS	2A	0.0016	1.3734	1.3631	1.3270	1.3216	0.0054	1.2884	2B	1.298	1.314	1.3286	1.3356	0.0070	1.3750
1⅜-24 or 1.375-24	UNS	2A	0.0013	1.3737	1.3665	1.3466	1.3423	0.0043	1.3241	2B	1.330	1.340	1.3479	1.3535	0.0056	1.3750
1½-10 or 1.500-10	UNS	2A	0.0019	1.4981	1.4852	1.4331	1.4267	0.0064	1.3791	2B	1.392	1.413	1.4350	1.4433	0.0083	1.5000
1½-14 or 1.500-14	UNS	2A	0.0017	1.4983	1.4880	1.4519	1.4464	0.0055	1.4133	2B	1.423	1.438	1.4536	1.4608	0.0072	1.5000
1½-24 or 1.500-24	UNS	2A	0.0013	1.4987	1.4915	1.4716	1.4672	0.0044	1.4491	2B	1.455	1.465	1.4729	1.4787	0.0058	1.5000
1⅝-10 or 1.625-10	UNS	2A	0.0019	1.6231	1.6102	1.5581	1.5517	0.0064	1.5041	2B	1.517	1.538	1.5600	1.5683	0.0083	1.6250
1⅝-14 or 1.625-14	UNS	2A	0.0017	1.6233	1.6130	1.5769	1.5714	0.0055	1.5383	2B	1.548	1.564	1.5786	1.5858	0.0072	1.6250
1⅝-24 or 1.625-24	UNS	2A	0.0013	1.6237	1.6165	1.5966	1.5922	0.0044	1.5741	2B	1.580	1.590	1.5979	1.6037	0.0058	1.6250
1¾-10 or 1.750-10	UNS	2A	0.0019	1.7481	1.7352	1.6831	1.6766	0.0065	1.6291	2B	1.642	1.663	1.6850	1.6934	0.0084	1.7500
1¾-14 or 1.750-14	UNS	2A	0.0017	1.7483	1.7380	1.7019	1.6963	0.0056	1.6632	2B	1.673	1.688	1.7036	1.7109	0.0073	1.7500
1¾-18 or 1.750-18	UNS	2A	0.0015	1.7485	1.7398	1.7124	1.7073	0.0051	1.6824	2B	1.690	1.703	1.7139	1.7205	0.0066	1.7500
1⅞-10 or 1.875-10	UNS	2A	0.0019	1.8731	1.8602	1.8081	1.8016	0.0065	1.7541	2B	1.767	1.788	1.8100	1.8184	0.0084	1.8750
1⅞-14 or 1.875-14	UNS	2A	0.0017	1.8733	1.8630	1.8269	1.8213	0.0056	1.7883	2B	1.798	1.814	1.8286	1.8359	0.0073	1.8750
1⅞-18 or 1.875-18	UNS	2A	0.0015	1.8735	1.8648	1.8374	1.8323	0.0051	1.8074	2B	1.815	1.828	1.8389	1.8455	0.0066	1.8750
2-10 or 2.000-10	UNS	2A	0.0020	1.9980	1.9851	1.9330	1.9265	0.0065	1.8790	2B	1.892	1.913	1.9350	1.9435	0.0085	2.0000
2-14 or 2.000-14	UNS	2A	0.0017	1.9983	1.9880	1.9519	1.9462	0.0057	1.9133	2B	1.923	1.938	1.9536	1.9610	0.0074	2.0000
2-18 or 2.000-18	UNS	2A	0.0015	1.9985	1.9898	1.9624	1.9573	0.0051	1.9324	2B	1.940	1.953	1.9639	1.9706	0.0067	2.0000
2 1/16-16 or 2.0625-16	UNS	2A	0.0016	2.0609	2.0515	2.0203	2.0149	0.0054	1.9864	2B	1.995	2.009	2.0219	2.0289	0.0070	2.0625
		3A	0.0000	2.0625	2.0531	2.0219	2.0179	0.0040	1.9880	3B	1.9950	2.0033	2.0219	2.0271	0.0052	2.0625
2 3/16-16 or 2.1875-16	UNS	2A	0.0016	2.1859	2.1765	2.1453	2.1399	0.0054	2.1114	2B	2.120	2.134	2.1469	2.1539	0.0070	2.1875
		3A	0.0000	2.1875	2.1781	2.1469	2.1428	0.0041	2.1130	3B	2.1200	2.1283	2.1469	2.1521	0.0052	2.1875
2¼-10 or 2.250-10	UNS	2A	0.0020	2.2480	2.2351	2.1830	2.1765	0.0065	2.1290	2B	2.142	2.163	2.1850	2.1935	0.0085	2.2500
2¼-14 or 2.250-14	UNS	2A	0.0017	2.2483	2.2380	2.2019	2.1962	0.0057	2.1633	2B	2.173	2.188	2.2036	2.2110	0.0074	2.2500
2¼-18 or 2.250-18	UNS	2A	0.0015	2.2485	2.2398	2.2124	2.2073	0.0051	2.1824	2B	2.190	2.203	2.2139	2.2206	0.0067	2.2500
2 5/16-16 or 2.3125-16	UNS	2A	0.0017	2.3108	2.3014	2.2702	2.2647	0.0055	2.2363	2B	2.245	2.259	2.2719	2.2791	0.0072	2.3125
		3A	0.0000	2.3125	2.3031	2.2719	2.2678	0.0041	2.2380	3B	2.2450	2.2533	2.2719	2.2773	0.0054	2.3125
2 7/16-16 or 2.4375-16	UNS	2A	0.0017	2.4358	2.4264	2.3952	2.3897	0.0055	2.3613	2B	2.370	2.384	2.3969	2.4041	0.0072	2.4375
		3A	0.0000	2.4375	2.4281	2.3969	2.3928	0.0041	2.3630	3B	2.3700	2.3783	2.3969	2.4023	0.0054	2.4375

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TABLE 3B LIMITS OF SIZE FOR SELECTED COMBINATIONS OF UNS/UNRS SERIES THREADS (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)								Internal (1)						
				Major Diameter		Pitch Diameter			UNR Minor Diam. Max. (3) (Ref.)		Minor Diameter		Pitch Diameter			Major Diam.
		Class	Allow-ance	Max. (2)	Min.	Max. (2)	Min.	Toler-ance		Class	Min.	Max.	Min.	Max.	Toler-ance	Min.
2½-10 or 2.500-10	UNS	2A	0.0020	2.4980	2.4851	2.4330	2.4263	0.0067	2.3790	2B	2.392	2.413	2.4350	2.4437	0.0087	2.5000
2½-14 or 2.500-14	UNS	2A	0.0017	2.4983	2.4880	2.4519	2.4461	0.0058	2.4133	2B	2.423	2.438	2.4536	2.4612	0.0076	2.5000
2½-18 or 2.500-18	UNS	2A	0.0016	2.4984	2.4897	2.4623	2.4570	0.0053	2.4323	2B	2.440	2.453	2.4639	2.4708	0.0069	2.5000
2¾-10 or 2.750-10	UNS	2A	0.0020	2.7480	2.7351	2.6830	2.6763	0.0067	2.6290	2B	2.642	2.663	2.6850	2.6937	0.0087	2.7500
2¾-14 or 2.750-14	UNS	2A	0.0017	2.7483	2.7380	2.7019	2.6961	0.0058	2.6633	2B	2.673	2.688	2.7036	2.7112	0.0076	2.7500
2¾-18 or 2.750-18	UNS	2A	0.0016	2.7484	2.7397	2.7123	2.7070	0.0053	2.6823	2B	2.690	2.703	2.7139	2.7208	0.0069	2.7500
3-10 or 3.000-10	UNS	2A	0.0020	2.9980	2.9851	2.9330	2.9262	0.0068	2.8790	2B	2.892	2.913	2.9350	2.9439	0.0089	3.0000
3-14 or 3.000-14	UNS	2A	0.0018	2.9982	2.9879	2.9518	2.9459	0.0059	2.9132	2B	2.923	2.938	2.9536	2.9613	0.0077	3.0000
3-18 or 3.000-18	UNS	2A	0.0016	2.9984	2.9897	2.9623	2.9569	0.0054	2.9323	2B	2.940	2.953	2.9639	2.9709	0.0070	3.0000
3¼-10 or 3.250-10	UNS	2A	0.0020	3.2480	3.2351	3.1830	3.1762	0.0068	3.1290	2B	3.142	3.163	3.1850	3.1939	0.0089	3.2500
3¼-14 or 3.250-14	UNS	2A	0.0018	3.2482	3.2379	3.2018	3.1959	0.0059	3.1632	2B	3.173	3.188	3.2036	3.2113	0.0077	3.2500
3¼-18 or 3.250-18	UNS	2A	0.0016	3.2484	3.2397	3.2123	3.2069	0.0054	3.1823	2B	3.190	3.203	3.2139	3.2209	0.0070	3.2500
3½-10 or 3.500-10	UNS	2A	0.0021	3.4979	3.4850	3.4329	3.4260	0.0069	3.3789	2B	3.392	3.413	3.4350	3.4440	0.0090	3.5000
3½-14 or 3.500-14	UNS	2A	0.0018	3.4982	3.4879	3.4518	3.4457	0.0061	3.4132	2B	3.423	3.438	3.4536	3.4615	0.0079	3.5000
3½-18 or 3.500-18	UNS	2A	0.0017	3.4983	3.4896	3.4622	3.4567	0.0055	3.4322	2B	3.440	3.453	3.4639	3.4711	0.0072	3.5000
3¾-10 or 3.750-10	UNS	2A	0.0021	3.7479	3.7350	3.6829	3.6760	0.0069	3.6289	2B	3.642	3.663	3.6850	3.6940	0.0090	3.7500
3¾-14 or 3.750-14	UNS	2A	0.0018	3.7482	3.7379	3.7018	3.6957	0.0061	3.6632	2B	3.673	3.688	3.7036	3.7115	0.0079	3.7500
3¾-18 or 3.750-18	UNS	2A	0.0017	3.7483	3.7396	3.7122	3.7067	0.0055	3.6822	2B	3.690	3.703	3.7139	3.7211	0.0072	3.7500
4-10 or 4.000-10	UNS	2A	0.0021	3.9979	3.9850	3.9329	3.9259	0.0070	3.8768	2B	3.892	3.913	3.9350	3.9441	0.0091	4.0000
4-14 or 4.000-14	UNS	2A	0.0018	3.9982	3.9879	3.9518	3.9456	0.0062	3.9132	2B	3.923	3.938	3.9536	3.9616	0.0080	4.0000
4¼-10 or 4.250-10	UNS	2A	0.0021	4.2479	4.2350	4.1829	4.1759	0.0070	4.1289	2B	4.142	4.163	4.1850	4.1941	0.0091	4.2500
4¼-14 or 4.250-14	UNS	2A	0.0018	4.2482	4.2379	4.2018	4.1956	0.0062	4.1632	2B	4.173	4.188	4.2036	4.2116	0.0080	4.2500
4½-10 or 4.500-10	UNS	2A	0.0021	4.4979	4.4850	4.4329	4.4259	0.0070	4.3789	2B	4.392	4.413	4.4350	4.4441	0.0091	4.5000
4½-14 or 4.500-14	UNS	2A	0.0018	4.4982	4.4879	4.4518	4.4456	0.0062	4.4132	2B	4.423	4.438	4.4536	4.4616	0.0080	4.5000
4¾-10 or 4.750-10	UNS	2A	0.0022	4.7478	4.7349	4.6828	4.6756	0.0072	4.6288	2B	4.642	4.663	4.6850	4.6944	0.0094	4.7500
4¾-14 or 4.750-14	UNS	2A	0.0019	4.7481	4.7378	4.7017	4.6953	0.0064	4.6631	2B	4.673	4.688	4.7036	4.7119	0.0083	4.7500
5-10 or 5.000-10	UNS	2A	0.0022	4.9978	4.9849	4.9328	4.9256	0.0072	4.8788	2B	4.892	4.913	4.9350	4.9444	0.0094	5.0000
5-14 or 5.000-14	UNS	2A	0.0019	4.9981	4.9878	4.9517	4.9453	0.0064	4.9131	2B	4.923	4.938	4.9536	4.9619	0.0083	5.0000

(Notes follow at end of table)

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TABLE 3B LIMITS OF SIZE FOR SELECTED COMBINATIONS OF UNS/UNRS SERIES THREADS (CONT'D)

Nominal Size and Threads/in.	Series Designation	External (1)								Internal (1)						
				Major Diameter		Pitch Diameter			UNR Minor Diam. Max. (3) (Ref.)		Minor Diameter		Pitch Diameter			Major Diam.
		Class	Allowance	Max. (2)	Min.	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
5¼-10 or 5.250-10	UNS	2A	0.0022	5.2478	5.2349	5.1828	5.1756	0.0072	5.1288	2B	5.142	5.163	5.1850	5.1944	0.0094	5.2500
5¼-14 or 5.250-14	UNS	2A	0.0019	5.2481	5.2378	5.2017	5.1953	0.0064	5.1631	2B	5.173	5.188	5.2036	5.2119	0.0083	5.2500
5½-10 or 5.500-10	UNS	2A	0.0022	5.4978	5.4849	5.4328	5.4256	0.0072	5.3788	2B	5.392	5.413	5.4350	5.4444	0.0094	5.5000
5½-14 or 5.500-14	UNS	2A	0.0019	5.4981	5.4878	5.4517	5.4453	0.0064	5.4131	2B	5.423	5.438	5.4536	5.4619	0.0083	5.5000
5¾-10 or 5.750-10	UNS	2A	0.0022	5.7478	5.7349	5.6828	5.6754	0.0074	5.6288	2B	5.642	5.663	5.6850	5.6946	0.0096	5.7500
5¾-14 or 5.750-14	UNS	2A	0.0020	5.7480	5.7377	5.7016	5.6951	0.0065	5.6630	2B	5.673	5.688	5.7036	5.7121	0.0085	5.7500
6-10 or 6.000-10	UNS	2A	0.0022	5.9978	5.9849	5.9328	5.9254	0.0074	5.8788	2B	5.892	5.913	5.9350	5.9446	0.0096	6.0000
6-14 or 6.000-14	UNS	2A	0.0020	5.9980	5.9877	5.9516	5.9451	0.0065	5.9130	2B	5.923	5.938	5.9536	5.9621	0.0085	6.0000

GENERAL NOTE:
Series designation shown indicates the UN thread form; however, the UNR thread form may be specified by substituting UNR in place of UN in all designations for external use only.

NOTES:
(1) Thread classes may be combined. See para. 4.2.
(2) For Class 2A threads having an additive finish, the maximum major and pitch diameters, after coating, may equal the basic sizes, whose values are the same as the maximum values shown for Class 3A in these columns. See paras. 4.1.1 and 4.1.3.
(3) UN series external thread maximum minor diameter is basic (D_1 in Section 11) for Class 3A and basic minus allowance for Classes 1A and 2A.

8.3.1 External Thread

(a) Maximum Major Diameter (External Threads)

(1) For Classes 1A and 2A, d = basic major diameter D bsc, minus allowance.

(2) For Class 3A, d = basic major diameter D bsc.

(b) Minimum Major Diameter (External Threads). For all classes, equals maximum major diameter, minus major diameter tolerance for respective class of thread.

(c) Maximum Pitch Diameter (External Threads)

(1) For Classes 1A and 2A, d_2 = basic pitch diameter D_2 bsc, minus allowance.

(2) For Class 3A, d_2 = basic pitch diameter D_2 bsc.

(d) Minimum Pitch Diameter (External Threads). For all classes, equals maximum pitch diameter, minus pitch diameter tolerance for respective class of thread.

(e) Maximum Minor Diameter (External Threads). In dimensioning UN series external threads, the minor diameter is not specified. In practice, the minor diameter is satisfactory when accepted by a standard GO thread gage in accordance with ANSI/ASME B1.2. When it is desirable to obtain minor diameter values for reference purposes and for UNR threads, they can be calculated as follows.

(1) For UN series threads, the formulas are:

(a) for Classes 1A and 2A, d_1 = basic minor diameter D_1 bsc, minus allowance;

(b) for Class 3A, d_1 = basic minor diameter D_1 bsc.

(2) For UNR series threads, the formulas are:

(a) for Classes 1A and 2A, d_3 = basic minor diameter D_1 bsc, minus allowance, minus $H/8$;

(b) for Class 3A, d_3 = basic minor diameter D_1 bsc, minus $H/8$.

(f) Minimum Minor Diameter (External Threads). When it is desirable for design purposes to calculate the minimum diameter, it can be obtained for all classes by the formula: minimum pitch diameter minus $0.649519P$.

8.3.2 Internal Thread

(a) Maximum Major Diameter (Internal Threads). In dimensioning internal threads, the maximum major diameter is not specified, being established by the crest of an unworn tool. In practice, the major diameter of an internal thread is satisfactory when accepted by a gage or gaging method that represents the maximum-material condition of an external thread that has no allowance.

(b) Minimum Major Diameter (Internal Threads) (D bsc). For all classes, equals basic diameter D bsc.

(c) Minimum Pitch Diameter. For all classes, D_2 bsc equals basic pitch diameter D_2 bsc.

(d) Maximum Pitch Diameter (Internal Threads). For all classes, equals minimum pitch diameter D_2 bsc, plus pitch diameter tolerance for respective class of thread.

(e) Minimum Minor Diameter (Internal Threads). For all classes, D_1 bsc equals minimum pitch diameter D_2 bsc, minus $H/2$, then rounded off to the nearest 0.001 in. for sizes 0.138 in. and larger. For Class 3B, a cipher is added to yield four decimal places.

(f) Maximum Minor Diameter (Internal Threads). For all classes, D_1 bsc equals minimum minor diameter before rounding off, plus minor diameter tolerance, then rounded off, for Classes 1B and 2B, to the nearest 0.001 in. for sizes 0.138 in. and larger. Class 3B values are not thus rounded off.

9 LEAD AND ANGLE TOLERANCES

9.1 Lead and Flank Angle Acceptance

Acceptance of lead and flank angles of product screw threads shall be in accordance with the following. Also, these are factors contributing to visual identification of gross defects in thread profile.

9.1.1 When Thread Gaging System 21 of ANSI/ASME B1.3M is specified, product thread lead (including helix) and flank angle variations are not considered as separate elements.

9.1.2 When Thread Gaging System 22 of ANSI/ASME B1.3M is specified, with the pitch diameter or thread-groove diameter inspection required, the product thread lead (including helix) and flank angles shall be considered acceptable when the minimum-material characteristic (pitch diameter or thread-groove diameter in Tables 1 and 2, columns C and D of ANSI/ASME B1.3M) and the maximum-material characteristic (GO in Tables 1 and 2, column A of ANSI/ASME B1.3M) are accepted by the gages specified for System 22, over the standard GO thread gage length.

When Thread Gaging System 22 is specified with NOT GO functional diameter combined with control of lead and flank option, agreements must be reached between the purchaser and the supplier on lead and flank angle limits and method of evaluation.

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9.1.3 When Thread Gaging System 23 of ANSI/ASME B1.3M is specified, product thread lead and flank angles shall be acceptable if within the allowable variations specified in Tables 4 and 5, respectively. Also, the minimum-material characteristic (pitch diameter or thread-groove diameter in Tables 1 and 2, columns C and D of ANSI/ASME B1.3M) and the maximum-material characteristic (GO in Tables 1 and 2, column A of ANSI/ASME B1.3M) must be accepted by the gages specified for System 23, over the standard GO thread gage length.

Allowable variations in lead and flank angles are maximum values. Maximum variation in these and pitch diameter tolerance cannot be taken simultaneously (see paras. 9.1.5 and 9.1.6 below).

9.1.4 When individual inspections of lead (including helix) and flank angle variations are required in addition to thread gaging System 21 or 22 of ANSI/ASME B1.3M, the allowable variations for these characteristics shall be as specified in Tables 4 and 5.

9.1.5 For sizes not included in Tables 4 and 5, the allowable lead variation is equal to 0.57735 times one-half the pitch diameter tolerance. This is the lead variation that causes a change in functional diameter equal to one-half the pitch diameter tolerance. The allowable flank half-angle variation in minutes of arc is equal to 30 plus 1.875 times the number of threads per inch, rounded to the nearest 5 min.

9.1.6 For the requirements of paras. 9.1.4 and 9.1.5, lead variation values tabulated or calculated are the maximum variations from specified lead between any two points not farther apart than the length of the standard GO thread gage. Flank angle variation values are maximum variations from the basic 30 deg. angle between thread flanks and perpendiculars to the thread axis.

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
0-80 or 0.060-80	UNF	2A 3A	0.00052 0.00038	0.00090 0.00065	2B 3B	0.00066 0.00048	0.00115 0.00085
1-64 or 0.073-64	UNC	2A 3A	0.00058 0.00043	0.00100 0.00075	2B 3B	0.00075 0.00055	0.00130 0.00095
1-72 or 0.073-72	UNF	2A 3A	0.00055 0.00040	0.00095 0.00070	2B 3B	0.00072 0.00055	0.00125 0.00095
2-56 or 0.086-56	UNC	2A 3A	0.00061 0.00046	0.00105 0.00080	2B 3B	0.00081 0.00061	0.00140 0.00105
2-64 or 0.086-64	UNF	2A 3A	0.00058 0.00043	0.00100 0.00075	2B 3B	0.00078 0.00058	0.00135 0.00100
3-48 or 0.099-48	UNC	2A 3A	0.00066 0.00049	0.00115 0.00085	2B 3B	0.00087 0.00064	0.00150 0.00110
3-56 or 0.099-56	UNF	2A 3A	0.00064 0.00046	0.00110 0.00080	2B 3B	0.00081 0.00061	0.00140 0.00105
4-40 or 0.112-40	UNC	2A 3A	0.00072 0.00055	0.00125 0.00095	2B 3B	0.00095 0.00069	0.00165 0.00120
4-48 or 0.112-48	UNF	2A 3A	0.00069 0.00052	0.00120 0.00090	2B 3B	0.00089 0.00066	0.00155 0.00115
5-40 or 0.125-40	UNC	2A 3A	0.00075 0.00055	0.00130 0.00095	2B 3B	0.00095 0.00072	0.00165 0.00125
5-44 or 0.125-44	UNF	2A 3A	0.00072 0.00055	0.00125 0.00095	2B 3B	0.00092 0.00069	0.00160 0.00120
6-32 or 0.138-32	UNC	2A 3A	0.00081 0.00061	0.00140 0.00105	2B 3B	0.00107 0.00078	0.00185 0.00135
6-40 or 0.138-40	UNF	2A 3A	0.00075 0.00058	0.00130 0.00100	2B 3B	0.00098 0.00072	0.00170 0.00125
8-32 or 0.164-32	UNC	2A 3A	0.00084 0.00064	0.00145 0.00110	2B 3B	0.00110 0.00081	0.00190 0.00140
8-36 or 0.164-36	UNF	2A 3A	0.00081 0.00061	0.00140 0.00105	2B 3B	0.00104 0.00078	0.00180 0.00135
10-24 or 0.190-24	UNC	2A 3A	0.00095 0.00072	0.00165 0.00125	2B 3B	0.00124 0.00092	0.00215 0.00160
10-32 or 0.190-32	UNF	2A 3A	0.00087 0.00066	0.00150 0.00115	2B 3B	0.00113 0.00084	0.00195 0.00145

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
12-24 or 0.216-24	UNC	2A	0.00098	0.00170	2B	0.00127	0.00220
		3A	0.00075	0.00130	3B	0.00095	0.00165
12-28 or 0.216-28	UNF	2A	0.00092	0.00160	2B	0.00121	0.00210
		3A	0.00069	0.00120	3B	0.00089	0.00155
12-32 or 0.216-32	UNEF	2A	0.00089	0.00155	2B	0.00118	0.00205
		3A	0.00069	0.00120	3B	0.00089	0.00155
1/4-20 or 0.250-20	UNC	1A	0.00162	0.00280	1B	0.00211	0.00365
		2A	0.00107	0.00185	2B	0.00141	0.00245
		3A	0.00081	0.00140	3B	0.00104	0.00180
1/4-28 or 0.250-28	UNF	1A	0.00144	0.00250	1B	0.00188	0.00325
		2A	0.00095	0.00165	2B	0.00124	0.00215
		3A	0.00072	0.00125	3B	0.00092	0.00160
1/4-32 or 0.250-32	UNEF	2A	0.00092	0.00160	2B	0.00121	0.00210
		3A	0.00069	0.00120	3B	0.00089	0.00155
5/16-18 or 0.3125-18	UNC	1A	0.00176	0.00305	1B	0.00223	0.00395
		2A	0.00115	0.00200	2B	0.00153	0.00265
		3A	0.00087	0.00150	3B	0.00113	0.00195
5/16-20 or 0.3125-20	UN	2A	0.00115	0.00200	2B	0.00150	0.00260
		3A	0.00087	0.00150	3B	0.00113	0.00195
5/16-24 or 0.3125-24	UNF	1A	0.00159	0.00275	1B	0.00205	0.00355
		2A	0.00107	0.00185	2B	0.00139	0.00240
		3A	0.00078	0.00135	3B	0.00104	0.00180
5/16-28 or 0.3125-28	UN	2A	0.00098	0.00170	2B	0.00127	0.00220
		3A	0.00075	0.00130	3B	0.00095	0.00165
5/16-32 or 0.3125-32	UNEF	2A	0.00092	0.00160	2B	0.00121	0.00210
		3A	0.00069	0.00120	3B	0.00089	0.00155
3/8-16 or 0.375-16	UNC	1A	0.00188	0.00325	1B	0.00245	0.00425
		2A	0.00127	0.00220	2B	0.00165	0.00285
		3A	0.00095	0.00165	3B	0.00124	0.00215
3/8-20 or 0.375-20	UN	2A	0.00118	0.00205	2B	0.00156	0.00270
		3A	0.00089	0.00155	3B	0.00115	0.00200
3/8-24 or 0.375-24	UNF	1A	0.00165	0.00285	1B	0.00214	0.00370
		2A	0.00110	0.00190	2B	0.00141	0.00245
		3A	0.00084	0.00145	3B	0.00107	0.00185
3/8-28 or 0.375-28	UN	2A	0.00104	0.00180	2B	0.00133	0.00230
		3A	0.00078	0.00135	3B	0.00101	0.00175

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)
(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
3/8-32 or 0.375-32	UNEF	2A	0.00098	0.00170	2B	0.00127	0.00220
		3A	0.00072	0.00125	3B	0.00095	0.00165
7/16-14 or 0.4375-14	UNC	1A	0.00205	0.00355	1B	0.00266	0.00460
		2A	0.00136	0.00235	2B	0.00176	0.00305
		3A	0.00101	0.00175	3B	0.00133	0.00230
7/16-16 or 0.4375-16	UN	2A	0.00133	0.00230	2B	0.00170	0.00295
		3A	0.00098	0.00170	3B	0.00130	0.00225
7/16-20 or 0.4375-20	UNF	1A	0.00182	0.00315	1B	0.00234	0.00405
		2A	0.00121	0.00210	2B	0.00156	0.00270
		3A	0.00089	0.00155	3B	0.00118	0.00205
7/16-28 or 0.4375-28	UNEF	2A	0.00104	0.00180	2B	0.00133	0.00230
		3A	0.00078	0.00135	3B	0.00101	0.00175
7/16-32 or 0.4375-32	UN	2A	0.00098	0.00170	2B	0.00127	0.00220
		3A	0.00072	0.00125	3B	0.00095	0.00165
1/2-13 or 0.500-13	UNC	1A	0.00214	0.00370	1B	0.00280	0.00485
		2A	0.00144	0.00250	2B	0.00188	0.00325
		3A	0.00107	0.00185	3B	0.00139	0.00240
1/2-16 or 0.500-16	UN	2A	0.00136	0.00235	2B	0.00176	0.00305
		3A	0.00101	0.00175	3B	0.00133	0.00230
1/2-20 or 0.500-20	UNF	1A	0.00185	0.00320	1B	0.00242	0.00420
		2A	0.00124	0.00215	2B	0.00162	0.00280
		3A	0.00092	0.00160	3B	0.00121	0.00210
1/2-28 or 0.500-28	UNEF	2A	0.00107	0.00185	2B	0.00139	0.00240
		3A	0.00081	0.00140	3B	0.00104	0.00180
1/2-32 or 0.500-32	UN	2A	0.00101	0.00175	2B	0.00130	0.00225
		3A	0.00075	0.00130	3B	0.00098	0.00170
9/16-12 or 0.5625-12	UNC	1A	0.00225	0.00390	1B	0.00294	0.00510
		2A	0.00150	0.00260	2B	0.00196	0.00340
		3A	0.00113	0.00195	3B	0.00147	0.00255
9/16-16 or 0.5625-16	UN	2A	0.00136	0.00235	2B	0.00176	0.00305
		3A	0.00101	0.00175	3B	0.00133	0.00230
9/16-18 or 0.5625-18	UNF	1A	0.00196	0.00340	1B	0.00257	0.00445
		2A	0.00130	0.00225	2B	0.00170	0.00295
		3A	0.00098	0.00170	3B	0.00127	0.00220
9/16-20 or 0.5625-20	UN	2A	0.00121	0.00210	2B	0.00159	0.00275
		3A	0.00092	0.00160	3B	0.00118	0.00205

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
9/16-24 or 0.5625-24	UNEF	2A	0.00113	0.00195	2B	0.00147	0.00255
		3A	0.00084	0.00145	3B	0.00110	0.00190
9/16-28 or 0.5625-28	UN	2A	0.00107	0.00185	2B	0.00139	0.00240
		3A	0.00081	0.00140	3B	0.00104	0.00180
9/16-32 or 0.5625-32	UN	2A	0.00101	0.00175	2B	0.00130	0.00225
		3A	0.00075	0.00130	3B	0.00098	0.00170
5/8-11 or 0.625-11	UNC	1A	0.00240	0.00415	1B	0.00309	0.00535
		2A	0.00159	0.00275	2B	0.00208	0.00360
		3A	0.00118	0.00205	3B	0.00156	0.00270
5/8-12 or 0.625-12	UN	2A	0.00156	0.00270	2B	0.00205	0.00355
		3A	0.00118	0.00205	3B	0.00153	0.00265
5/8-16 or 0.625-16	UN	2A	0.00139	0.00240	2B	0.00179	0.00310
		3A	0.00104	0.00180	3B	0.00133	0.00230
5/8-18 or 0.625-18	UNF	1A	0.00202	0.00350	1B	0.00263	0.00455
		2A	0.00136	0.00235	2B	0.00173	0.00300
		3A	0.00101	0.00175	3B	0.00130	0.00255
5/8-20 or 0.625-20	UN	2A	0.00124	0.00215	2B	0.00162	0.00280
		3A	0.00092	0.00160	3B	0.00121	0.00210
5/8-24 or 0.625-24	UNEF	2A	0.00115	0.00200	2B	0.00150	0.00260
		3A	0.00087	0.00150	3B	0.00113	0.00195
5/8-28 or 0.625-28	UN	2A	0.00110	0.00190	2B	0.00141	0.00245
		3A	0.00081	0.00140	3B	0.00107	0.00185
5/8-32 or 0.625-32	UN	2A	0.00104	0.00180	2B	0.00133	0.00230
		3A	0.00078	0.00135	3B	0.00101	0.00175
11/16-12 or 0.6875-12	UN	2A	0.00156	0.00270	2B	0.00205	0.00355
		3A	0.00118	0.00205	3B	0.00153	0.00265
11/16-16 or 0.6875-16	UN	2A	0.00139	0.00240	2B	0.00179	0.00310
		3A	0.00104	0.00130	3B	0.00133	0.00230
11/16-20 or 0.6875-20	UN	2A	0.00124	0.00215	2B	0.00162	0.00280
		3A	0.00092	0.00160	3B	0.00121	0.00210
11/16-24 or 0.6875-24	UNEF	2A	0.00115	0.00200	2B	0.00150	0.00260
		3A	0.00087	0.00150	3B	0.00113	0.00195
11/16-28 or 0.6875-28	UN	2A	0.00110	0.00190	2B	0.00141	0.00245
		3A	0.00081	0.00140	3B	0.00107	0.00185
11/16-32 or 0.6875-32	UN	2A	0.00104	0.00180	2B	0.00133	0.00230
		3A	0.00078	0.00135	3B	0.00101	0.00175

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)
(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
3/4-10 or 0.750-10	UNC	1A	0.00254	0.00440	1B	0.00332	0.00575
		2A	0.00170	0.00295	2B	0.00222	0.00385
		3A	0.00127	0.00220	3B	0.00165	0.00285
3/4-12 or 0.750-12	UN	2A	0.00159	0.00275	2B	0.00208	0.00360
		3A	0.00118	0.00205	3B	0.00156	0.00270
3/4-16 or 0.750-16	UNF	1A	0.00217	0.00375	1B	0.00283	0.00490
		2A	0.00144	0.00250	2B	0.00188	0.00325
		3A	0.00110	0.00190	3B	0.00141	0.00245
3/4-20 or 0.750-20	UNEF	2A	0.00127	0.00220	2B	0.00165	0.00285
		3A	0.00095	0.00165	3B	0.00124	0.00215
3/4-28 or 0.750-28	UN	2A	0.00110	0.00190	2B	0.00144	0.00250
		3A	0.00084	0.00145	3B	0.00107	0.00185
3/4-32 or 0.750-32	UN	2A	0.00104	0.00180	2B	0.00136	0.00235
		3A	0.00078	0.00135	3B	0.00104	0.00180
13/16-12 or 0.8125-12	UN	2A	0.00159	0.00275	2B	0.00208	0.00360
		3A	0.00118	0.00205	3B	0.00156	0.00270
13/16-16 or 0.8125-16	UN	2A	0.00141	0.00245	2B	0.00182	0.00315
		3A	0.00104	0.00180	3B	0.00136	0.00235
13/16-20 or 0.8125-20	UNEF	2A	0.00127	0.00220	2B	0.00165	0.00285
		3A	0.00095	0.00165	3B	0.00124	0.00215
13/16-28 or 0.8125-28	UN	2A	0.00110	0.00190	2B	0.00144	0.00250
		3A	0.00084	0.00145	3B	0.00107	0.00185
13/16-32 or 0.8125-32	UN	2A	0.00104	0.00180	2B	0.00136	0.00235
		3A	0.00078	0.00135	3B	0.00104	0.00180
7/8-9 or 0.875-9	UNC	1A	0.00274	0.00475	1B	0.00355	0.00615
		2A	0.00182	0.00315	2B	0.00237	0.00410
		3A	0.00136	0.00235	3B	0.00176	0.00305
7/8-12 or 0.875-12	UN	2A	0.00159	0.00275	2B	0.00208	0.00360
		3A	0.00118	0.00205	3B	0.00156	0.00270
7/8-14 or 0.875-14	UNF	1A	0.00234	0.00405	1B	0.00306	0.00530
		2A	0.00156	0.00270	2B	0.00202	0.00350
		3A	0.00118	0.00205	3B	0.00153	0.00265
7/8-16 or 0.875-16	UN	2A	0.00141	0.00245	2B	0.00182	0.00315
		3A	0.00104	0.00180	3B	0.00136	0.00235
7/8-20 or 0.875-20	UNEF	2A	0.00127	0.00220	2B	0.00165	0.00285
		3A	0.00095	0.00165	3B	0.00124	0.00215

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
7/8-28 or 0.875-28	UN	2A	0.00110	0.00190	2B	0.00144	0.00250
		3A	0.00084	0.00145	3B	0.00107	0.00185
7/8-32 or 0.875-32	UN	2A	0.00104	0.00180	2B	0.00136	0.00235
		3A	0.00078	0.00135	3B	0.00104	0.00180
15/16-12 or 0.9375-12	UN	2A	0.00165	0.00255	2B	0.00214	0.00370
		3A	0.00121	0.00210	3B	0.00159	0.00275
15/16-16 or 0.9375-16	UN	2A	0.00144	0.00250	2B	0.00188	0.00325
		3A	0.00107	0.00185	3B	0.00141	0.00245
15/16-20 or 0.9375-20	UNEF	2A	0.00130	0.00225	2B	0.00170	0.00295
		3A	0.00098	0.00170	3B	0.00127	0.00220
15/16-28 or 0.9375-28	UN	2A	0.00115	0.00200	2B	0.00150	0.00260
		3A	0.00087	0.00150	3B	0.00113	0.00195
15/16-32 or 0.9375-32	UN	2A	0.00110	0.00190	2B	0.00141	0.00245
		3A	0.00081	0.00140	3B	0.00107	0.00185
1-8 or 1.000-8	UNC	1A	0.00292	0.00505	1B	0.00381	0.00660
		2A	0.00196	0.00340	2B	0.00254	0.00440
		3A	0.00147	0.00255	3B	0.00191	0.00330
1-12 or 1.000-12	UNF	1A	0.00254	0.00440	1B	0.00329	0.00570
		2A	0.00170	0.00295	2B	0.00219	0.00380
		3A	0.00127	0.00220	3B	0.00165	0.00285
1-14 or 1.000-14	UNS	1A	0.00242	0.00420	1B	0.00315	0.00545
		2A	0.00162	0.00280	2B	0.00211	0.00365
		3A	0.00121	0.00210	3B	0.00156	0.00270
1-16 or 1.000-16	UN	2A	0.00144	0.00250	2B	0.00188	0.00325
		3A	0.00107	0.00185	3B	0.00141	0.00245
1-20 or 1.000-20	UNEF	2A	0.00130	0.00225	2B	0.00170	0.00295
		3A	0.00098	0.00170	3B	0.00127	0.00220
1-28 or 1.000-28	UN	2A	0.00115	0.00200	2B	0.00150	0.00260
		3A	0.00087	0.00150	3B	0.00113	0.00195
1-32 or 1.000-32	UN	2A	0.00110	0.00190	2B	0.00141	0.00245
		3A	0.00081	0.00140	3B	0.00107	0.00185
1 1/16-8 or 1.0625-8	UN	2A	0.00196	0.00340	2B	0.00257	0.00445
		3A	0.00147	0.00255	3B	0.00193	0.00335
1 1/16-12 or 1.0625-12	UN	2A	0.00165	0.00285	2B	0.00214	0.00370
		3A	0.00121	0.00210	3B	0.00159	0.00275

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/In.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, In. ±	5, In. +	6	7, In. ±	8, In. −
1 1/16-16 or 1.0625-16	UN	2A	0.00144	0.00250	2B	0.00188	0.00325
		3A	0.00107	0.00185	3B	0.00141	0.00245
1 1/16-18 or 1.0625-18	UNEF	2A	0.00136	0.00235	2B	0.00179	0.00310
		3A	0.00104	0.00180	3B	0.00133	0.00230
1 1/16-20 or 1.0625-20	UN	2A	0.00130	0.00225	2B	0.00170	0.00295
		3A	0.00098	0.00170	3B	0.00127	0.00220
1 1/16-28 or 1.0625-28	UN	2A	0.00115	0.00200	2B	0.00150	0.00260
		3A	0.00087	0.00150	3B	0.00113	0.00195
1 1/8-7 or 1.125-7	UNC	1A	0.00315	0.00545	1B	0.00407	0.00705
		2A	0.00208	0.00360	2B	0.00271	0.00470
		3A	0.00156	0.00270	3B	0.00205	0.00355
1 1/8-8 or 1.125-8	UN	2A	0.00199	0.00345	2B	0.00260	0.00450
		3A	0.00150	0.00260	3B	0.00193	0.00335
1 1/8-12 or 1.125-12	UNF	1A	0.00260	0.00450	1B	0.00338	0.00585
		2A	0.00173	0.00300	2B	0.00225	0.00390
		3A	0.00130	0.00225	3B	0.00170	0.00295
1 1/8-16 or 1.125-16	UN	2A	0.00144	0.00250	2B	0.00188	0.00325
		3A	0.00107	0.00185	3B	0.00141	0.00245
1 1/8-18 or 1.125-18	UNEF	2A	0.00136	0.00235	2B	0.00179	0.00310
		3A	0.00104	0.00180	3B	0.00133	0.00230
1 1/8-20 or 1.125-20	UN	2A	0.00130	0.00225	2B	0.00170	0.00295
		3A	0.00098	0.00170	3B	0.00127	0.00220
1 1/8-28 or 1.125-28	UN	2A	0.00115	0.00200	2B	0.00150	0.00260
		3A	0.00087	0.00150	3B	0.00113	0.00195
1 3/16-8 or 1.1875-8	UN	2A	0.00202	0.00350	2B	0.00263	0.00455
		3A	0.00150	0.00260	3B	0.00196	0.00340
1 3/16-12 or 1.1875-12	UN	2A	0.00167	0.00290	2B	0.00217	0.00375
		3A	0.00124	0.00215	3B	0.00162	0.00280
1 3/16-16 or 1.1875-16	UN	2A	0.00147	0.00255	2B	0.00191	0.00330
		3A	0.00110	0.00190	3B	0.00144	0.00250
1 3/16-18 or 1.1875-18	UNEF	2A	0.00141	0.00245	2B	0.00182	0.00315
		3A	0.00104	0.00180	3B	0.00136	0.00235
1 3/16-20 or 1.1875-20	UN	2A	0.00136	0.00235	2B	0.00176	0.00305
		3A	0.00101	0.00175	3B	0.00130	0.00225

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
1 3/16-28 or 1.1875-28	UN	2A	0.00118	0.00205	2B	0.00153	0.00265
		3A	0.00089	0.00155	3B	0.00115	0.00200
1 1/4-7 or 1.250-7	UNC	1A	0.00320	0.00555	1B	0.00416	0.00720
		2A	0.00214	0.00370	2B	0.00277	0.00480
		3A	0.00159	0.00275	3B	0.00208	0.00360
1 1/4-8 or 1.250-8	UN	2A	0.00202	0.00350	2B	0.00266	0.00460
		3A	0.00153	0.00265	3B	0.00199	0.00345
1 1/4-12 or 1.250-12	UNF	1A	0.00266	0.00460	1B	0.00346	0.00600
		2A	0.00179	0.00310	2B	0.00231	0.00400
		3A	0.00133	0.00230	3B	0.00173	0.00300
1 1/4-16 or 1.250-16	UN	2A	0.00147	0.00255	2B	0.00191	0.00330
		3A	0.00100	0.00190	3B	0.00144	0.00250
1 1/4-18 or 1.250-18	UNEF	2A	0.00141	0.00245	2B	0.00182	0.00315
		3A	0.00104	0.00180	3B	0.00136	0.00235
1 1/4-20 or 1.250-20	UN	2A	0.00136	0.00235	2B	0.00176	0.00305
		3A	0.00101	0.00175	3B	0.00130	0.00225
1 1/4-28 or 1.250-28	UN	2A	0.00118	0.00205	2B	0.00153	0.00265
		3A	0.00089	0.00155	3B	0.00115	0.00200
1 5/16-8 or 1.3125-8	UN	2A	0.00205	0.00355	2B	0.00266	0.00460
		3A	0.00153	0.00265	3B	0.00199	0.00345
1 5/16-12 or 1.3125-12	UN	2A	0.00167	0.00290	2B	0.00217	0.00375
		3A	0.00124	0.00215	3B	0.00162	0.00280
1 5/16-16 or 1.3125-16	UN	2A	0.00147	0.00255	2B	0.00191	0.00330
		3A	0.00110	0.00190	3B	0.00144	0.00250
1 5/16-18 or 1.3125-18	UNEF	2A	0.00141	0.00245	2B	0.00182	0.00315
		3A	0.00104	0.00180	3B	0.00136	0.00235
1 5/16-20 or 1.3125-20	UN	2A	0.00136	0.00235	2B	0.00176	0.00305
		3A	0.00101	0.00175	3B	0.00130	0.00225
1 5/16-28 or 1.3125-28	UN	2A	0.00118	0.00205	2B	0.00153	0.00265
		3A	0.00089	0.00155	3B	0.00115	0.00200
1 3/8-6 or 1.375-6	UNC	1A	0.00346	0.00600	1B	0.00447	0.00775
		2A	0.00231	0.00400	2B	0.00300	0.00520
		3A	0.00173	0.00300	3B	0.00225	0.00390
1 3/8-8 or 1.375-8	UN	2A	0.00208	0.00360	2B	0.00268	0.00465
		3A	0.00156	0.00270	3B	0.00202	0.00350

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)
(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/In.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
1⅜-12 or 1.375-12	UNF	1A	0.00271	0.00470	1B	0.00355	0.00615
		2A	0.00182	0.00315	2B	0.00237	0.00410
		3A	0.00136	0.00235	3B	0.00176	0.00305
1⅜-16 or 1.375-16	UN	2A	0.00147	0.00255	2B	0.00191	0.00330
		3A	0.00110	0.00190	3B	0.00144	0.00250
1⅜-18 or 1.375-18	UNEF	2A	0.00141	0.00245	2B	0.00182	0.00315
		3A	0.00104	0.00180	3B	0.00136	0.00235
1⅜-20 or 1.375-20	UN	2A	0.00136	0.00235	2B	0.00176	0.00305
		3A	0.00101	0.00175	3B	0.00130	0.00225
1⅜-28 or 1.375-28	UN	2A	0.00118	0.00205	2B	0.00153	0.00265
		3A	0.00089	0.00155	3B	0.00115	0.00200
1⁷⁄₁₆-6 or 1.4375-6	UN	2A	0.00231	0.00400	2B	0.00300	0.00520
		3A	0.00173	0.00300	3B	0.00225	0.00390
1⁷⁄₁₆-8 or 1.4375-8	UN	2A	0.00208	0.00360	2B	0.00271	0.00470
		3A	0.00156	0.00270	3B	0.00205	0.00355
1⁷⁄₁₆-12 or 1.4375-12	UN	2A	0.00170	0.00295	2B	0.00219	0.00380
		3A	0.00127	0.00220	3B	0.00165	0.00285
1⁷⁄₁₆-16 or 1.4375-16	UN	2A	0.00150	0.00260	2B	0.00196	0.00340
		3A	0.00113	0.00195	3B	0.00147	0.00255
1⁷⁄₁₆-18 or 1.4375-18	UNEF	2A	0.00144	0.00250	2B	0.00188	0.00325
		3A	0.00107	0.00185	3B	0.00139	0.00240
1⁷⁄₁₆-20 or 1.4375-20	UN	2A	0.00139	0.00240	2B	0.00179	0.00310
		3A	0.00104	0.00180	3B	0.00133	0.00230
1⁷⁄₁₆-28 or 1.4375-28	UN	2A	0.00121	0.00210	2B	0.00159	0.00275
		3A	0.00089	0.00155	3B	0.00118	0.00205
1½-6 or 1.500-6	UNC	1A	0.00349	0.00605	1B	0.00456	0.00790
		2A	0.00234	0.00405	2B	0.00303	0.00525
		3A	0.00176	0.00305	3B	0.00228	0.00305
1½-8 or 1.500-8	UN	2A	0.00211	0.00365	2B	0.00274	0.00475
		3A	0.00159	0.00275	3B	0.00205	0.00355
1½-12 or 1.500-12	UNF	1A	0.00277	0.00480	1B	0.00361	0.00625
		2A	0.00185	0.00320	2B	0.00240	0.00415
		3A	0.00139	0.00240	3B	0.00182	0.00315
1½-16 or 1.500-16	UN	2A	0.00150	0.00260	2B	0.00196	0.00340
		3A	0.00113	0.00195	3B	0.00147	0.00255

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
1½-18 or 1.500-18	UNEF	2A	0.00144	0.00250	2B	0.00188	0.00325
		3A	0.00107	0.00185	3B	0.00139	0.00240
1½-20 or 1.500-20	UN	2A	0.00139	0.00240	2B	0.00179	0.00310
		3A	0.00104	0.00180	3B	0.00133	0.00230
1½-28 or 1.500-28	UN	2A	0.00121	0.00210	2B	0.00159	0.00275
		3A	0.00089	0.00155	3B	0.00118	0.00205
1 9/16-6 or 1.5625-6	UN	2A	0.00237	0.00410	2B	0.00306	0.00530
		3A	0.00176	0.00305	3B	0.00231	0.00400
1 9/16-8 or 1.5625-8	UN	2A	0.00214	0.00370	2B	0.00277	0.00480
		3A	0.00159	0.00275	3B	0.00208	0.00360
1 9/16-12 or 1.5625-12	UN	2A	0.00170	0.00295	2B	0.00219	0.00380
		3A	0.00127	0.00220	3B	0.00165	0.00285
1 9/16-16 or 1.5625-16	UN	2A	0.00150	0.00260	2B	0.00196	0.00340
		3A	0.00113	0.00195	3B	0.00147	0.00255
1 9/16-18 or 1.5625-18	UNEF	2A	0.00144	0.00250	2B	0.00188	0.00325
		3A	0.00107	0.00185	3B	0.00139	0.00240
1 9/16-20 or 1.5625-20	UN	2A	0.00139	0.00240	2B	0.00179	0.00310
		3A	0.00104	0.00180	3B	0.00133	0.00230
1⅝-6 or 1.625-6	UN	2A	0.00237	0.00410	2B	0.00309	0.00535
		3A	0.00179	0.00310	3B	0.00231	0.00400
1⅝-8 or 1.625-8	UN	2A	0.00214	0.00370	2B	0.00280	0.00485
		3A	0.00162	0.00280	3B	0.00208	0.00360
1⅝-12 or 1.625-12	UN	2A	0.00170	0.00295	2B	0.00219	0.00380
		3A	0.00127	0.00220	3B	0.00165	0.00285
1⅝-16 or 1.625-16	UN	2A	0.00150	0.00260	2B	0.00196	0.00340
		3A	0.00113	0.00195	3B	0.00147	0.00255
1⅝-18 or 1.625-18	UNEF	2A	0.00144	0.00250	2B	0.00188	0.00325
		3A	0.00107	0.00185	3B	0.00130	0.00240
1⅝-20 or 1.625-20	UN	2A	0.00139	0.00240	2B	0.00179	0.00310
		3A	0.00104	0.00180	3B	0.00133	0.00230
1 11/16-6 or 1.6875-6	UN	2A	0.00240	0.00415	2B	0.00312	0.00540
		3A	0.00179	0.00310	3B	0.00234	0.00405
1 11/16-8 or 1.6875-8	UN	2A	0.00217	0.00375	2B	0.00280	0.00485
		3A	0.00162	0.00280	3B	0.00211	0.00365

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
1 11/16-12 or 1.6875-12	UN	2A	0.00173	0.00300	2B	0.00225	0.00390
		3A	0.00130	0.00225	3B	0.00167	0.00290
1 11/16-16 or 1.6875-16	UN	2A	0.00153	0.00265	2B	0.00199	0.00345
		3A	0.00115	0.00200	3B	0.00150	0.00260
1 11/16-18 or 1.6875-18	UNEF	2A	0.00147	0.00255	2B	0.00191	0.00330
		3A	0.00110	0.00190	3B	0.00141	0.00245
1 11/16-20 or 1.6875-20	UN	2A	0.00139	0.00240	2B	0.00182	0.00315
		3A	0.00104	0.00180	3B	0.00136	0.00235
1 3/4-5 or 1.750-5	UNC	1A	0.00387	0.00670	1B	0.00502	0.00870
		2A	0.00257	0.00445	2B	0.00335	0.00580
		3A	0.00193	0.00335	3B	0.00251	0.00435
1 3/4-6 or 1.750-6	UN	2A	0.00240	0.00415	2B	0.00312	0.00540
		3A	0.00182	0.00315	3B	0.00234	0.00405
1 3/4-8 or 1.750-8	UN	2A	0.00217	0.00375	2B	0.00283	0.00490
		3A	0.00165	0.00285	3B	0.00214	0.00370
1 3/4-12 or 1.750-12	UN	2A	0.00173	0.00300	2B	0.00225	0.00390
		3A	0.00130	0.00225	3B	0.00167	0.00290
1 3/4-16 or 1.750-16	UN	2A	0.00153	0.00265	2B	0.00199	0.00345
		3A	0.00115	0.00200	3B	0.00150	0.00260
1 3/4-20 or 1.750-20	UN	2A	0.00139	0.00240	2B	0.00182	0.00315
		3A	0.00104	0.00180	3B	0.00136	0.00235
1 13/16-6 or 1.8125-6	UN	2A	0.00242	0.00420	2B	0.00315	0.00545
		3A	0.00182	0.00315	3B	0.00237	0.00410
1 13/16-8 or 1.8125-8	UN	2A	0.00219	0.00380	2B	0.00286	0.00495
		3A	0.00165	0.00285	3B	0.00214	0.00370
1 13/16-12 or 1.8125-12	UN	2A	0.00173	0.00300	2B	0.00225	0.00390
		3A	0.00130	0.00225	3B	0.00167	0.00290
1 13/16-16 or 1.8125-16	UN	2A	0.00153	0.00265	2B	0.00199	0.00345
		3A	0.00115	0.00200	3B	0.00150	0.00260
1 13/16-20 or 1.8125-20	UN	2A	0.00139	0.00240	2B	0.00182	0.00315
		3A	0.00104	0.00180	3B	0.00136	0.00235
1 7/8-6 or 1.875-6	UN	2A	0.00242	0.00420	2B	0.00318	0.00550
		3A	0.00182	0.00315	3B	0.00237	0.00410

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/In.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
1⅞-8 or 1.875-8	UN	2A	0.00222	0.00385	2B	0.00289	0.00500
		3A	0.00165	0.00285	3B	0.00217	0.00375
1⅞-12 or 1.875-12	UN	2A	0.00173	0.00300	2B	0.00225	0.00390
		3A	0.00130	0.00225	3B	0.00167	0.00290
1⅞-16 or 1.875-16	UN	2A	0.00153	0.00265	2B	0.00199	0.00345
		3A	0.00115	0.00200	3B	0.00150	0.00260
1⅞-20 or 1.875-20	UN	2A	0.00139	0.00240	2B	0.00182	0.00315
		3A	0.00104	0.00180	3B	0.00136	0.00235
1 15/16-6 or 1.9375-6	UN	2A	0.00245	0.00425	2B	0.00320	0.00555
		3A	0.00185	0.00320	3B	0.00240	0.00415
1 15/16-8 or 1.9375-8	UN	2A	0.00222	0.00385	2B	0.00289	0.00500
		3A	0.00167	0.00290	3B	0.00217	0.00375
1 15/16-12 or 1.9375-12	UN	2A	0.00176	0.00305	2B	0.00228	0.00395
		3A	0.00130	0.00225	3B	0.00170	0.00295
1 15/16-16 or 1.9375-16	UN	2A	0.00156	0.00270	2B	0.00202	0.00350
		3A	0.00115	0.00200	3B	0.00150	0.00260
1 15/16-20 or 1.9375-20	UN	2A	0.00141	0.00245	2B	0.00185	0.00320
		3A	0.00107	0.00185	3B	0.00139	0.00240
2-4½ or 2.000-4.5	UNC	1A	0.00413	0.00715	1B	0.00537	0.00930
		2A	0.00274	0.00475	2B	0.00358	0.00620
		3A	0.00205	0.00355	3B	0.00268	0.00465
2-6 or 2.000-6	UN	2A	0.00248	0.00430	2B	0.00320	0.00555
		3A	0.00185	0.00320	3B	0.00240	0.00415
2-8 or 2.000-8	UN	2A	0.00225	0.00390	2B	0.00292	0.00505
		3A	0.00167	0.00290	3B	0.00219	0.00380
2-12 or 2.000-12	UN	2A	0.00176	0.00305	2B	0.00223	0.00395
		3A	0.00130	0.00225	3B	0.00170	0.00295
2-16 or 2.000-16	UN	2A	0.00156	0.00270	2B	0.00202	0.00350
		3A	0.00115	0.00200	3B	0.00150	0.00260
2-20 or 2.000-20	UN	2A	0.00141	0.00245	2B	0.00185	0.00320
		3A	0.00107	0.00185	3B	0.00139	0.00240
2⅛-6 or 2.125-6	UN	2A	0.00251	0.00435	2B	0.00326	0.00565
		3A	0.00188	0.00325	3B	0.00242	0.00420

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
2⅛-8 or 2.125-8	UN	2A	0.00228	0.00395	2B	0.00294	0.00510
		3A	0.00170	0.00295	3B	0.00212	0.00385
2⅛-12 or 2.125-12	UN	2A	0.00176	0.00305	2B	0.00228	0.00395
		3A	0.00130	0.00225	3B	0.00170	0.00295
2⅛-16 or 2.125-16	UN	2A	0.00156	0.00270	2B	0.00202	0.00350
		3A	0.00115	0.00200	3B	0.00150	0.00260
2⅛-20 or 2.125-20	UN	2A	0.00141	0.00245	2B	0.00185	0.00320
		3A	0.00107	0.00185	3B	0.00139	0.00240
2¼-4½ or 2.250-4.5	UNC	1A	0.00421	0.00730	1B	0.00548	0.00950
		2A	0.00280	0.00485	2B	0.00364	0.00630
		3A	0.00211	0.00365	3B	0.00274	0.00475
2¼-6 or 2.250-6	UN	2A	0.00254	0.00440	2B	0.00329	0.00570
		3A	0.00191	0.00330	3B	0.00214	0.00425
2¼-8 or 2.250-8	UN	2A	0.00231	0.00400	2B	0.00300	0.00520
		3A	0.00173	0.00300	3B	0.00225	0.00390
2¼-12 or 2.250-12	UN	2A	0.00176	0.00305	2B	0.00228	0.00395
		3A	0.00130	0.00225	3B	0.00170	0.00295
2¼-16 or 2.250-16	UN	2A	0.00156	0.00270	2B	0.00202	0.00350
		3A	0.00115	0.00200	3B	0.00150	0.00260
2¼-20 or 2.250-20	UN	2A	0.00141	0.00245	2B	0.00185	0.00320
		3A	0.00107	0.00185	3B	0.00139	0.00240
2⅜-6 or 2.375-6	UN	2A	0.00257	0.00445	2B	0.00332	0.00575
		3A	0.00191	0.00330	3B	0.00248	0.00430
2⅜-8 or 2.375-8	UN	2A	0.00234	0.00405	2B	0.00303	0.00525
		3A	0.00173	0.00300	3B	0.00228	0.00395
2⅜-12 or 2.375-12	UN	2A	0.00179	0.00310	2B	0.00234	0.00405
		3A	0.00133	0.00230	3B	0.00173	0.00300
2⅜-16 or 2.375-16	UN	2A	0.00159	0.00275	2B	0.00208	0.00360
		3A	0.00118	0.00205	3B	0.00155	0.00270
2⅜-20 or 2.375-20	UN	2A	0.00147	0.00255	2B	0.00191	0.00330
		3A	0.00110	0.00190	3B	0.00144	0.00250
2½-4 or 2.500-4	UNC	1A	0.00447	0.00775	1B	0.00583	0.01010
		2A	0.00300	0.00520	2B	0.00390	0.00675
		3A	0.00225	0.00390	3B	0.00292	0.00505

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
2½-6 or 2.500-6	UN	2A	0.00260	0.00450	2B	0.00335	0.00580
		3A	0.00193	0.00335	3B	0.00251	0.00435
2½-8 or 2.500-8	UN	2A	0.00237	0.00410	2B	0.00306	0.00530
		3A	0.00176	0.00305	3B	0.00231	0.00400
2½-12 or 2.500-12	UN	2A	0.00179	0.00310	2B	0.00234	0.00405
		3A	0.00133	0.00230	3B	0.00173	0.00300
2½-16 or 2.500-16	UN	2A	0.00159	0.00275	2B	0.00208	0.00360
		3A	0.00118	0.00205	3B	0.00156	0.00270
2½-20 or 2.500-20	UN	2A	0.00147	0.00255	2B	0.00191	0.00330
		3A	0.00110	0.00190	3B	0.00144	0.00250
2⅝-6 or 2.625-6	UN	2A	0.00260	0.00450	2B	0.00341	0.00590
		3A	0.00196	0.00340	3B	0.00254	0.00440
2⅝-8 or 2.625-8	UN	2A	0.00237	0.00410	2B	0.00309	0.00535
		3A	0.00179	0.00310	3B	0.00231	0.00400
2⅝-12 or 2.625-12	UN	2A	0.00179	0.00310	2B	0.00234	0.00405
		3A	0.00133	0.00230	3B	0.00173	0.00300
2⅝-16 or 2.625-16	UN	2A	0.00159	0.00275	2B	0.00208	0.00360
		3A	0.00118	0.00205	3B	0.00156	0.00270
2⅝-20 or 2.625-20	UN	2A	0.00147	0.00255	2B	0.00191	0.00330
		3A	0.00110	0.00190	3B	0.00144	0.00250
2¾-4 or 2.750-4	UNC	1A	0.00456	0.00790	1B	0.00595	0.01030
		2A	0.00303	0.00525	2B	0.00395	0.00685
		3A	0.00228	0.00395	3B	0.00297	0.00515
2¾-6 or 2.750-6	UN	2A	0.00263	0.00455	2B	0.00344	0.00595
		3A	0.00196	0.00340	3B	0.00257	0.00445
2¾-8 or 2.750-8	UN	2A	0.00240	0.00415	2B	0.00312	0.00540
		3A	0.00182	0.00315	3B	0.00234	0.00405
2¾-12 or 2.750-12	UN	2A	0.00179	0.00310	2B	0.00234	0.00405
		3A	0.00133	0.00230	3B	0.00173	0.00300
2¾-16 or 2.750-16	UN	2A	0.00159	0.00275	2B	0.00208	0.00360
		3A	0.00118	0.00205	3B	0.00156	0.00270
2¾-20 or 2.750-20	UN	2A	0.00147	0.00255	2B	0.00191	0.00330
		3A	0.00110	0.00190	3B	0.00144	0.00250

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
2⅞-6 or 2.875-6	UN	2A	0.00266	0.00460	2B	0.00346	0.00600
		3A	0.00199	0.00345	3B	0.00280	0.00450
2⅞-8 or 2.875-8	UN	2A	0.00242	0.00420	2B	0.00318	0.00550
		3A	0.00182	0.00315	3B	0.00237	0.00410
2⅞-12 or 2.875-12	UN	2A	0.00182	0.00315	2B	0.00237	0.00410
		3A	0.00136	0.00235	3B	0.00179	0.00310
2⅞-16 or 2.875-16	UN	2A	0.00162	0.00280	2B	0.00211	0.00365
		3A	0.00121	0.00210	3B	0.00159	0.00275
2⅞-20 or 2.875-20	UN	2A	0.00150	0.00260	2B	0.00196	0.00340
		3A	0.00113	0.00195	3B	0.00147	0.00255
3-4 or 3.000-4	UNC	1A	0.00465	0.00805	1B	0.00603	0.01045
		2A	0.00309	0.00535	2B	0.00401	0.00695
		3A	0.00231	0.00400	3B	0.00300	0.00520
3-6 or 3.000-6	UN	2A	0.00268	0.00465	2B	0.00349	0.00605
		3A	0.00202	0.00350	3B	0.00263	0.00455
3-8 or 3.000-8	UN	2A	0.00245	0.00425	2B	0.00320	0.00555
		3A	0.00185	0.00320	3B	0.00240	0.00415
3-12 or 3.000-12	UN	2A	0.00182	0.00315	2B	0.00237	0.00410
		3A	0.00136	0.00235	3B	0.00179	0.00310
3-16 or 3.000-16	UN	2A	0.00162	0.00280	2B	0.00211	0.00365
		3A	0.00121	0.00210	3B	0.00159	0.00275
3-20 or 3.000-20	UN	2A	0.00150	0.00260	2B	0.00196	0.00340
		3A	0.00113	0.00195	3B	0.00147	0.00255
3⅛-6 or 3.125-6	UN	2A	0.00271	0.00470	2B	0.00352	0.00610
		3A	0.00202	0.00350	3B	0.00266	0.00460
3⅛-8 or 3.125-8	UN	2A	0.00248	0.00430	2B	0.00323	0.00560
		3A	0.00185	0.00320	3B	0.00242	0.00420
3⅛-12 or 3.125-12	UN	2A	0.00182	0.00315	2B	0.00237	0.00410
		3A	0.00136	0.00235	3B	0.00179	0.00310
3⅛-16 or 3.125-16	UN	2A	0.00162	0.00280	2B	0.00211	0.00365
		3A	0.00121	0.00210	3B	0.00159	0.00275
3¼-4 or 3.250-4	UNC	1A	0.00471	0.00815	1B	0.00612	0.01060
		2A	0.00315	0.00545	2B	0.00407	0.00705
		3A	0.00237	0.00410	3B	0.00306	0.00530

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)
(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
3¼-6 or 3.250-6	UN	2A 3A	0.00274 0.00205	0.00475 0.00355	2B 3B	0.00355 0.00266	0.00615 0.00460
3¼-8 or 3.250-8	UN	2A 3A	0.00251 0.00188	0.00435 0.00325	2B 3B	0.00326 0.00245	0.00565 0.00425
3¼-12 or 3.250-12	UN	2A 3A	0.00182 0.00136	0.00315 0.00235	2B 3B	0.00237 0.00179	0.00410 0.00310
3¼-16 or 3.250-16	UN	2A 3A	0.00162 0.00121	0.00280 0.00210	2B 3B	0.00211 0.00159	0.00365 0.00275
3⅜-6 or 3.375-6	UN	2A 3A	0.00274 0.00208	0.00475 0.00360	2B 3B	0.00358 0.00258	0.00620 0.00465
3⅜-8 or 3.375-8	UN	2A 3A	0.00254 0.00191	0.00440 0.00330	2B 3B	0.00329 0.00245	0.00570 0.00425
3⅜-12 or 3.375-12	UN	2A 3A	0.00185 0.00139	0.00320 0.00242	2B 3B	0.00242 0.00182	0.00420 0.00315
3⅜-16 or 3.375-16	UN	2A 3A	0.00167 0.00124	0.00290 0.00215	2B 3B	0.00217 0.00162	0.00375 0.00280
3½-4 or 3.500-4	UNC	1A 2A 3A	0.00479 0.00318 0.00240	0.00830 0.00550 0.00415	1B 2B 3B	0.00621 0.00413 0.00312	0.01075 0.00715 0.00540
3½-6 or 3.500-6	UN	2A 3A	0.00277 0.00208	0.00480 0.00360	2B 3B	0.00361 0.00271	0.00625 0.00470
3½-8 or 3.500-8	UN	2A 3A	0.00254 0.00191	0.00440 0.00330	2B 3B	0.00332 0.00248	0.00575 0.00430
3½-12 or 3.500-12	UN	2A 3A	0.00185 0.00139	0.00320 0.00240	2B 3B	0.00242 0.00182	0.00420 0.00315
3½-16 or 3.500-16	UN	2A 3A	0.00167 0.00124	0.00290 0.00215	2B 3B	0.00217 0.00162	0.00375 0.00280
3⅝-6 or 3.625-6	UN	2A 3A	0.00280 0.00211	0.00485 0.00365	2B 3B	0.00364 0.00274	0.00630 0.00475
3⅝-8 or 3.625-8	UN	2A 3A	0.00257 0.00193	0.00445 0.00335	2B 3B	0.00335 0.00251	0.00580 0.00435
3⅝-12 or 3.625-12	UN	2A 3A	0.00185 0.00139	0.00320 0.00240	2B 3B	0.00242 0.00182	0.00420 0.00315

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
3⅝-16 or 3.625-16	UN	2A	0.00167	0.00290	2B	0.00217	0.00375
		3A	0.00124	0.00215	3B	0.00162	0.00280
3¾-4 or 3.750-4	UNC	1A	0.00485	0.00840	1B	0.00629	0.01090
		2A	0.00323	0.00560	2B	0.00419	0.00725
		3A	0.00242	0.00420	3B	0.00315	0.00545
3¾-6 or 3.750-6	UN	2A	0.00283	0.00490	2B	0.00367	0.00635
		3A	0.00211	0.00365	3B	0.00274	0.00475
3¾-8 or 3.750-8	UN	2A	0.00260	0.00450	2B	0.00338	0.00585
		3A	0.00193	0.00335	3B	0.00254	0.00440
3¾-12 or 3.750-12	UN	2A	0.00185	0.00320	2B	0.00242	0.00420
		3A	0.00139	0.00240	3B	0.00182	0.00315
3¾-16 or 3.750-16	UN	2A	0.00167	0.00290	2B	0.00217	0.00375
		3A	0.00124	0.00215	3B	0.00162	0.00280
3⅞-6 or 3.875-6	UN	2A	0.00286	0.00495	2B	0.00369	0.00640
		3A	0.00214	0.00370	3B	0.00277	0.00480
3⅞-8 or 3.875-8	UN	2A	0.00263	0.00455	2B	0.00341	0.00590
		3A	0.00196	0.00340	3B	0.00254	0.00440
3⅞-12 or 3.875-12	UN	2A	0.00188	0.00325	2B	0.00245	0.00425
		3A	0.00141	0.00245	3B	0.00185	0.00320
3⅞-16 or 3.875-16	UN	2A	0.00170	0.00295	2B	0.00219	0.00380
		3A	0.00127	0.00220	3B	0.00165	0.00285
4-4 or 4.000-4	UNC	1A	0.00491	0.00850	1B	0.00638	0.01105
		2A	0.00326	0.00565	2B	0.00424	0.00735
		3A	0.00245	0.00425	3B	0.00320	0.00555
4-6 or 4.000-6	UN	2A	0.00286	0.00495	2B	0.00372	0.00645
		3A	0.00214	0.00370	3B	0.00280	0.00485
4-8 or 4.000-8	UN	2A	0.00263	0.00455	2B	0.00344	0.00595
		3A	0.00196	0.00340	3B	0.00257	0.00445
4-12 or 4.000-12	UN	2A	0.00188	0.00325	2B	0.00245	0.00425
		3A	0.00141	0.00245	3B	0.00185	0.00320
4-16 or 4.000-16	UN	2A	0.00170	0.00295	2B	0.00219	0.00380
		3A	0.00127	0.00220	3B	0.00165	0.00285
4⅛-6 or 4.125-6	UN	2A	0.00289	0.00500	2B	0.00375	0.00650
		3A	0.00217	0.00375	3B	0.00280	0.00485

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)
(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
4⅛-8 or 4.125-8	UN	2A	0.00266	0.00460	2B	0.00346	0.00600
		3A	0.00199	0.00345	3B	0.00260	0.00450
4⅛-12 or 4.125-12	UN	2A	0.00188	0.00325	2B	0.00245	0.00425
		3A	0.00141	0.00245	3B	0.00185	0.00320
4⅛-16 or 4.125-16	UN	2A	0.00170	0.00295	2B	0.00219	0.00380
		3A	0.00127	0.00220	3B	0.00165	0.00285
4¼-4 or 4.250-4	UN	2A	0.00332	0.00575	2B	0.00430	0.00745
		3A	0.00248	0.00430	3B	0.00323	0.00560
4¼-6 or 4.250-6	UN	2A	0.00292	0.00505	2B	0.00378	0.00655
		3A	0.00217	0.00375	3B	0.00283	0.00490
4¼-8 or 4.250-8	UN	2A	0.00268	0.00465	2B	0.00346	0.00600
		3A	0.00202	0.00350	3B	0.00263	0.00455
4¼-12 or 4.250-12	UN	2A	0.00188	0.00325	2B	0.00245	0.00425
		3A	0.00141	0.00245	3B	0.00185	0.00320
4¼-16 or 4.250-16	UN	2A	0.00170	0.00295	2B	0.00219	0.00380
		3A	0.00127	0.00220	3B	0.00165	0.00285
4⅜-6 or 4.375-6	UN	2A	0.00292	0.00505	2B	0.00381	0.00660
		3A	0.00219	0.00380	3B	0.00286	0.00495
4⅜-8 or 4.375-8	UN	2A	0.00268	0.00465	2B	0.00346	0.00600
		3A	0.00202	0.00350	3B	0.00263	0.00455
4⅜-12 or 4.375-12	UN	2A	0.00188	0.00325	2B	0.00245	0.00425
		3A	0.00141	0.00245	3B	0.00185	0.00320
4⅜-16 or 4.375-16	UN	2A	0.00170	0.00295	2B	0.00219	0.00380
		3A	0.00127	0.00220	3B	0.00165	0.00285
4½-4 or 4.500-4	UN	2A	0.00335	0.00580	2B	0.00436	0.00755
		3A	0.00251	0.00435	3B	0.00326	0.00565
4½-6 or 4.500-6	UN	2A	0.00294	0.00510	2B	0.00384	0.00665
		3A	0.00222	0.00385	3B	0.00286	0.00495
4½-8 or 4.500-8	UN	2A	0.00271	0.00470	2B	0.00352	0.00610
		3A	0.00205	0.00355	3B	0.00266	0.00460
4½-12 or 4.500-12	UN	2A	0.00188	0.00325	2B	0.00245	0.00425
		3A	0.00141	0.00245	3B	0.00185	0.00320
4½-16 or 4.500-16	UN	2A	0.00170	0.00295	2B	0.00219	0.00380
		3A	0.00127	0.00220	3B	0.00165	0.00285

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
4⅝-6 or 4.625-6	UN	2A 3A	0.00297 0.00222	0.00515 0.00385	2B 3B	0.00384 0.00289	0.00665 0.00500
4⅝-8 or 4.625-8	UN	2A 3A	0.00274 0.00205	0.00475 0.00355	2B 3B	0.00358 0.00268	0.00620 0.00465
4⅝-12 or 4.625-12	UN	2A 3A	0.00193 0.00144	0.00335 0.00250	2B 3B	0.00251 0.00191	0.00435 0.00330
4⅝-16 or 4.625-16	UN	2A 3A	0.00176 0.00130	0.00305 0.00225	2B 3B	0.00228 0.00170	0.00395 0.00295
4¾-4 or 4.750-4	UN	2A 3A	0.00338 0.00254	0.00585 0.00440	2B 3B	0.00442 0.00329	0.00765 0.00570
4¾-6 or 4.750-6	UN	2A 3A	0.00297 0.00222	0.00515 0.00385	2B 3B	0.00387 0.00292	0.00670 0.00505
4¾-8 or 4.750-8	UN	2A 3A	0.00274 0.00205	0.00475 0.00355	2B 3B	0.00358 0.00268	0.00620 0.00465
4¾-12 or 4.750-12	UN	2A 3A	0.00193 0.00144	0.00335 0.00250	2B 3B	0.00251 0.00191	0.00435 0.00330
4¾-16 or 4.750-16	UN	2A 3A	0.00176 0.00130	0.00305 0.00225	2B 3B	0.00228 0.00170	0.00395 0.00295
4⅞-6 or 4.875-6	UN	2A 3A	0.00300 0.00225	0.00520 0.00390	2B 3B	0.00390 0.00292	0.00675 0.00505
4⅞-8 or 4.875-8	UN	2A 3A	0.00277 0.00208	0.00480 0.00360	2B 3B	0.00361 0.00271	0.00625 0.00470
4⅞-12 or 4.875-12	UN	2A 3A	0.00193 0.00144	0.00335 0.00250	2B 3B	0.00251 0.00101	0.00435 0.00330
4⅞-16 or 4.875-16	UN	2A 3A	0.00176 0.00130	0.00305 0.00225	2B 3B	0.00228 0.00170	0.00395 0.00295
5-4 or 5.000-4	UN	2A 3A	0.00344 0.00257	0.00595 0.00445	2B 3B	0.00445 0.00335	0.00770 0.00580
5-6 or 5.000-6	UN	2A 3A	0.00303 0.00225	0.00525 0.00390	2B 3B	0.00393 0.00294	0.00680 0.00510
5-8 or 5.000-8	UN	2A 3A	0.00280 0.00211	0.00485 0.00365	2B 3B	0.00364 0.00274	0.00630 0.00475
5-12 or 5.000-12	UN	2A 3A	0.00193 0.00144	0.00335 0.00250	2B 3B	0.00251 0.00191	0.00435 0.00330

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
5-16 or 5.000-16	UN	2A 3A	0.00176 0.00130	0.00305 0.00225	2B 3B	0.00228 0.00170	0.00305 0.00295
5⅛-8 or 5.125-8	UN	2A 3A	0.00280 0.00211	0.00485 0.00365	2B 3B	0.00364 0.00274	0.00630 0.00475
5⅛-12 or 5.125-12	UN	2A 3A	0.00193 0.00144	0.00335 0.00250	2B 3B	0.00251 0.00191	0.00435 0.00330
5⅛-16 or 5.125-16	UN	2A 3A	0.00176 0.00130	0.00305 0.00225	2B 3B	0.00228 0.00170	0.00395 0.00295
5¼-4 or 5.250-4	UN	2A 3A	0.00346 0.00260	0.00600 0.00450	2B 3B	0.00450 0.00385	0.00780 0.00585
5¼-8 or 5.250-8	UN	2A 3A	0.00283 0.00214	0.00490 0.00370	2B 3B	0.00367 0.00277	0.00635 0.00480
5¼-12 or 5.250-12	UN	2A 3A	0.00193 0.00144	0.00335 0.00250	2B 3B	0.00251 0.00191	0.00435 0.00330
5¼-16 or 5.250-16	UN	2A 3A	0.00176 0.00130	0.00305 0.00225	2B 3B	0.00228 0.00170	0.00395 0.00295
5⅜-8 or 5.375-8	UN	2A 3A	0.00286 0.00214	0.00495 0.00370	2B 3B	0.00372 0.00280	0.00645 0.00485
5⅜-12 or 5.375-12	UN	2A 3A	0.00193 0.00144	0.00335 0.00250	2B 3B	0.00251 0.00191	0.00435 0.00330
5⅜-16 or 5.375-16	UN	2A 3A	0.00176 0.00130	0.00305 0.00225	2B 3B	0.00231 0.00170	0.00395 0.00295
5½-4 or 5.500-4	UN	2A 3A	0.00349 0.00263	0.00605 0.00455	2B 3B	0.00456 0.00341	0.00790 0.00500
5½-8 or 5.500-8	UN	2A 3A	0.00286 0.00214	0.00495 0.00370	2B 3B	0.00372 0.00280	0.00645 0.00485
5½-12 or 5.500-12	UN	2A 3A	0.00193 0.00144	0.00335 0.00250	2B 3B	0.00251 0.00191	0.00435 0.00330
5½-16 or 5.500-16	UN	2A 3A	0.00176 0.00130	0.00305 0.00225	2B 3B	0.00228 0.00170	0.00395 0.00295
5⅝-8 or 5.625-8	UN	2A 3A	0.00289 0.00217	0.00500 0.00375	2B 3B	0.00375 0.00283	0.00650 0.00490
5⅝-12 or 5.625-12	UN	2A 3A	0.00199 0.00150	0.00345 0.00260	2B 3B	0.00260 0.00193	0.00450 0.00335

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TABLE 4 ALLOWABLE VARIATIONS IN LEAD AND EQUIVALENT CHANGE IN FUNCTIONAL DIAMETER (CONT'D)

(See Paragraphs 9.1.3 Through 9.1.6 for Applicability)

Nominal Size and Threads/in.	Series Designation	External			Internal		
		Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter	Class	Allowable Variation in Lead	Equivalent Change in Functional Diameter
1	2	3	4, in. ±	5, in. +	6	7, in. ±	8, in. −
5⅝-16 or 5.625-16	UN	2A 3A	0.00179 0.00136	0.00310 0.00235	2B 3B	0.00234 0.00176	0.00405 0.00305
5¾-4 or 5.750-4	UN	2A 3A	0.00352 0.00266	0.00610 0.00460	2B 3B	0.00459 0.00344	0.00795 0.00595
5¾-8 or 5.750-8	UN	2A 3A	0.00289 0.00217	0.00500 0.00375	2B 3B	0.00375 0.00283	0.00650 0.00490
5¾-12 or 5.750-12	UN	2A 3A	0.00199 0.00150	0.00345 0.00260	2B 3B	0.00260 0.00193	0.00450 0.00335
5¾-16 or 5.750-16	UN	2A 3A	0.00179 0.00136	0.00310 0.00235	2B 3B	0.00234 0.00176	0.00405 0.00305
5⅞-8 or 5.875-8	UN	2A 3A	0.00292 0.00219	0.00505 0.00380	2B 3B	0.00378 0.00283	0.00655 0.00490
5⅞-12 or 5.875-12	UN	2A 3A	0.00199 0.00150	0.00345 0.00260	2B 3B	0.00260 0.00193	0.00450 0.00335
5⅞-16 or 5.875-16	UN	2A 3A	0.00179 0.00136	0.00310 0.00235	2B 3B	0.00234 0.00176	0.00405 0.00305
6-4 or 6.000-4	UN	2A 3A	0.00358 0.00268	0.00620 0.00465	2B 3B	0.00455 0.00346	0.00805 0.00600
6-8 or 6.000-8	UN	2A 3A	0.00294 0.00222	0.00510 0.00385	2B 3B	0.00384 0.00286	0.00665 0.00495
6-12 or 6.000-12	UN	2A 3A	0.00199 0.00150	0.00315 0.00260	2B 3B	0.00260 0.00193	0.00450 0.00335
6-16 or 6.000-16	UN	2A 3A	0.00179 0.00136	0.00310 0.00235	2B 3B	0.00234 0.00176	0.00405 0.00305

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TABLE 5 ALLOWABLE VARIATION IN 30 DEG. BASIC HALF ANGLE OF EXTERNAL AND INTERNAL SCREW THREADS

	Allowable Variation in Half Angle of Thread	
Threads/in.	±deg.	min
80	3	00
72	2	45
64	2	30
56	2	15
48	2	00
44	1	50
40	1	45
36	1	35
32	1	30
28	1	20
27	1	20
24	1	15
20	1	10
18	1	05
16	1	00
14	0	55
13	0	55
12	0	50
11½	0	50
11	0	50
10	0	50
9	0	50
8	0	45
7	0	45
6	0	40
5	0	40
4½	0	40
4	0	40

GENERAL NOTE:
See paras. 9.1.3 through 9.1.6 for applicability.

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10 FORMULAS AND SYMBOLS FOR THREAD FORM

10.1 Thread Form Formulas and Symbols

Formulas are given below; data are tabulated in Table 6.

The general symbols used are defined in Table 7 and application of the symbols is shown in Fig. 6. Angle of thread

$$2\alpha = 60 \text{ deg.}$$

Half angle of thread

$$\alpha = 30 \text{ deg.}$$

Number of threads/in. is $1/P$. Pitch of thread

$$P = 1/(\text{no. of threads/in.})$$

Height of sharp V-thread (fundamental triangle)

$$H = 0.866025P$$

Height of UNR external thread, design form

$$h_s = 0.59539P$$

$$= {}^{11}/_{16}H$$

Height of internal thread and UN external thread

$$h_s = h_n = 0.54127P$$

$$= {}^{5}/_{8}H$$

Height of thread engagement

$$h_s = 0.54127P$$

$$= {}^{5}/_{8}H$$

Flat at crest of external thread

$$F_{cs} = 0.125P = P/8$$

Truncation of external thread crest

$$f_{cs} = 0.10825P$$

$$= H/8$$

Truncation of UNR external thread (for calculating minor diameter values in tables)

$$S_{rs} = 0.16238P$$

$$= {}^{3}/_{16}H$$

Basic flat at crest of internal thread and root of external thread

$$F_{cn} = 0.25P = P/4$$

Truncation of internal thread crest

$$f_{cn} = 0.21651P$$

$$= H/4$$

Flat at root of internal thread

$$F_{rn} = 0.125P = P/8$$

Truncation of internal thread root

$$f_{rn} = 0.10825P$$

$$= H/8$$

Addendum of external thread

$$h_{as} = 0.32476P$$

$$= {}^{3}/_{8}H$$

Major diameter of external thread is d. Pitch diameter of external thread

$$d_2 = d - 2h_{as}$$

$$= d - 0.64952P$$

Minor diameter of UNR external thread

$$d_3 = d - 2h_s$$

$$= d - 1.19078P$$

Minor diameter of UN external thread

$$d_1 = d - 2h_s$$

$$= d - 1.08253P$$

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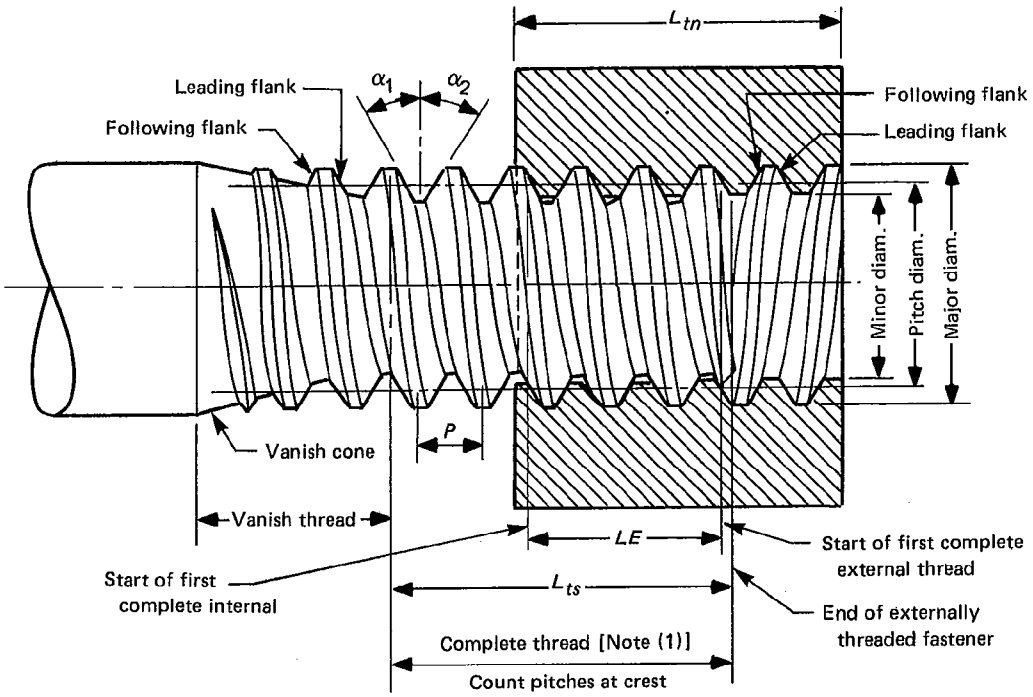
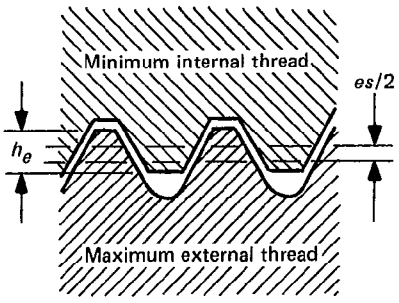
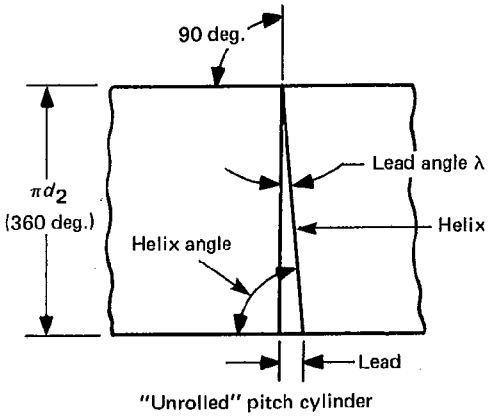




Thread With an Allowance



Lead and Helix Angles

NOTE:
(1) Portion of thread fully formed at crest and root.

FIG. 6 APPLICATION OF GENERAL THREAD SYMBOLS (See Table 6)

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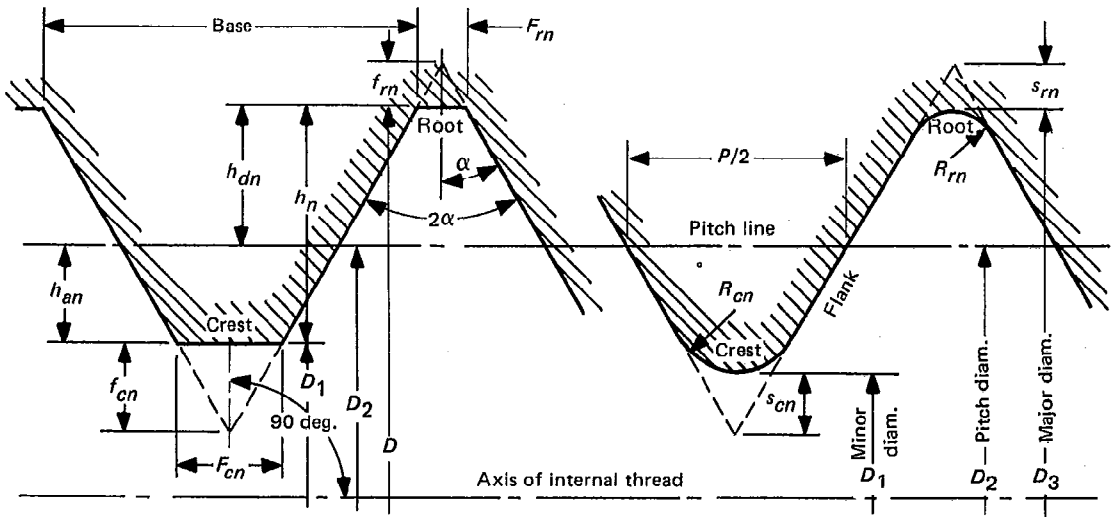
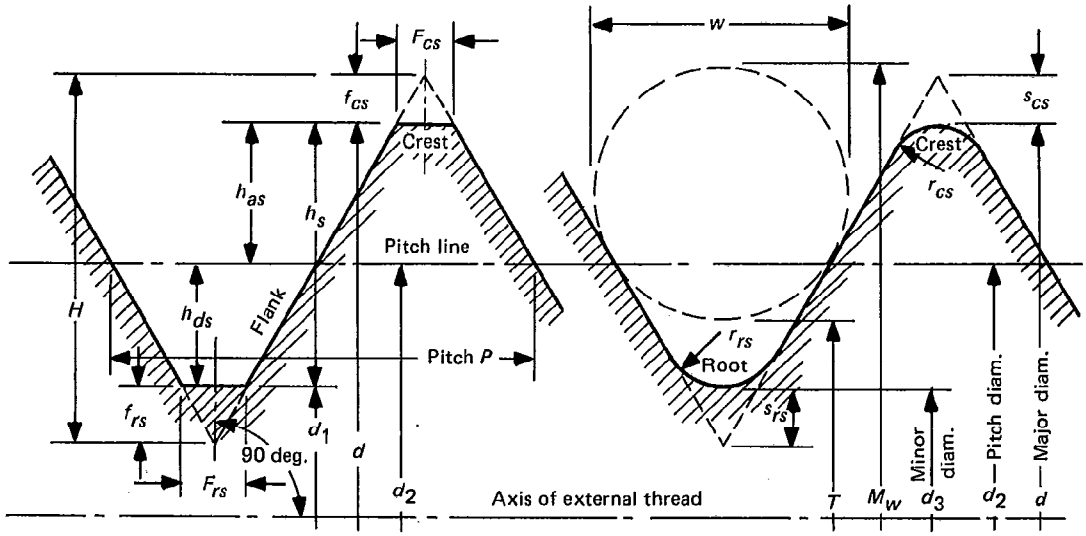


Internal Thread



External Thread

GENERAL NOTE:
These diagrams are not intended to show standard thread forms, but only to illustrate the application of symbols.

FIG. 6 APPLICATION OF GENERAL THREAD SYMBOLS (CONT'D)
(See Table 6)

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TABLE 6 THREAD FORM DATA

Threads/in.	Pitch P	Basic Flat at Internal Thread Crest, and External UN Thread Root, $F_{ts} = F_{cn} = P/4 = 0.25P$	Flat at Internal Thread Root and External Thread Crest, $F_{rn} = F_{cs} = P/8 = 0.125P$	Height of Sharp V-Thread, $H = 0.866025P$	Truncation of Internal Thread Root and External Thread Crest, $f_{rn} = f_{es} = 0.125H = 0.10825P$ (1)	External Thread Root Radius Max., $r_{rs} = 0.166667H = 0.14434P$	Truncation of UNR Design Profile External Thread Root and Half Addendum of External Thread, $S_{rs} = 0.1875H = 0.16238P$	External Thread Root and Truncation of Internal Thread Crest, $f_{rs} = f_{cn} = 0.250H = 0.21651P$ (2)
1	2	3	4	5	6	7	8	9
80	0.012500	0.00312	0.00156	0.010825	0.00135	0.00180	0.00203	0.00271
72	0.013889	0.00347	0.00174	0.012028	0.00150	0.00200	0.00226	0.00301
64	0.015625	0.00391	0.00195	0.013532	0.00169	0.00226	0.00254	0.00338
56	0.017857	0.00446	0.00223	0.015465	0.00193	0.00258	0.00290	0.00387
48	0.020833	0.00521	0.00260	0.018042	0.00226	0.00301	0.00338	0.00451
44	0.022727	0.00568	0.00284	0.019682	0.00246	0.00328	0.00369	0.00492
40	0.025000	0.00625	0.00312	0.021651	0.00271	0.00361	0.00406	0.00541
36	0.027778	0.00694	0.00347	0.024056	0.00301	0.00401	0.00451	0.00601
32	0.031250	0.00781	0.00391	0.027063	0.00338	0.00451	0.00507	0.00677
28	0.035714	0.00893	0.00446	0.030929	0.00387	0.00515	0.00580	0.00773
27	0.037037	0.00926	0.00463	0.032075	0.00401	0.00535	0.00601	0.00802
24	0.041667	0.01042	0.00521	0.036084	0.00451	0.00601	0.00677	0.00902
20	0.050000	0.01250	0.00625	0.043301	0.00541	0.00722	0.00812	0.01083
18	0.055556	0.01389	0.00694	0.048113	0.00601	0.00802	0.00902	0.01203
16	0.062500	0.01562	0.00781	0.054127	0.00677	0.00902	0.01015	0.01353
14	0.071429	0.01786	0.00893	0.061859	0.00773	0.01031	0.01160	0.01546
13	0.076923	0.01923	0.00962	0.066617	0.00833	0.01110	0.01249	0.01665
12	0.083333	0.02083	0.01042	0.072169	0.00902	0.01203	0.01353	0.01804
11½	0.086957	0.02174	0.01087	0.075307	0.00941	0.01255	0.01412	0.01883
11	0.090909	0.02273	0.01136	0.078730	0.00984	0.01312	0.01476	0.01968
10	0.100000	0.02500	0.01250	0.086603	0.01083	0.01443	0.01624	0.02165
9	0.111111	0.02778	0.01389	0.096225	0.01203	0.01604	0.01804	0.02406
8	0.125000	0.03125	0.01562	0.108253	0.01353	0.01804	0.02030	0.02706
7	0.142857	0.03571	0.01786	0.123718	0.01546	0.02062	0.02320	0.03093
6	0.166667	0.04167	0.02083	0.144338	0.01804	0.02406	0.02706	0.03608
5	0.200000	0.05000	0.02500	0.173205	0.02165	0.02887	0.03248	0.04330
4½	0.222222	0.05556	0.02778	0.192450	0.02406	0.03208	0.03608	0.04811
4	0.250000	0.06250	0.03125	0.216506	0.02706	0.03608	0.04059	0.05413

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TABLE 6 THREAD FORM DATA

Addendum of External Thread, h_{as} = 0.375H = 0.32476P (3)	Height of Internal Thread, UN External Thread, and Depth of Thread Engagement, $h_s = h_n = h_e$ = 0.625H = 0.54127P	Height of UNR External Thread, h_s = 0.6875H = 0.59539P	Twice the External Thread Addendum, $h_b = 2h_{as}$ = 0.750H = 0.649519P	Difference Between Max. Major and Pitch Diameters of Internal Thread, 0.916667H = 0.79386P	Double Height of Internal Thread and External UN Thread, $2h_n$ = 1.250H = 1.08253P	Double Height of External UNR Thread, $2h_s$ = 1.375H = 1.19078P	$H/2$ = 0.43301P	Threads/in.
10	11	12	13	14	15	16	17	1
0.00406	0.00677	0.00744	0.008119	0.00992	0.01353	0.01488	0.00541	80
0.00451	0.00752	0.00827	0.009021	0.01103	0.01504	0.01654	0.00601	72
0.00507	0.00846	0.00930	0.010149	0.01240	0.01691	0.01861	0.00677	64
0.00580	0.00967	0.01063	0.011599	0.01418	0.01933	0.02126	0.00773	56
0.00677	0.01128	0.01240	0.013532	0.01654	0.02255	0.02481	0.00902	48
0.00738	0.01230	0.01353	0.014762	0.01804	0.02460	0.02706	0.00984	44
0.00812	0.01353	0.01488	0.016238	0.01985	0.02706	0.02977	0.01083	40
0.00902	0.01504	0.01654	0.018042	0.02205	0.03007	0.03308	0.01203	36
0.01015	0.01691	0.01861	0.020297	0.02481	0.03383	0.03721	0.01353	32
0.01160	0.01933	0.02126	0.023197	0.02835	0.03866	0.04253	0.01546	28
0.01203	0.02005	0.02205	0.024056	0.02940	0.04009	0.04410	0.01604	27
0.01353	0.02255	0.02481	0.027063	0.03308	0.04511	0.04962	0.01804	24
0.01624	0.02706	0.02977	0.032476	0.03969	0.05413	0.05954	0.02165	20
0.01804	0.03007	0.03308	0.036084	0.04410	0.06014	0.06615	0.02406	18
0.02030	0.03383	0.03721	0.040595	0.04962	0.06766	0.07442	0.02706	16
0.02320	0.03866	0.04253	0.046394	0.05670	0.07732	0.08506	0.03093	14
0.02498	0.04164	0.04580	0.049963	0.06107	0.08327	0.09160	0.03331	13
0.02706	0.04511	0.04962	0.054127	0.06615	0.09021	0.09923	0.03608	12
0.02824	0.04707	0.05177	0.056480	0.06903	0.09413	0.10355	0.03765	11½
0.02952	0.04921	0.05413	0.059047	0.07217	0.09841	0.10825	0.03936	11
0.03248	0.05413	0.05954	0.064952	0.07939	0.10825	0.11908	0.04330	10
0.03608	0.06014	0.06615	0.072169	0.08821	0.12028	0.13231	0.04811	9
0.04059	0.06766	0.07442	0.081190	0.09923	0.13532	0.14885	0.05413	8
0.04639	0.07732	0.08506	0.092788	0.11341	0.15465	0.17011	0.06186	7
0.05413	0.09021	0.09923	0.108253	0.13231	0.18042	0.19846	0.07217	6
0.06495	0.10825	0.11908	0.129904	0.15877	0.21651	0.23816	0.08660	5
0.07217	0.12028	0.13231	0.144338	0.17641	0.24056	0.26462	0.09623	4½
0.08119	0.13532	0.14885	0.162380	0.19846	0.27063	0.29770	0.10825	4

NOTES:
(1) The values tabulated in column 6 also pertain to the minimum root radius of UNR screw threads. See paras. 2.3.1 and 2.3.1(a).
(2) $h_{an} = f_{cn} = 0.25H$.
(3) $h_{dn} = h_{as} = 0.375H$.

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TABLE 7 GENERAL SYMBOLS
(See Fig. 6)

Symbol	Dimension	Remarks	Symbol	Dimension	Remarks
d	Major diameter, external thread			Distance from apex of fundamental triangle to:	
D, D_3	Major diameter, internal thread		f_{cs}	flat at crest of external thread	
d_2	Pitch diameter, external thread		f_{rs}	flat at root of external thread	
D_2	Pitch diameter, internal thread		f_{cn}	flat at crest of internal thread	
d_1, d_3	Minor diameter, external thread		f_{rn}	flat at root of internal thread	
D_1	Minor diameter, internal thread			Width of:	
P	Pitch		F	flat (general)	
$1/P$	Number of threads per unit of length (per inch)		F_{cs}	flat at crest of external thread	
$1/L$	Number of turns per unit of length (per inch)		F_{rs}	flat at root of external thread	
H	Height of fundamental triangle		F_{cn}	flat at crest of internal thread	
h	Thread height (or depth)		F_{rm}	flat at root of internal thread	
h_a	Addendum		es	Allowance at major, pitch, and minor diameters of external thread	
h_d	Dedendum				
h_e	Depth of thread engagement				
α	Half angle of symmetrical thread		L_{ts}	Length of complete external thread	
α_1	Angle between leading flank of thread and normal to axis of thread		L_{tm}	Length of complete internal thread, including chamfer	
α_2	Angle between following flank of thread and normal to axis of thread		LE	Length of thread engagement	
λ	Lead angle	$\tan \lambda = \frac{L}{\pi(d_2 \text{ or } D_2)}$	w	Diameter of measuring wires	
	Radius of rounding at:		M_w	Measurement over wires	
r	crest of external thread		C	Correction to measurement over wires to give pitch diameter	d_2 or $D_2 = M_w - C - c$ $C = w(1 + \text{cosec } \alpha) - (\cot \alpha)/2n$
r_{rs}	root of external thread				
r_{cn}	crest of internal thread				
r_{rm}	root of internal thread				
	Radial distance from apex of fundamental triangle to:		λ'	Wire angle	
s_{cs}	rounded crest of external thread		c	Wire angle correction	See ANSI/ASME B1.2
s_{rs}	rounded root of external thread		Prefix symbol with Δ	Variation in any dimension	Examples: Variation in pitch, ΔP; variation in half angle, $\Delta\alpha_1$ or $\Delta\alpha_2$
s_{cn}	rounded crest of internal thread		$\Delta d_2\alpha$, $\Delta D_2\alpha$	Pitch diameter equivalent of variation in flank angles	
s_{rn}	rounded root of internal thread		$\Delta d_2\lambda$, $\Delta D_2\lambda$	Pitch diameter equivalent of variation in pitch (lead)	

GENERAL NOTE: Refer to ANSI/ASME B1.7M for latest symbol identification. Greek alphabet is below.

A α Alpha	Δ δ Delta	H η Eta	K κ Kappa	N ν Nu	Π π Pi	T τ Tau	X χ Chi
B β Beta	E ϵ Epsilon	Θ θ Theta	Λ λ Lambda	Ξ ξ Xi	P ρ Rho	Υ υ Upsilon	Ψ ψ Psi
Γ γ Gamma	Z ζ Zeta	I ι Iota	M μ Mu	O o Omicron	Σ σ Sigma	Φ ϕ Phi	Ω ω Omega

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Major diameter of internal thread is D. Pitch diameter of internal thread is D_2. Minor diameter of internal thread

$$D_1 = D - 2h_n$$

$$= D - 1.08253P$$

11 TABLES OF BASIC DIMENSIONS

11.1 Table Content

The basic dimensions tabulated in Tables 8 through 18 include major diameter, pitch diameter, minor diameter of external threads, minor diameter of internal threads, lead angle, cross-sectional area at the minor diameter, and the tensile stress area.

11.2 Thread Series

Basic dimensions are given for each of the standard series threads.

12 TABLES OF ALLOWANCE AND TOLERANCE FOR STANDARD SERIES THREADS (UN/UNR)

12.1 Table Content

Tables 19 through 30 provide the allowance for Classes 1A and 2A (external threads); major diameter tolerance for Classes 1A, 2A, and 3A (external threads); pitch diameter tolerance for Classes 1B, 2B, and 3B (internal threads); and minor diameter tolerance for Classes 1B, 2B, and 3B (internal threads).

12.2 Relationship to Limits of Size

The allowance and tolerance values given in this Section can be combined with the basic dimensions given in Section 11 to calculate limits of size as explained in Section 8.

Final figures may have 0.0001 difference between the limited values calculated in this manner and the standard values in Table 3A, due to the use of rounded four decimal place numbers.

13 TABLES OF ALLOWANCE AND TOLERANCE FOR THREADS OF SPECIAL DIAMETERS, PITCHES, AND LENGTHS OF ENGAGEMENT (UNS/UNRS)

13.1 Table Content

Tables 31 through 40 provide the allowance for Classes 1A and 2A (external threads); major diameter tolerance for Classes 1A, 2A, and 3A (external threads); pitch diameter tolerance for Classes 1B, 2B, and 3B (internal threads); and minor diameter tolerance for Classes 1B, 2B, and 3B (internal threads).

13.2 Relationship to Limits of Size

The allowance and tolerance values given in this Section can be combined with the basic dimensions given in Section 11 to calculate limits of size as explained in Section 8.

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TABLE 8 BASIC DIMENSIONS FOR COARSE THREAD SERIES (UNC/UNRC)

Nominal Size (1)	Basic Major Diameter D, in.	Threads/ in.	Basic Pitch Diameter D_2, in.	UNR Design Minor Diameter External (Ref.) d_3, in.	Basic Minor Diameter Internal D_1, in.	Lead Angle at Basic Pitch Diameter λ		Section at Minor Diameter at $D - 2h_b$, sq in.	Tensile Stress Area, sq in. (2)
						deg.	min		
1 (0.073)*	0.0730	64	0.0629	0.0544	0.0561	4	31	0.00218	0.00263
2 (0.086)	0.0860	56	0.0744	0.0648	0.0667	4	22	0.00310	0.00370
3 (0.099)*	0.0990	48	0.0855	0.0741	0.0764	4	26	0.00406	0.00487
4 (0.112)	0.1120	40	0.0958	0.0822	0.0849	4	45	0.00496	0.00604
5 (0.125)	0.1250	40	0.1088	0.0952	0.0979	4	11	0.00672	0.00796
6 (0.138)	0.1380	32	0.1177	0.1008	0.1042	4	50	0.00745	0.00909
8 (0.164)	0.1640	32	0.1437	0.1268	0.1302	3	58	0.01196	0.0140
10 (0.190)	0.1900	24	0.1629	0.1404	0.1449	4	39	0.01450	0.0175
12 (0.216)*	0.2160	24	0.1889	0.1664	0.1709	4	1	0.0206	0.0242
1/4	0.2500	20	0.2175	0.1905	0.1959	4	11	0.0269	0.0318
5/16	0.3125	18	0.2764	0.2464	0.2524	3	40	0.0454	0.0524
3/8	0.3750	16	0.3344	0.3005	0.3073	3	24	0.0678	0.0775
7/16	0.4375	14	0.3911	0.3525	0.3602	3	20	0.0933	0.1063
1/2	0.5000	13	0.4500	0.4084	0.4167	3	7	0.1257	0.1419
9/16	0.5625	12	0.5084	0.4633	0.4723	2	59	0.162	0.182
5/8	0.6250	11	0.5660	0.5168	0.5266	2	56	0.202	0.226
3/4	0.7500	10	0.6850	0.6309	0.6417	2	40	0.302	0.334
7/8	0.8750	9	0.8028	0.7427	0.7547	2	31	0.419	0.462
1	1.0000	8	0.9188	0.8512	0.8647	2	29	0.551	0.606
1 1/8	1.1250	7	1.0322	0.9549	0.9704	2	31	0.693	0.763
1 1/4	1.2500	7	1.1572	1.0799	1.0954	2	15	0.890	0.969
1 3/8	1.3750	6	1.2667	1.1766	1.1946	2	24	1.054	1.155
1 1/2	1.5000	6	1.3917	1.3016	1.3196	2	11	1.294	1.405
1 3/4	1.7500	5	1.6201	1.5119	1.5335	2	15	1.74	1.90
2	2.0000	4 1/2	1.8557	1.7353	1.7594	2	11	2.30	2.50
2 1/4	2.2500	4 1/2	2.1057	1.9853	2.0094	1	55	3.02	3.25
2 1/2	2.5000	4	2.3376	2.2023	2.2294	1	57	3.72	4.00
2 3/4	2.7500	4	2.5876	2.4523	2.4794	1	46	4.62	4.93
3	3.0000	4	2.8376	2.7023	2.7294	1	36	5.62	5.97
3 1/4	3.2500	4	3.0876	2.9523	2.9794	1	29	6.72	7.10
3 1/2	3.5000	4	3.3376	3.2023	3.2294	1	22	7.92	8.33
3 3/4	3.7500	4	3.5876	3.4523	3.4794	1	16	9.21	9.66
4	4.0000	4	3.8376	3.7023	3.7294	1	11	10.61	11.08

NOTES:
(1) Asterisks denote secondary sizes.
(2) See formulas in Appendix B, para. B1.

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TABLE 9 BASIC DIMENSIONS FOR FINE THREAD SERIES (UNF/UNRF)

Nominal Size (1)	Basic Major Diameter D, in.	Threads/ in.	Basic Pitch Diameter D_2, in.	UNR Design Minor Diameter External (Ref.) d_3, in.	Basic Minor Diameter Internal D_1, in.	Lead Angle at Basic Pitch Diameter λ		Section at Minor Diameter at $D - 2h_b$, sq in.	Tensile Stress Area, sq in. (2)
						deg.	min		
0 (0.060)	0.0600	80	0.0519	0.0451	0.0465	4	23	0.00151	0.00180
1 (0.073)*	0.0730	72	0.0640	0.0565	0.0580	3	57	0.00237	0.00278
2 (0.086)	0.0860	64	0.0759	0.0674	0.0691	3	45	0.00339	0.00394
3 (0.099)*	0.0990	56	0.0874	0.0778	0.0797	3	43	0.00451	0.00523
4 (0.112)	0.1120	48	0.0985	0.0871	0.0894	3	51	0.00566	0.00661
5 (0.125)	0.1250	44	0.1102	0.0979	0.1004	3	45	0.00716	0.00830
6 (0.138)	0.1380	40	0.1218	0.1082	0.1109	3	44	0.00874	0.01015
8 (0.164)	0.1640	36	0.1460	0.1309	0.1339	3	28	0.01285	0.01474
10 (0.190)	0.1900	32	0.1697	0.1528	0.1562	3	21	0.0175	0.0200
12 (0.216)*	0.2160	28	0.1928	0.1734	0.1773	3	22	0.0226	0.0258
1/4	0.2500	28	0.2268	0.2074	0.2113	2	52	0.0326	0.0364
5/16	0.3125	24	0.2854	0.2629	0.2674	2	40	0.0524	0.0580
3/8	0.3750	24	0.3479	0.3254	0.3299	2	11	0.0809	0.0878
7/16	0.4375	20	0.4050	0.3780	0.3834	2	15	0.1090	0.1187
1/2	0.5000	20	0.4675	0.4405	0.4459	1	57	0.1486	0.1599
9/16	0.5625	18	0.5264	0.4964	0.5024	1	55	0.189	0.203
5/8	0.6250	18	0.5889	0.5589	0.5649	1	43	0.240	0.256
3/4	0.7500	16	0.7094	0.6763	0.6823	1	36	0.351	0.373
7/8	0.8750	14	0.8286	0.7900	0.7977	1	34	0.480	0.509
1	1.0000	12	0.9459	0.9001	0.9098	1	36	0.625	0.663
1 1/8	1.1250	12	1.0709	1.0258	1.0348	1	25	0.812	0.856
1 1/4	1.2500	12	1.1959	1.1508	1.1598	1	16	1.024	1.073
1 3/8	1.3750	12	1.3209	1.2758	1.2848	1	9	1.260	1.315
1 1/2	1.5000	12	1.4459	1.4008	1.4098	1	3	1.521	1.581

NOTES:
(1) Asterisks denote secondary sizes.
(2) See formulas in Appendix B, para. B1.

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TABLE 10 BASIC DIMENSIONS FOR EXTRA-FINE THREAD SERIES (UNEF/UNREF)

Nominal Size, in.		Basic Major Diameter D, in.	Threads/ in.	Basic Pitch Diameter D_2, in.	UNR Design Minor Diameter External (Ref.) d_3, in.	Basic Minor Diameter Internal D_1, in.	Lead Angle at Basic Pitch Diameter λ		Section at Minor Diameter at $D - 2h_b$, sq in.	Tensile Stress Area, sq in. (1)
Primary	Secondary						deg.	min		
...	12 (0.216)	0.2160	32	0.1957	0.1788	0.1822	2	55	0.0242	0.0270
1/4	...	0.2500	32	0.2297	0.2128	0.2162	2	29	0.0344	0.0379
5/16	...	0.3125	32	0.2922	0.2753	0.2787	1	57	0.0581	0.0625
3/8	...	0.3750	32	0.3547	0.3378	0.3412	1	36	0.0878	0.0932
7/16	...	0.4375	28	0.4143	0.3949	0.3988	1	34	0.1201	0.1274
1/2	...	0.5000	28	0.4768	0.4574	0.4613	1	22	0.162	0.170
9/16	...	0.5625	24	0.5354	0.5129	0.5174	1	25	0.203	0.214
5/8	...	0.6250	24	0.5979	0.5754	0.5799	1	16	0.256	0.268
...	11/16	0.6875	24	0.6604	0.6379	0.6424	1	9	0.315	0.329
3/4	...	0.7500	20	0.7175	0.6905	0.6959	1	16	0.369	0.386
...	13/16	0.8125	20	0.7800	0.7530	0.7584	1	10	0.439	0.458
7/8	...	0.8750	20	0.8425	0.8155	0.8209	1	5	0.515	0.536
...	15/16	0.9375	20	0.9050	0.8780	0.8834	1	0	0.598	0.620
1	...	1.0000	20	0.9675	0.9405	0.9459	0	57	0.687	0.711
...	1 1/16	1.0625	18	1.0264	0.9964	1.0024	0	59	0.770	0.799
1 1/8	...	1.1250	18	1.0889	1.0589	1.0649	0	56	0.871	0.901
...	1 3/16	1.1875	18	1.1514	1.1214	1.1274	0	53	0.977	1.009
1 1/4	...	1.2500	18	1.2139	1.1839	1.1899	0	50	1.090	1.123
...	1 5/16	1.3125	18	1.2764	1.2464	1.2524	0	48	1.208	1.244
1 3/8	...	1.3750	18	1.3389	1.3089	1.3149	0	45	1.333	1.370
...	1 7/16	1.4375	18	1.4014	1.3714	1.3774	0	43	1.464	1.503
1 1/2	...	1.5000	18	1.4639	1.4339	1.4399	0	42	1.60	1.64
...	1 9/16	1.5625	18	1.5264	1.4964	1.5024	0	40	1.74	1.79
1 5/8	...	1.6250	18	1.5889	1.5589	1.5649	0	38	1.89	1.94
...	1 11/16	1.6875	18	1.6514	1.6214	1.6274	0	37	2.05	2.10

NOTE:
(1) See formulas in Appendix B, para. B1.

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TABLE 11 BASIC DIMENSIONS FOR 4-THREAD SERIES (4-UN/4-UNR)

Nominal Size, in. (1)		Basic Major Diameter D, in.	Basic Pitch Diameter D_2, in.	UNR Design Minor Diameter External (Ref.) d_3, in.	Basic Minor Diameter Internal D_1, in.	Lead Angle at Basic Pitch Diameter λ		Section at Minor Diameter at $D - 2h_b$, sq in.	Tensile Stress Area, sq in. (2)
Primary	Seoondary					deg.	min		
2½*	...	2.5000	2.3376	2.2023	2.2294	1	57	3.72	4.00
...	2⅝	2.6250	2.4626	2.3273	2.3544	1	51	4.16	4.45
2¾*	...	2.7500	2.5876	2.4523	2.4794	1	46	4.62	4.93
...	2⅞	2.8750	2.7126	2.5773	2.6044	1	41	5.11	5.44
3*	...	3.0000	2.8376	2.7023	2.7294	1	36	5.62	5.97
...	3⅛	3.1250	2.9626	2.8273	2.8544	1	32	6.16	6.52
3¼*	...	3.2500	3.0876	2.9523	2.9794	1	29	6.72	7.10
...	3⅜	3.3750	3.2126	3.0773	3.1044	1	25	7.31	7.70
3½*	...	3.5000	3.3376	3.2023	3.2294	1	22	7.92	8.33
...	3⅝	3.6250	3.4626	3.3273	3.3544	1	19	8.55	9.00
3¾*	...	3.7500	3.5876	3.4523	3.4794	1	16	9.21	9.66
...	3⅞	3.8750	3.7126	3.5773	3.6044	1	14	9.90	10.36
4*	...	4.0000	3.8376	3.7023	3.7294	1	11	10.61	11.08
...	4⅛	4.1250	3.9626	3.8273	3.8544	1	9	11.34	11.83
4¼	...	4.2500	4.0876	3.9523	3.9794	1	7	12.10	12.61
...	4⅜	4.3750	4.2126	4.0773	4.1044	1	5	12.88	13.41
4½	...	4.5000	4.3376	4.2023	4.2294	1	3	13.69	14.23
...	4⅝	4.6250	4.4626	4.3273	4.3544	1	1	14.52	15.1
4¾	...	4.7500	4.5876	4.4523	4.4794	1	0	15.4	15.9
...	4⅞	4.8750	4.7126	4.5773	4.6044	0	58	16.3	16.8
5	...	5.0000	4.8376	4.7023	4.7294	0	57	17.2	17.8
...	5⅛	5.1250	4.9626	4.8273	4.8544	0	55	18.1	18.7
5¼	...	5.2500	5.0876	4.9523	4.9794	0	54	19.1	19.7
...	5⅜	5.3750	5.2126	5.0773	5.1044	0	52	20.0	20.7
5½	...	5.5000	5.3376	5.2023	5.2294	0	51	21.0	21.7
...	5⅝	5.6250	5.4626	5.3273	5.3544	0	50	22.1	22.7
5¾	...	5.7500	5.5876	5.4523	5.4794	0	49	23.1	23.8
...	5⅞	5.8750	5.7126	5.5773	5.6044	0	48	24.2	24.9
6	...	6.0000	5.8376	5.7023	5.7294	0	47	25.3	26.0

NOTES:
(1) Asterisks denote standard sizes of the UNC series.
(2) See formulas in Appendix B, para. B1.

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TABLE 12 BASIC DIMENSIONS FOR 6-THREAD SERIES (6-UN/6-UNR)

Nominal Size, in. (1)		Basic Major Diameter	Basic Pitch Diameter	UNR Design Minor Diameter External	Basic Minor Diameter Internal	Lead Angle at Basic Pitch Diameter λ		Section at Minor Diameter at	Tensile Stress Area,
Primary	Secondary	D, in.	D_2, in.	(Ref.) d_3, in.	D_1, in.	deg.	min	$D - 2h_b$, sq in.	sq in. (2)
1 3/8*	...	1.3750	1.2667	1.1766	1.1946	2	24	1.054	1.155
...	1 7/16	1.4375	1.3292	1.2391	1.2571	2	17	1.171	1.277
1 1/2*	...	1.5000	1.3917	1.3016	1.3196	2	11	1.294	1.405
...	1 9/16	1.5625	1.4542	1.3641	1.3821	2	5	1.423	1.54
1 5/8	...	1.6250	1.5167	1.4271	1.4446	2	0	1.56	1.68
...	1 11/16	1.6875	1.5792	1.4891	1.5071	1	55	1.70	1.83
1 3/4	...	1.7500	1.6417	1.5516	1.5696	1	51	1.85	1.98
...	1 13/16	1.8125	1.7042	1.6141	1.6321	1	47	2.00	2.14
1 7/8	...	1.8750	1.7667	1.6766	1.6946	1	43	2.16	2.30
...	1 15/16	1.9375	1.8292	1.7391	1.7571	1	40	2.33	2.47
2	...	2.0000	1.8917	1.8016	1.8196	1	36	2.50	2.65
...	2 1/8	2.1250	2.0167	1.9266	1.9446	1	30	2.86	3.03
2 1/4	...	2.2500	2.1417	2.0516	2.0696	1	25	3.25	3.42
...	2 3/8	2.3750	2.2667	2.1766	2.1946	1	20	3.66	3.85
2 1/2	...	2.5000	2.3917	2.3016	2.3196	1	16	4.10	4.29
...	2 5/8	2.6250	2.5167	2.4266	2.4446	1	12	4.56	4.76
2 3/4	...	2.7500	2.6417	2.5516	2.5696	1	9	5.04	5.26
...	2 7/8	2.8750	2.7667	2.6766	2.6946	1	6	5.55	5.78
3	...	3.0000	2.8917	2.8016	2.8196	1	3	6.09	6.33
...	3 1/8	3.1250	3.0167	2.9266	2.9446	1	0	6.64	6.89
3 1/4	...	3.2500	3.1417	3.0516	3.0696	0	58	7.23	7.49
...	3 3/8	3.3750	3.2667	3.1766	3.1946	0	56	7.84	8.11
3 1/2	...	3.5000	3.3917	3.3016	3.3196	0	54	8.47	8.75
...	3 5/8	3.6250	3.5167	3.4266	3.4446	0	52	9.12	9.42
3 3/4	...	3.7500	3.6417	3.5516	3.5696	0	50	9.81	10.11
...	3 7/8	3.8750	3.7667	3.6766	3.6946	0	48	10.51	10.83
4	...	4.0000	3.8917	3.8016	3.8196	0	47	11.24	11.57
...	4 1/8	4.1250	4.0167	3.9266	3.9446	0	45	12.00	12.33
4 1/4	...	4.2500	4.1417	4.0516	4.0696	0	44	12.78	13.12
...	4 3/8	4.3750	4.2667	4.1766	4.1946	0	43	13.58	13.94
4 1/2	...	4.5000	4.3917	4.3016	4.3196	0	42	14.41	14.78
...	4 5/8	4.6250	4.5167	4.4266	4.4446	0	40	15.3	15.6
4 3/4	...	4.7500	4.6417	4.5516	4.5696	0	39	16.1	16.5
...	4 7/8	4.8750	4.7667	4.6766	4.6946	0	38	17.0	17.5
5	...	5.0000	4.8917	4.8016	4.8196	0	37	18.0	18.4
...	5 1/8	5.1250	5.0167	4.9266	4.9446	0	36	18.9	19.3
5 1/4	...	5.2500	5.1417	5.0516	5.0696	0	35	19.9	20.3
...	5 3/8	5.3750	5.2667	5.1766	5.1946	0	35	20.9	21.3
5 1/2	...	5.5000	5.3917	5.3016	5.3196	0	34	21.9	22.4
...	5 5/8	5.6250	5.5167	5.4266	5.4446	0	33	23.0	23.4
5 3/4	...	5.7500	5.6417	5.5516	5.5696	0	32	24.0	24.5
...	5 7/8	5.8750	5.7667	5.6766	5.6946	0	32	25.1	25.6
6	...	6.0000	5.8917	5.8016	5.8196	0	31	26.3	26.8

NOTES:
(1) Asterisks denote standard sizes of the UNC series.
(2) See formulas in Appendix B, para. B1.

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TABLE 13 BASIC DIMENSIONS FOR 8-THREAD SERIES (8-UN/8-UNR)

Nominal Size, in. (1)		Basic Major Diameter D, in.	Basic Pitch Diameter D_2, in.	UNR Design Minor Diameter External (Ref.) d_3, in.	Basic Minor Diameter Internal D_1, in.	Lead Angle at Basic Pitch Diameter λ		Section at Minor Diameter at $D - 2h_b$, sq in.	Tensile Stress Area, sq in. (2)
Primary	Secondary					deg.	min		
1*	...	1.0000	0.9188	0.8512	0.8647	2	29	0.551	0.606
...	1 1/16	1.0625	0.9813	0.9137	0.9272	2	19	0.636	0.695
1 1/8	...	1.1250	1.0438	0.9792	0.9897	2	11	0.728	0.790
...	1 3/16	1.1875	1.1063	1.0387	1.0522	2	4	0.825	0.892
1 1/4	...	1.2500	1.1688	1.1012	1.1147	1	57	0.929	1.000
...	1 5/16	1.5625	1.2313	1.1637	1.1772	1	51	1.039	1.114
1 3/8	...	1.3750	1.2938	1.2262	1.2397	1	46	1.155	1.233
...	1 7/16	1.4375	1.3563	1.2887	1.3022	1	41	1.277	1.360
1 1/2	...	1.5000	1.4188	1.3512	1.3647	1	36	1.405	1.492
...	1 9/16	1.5625	1.4813	1.4137	1.4272	1	32	1.54	1.63
1 5/8	...	1.6250	1.5438	1.4806	1.4897	1	29	1.68	1.78
...	1 11/16	1.6875	1.6063	1.5387	1.5522	1	25	1.83	1.93
1 3/4	...	1.7500	1.6688	1.6012	1.6147	1	22	1.98	2.08
...	1 13/16	1.8125	1.7313	1.6637	1.6772	1	19	2.14	2.25
1 7/8	...	1.8750	1.7938	1.7262	1.7397	1	16	2.30	2.41
...	1 15/16	1.9375	1.8563	1.7887	1.8022	1	14	2.47	2.59
2	...	2.0000	1.9188	1.8512	1.8647	1	11	2.65	2.77
...	2 1/8	2.1250	2.0438	1.9762	1.9897	1	7	3.03	3.15
2 1/4	...	2.2500	2.1688	2.1012	2.1147	1	3	3.42	3.56
...	2 3/8	2.3750	2.2938	2.2262	2.2397	1	0	3.85	3.99
2 1/2	...	2.5000	2.4188	2.3512	2.3647	0	57	4.29	4.44
...	2 5/8	2.6250	2.5438	2.4762	2.4897	0	54	4.76	4.92
2 3/4	...	2.7500	2.6688	2.6012	2.6147	0	51	5.26	5.43
...	2 7/8	2.8750	2.7938	2.7262	2.7397	0	49	5.78	5.95
3	...	3.0000	2.9188	2.8512	2.8647	0	47	6.32	6.51
...	3 1/8	3.1250	3.0438	2.9762	2.9897	0	45	6.89	7.08
3 1/4	...	3.2500	3.1688	3.1012	3.1147	0	43	7.49	7.69
...	3 3/8	3.3750	3.2938	3.2262	3.2397	0	42	8.11	8.31
3 1/2	...	3.5000	3.4188	3.3512	3.3647	0	40	8.75	8.96
...	3 5/8	3.6250	3.5438	3.4762	3.4897	0	39	9.42	9.64
3 3/4	...	3.7500	3.6688	3.6012	3.6147	0	37	10.11	10.34
...	3 7/8	3.8750	3.7938	3.7262	3.7397	0	36	10.83	11.06
4	...	4.0000	3.9188	3.8512	3.8647	0	35	11.57	11.81
...	4 1/8	4.1250	4.0438	3.9762	3.9897	0	34	12.34	12.59
4 1/4	...	4.2500	4.1688	4.1012	4.1147	0	33	13.12	13.38
...	4 3/8	4.3750	4.2938	4.2262	4.2397	0	32	13.94	14.21
4 1/2	...	4.5000	4.4188	4.3512	4.3647	0	31	14.78	15.1
...	4 5/8	4.6250	4.5438	4.4762	4.4897	0	30	15.6	15.9
4 3/4	...	4.7500	4.6688	4.6012	4.6147	0	29	16.5	16.8
...	4 7/8	4.8750	4.7938	4.7262	4.7397	0	29	17.4	17.7
5	...	5.0000	4.9188	4.8512	4.8647	0	28	18.4	18.7
...	5 1/8	5.1250	5.0438	4.9762	4.9897	0	27	19.3	19.7
5 1/4	...	5.2500	5.1688	5.1012	5.1147	0	26	20.3	20.7
...	5 3/8	5.3750	5.2938	5.2262	5.2397	0	26	21.3	21.7

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TABLE 13 BASIC DIMENSIONS FOR 8-THREAD SERIES (8-UN/8-UNR) (CONT'D)

Nominal Size, in. (1)		Basic Major Diameter	Basic Pitch Diameter	UNR Design Minor Diameter External	Basic Minor Diameter Internal	Lead Angle at Basic Pitch Diameter λ		Section at Minor Diameter at	Tensile Stress Area,
Primary	Secondary	D, in.	D_2, in.	(Ref.) d_3, in.	D_1, in.	deg.	min	$D - 2h_b$, sq in.	sq in. (2)
5½	. . .	5.5000	5.4188	5.3512	5.3647	0	25	22.4	22.7
. . .	5⅝	5.6250	5.5438	5.4762	5.4897	0	25	23.4	23.8
5¾	. . .	5.7500	5.6688	5.6012	5.6147	0	24	24.5	24.9
. . .	5⅞	5.8750	5.7938	5.7262	5.7397	0	24	25.6	26.0
6	. . .	6.0000	5.9188	5.8512	5.8647	0	23	26.8	27.1

GENERAL NOTE:
The 8-UN specified limits for all sizes to and including 6 in. are shown in Table 3A based on a length of engagement equal to the basic major (nominal) diameter.

NOTES:
(1) Asterisk denotes standard size of the UNC series.
(2) See formulas in Appendix B, para. B1.

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TABLE 14 BASIC DIMENSIONS FOR 12-THREAD SERIES (12-UN/12-UNR)

Nominal Size, in. (1)		Basic Major Diameter	Basic Pitch Diameter	UNR Design Minor Diameter External	Basic Minor Diameter Internal	Lead Angle at Basic Pitch Diameter λ		Section at Minor Diameter at	Tensile Stress Area,
Primary	Secondary	D, in.	D_2, in.	(Ref.) d_3, in.	D_1, in.	deg.	min	$D - 2h_b$, sq in.	sq in. (2)
9/16*	...	0.5625	0.5084	0.4633	0.4723	2	59	0.162	0.182
5/8	...	0.6250	0.5709	0.5258	0.5348	2	40	0.210	0.232
...	11/16	0.6875	0.6334	0.5883	0.5973	2	24	0.264	0.289
3/4	...	0.7500	0.6959	0.6508	0.6598	2	11	0.323	0.351
...	13/16	0.8125	0.7584	0.7133	0.7223	2	0	0.390	0.420
7/8	...	0.8750	0.8209	0.7758	0.7848	1	51	0.462	0.495
...	15/16	0.9375	0.8834	0.8383	0.8473	1	43	0.540	0.576
1*	...	1.0000	0.9459	0.9008	0.9098	1	36	0.625	0.663
...	1 1/16	1.0625	1.0084	0.9633	0.9723	1	30	0.715	0.756
1 1/8*	...	1.1250	1.0709	1.0258	1.0348	1	25	0.812	0.856
...	1 3/16	1.1875	1.1334	1.0883	1.0973	1	20	0.915	0.961
1 1/4*	...	1.2500	1.1959	1.1508	1.1598	1	16	1.024	1.073
...	1 5/16	1.3125	1.2584	1.2133	1.2223	1	12	1.139	1.191
1 3/8*	...	1.3750	1.3209	1.2758	1.2848	1	9	1.260	1.315
...	1 7/16	1.4375	1.3834	1.3383	1.3473	1	6	1.388	1.445
1 1/2*	...	1.5000	1.4459	1.4008	1.4098	1	3	1.52	1.58
...	1 9/16	1.5625	1.5084	1.4633	1.4723	1	0	1.66	1.72
1 5/8	...	1.6250	1.5709	1.5258	1.5348	0	58	1.81	1.87
...	1 11/16	1.6875	1.6334	1.5883	1.5973	0	56	1.96	2.03
1 3/4	...	1.7500	1.6959	1.6508	1.6598	0	54	2.12	2.19
...	1 13/16	1.8125	1.7584	1.7133	1.7223	0	52	2.28	2.35
1 7/8	...	1.8750	1.8209	1.7758	1.7848	0	50	2.45	2.53
...	1 15/16	1.9375	1.8834	1.8383	1.8473	0	48	2.63	2.71
2	...	2.0000	1.9459	1.9008	1.9098	0	47	2.81	2.89
...	2 1/8	2.1250	2.0709	2.0258	2.0348	0	44	3.19	3.28
2 1/4	...	2.2500	2.1959	2.1508	2.1598	0	42	3.60	3.69
...	2 3/8	2.3750	2.3209	2.2758	2.2848	0	39	4.04	4.13
2 1/2	...	2.5000	2.4459	2.4008	2.4098	0	37	4.49	4.60
...	2 5/8	2.6250	2.5709	2.5258	2.5348	0	35	4.97	5.08
2 3/4	...	2.7500	2.6959	2.6508	2.6598	0	34	5.48	5.59
...	2 7/8	2.8750	2.8209	2.7758	2.7848	0	32	6.01	6.13
3	...	3.0000	2.9459	2.9008	2.9098	0	31	6.57	6.69
...	3 1/8	3.1250	3.0709	3.0258	3.0348	0	30	7.15	7.28
3 1/4	...	3.2500	3.1959	3.1508	3.1598	0	29	7.75	7.89
...	3 3/8	3.3750	3.3209	3.2758	3.2848	0	27	8.38	8.52
3 1/2	...	3.5000	3.4459	3.4008	3.4098	0	26	9.03	9.18
...	3 5/8	3.6250	3.5709	3.5258	3.5348	0	26	9.71	9.86
3 3/4	...	3.7500	3.6959	3.6508	3.6598	0	25	10.42	10.57
...	3 7/8	3.8750	3.8209	3.7758	3.7848	0	24	11.14	11.30
4	...	4.0000	3.9459	3.9008	3.9098	0	23	11.90	12.06
...	4 1/8	4.1250	4.0709	4.0258	4.0348	0	22	12.67	12.84
4 1/4	...	4.2500	4.1959	4.1508	4.1598	0	22	13.47	13.65
...	4 3/8	4.3750	4.3209	4.2758	4.2848	0	21	14.30	14.48

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TABLE 14 BASIC DIMENSIONS FOR 12-THREAD SERIES (12-UN/12-UNR) (CONT'D)

Nominal Size, in. (1)		Basic Major Diameter D, in.	Basic Pitch Diameter D_2, in.	UNR Design Minor Diameter External (Ref.) d_3, in.	Basic Minor Diameter Internal D_1, in.	Lead Angle at Basic Pitch Diameter λ		Section at Minor Diameter at $D - 2h_b$, sq in.	Tensile Stress Area, sq in. (2)
Primary	Secondary					deg.	min		
4½	...	4.5000	4.4459	4.4008	4.4098	0	21	15.1	15.3
...	4⅝	4.6250	4.5709	4.5258	4.5348	0	20	16.0	16.2
4¾	...	4.7500	4.6959	4.6508	4.6598	0	19	16.9	17.1
...	4⅞	4.8750	4.8209	4.7758	4.7848	0	19	17.8	18.0
5	...	5.0000	4.9459	4.9008	4.9098	0	18	18.8	19.0
...	5⅛	5.1250	5.0709	5.0258	5.0348	0	18	19.8	20.0
5¼	...	5.2500	5.1959	5.1508	5.1598	0	18	20.8	21.0
...	5⅜	5.3750	5.3209	5.2758	5.2848	0	17	21.8	22.0
5½	...	5.5000	5.4459	5.4008	5.4098	0	17	22.8	23.1
...	5⅝	5.6250	5.5709	5.5258	5.5348	0	16	23.9	24.1
5¾	...	5.7500	5.6959	5.6508	5.6598	0	16	25.0	25.2
...	5⅞	5.8750	5.8209	5.7758	5.7848	0	16	26.1	26.4
6	...	6.0000	5.9459	5.9008	5.9098	0	15	27.3	27.5

NOTES:
(1) Asterisks denote standard sizes of the UNC or UNF series.
(2) See formulas in Appendix B, para. B1.

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TABLE 15 BASIC DIMENSIONS FOR 16-THREAD SERIES (16-UN/16-UNR)

Nominal Size, in. (1)		Basic Major Diameter	Basic Pitch Diameter	UNR Design Minor Diameter External	Basic Minor Diameter Internal	Lead Angle at Basic Pitch Diameter λ		Section at Minor Diameter at	Tensile Stress Area,
Primary	Secondary	D, in.	D_2, in.	(Ref.) d_3, in.	D_1, in.	deg.	min	$D - 2h_b$, sq in.	sq in. (2)
3/8*	...	0.3750	0.3344	0.3005	0.3073	3	24	0.0678	0.0775
7/16	...	0.4375	0.3969	0.3630	0.3698	2	52	0.0997	0.1114
1/2	...	0.5000	0.4594	0.4255	0.4323	2	29	0.1378	0.151
9/16	...	0.5625	0.5219	0.4880	0.4948	2	11	0.182	0.198
5/8	...	0.6250	0.5844	0.5505	0.5573	1	57	0.232	0.250
...	11/16	0.6875	0.6469	0.6130	0.6198	1	46	0.289	0.308
3/4*	...	0.7500	0.7094	0.6755	0.6823	1	36	0.351	0.373
...	13/16	0.8125	0.7719	0.7380	0.7448	1	29	0.420	0.444
7/8	...	0.8750	0.8344	0.8005	0.8073	1	22	0.495	0.521
...	15/16	0.9375	0.8969	0.8630	0.8698	1	16	0.576	0.604
1	...	1.0000	0.9594	0.9255	0.9323	1	11	0.663	0.693
...	1 1/16	1.0625	1.0219	0.9880	0.9948	1	7	0.756	0.788
1 1/8	...	1.1250	1.0844	1.0505	1.0573	1	3	0.856	0.889
...	1 3/16	1.1875	1.1469	1.1130	1.1198	1	0	0.961	0.997
1 1/4	...	1.2500	1.2094	1.1755	1.1823	0	57	1.073	1.111
...	1 5/16	1.3125	1.2719	1.2380	1.2448	0	54	1.191	1.230
1 3/8	...	1.3750	1.3344	1.3005	1.3073	0	51	1.315	1.356
...	1 7/16	1.4375	1.3969	1.3630	1.3698	0	49	1.445	1.488
1 1/2	...	1.5000	1.4594	1.4255	1.4323	0	47	1.58	1.63
...	1 9/16	1.5625	1.5219	1.4880	1.4948	0	45	1.72	1.77
1 5/8	...	1.6250	1.5844	1.5505	1.5573	0	43	1.87	1.92
...	1 11/16	1.6875	1.6469	1.6130	1.6198	0	42	2.03	2.08
1 3/4	...	1.7500	1.7094	1.6755	1.6823	0	40	2.19	2.24
...	1 13/16	1.8125	1.7719	1.7380	1.7448	0	39	2.35	2.41
1 7/8	...	1.8750	1.8344	1.8005	1.8073	0	37	2.53	2.58
...	1 15/16	1.9375	1.8969	1.8630	1.8698	0	36	2.71	2.77
2	...	2.0000	1.9594	1.9255	1.9323	0	35	2.89	2.95
...	2 1/8	2.1250	2.0844	2.0505	2.0573	0	33	3.28	3.35
2 1/4	...	2.2500	2.2094	2.1755	2.1823	0	31	3.69	3.76
...	2 3/8	2.3750	2.3344	2.3005	2.3073	0	29	4.13	4.21
2 1/2	...	2.5000	2.4594	2.4255	2.4323	0	28	4.60	4.67
...	2 5/8	2.6250	2.5844	2.5505	2.5573	0	26	5.08	5.16
2 3/4	...	2.7500	2.7094	2.6755	2.6823	0	25	5.59	5.68
...	2 7/8	2.8750	2.8344	2.8005	2.8073	0	24	6.13	6.22
3	...	3.0000	2.9594	2.9255	2.9323	0	23	6.69	6.78
...	3 1/8	3.1250	3.0844	3.0505	3.0573	0	22	7.28	7.37
3 1/4	...	3.2500	3.2094	3.1755	3.1823	0	21	7.89	7.99
...	3 3/8	3.3750	3.3344	3.3005	3.3073	0	21	8.52	8.63
3 1/2	...	3.5000	3.4594	3.4255	3.4323	0	20	9.18	9.29
...	3 5/8	3.6250	3.5844	3.5505	3.5573	0	19	9.86	9.98
3 3/4	...	3.7500	3.7094	3.6755	3.6823	0	18	10.57	10.69
...	3 7/8	3.8750	3.8344	3.8005	3.8073	0	18	11.30	11.43
4	...	4.0000	3.9594	3.9255	3.9323	0	17	12.06	12.19
...	4 1/8	4.1250	4.0844	4.0505	4.0573	0	17	12.84	12.97
4 1/4	...	4.2500	4.2094	4.1755	4.1823	0	16	13.65	13.78
...	4 3/8	4.3750	4.3344	4.3005	4.3073	0	16	14.48	14.62

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TABLE 15 BASIC DIMENSIONS FOR 16-THREAD SERIES (16-UN/16-UNR) (CONT'D)

Nominal Size, in. (1)		Basic Major Diameter D, In.	Basic Pitch Diameter D_2, in.	UNR Design Minor Diameter External (Ref.) d_3, in.	Basic Minor Diameter Internal D_1, in.	Lead Angle at Basic Pitch Diameter λ		Section at Minor Diameter at $D - 2h_b$, sq in.	Tensile Stress Area, sq in. (2)
Primary	Secondary					deg.	min		
4½	...	4.5000	4.4594	4.4255	4.4323	0	15	15.34	15.5
...	4⅝	4.6250	4.5844	4.5505	4.5573	0	15	16.2	16.4
4¾	...	4.7500	4.7094	4.6755	4.6823	0	15	17.1	17.3
...	4⅞	4.8750	4.8344	4.8005	4.8073	0	14	18.0	18.2
5	...	5.0000	4.9594	4.9255	4.9323	0	14	19.0	19.2
...	5⅛	5.1250	5.0844	5.0505	5.0573	0	13	20.0	20.1
5¼	...	5.2500	5.2094	5.1755	5.1823	0	13	21.0	21.1
...	5⅜	5.3750	5.3344	5.3005	5.3073	0	13	22.0	22.2
5½	...	5.5000	5.4594	5.4255	5.4323	0	13	23.1	23.2
...	5⅝	5.6250	5.5844	5.5505	5.5573	0	12	24.1	24.3
5¾	...	5.7500	5.7094	5.6755	5.6823	0	12	25.2	25.4
...	5⅞	5.8750	5.8344	5.8005	5.8073	0	12	26.4	26.5
6	...	6.0000	5.9594	5.9255	5.9323	0	11	27.5	27.7

NOTES:
(1) Asterisks denote standard sizes of the UNC or UNF series.
(2) See formulas in Appendix B, para. B1.

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TABLE 16 BASIC DIMENSIONS FOR 20-THREAD SERIES (20-UN/20-UNR)

Nominal Size, in. (1)		Basic Major Diameter	Basic Pitch Diameter	UNR Design Minor Diameter External	Basic Minor Diameter Internal	Lead Angle at Basic Pitch Diameter λ		Section at Minor Diameter at	Tensile Stress Area,
Primary	Secondary	D, in.	D_2, in.	(Ref.) d_3, in.	D_1, in.	deg.	min	$D - 2h_b$, sq in.	sq in. (2)
1/4*	...	0.2500	0.2175	0.1905	0.1959	4	11	0.0269	0.0318
5/16	...	0.3125	0.2800	0.2530	0.2584	3	15	0.0481	0.0547
3/8	...	0.3750	0.3425	0.3155	0.3209	2	40	0.0755	0.0836
7/16*	...	0.4375	0.4050	0.3780	0.3834	2	15	0.1090	0.1187
1/2*	...	0.5000	0.4675	0.4405	0.4459	1	57	0.1486	0.160
9/16	...	0.5625	0.5300	0.5030	0.5084	1	43	0.194	0.207
5/8	...	0.6250	0.5925	0.5655	0.5709	1	32	0.246	0.261
...	11/16	0.6875	0.6550	0.6280	0.6334	1	24	0.304	0.320
3/4*	...	0.7500	0.7175	0.6905	0.6959	1	16	0.369	0.386
...	13/16*	0.8125	0.7800	0.7530	0.7584	1	10	0.439	0.458
7/8*	...	0.8750	0.8425	0.8155	0.8209	1	5	0.515	0.536
...	15/16*	0.9375	0.9050	0.8780	0.8834	1	0	0.598	0.620
1*	...	1.0000	0.9675	0.9405	0.9459	0	57	0.687	0.711
...	1 1/16	1.0625	1.0300	1.0030	1.0084	0	53	0.782	0.807
1 1/8	...	1.1250	1.0925	1.0655	1.0709	0	50	0.882	0.910
...	1 3/16	1.1875	1.1550	1.1280	1.1334	0	47	0.990	1.018
1 1/4	...	1.2500	1.2175	1.1905	1.1959	0	45	1.103	1.133
...	1 5/16	1.3125	1.2800	1.2530	1.2584	0	43	1.222	1.254
1 3/8	...	1.3750	1.3425	1.3155	1.3209	0	41	1.348	1.382
...	1 7/16	1.4375	1.4050	1.3780	1.3834	0	39	1.479	1.51
1 1/2	...	1.5000	1.4675	1.4405	1.4459	0	37	1.62	1.65
...	1 9/16	1.5625	1.5300	1.5030	1.5084	0	36	1.76	1.80
1 5/8	...	1.6250	1.5925	1.5655	1.5709	0	34	1.91	1.95
...	1 11/16	1.6875	1.6550	1.6280	1.6334	0	33	2.07	2.11
1 3/4	...	1.7500	1.7175	1.6905	1.6959	0	32	2.23	2.27
...	1 13/16	1.8125	1.7800	1.7530	1.7584	0	31	2.40	2.44
1 7/8	...	1.8750	1.8425	1.8155	1.8209	0	30	2.57	2.62
...	1 15/16	1.9375	1.9050	1.8780	1.8834	0	29	2.75	2.80
2	...	2.0000	1.9675	1.9405	1.9459	0	28	2.94	2.99
...	2 1/8	2.1250	2.0925	2.0655	2.0709	0	26	3.33	3.39
2 1/4	...	2.2500	2.2175	2.1905	2.1959	0	25	3.75	3.81
...	2 3/8	2.3750	2.3425	2.3155	2.3209	0	23	4.19	4.25
2 1/2	...	2.5000	2.4675	2.4405	2.4459	0	22	4.66	4.72
...	2 5/8	2.6250	2.5925	2.5655	2.5709	0	21	5.15	5.21
2 3/4	...	2.7500	2.7175	2.6905	2.6959	0	20	5.66	5.73
...	2 7/8	2.8750	2.8425	2.8155	2.8209	0	19	6.20	6.27
3	...	3.0000	2.9675	2.9405	2.9459	0	18	6.77	6.84

NOTES:
(1) Asterisks denote standard sizes of the UNC, UNF, or UNEF series.
(2) See formulas in Appendix B, para. B1.

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TABLE 17 BASIC DIMENSIONS FOR 28-THREAD SERIES (28-UN/28-UNR)

Nominal Size, in. (1)		Basic Major Diameter D, in.	Basic Pitch Diameter D_2, in.	UNR Design Minor Diameter External (Ref.) d_3, in.	Basic Minor Diameter Internal D_1, in.	Lead Angle at Basic Pitch Diameter λ		Section at Minor Diameter at $D - 2h_b$, sq in.	Tensile Stress Area, sq in. (2)
Primary	Secondary					deg.	min		
...	12* (0.216)	0.2160	0.1928	0.1734	0.1773	3	22	0.0226	0.0258
1/4*	...	0.2500	0.2268	0.2074	0.2113	2	52	0.0326	0.0364
5/16	...	0.3125	0.2893	0.2699	0.2738	2	15	0.0556	0.0606
3/8	...	0.3750	0.3518	0.3324	0.3363	1	51	0.0848	0.0909
7/16*	...	0.4375	0.4143	0.3949	0.3988	1	34	0.1201	0.1274
1/2*	...	0.5000	0.4768	0.4574	0.4613	1	22	0.162	0.170
9/16	...	0.5625	0.5393	0.5199	0.5238	1	12	0.209	0.219
5/8	...	0.6250	0.6018	0.5824	0.5863	1	5	0.263	0.274
...	11/16	0.6875	0.6643	0.6449	0.6488	0	59	0.323	0.335
3/4	...	0.7500	0.7268	0.7074	0.7113	0	54	0.389	0.402
...	13/16	0.8125	0.7893	0.7699	0.7738	0	50	0.461	0.475
7/8	...	0.8750	0.8518	0.8324	0.8363	0	46	0.539	0.554
...	15/16	0.9375	0.9143	0.8949	0.8988	0	43	0.624	0.640
1	...	1.0000	0.9768	0.9574	0.9613	0	40	0.714	0.732
...	1 1/16	1.0625	1.0393	1.0199	1.0238	0	38	0.811	0.830
1 1/8	...	1.1250	1.1018	1.0824	1.0863	0	35	0.914	0.933
...	1 3/16	1.1875	1.1643	1.1449	1.1488	0	34	1.023	1.044
1 1/4	...	1.2500	1.2268	1.2074	1.2113	0	32	1.138	1.160
...	1 5/16	1.3125	1.2893	1.2699	1.2738	0	30	1.259	1.282
1 3/8	...	1.3750	1.3518	1.3324	1.3363	0	29	1.386	1.411
...	1 7/16	1.4375	1.4143	1.3949	1.3988	0	28	1.52	1.55
1 1/2	...	1.5000	1.4768	1.4574	1.4613	0	26	1.66	1.69

NOTES:
(1) Asterisks denote standard sizes of the UNF or UNEF series.
(2) See formulas in Appendix B, para. B1.

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TABLE 18 BASIC DIMENSIONS FOR 32-THREAD SERIES (32-UN/32-UNR)

Nominal Size, in. (1)		Basic Major Diameter D, in.	Basic Pitch Diameter D_2, in.	UNR Design Minor Diameter External (Ref.) d_3, in.	Basic Minor Diameter Internal D_1, in.	Lead Angle at Basic Pitch Diameter λ		Section at Minor Diameter at $D - 2h_b$, sq in.	Tensile Stress Area, sq in. (2)
Primary	Secondary					deg.	min		
6* (0.138)	...	0.1380	0.1177	0.1008	0.1042	4	50	0.00745	0.00909
8* (0.164)	...	0.1640	0.1437	0.1268	0.1302	3	58	0.01196	0.0140
10* (0.190)	...	0.1900	0.1697	0.1528	0.1562	3	21	0.01750	0.0200
...	12* (0.216)	0.2160	0.1957	0.1788	0.1822	2	55	0.0242	0.0270
1/4*	...	0.2500	0.2297	0.2128	0.2162	2	29	0.0344	0.0379
5/16*	...	0.3125	0.2922	0.2753	0.2787	1	57	0.0581	0.0625
3/8*	...	0.3750	0.3547	0.3378	0.3412	1	36	0.0878	0.0932
7/16	...	0.4375	0.4172	0.4003	0.4037	1	22	0.1237	0.1301
1/2	...	0.5000	0.4797	0.4628	0.4662	1	11	0.166	0.173
9/16	...	0.5625	0.5422	0.5253	0.5287	1	3	0.214	0.222
5/8	...	0.6250	0.6047	0.5878	0.5912	0	57	0.268	0.278
...	11/16	0.6875	0.6672	0.6503	0.6537	0	51	0.329	0.339
3/4	...	0.7500	0.7297	0.7128	0.7162	0	47	0.395	0.407
...	13/16	0.8125	0.7922	0.7753	0.7787	0	43	0.468	0.480
7/8	...	0.8750	0.8547	0.8378	0.8412	0	40	0.547	0.560
...	15/16	0.9375	0.9172	0.9003	0.9037	0	37	0.632	0.646
1	...	1.0000	0.9797	0.9628	0.9662	0	35	0.723	0.738

NOTES:
(1) Asterisks denote standard sizes of the UNC, UNF, or UNEF series.
(2) See formulas in Appendix B, para. B1.

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TABLE 19 INCREMENTS IN PITCH DIAMETER TOLERANCE — CLASS 2A

(PD Tolerance = $0.0015\sqrt[3]{D} + 0.0015\sqrt{LE} + 0.015\sqrt[3]{P^2}$)

Diameter *D*				Length of Engagement *LE*												Pitch *P*	
				Based on (1)					Based on (1)				Based on (1)				
D	$0.0015\sqrt[3]{D}$	*D*	$0.0015\sqrt[3]{D}$	1 *D* for Sizes	9*P* for TPI	20*P* for TPI	*LE*	$0.0015 \times \sqrt{LE}$	1 *D* for Sizes	9*P* for TPI	20*P* for TPI	*LE*	$0.0015 \times \sqrt{LE}$	1 *D* for Sizes	20*P* for TPI	*LE*	$0.0015 \times \sqrt{LE}$	Threads/ in.	$0.015\sqrt[3]{P^2}$
0.0600	0.000587	1.9375	0.001870	#0	...	...	0.0600	0.000367	½	18	40	0.5000	0.001061	2⅜	...	2.3750	0.002312	80	0.000808
0.0625	0.000595	2.0000	0.001890	1/16	...	...	0.0625	0.000375	...	...	36	0.5556	0.001118	2½	8	2.5000	0.002372	72	0.000867
0.0730	0.000627	2.1250	0.001928	#1	...	...	0.0730	0.000405	9/16	16	...	0.5625	0.001125	2⅝	...	2.6250	0.002430	64	0.000938
0.0860	0.000662	2.2500	0.001966	3/64	...	...	0.0781	0.000419	⅝	...	32	0.6250	0.001186	2¾	...	2.7500	0.002487	60	0.000979
0.0938	0.000682	2.3750	0.002001	#2	...	...	0.0860	0.000440	...	14	...	0.6429	0.001203	...	7	2.8571	0.002535	56	0.001025
0.0990	0.000694	2.5000	0.002036	3/32	...	...	0.0938	0.000459	11/16	...	...	0.6875	0.001244	2⅞	...	2.8750	0.002543	50	0.001105
0.1120	0.000723	2.6250	0.002069	#3	...	...	0.0990	0.000472	...	13	...	0.6923	0.001248	3	...	3.0000	0.002598	48	0.001136
0.1250	0.000750	2.7500	0.002102	7/64	...	...	0.1094	0.000496	...	...	28	0.7143	0.001268	3⅛	...	3.1250	0.002652	44	0.001204
0.1380	0.000775	2.8750	0.002133	#4	...	...	0.1120	0.000502	...	...	27	0.7407	0.001291	3¼	...	3.2500	0.002704	42	0.001241
0.1640	0.000821	3.0000	0.002163	...	80	...	0.1125	0.000503	¾	12	...	0.7500	0.001299	...	6	3.3333	0.002739	40	0.001282
0.1875	0.000859	3.1250	0.002193	#5	72	...	0.1250	0.000530	...	11½	...	0.7826	0.001327	3⅜	...	3.3750	0.002756	36	0.001376
0.1900	0.000862	3.2500	0.002222	#6	...	...	0.1380	0.000557	13/16	...	...	0.8125	0.001352	3½	...	3.5000	0.002806	34	0.001429
0.2160	0.000900	3.3750	0.002250	...	64	...	0.1406	0.000562	...	11	...	0.8182	0.001357	3⅝	...	3.6250	0.002856	32	0.001488
0.2500	0.000945	3.5000	0.002277	5/32	...	...	0.1562	0.000593	...	...	24	0.8333	0.001369	3¾	...	3.7500	0.002905	30	0.001554
0.3125	0.001018	3.6250	0.002304	...	56	...	0.1607	0.000601	⅞	...	...	0.8750	0.001403	3⅞	...	3.8750	0.002953	28	0.001627
0.3750	0.001082	3.7500	0.002330	#8	...	...	0.1640	0.000607	...	10	...	0.9000	0.001423	4	5	4.0000	0.003000	27	0.001667
0.4375	0.001139	3.8750	0.002356	11/64	...	...	0.1719	0.000622	15/16	...	...	0.9375	0.001452	4⅛	...	4.1250	0.003047	26	0.001709
0.5000	0.001191	4.0000	0.002381	3/16	48	...	0.1875	0.000650	1	9	20	1.0000	0.001500	4¼	...	4.2500	0.003092	24	0.001803
0.5625	0.001238	4.1250	0.002406	#10	...	...	0.1900	0.000654	1 1/16	...	...	1.0625	0.001546	4⅜	...	4.3750	0.003137	22	0.001910
0.6250	0.001282	4.2500	0.002430	13/64	...	...	0.2031	0.000676	...	...	18	1.1111	0.001581	...	4½	4.4444	0.003162	20	0.002036
0.6875	0.001324	4.3750	0.002453	...	44	...	0.2045	0.000678	1⅛	8	...	1.1250	0.001591	4½	...	4.5000	0.003182	18	0.002184
0.7500	0.001363	4.5000	0.002476	#12	...	...	0.2160	0.000697	1 3/16	...	...	1.1875	0.001635	4⅝	...	4.6250	0.003226	16	0.002362
0.8125	0.001400	4.6250	0.002499	7/32	...	...	0.2188	0.000702	1¼	...	16	1.2500	0.001677	4¾	...	4.7500	0.003269	14	0.002582
0.8750	0.001435	4.7500	0.002521	...	40	...	0.2250	0.000712	...	7	...	1.2857	0.001701	4⅞	...	4.8750	0.003312	13	0.002713
0.9375	0.001468	4.8750	0.002543	15/64	...	...	0.2344	0.000726	1 5/16	...	...	1.3125	0.001718	5	4	5.0000	0.003354	12	0.002862
1.0000	0.001500	5.0000	0.002565	¼	36	80	0.2500	0.000750	1⅜	...	...	1.3750	0.001759	5⅛	...	5.1250	0.003396	11½	0.002944
1.0625	0.001531	5.1250	0.002586	17/64	...	...	0.2656	0.000773	...	...	14	1.4286	0.001793	5¼	...	5.2500	0.003437	11	0.003033
1.1250	0.001560	5.2500	0.002607	...	...	72	0.2778	0.000791	1 7/16	...	...	1.4375	0.001798	5⅜	...	5.3750	0.003478	10	0.003232
1.1875	0.001588	5.3750	0.002628	...	32	...	0.2812	0.000795	1½	6	...	1.5000	0.001837	5½	...	5.5000	0.003518	9	0.003467
1.2500	0.001616	5.5000	0.002648	19/64	...	...	0.2969	0.000817	...	...	13	1.5385	0.001861	5⅝	...	5.6250	0.003558	8	0.003750
1.3125	0.001642	5.6250	0.002668	5/16	...	64	0.3125	0.000839	1 9/16	...	...	1.5625	0.001875	5¾	...	5.7500	0.003597	7	0.004099
1.3750	0.001668	5.7500	0.002687	...	28	...	0.3214	0.000850	1⅝	...	...	1.6250	0.001912	5⅞	...	5.8750	0.003636	6	0.004543
1.4375	0.001693	5.8750	0.002707	21/64	...	...	0.3281	0.000859	...	...	12	1.6667	0.001936	6	...	6.0000	0.003674	5½	0.004814
1.5000	0.001717	6.0000	0.002726	...	27	60	0.3333	0.000866	1 11/16	...	...	1.6875	0.001949	6½	...	6.5000	0.003824	5	0.005130
1.5625	0.001741	7.0000	0.002869	11/32	...	...	0.3438	0.000880	...	...	11½	1.7391	0.001978	7	...	7.0000	0.003969	4½	0.005503

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TABLE 19 INCREMENTS IN PITCH DIAMETER TOLERANCE — CLASS 2A (CONT'D)

(PD Tolerance = $0.0015\sqrt[3]{D} + 0.0015\sqrt{LE} + 0.015\sqrt[3]{P^2}$)

Diameter *D*				Length of Engagement *LE*														Pitch *P*	
				Based on (1)					Based on (1)					Based on (1)					
D	$0.0015\sqrt[3]{D}$	*D*	$0.0015\sqrt[3]{D}$	1 *D* for Sizes	9*P* for TPI	20*P* for TPI	*LE*	$0.0015 \times \sqrt{LE}$	1 *D* for Sizes	9*P* for TPI	20*P* for TPI	*LE*	$0.0015 \times \sqrt{LE}$	1 *D* for Sizes	20*P* for TPI	*LE*	$0.0015 \times \sqrt{LE}$	Threads/ in.	$0.015\sqrt[3]{P^2}$
1.6250	0.001764	8.0000	0.003000	...	...	56	0.3571	0.000896	1¾	...	...	1.7500	0.001984	7½	...	7.5000	0.004108	4	0.005953
1.6875	0.001786	9.0000	0.003120	23/64	...	...	0.3594	0.000899	...	5	...	1.8000	0.002012	8	...	8.0000	0.004243	...	...
1.7500	0.001808	10.0000	0.003232	3/8	24	...	0.3750	0.000919	1 13/16	...	...	1.8125	0.002019	8½	...	8.5000	0.004373	...	...
1.8125	0.001829	12.0000	0.003434	25/64	...	...	0.3906	0.000937	...	...	11	1.8182	0.002023	9	...	9.0000	0.004500	...	...
1.8750	0.001850	14.0000	0.003615	13/32	...	...	0.4063	0.000956	1⅞	...	...	1.8750	0.002054	9½	...	9.5000	0.004623	...	...
...	...	16.0000	0.003780	...	...	48	0.4167	0.000968	1 15/16	...	...	1.9375	0.002088	10	...	10.0000	0.004743	...	...
...	...	18.0000	0.003931	27/64	...	...	0.4219	0.000974	2	4½	10	2.0000	0.002121	10½	...	10.5000	0.004861	...	...
...	...	20.0000	0.004072	7/16	...	...	0.4375	0.000992	2⅛	...	...	2.1250	0.002187	11	...	11.0000	0.004975	...	...
...	...	24.0000	0.004327	...	20	...	0.4500	0.001006	...	...	9	2.2222	0.002236	11½	...	11.5000	0.005087	...	...
				...	...	44	0.4545	0.001011	2¼	4	...	2.2500	0.002250	12	...	12.0000	0.005196	...	...

GENERAL NOTE:
Class 2A tolerances are the bases for the tolerances for Classes 1A, 3A, 1B, 2B, and 3B.

NOTE:
(1) For example: *LE* = 0.5000 is equivalent to one diameter for the ½ in. size, 9 pitches for 18 threads per inch, or 20 pitches for 40 threads per inch.

TABLE 20 ALLOWANCES AND TOLERANCES FOR COARSE THREAD SERIES (UNC/UNRC)

Nominal Size	Basic Major Diameter *D*	Threads/in.	Allowances (1)	Tolerances									
				Major Diameter, External Threads (2)		Pitch Diameter						Minor Diameter, Internal Threads (3,4)	
			Classes 1A, 2A	Classes 1A, 2A (5)	Classes 2A, 3A	Class 1A	Class 1B	Class 2A	Class 2B	Class 3A	Class 3B	Classes 1B, 2B	Class 3B
1 (0.073)	0.0730	64	0.0006	...	0.0038	...	...	0.0020	0.0026	0.0015	0.0019	0.0062	0.0062
2 (0.086)	0.0860	56	0.0006	...	0.0041	...	...	0.0021	0.0028	0.0016	0.0021	0.0070	0.0070
3 (0.099)	0.0990	48	0.0007	...	0.0045	...	...	0.0023	0.0030	0.0017	0.0022	0.0081	0.0081
4 (0.112)	0.1120	40	0.0008	...	0.0051	...	...	0.0025	0.0033	0.0019	0.0024	0.0090	0.0090
5 (0.125)	0.1250	40	0.0008	...	0.0051	...	...	0.0026	0.0033	0.0019	0.0025	0.0083	0.0083
6 (0.138)	0.1380	32	0.0008	...	0.0060	...	...	0.0028	0.0037	0.0021	0.0027	0.0098	0.0098
8 (0.164)	0.1640	32	0.0009	...	0.0060	...	...	0.0029	0.0038	0.0022	0.0028	0.0087	0.0087
10 (0.190)	0.1900	24	0.0010	...	0.0072	...	...	0.0033	0.0043	0.0025	0.0032	0.0106	0.0106
12 (0.216)	0.2160	24	0.0010	...	0.0072	...	...	0.0034	0.0044	0.0026	0.0033	0.0098	0.0098
1/4	0.2500	20	0.0011	0.0122	0.0081	0.0056	0.0073	0.0037	0.0049	0.0028	0.0036	0.0115	0.0108
5/16	0.3125	18	0.0012	0.0131	0.0087	0.0061	0.0079	0.0040	0.0053	0.0030	0.0039	0.0127	0.0106
3/8	0.3750	16	0.0013	0.0142	0.0094	0.0065	0.0085	0.0044	0.0057	0.0033	0.0043	0.0141	0.0109
7/16	0.4375	14	0.0014	0.0155	0.0103	0.0071	0.0092	0.0047	0.0061	0.0035	0.0046	0.0158	0.0115
1/2	0.5000	13	0.0015	0.0163	0.0109	0.0074	0.0097	0.0050	0.0065	0.0037	0.0048	0.0169	0.0117
9/16	0.5625	12	0.0016	0.0172	0.0114	0.0078	0.0102	0.0052	0.0068	0.0039	0.0051	0.0180	0.0120
5/8	0.6250	11	0.0016	0.0182	0.0121	0.0083	0.0107	0.0055	0.0072	0.0041	0.0054	0.0194	0.0125
3/4	0.7500	10	0.0018	0.0194	0.0129	0.0088	0.0115	0.0059	0.0077	0.0044	0.0057	0.0210	0.0128
7/8	0.8750	9	0.0019	0.0208	0.0139	0.0095	0.0123	0.0063	0.0082	0.0047	0.0061	0.0228	0.0134
1	1.0000	8	0.0020	0.0225	0.0150	0.0101	0.0132	0.0068	0.0088	0.0051	0.0066	0.0250	0.0150
1 1/8	1.1250	7	0.0022	0.0246	0.0164	0.0109	0.0141	0.0072	0.0094	0.0054	0.0071	0.0276	0.0171
1 1/4	1.2500	7	0.0022	0.0246	0.0164	0.0111	0.0144	0.0074	0.0096	0.0055	0.0072	0.0276	0.0171
1 3/8	1.3750	6	0.0024	0.0273	0.0182	0.0120	0.0155	0.0080	0.0104	0.0060	0.0078	0.0306	0.0200
1 1/2	1.5000	6	0.0024	0.0273	0.0182	0.0121	0.0158	0.0081	0.0105	0.0061	0.0079	0.0306	0.0200
1 3/4	1.7500	5	0.0027	0.0308	0.0205	0.0134	0.0174	0.0089	0.0116	0.0067	0.0087	0.0340	0.0240
2	2.0000	4 1/2	0.0029	0.0330	0.0220	0.0143	0.0186	0.0095	0.0124	0.0071	0.0093	0.0358	0.0267
2 1/4	2.2500	4 1/2	0.0029	0.0330	0.0220	0.0146	0.0190	0.0097	0.0126	0.0073	0.0095	0.0358	0.0267
2 1/2	2.5000	4	0.0031	0.0357	0.0238	0.0155	0.0202	0.0104	0.0135	0.0078	0.0101	0.0375	0.0300
2 3/4	2.7500	4	0.0032	0.0357	0.0238	0.0158	0.0206	0.0105	0.0137	0.0079	0.0103	0.0375	0.0300
3	3.0000	4	0.0032	0.0357	0.0238	0.0161	0.0209	0.0107	0.0139	0.0080	0.0104	0.0375	0.0300
3 1/4	3.2500	4	0.0033	0.0357	0.0238	0.0163	0.0212	0.0109	0.0141	0.0082	0.0105	0.0375	0.0300
3 1/2	3.5000	4	0.0033	0.0357	0.0238	0.0166	0.0215	0.0110	0.0143	0.0083	0.0108	0.0375	0.0300
3 3/4	3.7500	4	0.0034	0.0357	0.0238	0.0168	0.0218	0.0112	0.0145	0.0084	0.0109	0.0375	0.0300
4	4.0000	4	0.0034	0.0357	0.0238	0.0170	0.0221	0.0113	0.0147	0.0085	0.0111	0.0375	0.0300

GENERAL NOTE:
See Section 5 for application of allowances and tolerances.

NOTES:
(1) Allowances apply to external thread Classes 1A and 2A only.
(2) Major diameter of internal threads may extend to a *P*/24 flat.
(3) Minor diameter of external threads may extend to a *P*/8 flat.
(4) Values are based on a length of engagement equal to the nominal diameter.
(5) For unfinished hot-rolled material threaded portion only, but does not include standard fasteners with rolled threads.

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TABLE 21 ALLOWANCES AND TOLERANCES FOR FINE THREAD SERIES (UNF/UNRF)

Nominal Size (1)	Basic Major Diameter *D*	Threads/In.	Allowances (2)	Tolerances									
				Major Diameter, External Threads (3)		Pitch Diameter						Minor Diameter, Internal Threads (4,5)	
			Classes 1A, 2A	Class 1A	Classes 2A, 3A	Class 1A	Class 1B	Class 2A	Class 2B	Class 3A	Class 3B	Classes 1B, 2B	Class 3B
0 (0.060)	0.0600	80	0.0005	...	0.0032	...	...	0.0018	0.0023	0.0013	0.0017	0.0049	0.0049
1 (0.073)	0.0730	72	0.0006	...	0.0035	...	...	0.0019	0.0025	0.0014	0.0019	0.0055	0.0055
2 (0.086)	0.0860	64	0.0006	...	0.0038	...	...	0.0020	0.0027	0.0015	0.0020	0.0062	0.0062
3 (0.099)	0.0990	56	0.0007	...	0.0041	...	...	0.0022	0.0028	0.0016	0.0021	0.0068	0.0068
4 (0.112)	0.1120	48	0.0007	...	0.0045	...	...	0.0024	0.0031	0.0018	0.0023	0.0074	0.0074
5 (0.125)	0.1250	44	0.0007	...	0.0048	...	...	0.0025	0.0032	0.0019	0.0024	0.0075	0.0075
6 (0.138)	0.1380	40	0.0008	...	0.0051	...	...	0.0026	0.0034	0.0020	0.0025	0.0077	0.0077
8 (0.164)	0.1640	36	0.0008	...	0.0055	...	...	0.0028	0.0036	0.0021	0.0027	0.0077	0.0077
10 (0.190)	0.1900	32	0.0009	...	0.0060	...	...	0.0030	0.0039	0.0023	0.0029	0.0079	0.0079
12 (0.216)	0.2160	28	0.0010	...	0.0065	...	...	0.0032	0.0042	0.0024	0.0031	0.0084	0.0084
1/4	0.2500	28	0.0010	0.0098	0.0065	0.0050	0.0065	0.0033	0.0043	0.0025	0.0032	0.0084	0.0077
5/16	0.3125	24	0.0011	0.0108	0.0072	0.0055	0.0071	0.0037	0.0048	0.0027	0.0036	0.0097	0.0080
3/8	0.3750	24	0.0011	0.0108	0.0072	0.0057	0.0074	0.0038	0.0049	0.0029	0.0037	0.0097	0.0073
7/16	0.4375	20	0.0013	0.0122	0.0081	0.0062	0.0081	0.0042	0.0054	0.0031	0.0041	0.0115	0.0082
1/2	0.5000	20	0.0013	0.0122	0.0081	0.0064	0.0084	0.0043	0.0056	0.0032	0.0042	0.0115	0.0078
9/16	0.5625	18	0.0014	0.0131	0.0087	0.0068	0.0089	0.0045	0.0059	0.0034	0.0044	0.0127	0.0082
5/8	0.6250	18	0.0014	0.0131	0.0087	0.0070	0.0091	0.0047	0.0060	0.0035	0.0045	0.0127	0.0081
3/4	0.7500	16	0.0015	0.0142	0.0094	0.0075	0.0098	0.0050	0.0065	0.0038	0.0049	0.0141	0.0085
7/8	0.8750	14	0.0016	0.0155	0.0103	0.0081	0.0106	0.0054	0.0070	0.0041	0.0053	0.0158	0.0091
1*	1.0000	14	...	...	...	...	...	...	...	...	...	...	...
1	1.0000	12	0.0018	0.0172	0.0114	0.0088	0.0114	0.0059	0.0076	0.0044	0.0057	0.0180	0.0100
1 1/8	1.1250	12	0.0018	0.0172	0.0114	0.0090	0.0117	0.0060	0.0078	0.0045	0.0059	0.0180	0.0100
1 1/4	1.2500	12	0.0018	0.0172	0.0114	0.0092	0.0120	0.0062	0.0080	0.0046	0.0060	0.0180	0.0100
1 3/8	1.3750	12	0.0019	0.0172	0.0114	0.0094	0.0123	0.0063	0.0082	0.0047	0.0061	0.0180	0.0100
1 1/2	1.5000	12	0.0019	0.0172	0.0114	0.0096	0.0125	0.0064	0.0083	0.0048	0.0063	0.0180	0.0100

GENERAL NOTE:
See Section 5 for application of allowances and tolerances.

NOTES:
(1) Asterisk denotes NS designation.
(2) Allowances apply to external thread Classes 1A and 2A only.
(3) Major diameter of internal threads may extend to a *P*/24 flat.
(4) Minor diameter of external threads may extend to a *P*/8 flat.
(5) Values are based on a length of engagement equal to the nominal diameter.

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TABLE 22 ALLOWANCES AND TOLERANCES FOR EXTRA-FINE THREAD SERIES (UNEF/UNREF)

Nominal Size	Basic Major Diameter *D*	Threads/in.	Allowances (1)	Tolerances						
				Major Diameter, External Threads (2)	Pitch Diameter (3)				Minor Diameter, Internal Threads (4,5)	
			Class 2A	Classes 2A, 3A	Class 2A	Class 2B	Class 3A	Class 3B	Class 2B	Class 3B
12 (0.216)	0.2160	32	0.0009	0.0060	0.0031	0.0041	0.0024	0.0031	0.0074	0.0073
1/4	0.2500	32	0.0010	0.0060	0.0032	0.0042	0.0024	0.0031	0.0074	0.0067
5/16	0.3125	32	0.0010	0.0060	0.0032	0.0042	0.0024	0.0031	0.0074	0.0060
3/8	0.3750	32	0.0010	0.0060	0.0034	0.0044	0.0025	0.0033	0.0074	0.0057
7/16	0.4375	28	0.0011	0.0065	0.0036	0.0046	0.0027	0.0035	0.0084	0.0063
1/2	0.5000	28	0.0011	0.0065	0.0037	0.0048	0.0028	0.0036	0.0084	0.0063
9/16	0.5625	24	0.0012	0.0072	0.0039	0.0051	0.0029	0.0038	0.0097	0.0070
5/8	0.6250	24	0.0012	0.0072	0.0040	0.0052	0.0030	0.0039	0.0097	0.0070
11/16	0.6875	24	0.0012	0.0072	0.0040	0.0052	0.0030	0.0039	0.0097	0.0070
3/4	0.7500	20	0.0013	0.0081	0.0044	0.0057	0.0033	0.0043	0.0115	0.0078
13/16	0.8125	20	0.0013	0.0081	0.0044	0.0057	0.0033	0.0043	0.0115	0.0078
7/8	0.8750	20	0.0013	0.0081	0.0044	0.0057	0.0033	0.0043	0.0115	0.0078
15/16	0.9375	20	0.0014	0.0081	0.0045	0.0059	0.0034	0.0044	0.0115	0.0078
1	1.0000	20	0.0014	0.0081	0.0045	0.0059	0.0034	0.0044	0.0115	0.0078
1 1/16	1.0625	18	0.0014	0.0087	0.0047	0.0062	0.0036	0.0046	0.0127	0.0081
1 1/8	1.1250	18	0.0014	0.0087	0.0047	0.0062	0.0036	0.0046	0.0127	0.0081
1 3/16	1.1875	18	0.0015	0.0087	0.0049	0.0063	0.0036	0.0047	0.0127	0.0081
1 1/4	1.2500	18	0.0015	0.0087	0.0049	0.0063	0.0036	0.0047	0.0127	0.0081
1 5/16	1.3125	18	0.0015	0.0087	0.0049	0.0063	0.0036	0.0047	0.0127	0.0081
1 3/8	1.3750	18	0.0015	0.0087	0.0049	0.0063	0.0036	0.0047	0.0127	0.0081
1 7/16	1.4375	18	0.0015	0.0087	0.0050	0.0065	0.0037	0.0048	0.0127	0.0081
1 1/2	1.5000	18	0.0015	0.0087	0.0050	0.0065	0.0037	0.0048	0.0127	0.0081
1 9/16	1.5625	18	0.0015	0.0087	0.0050	0.0065	0.0037	0.0048	0.0127	0.0081
1 5/8	1.6250	18	0.0015	0.0087	0.0050	0.0065	0.0037	0.0048	0.0127	0.0081
1 11/16	1.6875	18	0.0015	0.0087	0.0051	0.0066	0.0038	0.0049	0.0127	0.0081

GENERAL NOTE:
See Section 5 for application of allowances and tolerances.

NOTES:
(1) Allowances apply to external thread Class 2A only and are taken from Table 32.
(2) Major diameter of internal threads may extend to a *P*/24 flat.
(3) Values for pitch diameter are based on a length of engagement of nine pitches, and those for Classes 2A and 2B are taken from the respective step tables.
(4) Minor diameter of external threads may extend to a *P*/8 flat.
(5) Values for minor diameter are based on a length of engagement of one diameter.

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TABLE 23 ALLOWANCES AND TOLERANCES FOR 4-THREAD SERIES (4-UN/4-UNR)

Nominal Size (1)	Basic Major Diameter *D*	Allowances (2)	Tolerances						
			Major Diameter, External Threads (3)	Pitch Diameter (4)				Minor Diameter, Internal Threads (5,6)	
		Class 2A	Classes 2A, 3A	Class 2A	Class 2B	Class 3A	Class 3B	Class 2B	Class 3B
2½*	2.5000	0.0031	0.0238	0.0104	0.0135	0.0078	0.0101	0.0375	0.0300
2¾*	2.7500	0.0032	0.0238	0.0105	0.0137	0.0079	0.0103	0.0375	0.0300
3*	3.0000	0.0032	0.0238	0.0107	0.0139	0.0080	0.0104	0.0375	0.0300
3¼*	3.2500	0.0033	0.0238	0.0109	0.0141	0.0082	0.0106	0.0375	0.0300
3½*	3.5000	0.0033	0.0238	0.0110	0.0143	0.0083	0.0108	0.0375	0.0300
3¾*	3.7500	0.0034	0.0238	0.0112	0.0145	0.0084	0.0109	0.0375	0.0300
4*	4.0000	0.0034	0.0238	0.0113	0.0147	0.0085	0.0111	0.0375	0.0300
4¼	4.2500	0.0032	0.0238	0.0115	0.0149	0.0086	0.0112	0.0375	0.0300
4½	4.5000	0.0032	0.0238	0.0116	0.0151	0.0087	0.0113	0.0375	0.0300
4¾	4.7500	0.0032	0.0238	0.0117	0.0153	0.0088	0.0114	0.0375	0.0300
5	5.0000	0.0032	0.0238	0.0119	0.0154	0.0089	0.0116	0.0375	0.0300
5¼	5.2500	0.0032	0.0238	0.0120	0.0156	0.0090	0.0117	0.0375	0.0300
5½	5.5000	0.0032	0.0238	0.0121	0.0158	0.0091	0.0118	0.0375	0.0300
5¾	5.7500	0.0033	0.0238	0.0122	0.0159	0.0092	0.0119	0.0375	0.0300
6	6.0000	0.0033	0.0238	0.0124	0.0161	0.0093	0.0120	0.0375	0.0300

GENERAL NOTE:
See Section 5 for application of allowances and tolerances.

NOTES:
(1) Asterisks denote standard sizes of the UNC series.
(2) Allowances apply to external thread Class 2A only.
(3) Major diameter of internal threads may extend to a *P*/24 flat.
(4) Classes 2A, 2B, 3A, and 3B PD tolerances are based on a length of engagement equal to the nominal diameter.
(5) Minor diameter of external threads may extend to a *P*/8 flat.
(6) Classes 2B and 3B minor diameter tolerances are based on a length of engagement of one diameter.

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TABLE 24 ALLOWANCES AND TOLERANCES FOR 6-THREAD SERIES (6-UN/6-UNR)

Nominal Size (1)	Basic Major Diameter D	Allowances (2)	Tolerances						
			Major Diameter, External Threads (3)	Pitch Diameter (4)				Minor Diameter, Internal Threads (5,6)	
		Class 2A	Classes 2A, 3A	Class 2A	Class 2B	Class 3A	Class 3B	Class 2B	Class 3B
1⅜*	1.3750	0.0024	0.0182	0.0080	0.0104	0.0060	0.0078	0.0306	0.0200
1⁷⁄₁₆	1.4375	0.0024	0.0182	0.0080	0.0104	0.0060	0.0078	0.0306	0.0200
1½*	1.5000	0.0024	0.0182	0.0081	0.0105	0.0061	0.0079	0.0306	0.0200
1⁹⁄₁₆	1.5625	0.0024	0.0182	0.0082	0.0106	0.0061	0.0080	0.0306	0.0200
1⅝	1.6250	0.0025	0.0182	0.0082	0.0107	0.0062	0.0080	0.0306	0.0200
1¹¹⁄₁₆	1.6875	0.0025	0.0182	0.0083	0.0108	0.0062	0.0081	0.0306	0.0200
1¾	1.7500	0.0025	0.0182	0.0083	0.0108	0.0063	0.0081	0.0306	0.0200
1¹³⁄₁₆	1.8125	0.0025	0.0182	0.0084	0.0109	0.0063	0.0082	0.0306	0.0200
1⅞	1.8750	0.0025	0.0182	0.0084	0.0110	0.0063	0.0082	0.0306	0.0200
1¹⁵⁄₁₆	1.9375	0.0026	0.0182	0.0085	0.0111	0.0064	0.0083	0.0306	0.0200
2	2.0000	0.0026	0.0182	0.0086	0.0111	0.0064	0.0083	0.0306	0.0200
2⅛	2.1250	0.0026	0.0182	0.0087	0.0113	0.0065	0.0084	0.0306	0.0200
2¼	2.2500	0.0026	0.0182	0.0088	0.0114	0.0066	0.0085	0.0306	0.0200
2⅜	2.3750	0.0027	0.0182	0.0089	0.0115	0.0066	0.0086	0.0306	0.0200
2½	2.5000	0.0027	0.0182	0.0090	0.0116	0.0067	0.0087	0.0306	0.0200
2⅝	2.6250	0.0027	0.0182	0.0090	0.0118	0.0068	0.0088	0.0306	0.0200
2¾	2.7500	0.0027	0.0182	0.0091	0.0119	0.0068	0.0089	0.0306	0.0200
2⅞	2.8750	0.0028	0.0182	0.0092	0.0120	0.0069	0.0090	0.0306	0.0200
3	3.0000	0.0028	0.0182	0.0093	0.0121	0.0070	0.0091	0.0306	0.0200
3⅛	3.1250	0.0028	0.0182	0.0094	0.0122	0.0070	0.0092	0.0306	0.0200
3¼	3.2500	0.0028	0.0182	0.0095	0.0123	0.0071	0.0092	0.0306	0.0200
3⅜	3.3750	0.0029	0.0182	0.0095	0.0124	0.0072	0.0093	0.0306	0.0200
3½	3.5000	0.0029	0.0182	0.0096	0.0125	0.0072	0.0094	0.0306	0.0200
3⅝	3.6250	0.0029	0.0182	0.0097	0.0126	0.0073	0.0095	0.0306	0.0200
3¾	3.7500	0.0029	0.0182	0.0098	0.0127	0.0073	0.0095	0.0306	0.0200
3⅞	3.8750	0.0030	0.0182	0.0099	0.0128	0.0074	0.0096	0.0306	0.0200
4	4.0000	0.0030	0.0182	0.0099	0.0129	0.0074	0.0097	0.0306	0.0200
4⅛	4.1250	0.0030	0.0182	0.0100	0.0130	0.0075	0.0097	0.0306	0.0200
4¼	4.2500	0.0030	0.0182	0.0101	0.0131	0.0075	0.0098	0.0306	0.0200
4⅜	4.3750	0.0030	0.0182	0.0101	0.0132	0.0076	0.0099	0.0306	0.0200
4½	4.5000	0.0031	0.0182	0.0102	0.0133	0.0077	0.0099	0.0306	0.0200
4⅝	4.6250	0.0031	0.0182	0.0103	0.0133	0.0077	0.0100	0.0306	0.0200
4¾	4.7500	0.0031	0.0182	0.0103	0.0134	0.0077	0.0101	0.0306	0.0200
4⅞	4.8750	0.0031	0.0182	0.0104	0.0135	0.0078	0.0101	0.0306	0.0200
5	5.0000	0.0031	0.0182	0.0105	0.0136	0.0078	0.0102	0.0306	0.0200
5⅛	5.1250	0.0032	0.0182	0.0105	0.0137	0.0079	0.0103	0.0306	0.0200
5¼	5.2500	0.0032	0.0182	0.0106	0.0138	0.0079	0.0103	0.0306	0.0200
5⅜	5.3750	0.0032	0.0182	0.0106	0.0138	0.0080	0.0104	0.0306	0.0200
5½	5.5000	0.0032	0.0182	0.0107	0.0139	0.0080	0.0104	0.0306	0.0200
5⅝	5.6250	0.0032	0.0182	0.0108	0.0140	0.0081	0.0105	0.0306	0.0200
5¾	5.7500	0.0032	0.0182	0.0108	0.0141	0.0081	0.0106	0.0306	0.0200
5⅞	5.8750	0.0033	0.0182	0.0109	0.0142	0.0082	0.0106	0.0306	0.0200
6	6.0000	0.0033	0.0182	0.0109	0.0142	0.0082	0.0107	0.0306	0.0200

(Notes are on next page)

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TABLE 24 (CONT'D)

GENERAL NOTE:
See Section 5 for application of allowances and tolerances.

NOTES:
(1) Asterisks denote standard sizes of the UNC thread series. See Note (4).
(2) Allowances apply to external thread Class 2A only and are taken from Table 32.
(3) Major diameter of internal threads may extend to a *P*/24 flat.
(4) Classes 2A, 2B, 3A, and 3B PD tolerances will be based on a length of engagement to be determined later by negotiation, except that for the 1⅜ in. and 1½ in. sizes they are based on a length of engagement equal to the nominal diameter.
(5) Minor diameter of external threads may extend to a *P*/8 flat.
(6) Class 2B minor diameter tolerances are based on a length of engagement of one diameter.

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TABLE 25 ALLOWANCES AND TOLERANCES FOR 8-THREAD SERIES (8-UN/8-UNR)

Nominal Size (1)	Basic Major Diameter *D*	Allowances (2)	Tolerances						
			Major Diameter, External Threads (3)	Pitch Diameter (4)				Minor Diameter, Internal Threads (5,6)	
		Class 2A	Classes 2A, 3A	Class 2A	Class 2B	Class 3A	Class 3B	Class 2B	Class 3B
1*	1.0000	0.0020	0.0150	0.0068	0.0088	0.0051	0.0066	0.0250	0.0150
1 1/16	1.0625	0.0020	0.0150	0.0068	0.0089	0.0051	0.0067	0.0250	0.0150
1 1/8	1.1250	0.0021	0.0150	0.0069	0.0090	0.0052	0.0067	0.0250	0.0150
1 3/16	1.1875	0.0021	0.0150	0.0070	0.0091	0.0052	0.0068	0.0250	0.0150
1 1/4	1.2500	0.0021	0.0150	0.0070	0.0092	0.0053	0.0069	0.0250	0.0150
1 5/16	1.3125	0.0021	0.0150	0.0071	0.0092	0.0053	0.0069	0.0250	0.0150
1 3/8	1.3750	0.0022	0.0150	0.0072	0.0093	0.0054	0.0070	0.0250	0.0150
1 7/16	1.4375	0.0022	0.0150	0.0072	0.0094	0.0054	0.0071	0.0250	0.0150
1 1/2	1.5000	0.0022	0.0150	0.0073	0.0095	0.0055	0.0071	0.0250	0.0150
1 9/16	1.5625	0.0022	0.0150	0.0074	0.0096	0.0055	0.0072	0.0250	0.0150
1 5/8	1.6250	0.0022	0.0150	0.0074	0.0097	0.0056	0.0072	0.0250	0.0150
1 11/16	1.6875	0.0022	0.0150	0.0075	0.0097	0.0056	0.0073	0.0250	0.0150
1 3/4	1.7500	0.0023	0.0150	0.0075	0.0098	0.0057	0.0074	0.0250	0.0150
1 13/16	1.8125	0.0023	0.0150	0.0076	0.0099	0.0057	0.0074	0.0250	0.0150
1 7/8	1.8750	0.0023	0.0150	0.0077	0.0100	0.0057	0.0075	0.0250	0.0150
1 15/16	1.9375	0.0023	0.0150	0.0077	0.0100	0.0058	0.0075	0.0250	0.0150
2	2.0000	0.0023	0.0150	0.0078	0.0101	0.0058	0.0076	0.0250	0.0150
2 1/8	2.1250	0.0024	0.0150	0.0079	0.0102	0.0059	0.0077	0.0250	0.0150
2 1/4	2.2500	0.0024	0.0150	0.0080	0.0104	0.0060	0.0078	0.0250	0.0150
2 3/8	2.3750	0.0024	0.0150	0.0081	0.0105	0.0060	0.0079	0.0250	0.0150
2 1/2	2.5000	0.0024	0.0150	0.0082	0.0106	0.0061	0.0080	0.0250	0.0150
2 5/8	2.6250	0.0025	0.0150	0.0082	0.0107	0.0062	0.0080	0.0250	0.0150
2 3/4	2.7500	0.0025	0.0150	0.0083	0.0108	0.0063	0.0081	0.0250	0.0150
2 7/8	2.8750	0.0025	0.0150	0.0084	0.0110	0.0063	0.0082	0.0250	0.0150
3	3.0000	0.0026	0.0150	0.0085	0.0111	0.0064	0.0083	0.0250	0.0150
3 1/8	3.1250	0.0026	0.0150	0.0086	0.0112	0.0064	0.0084	0.0250	0.0150
3 1/4	3.2500	0.0026	0.0150	0.0087	0.0113	0.0065	0.0085	0.0250	0.0150
3 3/8	3.3750	0.0026	0.0150	0.0088	0.0114	0.0066	0.0085	0.0250	0.0150
3 1/2	3.5000	0.0026	0.0150	0.0088	0.0115	0.0066	0.0086	0.0250	0.0150
3 5/8	3.6250	0.0027	0.0150	0.0089	0.0116	0.0067	0.0087	0.0250	0.0150
3 3/4	3.7500	0.0027	0.0150	0.0090	0.0117	0.0067	0.0088	0.0250	0.0150
3 7/8	3.8750	0.0027	0.0150	0.0091	0.0118	0.0068	0.0088	0.0250	0.0150
4	4.0000	0.0027	0.0150	0.0091	0.0119	0.0068	0.0089	0.0250	0.0150
4 1/8	4.1250	0.0028	0.0150	0.0092	0.0120	0.0069	0.0090	0.0250	0.0150
4 1/4	4.2500	0.0028	0.0150	0.0093	0.0120	0.0070	0.0091	0.0250	0.0150
4 3/8	4.3750	0.0028	0.0150	0.0093	0.0120	0.0070	0.0091	0.0250	0.0150
4 1/2	4.5000	0.0028	0.0150	0.0094	0.0122	0.0071	0.0092	0.0250	0.0150
4 5/8	4.6250	0.0029	0.0150	0.0095	0.0124	0.0071	0.0093	0.0250	0.0150
4 3/4	4.7500	0.0029	0.0150	0.0095	0.0124	0.0071	0.0093	0.0250	0.0150
4 7/8	4.8750	0.0029	0.0150	0.0096	0.0125	0.0072	0.0094	0.0250	0.0150

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TABLE 25 ALLOWANCES AND TOLERANCES FOR 8-THREAD SERIES (8-UN/8-UNR) (CONT'D)

Nominal Size (1)	Basic Major Diameter *D*	Allowances (2)	Tolerances						
			Major Diameter, External Threads (3)	Pitch Diameter (4)				Minor Diameter, Internal Threads (5,6)	
		Class 2A	Classes 2A, 3A	Class 2A	Class 2B	Class 3A	Class 3B	Class 2B	Class 3B
5	5.0000	0.0029	0.0150	0.0097	0.0126	0.0073	0.0095	0.0250	0.0150
5⅛	5.1250	0.0029	0.0150	0.0097	0.0126	0.0073	0.0095	0.0250	0.0150
5¼	5.2500	0.0029	0.0150	0.0098	0.0127	0.0074	0.0096	0.0250	0.0150
5⅜	5.3750	0.0030	0.0150	0.0099	0.0129	0.0074	0.0097	0.0250	0.0150
5½	5.5000	0.0030	0.0150	0.0099	0.0129	0.0074	0.0097	0.0250	0.0150
5⅝	5.6250	0.0030	0.0150	0.0100	0.0130	0.0075	0.0098	0.0250	0.0150
5¾	5.7500	0.0030	0.0150	0.0100	0.0130	0.0075	0.0098	0.0250	0.0150
5⅞	5.8750	0.0031	0.0150	0.0101	0.0131	0.0076	0.0098	0.0250	0.0150
6	6.0000	0.0031	0.0150	0.0102	0.0133	0.0077	0.0099	0.0250	0.0150

GENERAL NOTE:
See Section 5 for application of allowances and tolerances.

NOTES:
(1) Asterisk denotes standard size of the UNC series.
(2) Allowances apply to external thread Class 2A only.
(3) Major diameter of internal threads may extend to a *P*/24 flat. For major diameter tolerances for Classes 2A and 2B unfinished hot-rolled material, see Tables 3A and 3B.
(4) The values for 8-UN Classes 2A, 2B, 3A, and 3B are based on a length of engagement equal to the nominal diameter.
(5) Minor diameter of external threads may extend to a *P*/8 flat.
(6) Values for minor diameter are based on a length of engagement of one diameter.

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TABLE 26 ALLOWANCES AND TOLERANCES FOR 12-THREAD SERIES (12-UN/12-UNR)

Nominal Size (1)	Basic Major Diameter D	Allowances (2)	Tolerances						
			Major Diameter, External Threads (3)	Pitch Diameter (4)				Minor Diameter, Internal Threads (5,6)	
		Class 2A	Classes 2A, 3A	Class 2A	Class 2B	Class 3A	Class 3B	Class 2B	Class 3B
9/16*	0.5625	0.0016	0.0114	0.0052	0.0068	0.0039	0.0051	0.0180	0.0100
5/8	0.6250	0.0016	0.0114	0.0054	0.0071	0.0041	0.0053	0.0180	0.0100
11/16	0.6875	0.0016	0.0114	0.0054	0.0071	0.0041	0.0053	0.0180	0.0100
3/4	0.7500	0.0017	0.0114	0.0055	0.0072	0.0041	0.0054	0.0180	0.0100
13/16	0.8125	0.0017	0.0114	0.0055	0.0072	0.0041	0.0054	0.0180	0.0100
7/8	0.8750	0.0017	0.0114	0.0055	0.0072	0.0041	0.0054	0.0180	0.0100
15/16	0.9375	0.0017	0.0114	0.0057	0.0074	0.0041	0.0055	0.0180	0.0100
1*	1.0000	0.0018	0.0114	0.0059	0.0076	0.0044	0.0057	0.0180	0.0100
1 1/16	1.0625	0.0017	0.0114	0.0057	0.0074	0.0042	0.0055	0.0180	0.0100
1 1/8*	1.1250	0.0018	0.0114	0.0060	0.0078	0.0045	0.0059	0.0180	0.0100
1 3/16	1.1875	0.0017	0.0114	0.0058	0.0075	0.0043	0.0056	0.0180	0.0100
1 1/4*	1.2500	0.0018	0.0114	0.0062	0.0080	0.0046	0.0060	0.0180	0.0100
1 5/16	1.3125	0.0017	0.0114	0.0058	0.0075	0.0043	0.0056	0.0180	0.0100
1 3/8*	1.3750	0.0019	0.0114	0.0063	0.0082	0.0047	0.0061	0.0180	0.0100
1 7/16	1.4375	0.0018	0.0114	0.0059	0.0076	0.0044	0.0057	0.0180	0.0100
1 1/2*	1.5000	0.0019	0.0114	0.0064	0.0083	0.0048	0.0063	0.0180	0.0100
1 9/16	1.5625	0.0018	0.0114	0.0059	0.0076	0.0044	0.0057	0.0180	0.0100
1 5/8	1.6250	0.0018	0.0114	0.0059	0.0076	0.0044	0.0057	0.0180	0.0100
1 11/16	1.6875	0.0018	0.0114	0.0060	0.0078	0.0045	0.0058	0.0180	0.0100
1 3/4	1.7500	0.0018	0.0114	0.0060	0.0078	0.0045	0.0058	0.0180	0.0100
1 13/16	1.8125	0.0018	0.0114	0.0060	0.0078	0.0045	0.0058	0.0180	0.0100
1 7/8	1.8750	0.0018	0.0114	0.0060	0.0078	0.0045	0.0058	0.0180	0.0100
1 15/16	1.9375	0.0018	0.0114	0.0061	0.0079	0.0045	0.0059	0.0180	0.0100
2	2.0000	0.0018	0.0114	0.0061	0.0079	0.0045	0.0059	0.0180	0.0100
2 1/16	2.1250	0.0018	0.0114	0.0061	0.0079	0.0045	0.0059	0.0180	0.0100
2 1/4	2.2500	0.0018	0.0114	0.0061	0.0079	0.0045	0.0059	0.0180	0.0100
2 3/8	2.3750	0.0019	0.0114	0.0062	0.0081	0.0046	0.0060	0.0180	0.0100
2 1/2	2.5000	0.0019	0.0114	0.0062	0.0081	0.0046	0.0060	0.0180	0.0100
2 5/8	2.6250	0.0019	0.0114	0.0062	0.0081	0.0046	0.0060	0.0180	0.0100
2 3/4	2.7500	0.0019	0.0114	0.0062	0.0081	0.0046	0.0060	0.0180	0.0100
2 7/8	2.8750	0.0019	0.0114	0.0063	0.0082	0.0047	0.0062	0.0180	0.0100
3	3.0000	0.0019	0.0114	0.0063	0.0082	0.0047	0.0062	0.0180	0.0100
3 1/8	3.1250	0.0019	0.0114	0.0063	0.0082	0.0047	0.0062	0.0180	0.0100
3 1/4	3.2500	0.0019	0.0114	0.0063	0.0082	0.0047	0.0062	0.0180	0.0100
3 3/8	3.3750	0.0019	0.0114	0.0064	0.0084	0.0048	0.0063	0.0180	0.0100
3 1/2	3.5000	0.0019	0.0114	0.0064	0.0084	0.0048	0.0063	0.0180	0.0100
3 5/8	3.6250	0.0019	0.0114	0.0064	0.0084	0.0048	0.0063	0.0180	0.0100
3 3/4	3.7500	0.0019	0.0114	0.0064	0.0084	0.0048	0.0063	0.0180	0.0100
3 7/8	3.8750	0.0020	0.0114	0.0065	0.0085	0.0049	0.0064	0.0180	0.0100
4	4.0000	0.0020	0.0114	0.0065	0.0085	0.0049	0.0064	0.0180	0.0100
4 1/8	4.1250	0.0020	0.0114	0.0065	0.0085	0.0049	0.0064	0.0180	0.0100
4 1/4	4.2500	0.0020	0.0114	0.0065	0.0085	0.0049	0.0064	0.0180	0.0100
4 3/8	4.3750	0.0020	0.0114	0.0065	0.0085	0.0049	0.0064	0.0180	0.0100

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TABLE 26 ALLOWANCES AND TOLERANCES FOR 12-THREAD SERIES (12-UN/12-UNR) (CONT'D)

Nominal Size (1)	Basic Major Diameter *D*	Allowances (2)	Tolerances						
			Major Diameter, External Threads (3)	Pitch Diameter (4)				Minor Diameter, Internal Threads (5,6)	
		Class 2A	Classes 2A, 3A	Class 2A	Class 2B	Class 3A	Class 3B	Class 2B	Class 3B
4½	4.5000	0.0020	0.0114	0.0065	0.0085	0.0049	0.0064	0.0180	0.0100
4⅝	4.6250	0.0020	0.0114	0.0067	0.0087	0.0050	0.0066	0.0180	0.0100
4¾	4.7500	0.0020	0.0114	0.0067	0.0087	0.0050	0.0066	0.0180	0.0100
4⅞	4.8750	0.0020	0.0114	0.0067	0.0087	0.0050	0.0066	0.0180	0.0100
5	5.0000	0.0020	0.0114	0.0067	0.0087	0.0050	0.0066	0.0180	0.0100
5⅛	5.1250	0.0020	0.0114	0.0067	0.0087	0.0050	0.0066	0.0180	0.0100
5¼	5.2500	0.0020	0.0114	0.0067	0.0087	0.0050	0.0066	0.0180	0.0100
5⅜	5.3750	0.0020	0.0114	0.0067	0.0087	0.0050	0.0066	0.0180	0.0100
5½	5.5000	0.0020	0.0114	0.0067	0.0087	0.0050	0.0066	0.0180	0.0100
5⅝	5.6250	0.0021	0.0114	0.0069	0.0090	0.0052	0.0067	0.0180	0.0100
5¾	5.7500	0.0021	0.0114	0.0069	0.0090	0.0052	0.0067	0.0180	0.0100
5⅞	5.8750	0.0021	0.0114	0.0069	0.0090	0.0052	0.0067	0.0180	0.0100
6	6.0000	0.0021	0.0114	0.0069	0.0090	0.0052	0.0067	0.0180	0.0100

GENERAL NOTE:
See Section 5 for application of allowances and tolerances.

NOTES:
(1) Asterisks denote standard sizes of the UNC or UNF series and tolerances are the same as for those series, being based on a length of engagement equal to the nominal diameter. See Note (4).
(2) Allowances apply to external thread Class 2A only and are taken from Table 32.
(3) Major diameter of internal threads may extend to a *P*/24 flat.
(4) Classes 2A, 2B, 3A, and 3B tolerances are based on a length of engagement of nine pitches and are taken from Tables 34, 35, 37, and 38, except as indicated by an asterisk.
(5) Minor diameter of external threads may extend to a *P*/8 flat.
(6) Classes 2B and 3B minor diameter tolerances are based on a length of engagement of one diameter.

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TABLE 27 ALLOWANCES AND TOLERANCES FOR 16-THREAD SERIES (16-UN/16-UNR)

Nominal Size (1)	Basic Major Diameter D	Allowances (2)	Tolerances						
			Major Diameter, External Threads (3)	Pitch Diameter (4)				Minor Diameter, Internal Threads (5,6)	
		Class 2A	Classes 2A, 3A	Class 2A	Class 2B	Class 3A	Class 3B	Class 2B	Class 3B
3/8*	0.3750	0.0013	0.0094	0.0044	0.0057	0.0033	0.0043	0.0141	0.0109
7/16	0.4375	0.0014	0.0094	0.0046	0.0059	0.0034	0.0045	0.0141	0.0102
1/2	0.5000	0.0014	0.0094	0.0047	0.0061	0.0035	0.0046	0.0141	0.0096
9/16	0.5625	0.0014	0.0094	0.0047	0.0061	0.0035	0.0046	0.0141	0.0092
5/8	0.6250	0.0014	0.0094	0.0048	0.0062	0.0036	0.0046	0.0141	0.0089
11/16	0.6875	0.0014	0.0094	0.0048	0.0062	0.0036	0.0046	0.0141	0.0086
3/4*	0.7500	0.0015	0.0094	0.0050	0.0065	0.0038	0.0049	0.0141	0.0085
13/16	0.8125	0.0015	0.0094	0.0049	0.0063	0.0036	0.0047	0.0141	0.0085
7/8	0.8750	0.0015	0.0094	0.0049	0.0063	0.0036	0.0047	0.0141	0.0085
15/16	0.9375	0.0015	0.0094	0.0050	0.0065	0.0037	0.0049	0.0141	0.0085
1	1.0000	0.0015	0.0094	0.0050	0.0065	0.0037	0.0049	0.0141	0.0085
1 1/16	1.0625	0.0015	0.0094	0.0050	0.0065	0.0037	0.0049	0.0141	0.0085
1 1/8	1.1250	0.0015	0.0094	0.0050	0.0065	0.0037	0.0049	0.0141	0.0085
1 3/16	1.1875	0.0015	0.0094	0.0051	0.0066	0.0038	0.0050	0.0141	0.0085
1 1/4	1.2500	0.0015	0.0094	0.0051	0.0066	0.0038	0.0050	0.0141	0.0085
1 5/16	1.3125	0.0015	0.0094	0.0051	0.0066	0.0038	0.0050	0.0141	0.0085
1 3/8	1.3750	0.0015	0.0094	0.0051	0.0066	0.0038	0.0050	0.0141	0.0085
1 7/16	1.4375	0.0016	0.0094	0.0052	0.0068	0.0039	0.0051	0.0141	0.0085
1 1/2	1.5000	0.0016	0.0094	0.0052	0.0068	0.0039	0.0051	0.0141	0.0085
1 9/16	1.5625	0.0016	0.0094	0.0052	0.0068	0.0039	0.0051	0.0141	0.0085
1 5/8	1.6250	0.0016	0.0094	0.0052	0.0068	0.0039	0.0051	0.0141	0.0085
1 11/16	1.6875	0.0016	0.0094	0.0053	0.0069	0.0040	0.0052	0.0141	0.0085
1 3/4*	1.7500	0.0016	0.0094	0.0053	0.0069	0.0040	0.0052	0.0141	0.0085
1 13/16	1.8125	0.0016	0.0094	0.0053	0.0069	0.0040	0.0052	0.0141	0.0085
1 7/8	1.8750	0.0016	0.0094	0.0053	0.0069	0.0040	0.0052	0.0141	0.0085
1 15/16	1.9375	0.0016	0.0094	0.0054	0.0070	0.0040	0.0052	0.0141	0.0085
2*	2.0000	0.0016	0.0094	0.0054	0.0070	0.0040	0.0052	0.0141	0.0085
2 1/8	2.1250	0.0016	0.0094	0.0054	0.0070	0.0041	0.0052	0.0141	0.0085
2 1/4	2.2500	0.0016	0.0094	0.0054	0.0070	0.0041	0.0052	0.0141	0.0085
2 3/8	2.3750	0.0017	0.0094	0.0055	0.0072	0.0041	0.0054	0.0141	0.0085
2 1/2	2.5000	0.0017	0.0094	0.0055	0.0072	0.0041	0.0054	0.0141	0.0085
2 5/8	2.6250	0.0017	0.0094	0.0055	0.0072	0.0041	0.0054	0.0141	0.0085
2 3/4	2.7500	0.0017	0.0094	0.0055	0.0072	0.0041	0.0054	0.0141	0.0085
2 7/8	2.8750	0.0017	0.0094	0.0056	0.0073	0.0042	0.0055	0.0141	0.0085
3	3.0000	0.0017	0.0094	0.0056	0.0073	0.0042	0.0055	0.0141	0.0085
3 1/8	3.1250	0.0017	0.0094	0.0056	0.0073	0.0042	0.0055	0.0141	0.0085
3 1/4	3.2500	0.0017	0.0094	0.0056	0.0073	0.0042	0.0055	0.0141	0.0085
3 3/8	3.3750	0.0017	0.0094	0.0058	0.0075	0.0043	0.0056	0.0141	0.0085
3 1/2	3.5000	0.0017	0.0094	0.0058	0.0075	0.0043	0.0056	0.0141	0.0085
3 5/8	3.6250	0.0017	0.0094	0.0058	0.0075	0.0043	0.0056	0.0141	0.0085
3 3/4	3.7500	0.0017	0.0094	0.0058	0.0075	0.0043	0.0056	0.0141	0.0085
3 7/8	3.8750	0.0018	0.0094	0.0059	0.0076	0.0044	0.0057	0.0141	0.0085

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TABLE 27 ALLOWANCES AND TOLERANCES FOR 16-THREAD SERIES (16-UN/16-UNR) (CONT'D)

Nominal Size (1)	Basic Major Diameter *D*	Allowances (2)	Tolerances						
			Major Diameter, External Threads (3)	Pitch Diameter (4)				Minor Diameter, Internal Threads (5,6)	
		Class 2A	Classes 2A, 3A	Class 2A	Class 2B	Class 3A	Class 3B	Class 2B	Class 3B
4	4.0000	0.0018	0.0094	0.0059	0.0076	0.0044	0.0057	0.0141	0.0085
4⅛	4.1250	0.0018	0.0094	0.0059	0.0076	0.0044	0.0057	0.0141	0.0085
4¼	4.2500	0.0018	0.0094	0.0059	0.0076	0.0044	0.0057	0.0141	0.0085
4⅜	4.3750	0.0018	0.0094	0.0059	0.0076	0.0044	0.0057	0.0141	0.0085
4½	4.5000	0.0018	0.0094	0.0059	0.0076	0.0044	0.0057	0.0141	0.0085
4⅝	4.6250	0.0018	0.0094	0.0061	0.0079	0.0045	0.0059	0.0141	0.0085
4¾	4.7500	0.0018	0.0094	0.0061	0.0079	0.0045	0.0059	0.0141	0.0085
4⅞	4.8750	0.0018	0.0094	0.0061	0.0079	0.0045	0.0059	0.0141	0.0085
5	5.0000	0.0018	0.0094	0.0061	0.0079	0.0045	0.0059	0.0141	0.0085
5⅛	5.1250	0.0018	0.0094	0.0061	0.0079	0.0045	0.0059	0.0141	0.0085
5¼	5.2500	0.0018	0.0094	0.0061	0.0079	0.0045	0.0059	0.0141	0.0085
5⅜	5.3750	0.0018	0.0094	0.0061	0.0079	0.0045	0.0059	0.0141	0.0085
5½	5.5000	0.0018	0.0094	0.0061	0.0079	0.0045	0.0059	0.0141	0.0085
5⅝	5.6250	0.0019	0.0094	0.0062	0.0081	0.0047	0.0061	0.0141	0.0085
5¾	5.7500	0.0019	0.0094	0.0062	0.0081	0.0047	0.0061	0.0141	0.0085
5⅞	5.8750	0.0019	0.0094	0.0062	0.0081	0.0047	0.0061	0.0141	0.0085
6	6.0000	0.0019	0.0094	0.0062	0.0081	0.0047	0.0061	0.0141	0.0085

GENERAL NOTE:
See Section 5 for application of allowances and tolerances.

NOTES:
(1) Asterisks denote standard sizes of the UNC or UN thread series. See Note (4).
(2) Allowances apply to external thread Class 2A only and are taken from Table 32.
(3) Major diameter of internal threads may extend to a *P*/24 flat.
(4) Classes 2A, 2B, 3A, and 3B PD tolerances are based on a length of engagement of nine pitches and are taken from Tables 34, 35, 37, and 38, except that for the ⅜ in. and ¾ in. sizes they are based on a length of engagement equal to the nominal diameter.
(5) Minor diameter of external threads may extend to a *P*/8 flat.
(6) Classes 2B and 3B minor diameter tolerances are based on a length of engagement of one diameter.

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TABLE 28 ALLOWANCES AND TOLERANCES FOR 20-THREAD SERIES (20-UN/20-UNR)

Nominal Size (1)	Basic Major Diameter *D*	Allowances (2)	Tolerances						
			Major Diameter, External Threads (3)	Pitch Diameter (4)				Minor Diameter, Internal Threads (5,6)	
		Class 2A	Classes 2A, 3A	Class 2A	Class 2B	Class 3A	Class 3B	Class 2B	Class 3B
1/4*	0.2500	0.0011	0.0081	0.0037	0.0048	0.0028	0.0036	0.0115	0.0108
5/16	0.3125	0.0012	0.0081	0.0040	0.0052	0.0030	0.0039	0.0115	0.0096
3/8	0.3750	0.0012	0.0081	0.0041	0.0054	0.0031	0.0040	0.0115	0.0088
7/16*	0.4375	0.0013	0.0081	0.0042	0.0054	0.0031	0.0041	0.0115	0.0082
1/2*	0.5000	0.0013	0.0081	0.0043	0.0056	0.0032	0.0042	0.0115	0.0078
9/16	0.5625	0.0013	0.0081	0.0042	0.0055	0.0032	0.0041	0.0115	0.0078
5/8	0.6250	0.0013	0.0081	0.0043	0.0056	0.0032	0.0042	0.0115	0.0078
11/16	0.6875	0.0013	0.0081	0.0043	0.0056	0.0032	0.0042	0.0115	0.0078
3/4*	0.7500	0.0013	0.0081	0.0044	0.0057	0.0033	0.0043	0.0115	0.0078
13/16*	0.8125	0.0013	0.0081	0.0044	0.0057	0.0033	0.0043	0.0115	0.0078
7/8	0.8750	0.0013	0.0081	0.0044	0.0057	0.0033	0.0043	0.0115	0.0078
15/16*	0.9375	0.0014	0.0081	0.0045	0.0059	0.0034	0.0044	0.0115	0.0078
1*	1.0000	0.0014	0.0081	0.0045	0.0059	0.0034	0.0044	0.0115	0.0078
1 1/16	1.0625	0.0014	0.0081	0.0045	0.0059	0.0034	0.0044	0.0115	0.0078
1 1/8	1.1250	0.0014	0.0081	0.0045	0.0059	0.0034	0.0044	0.0115	0.0078
1 3/16	1.1875	0.0014	0.0081	0.0047	0.0061	0.0035	0.0045	0.0115	0.0078
1 1/4	1.2500	0.0014	0.0081	0.0047	0.0061	0.0035	0.0045	0.0115	0.0078
1 5/16	1.3125	0.0014	0.0081	0.0047	0.0061	0.0035	0.0045	0.0115	0.0078
1 3/8	1.3750	0.0014	0.0081	0.0047	0.0061	0.0035	0.0045	0.0115	0.0078
1 7/16	1.4375	0.0014	0.0081	0.0048	0.0062	0.0036	0.0046	0.0115	0.0078
1 1/2	1.5000	0.0014	0.0081	0.0048	0.0062	0.0036	0.0046	0.0115	0.0078
1 9/16	1.5625	0.0014	0.0081	0.0048	0.0062	0.0036	0.0046	0.0115	0.0078
1 5/8	1.6250	0.0014	0.0081	0.0048	0.0062	0.0036	0.0046	0.0115	0.0078
1 11/16	1.6875	0.0015	0.0081	0.0048	0.0063	0.0036	0.0047	0.0115	0.0078
1 3/4	1.7500	0.0015	0.0081	0.0048	0.0063	0.0036	0.0047	0.0115	0.0078
1 13/16	1.8125	0.0015	0.0081	0.0048	0.0063	0.0036	0.0047	0.0115	0.0078
1 7/8	1.8750	0.0015	0.0081	0.0048	0.0063	0.0036	0.0047	0.0115	0.0078
1 15/16	1.9375	0.0015	0.0081	0.0049	0.0064	0.0037	0.0048	0.0115	0.0078
2	2.0000	0.0015	0.0081	0.0049	0.0064	0.0037	0.0048	0.0115	0.0078
2 1/8	2.1250	0.0015	0.0081	0.0049	0.0064	0.0037	0.0048	0.0115	0.0078
2 1/4	2.2500	0.0015	0.0081	0.0049	0.0064	0.0038	0.0048	0.0115	0.0078
2 3/8	2.3750	0.0015	0.0081	0.0051	0.0066	0.0038	0.0050	0.0115	0.0078
2 1/2	2.5000	0.0015	0.0081	0.0051	0.0066	0.0038	0.0050	0.0115	0.0078
2 5/8	2.6250	0.0015	0.0081	0.0051	0.0066	0.0038	0.0050	0.0115	0.0078
2 3/4	2.7500	0.0015	0.0081	0.0051	0.0066	0.0038	0.0050	0.0115	0.0078
2 7/8	2.8750	0.0016	0.0081	0.0052	0.0068	0.0039	0.0051	0.0115	0.0078
3	3.0000	0.0016	0.0081	0.0052	0.0068	0.0039	0.0051	0.0115	0.0078

GENERAL NOTE:
See Section 5 for application of allowances and tolerances.

NOTES:
(1) Asterisks denote standard sizes of the UNC, UNF, or UNEF thread series. See Note (4).
(2) Allowances apply to external thread Class 2A only and are taken from Table 32.
(3) Major diameter of internal threads may extend to a *P*/24 flat.

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NOTES TO TABLE 28 (CONT'D)

(4) Classes 2A, 2B, 3A, and 3B PD tolerances are based on a length of engagement of nine pitches and are taken from Tables 34, 35, 37, and 38, except that for the ¼, 7/16, and ½ in. sizes they are based on a length of engagement equal to the nominal diameter.
(5) Minor diameter of external threads may extend to a *P*/8 flat.
(6) Classes 2B and 3B minor diameter tolerances are based on a length of engagement of one diameter.

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TABLE 29 ALLOWANCES AND TOLERANCES FOR 28-THREAD SERIES (28-UN/28-UNR)

Nominal Size (1)	Basic Major Diameter *D*	Allowances (2)	Tolerances						
			Major Diameter, External Threads (3)	Pitch Diameter (4)				Minor Diameter, Internal Threads (5,6)	
		Class 2A	Classes 2A, 3A	Class 2A	Class 2B	Class 3A	Class 3B	Class 2B	Class 3B
12 (0.216)*	0.2160	0.0010	0.0065	0.0032	0.0042	0.0024	0.0031	0.0084	0.0084
1/4*	0.2500	0.0010	0.0065	0.0033	0.0043	0.0025	0.0032	0.0084	0.0077
5/16	0.3125	0.0010	0.0065	0.0034	0.0044	0.0026	0.0033	0.0084	0.0069
3/8	0.3750	0.0011	0.0065	0.0036	0.0046	0.0027	0.0035	0.0084	0.0063
7/16*	0.4375	0.0011	0.0065	0.0036	0.0046	0.0027	0.0035	0.0084	0.0063
1/2*	0.5000	0.0011	0.0065	0.0037	0.0048	0.0028	0.0036	0.0084	0.0063
9/16	0.5625	0.0011	0.0065	0.0037	0.0048	0.0028	0.0036	0.0084	0.0063
5/8	0.6250	0.0011	0.0065	0.0038	0.0049	0.0028	0.0037	0.0084	0.0063
11/16	0.6875	0.0011	0.0065	0.0038	0.0049	0.0028	0.0037	0.0084	0.0063
3/4	0.7500	0.0012	0.0065	0.0038	0.0050	0.0029	0.0037	0.0084	0.0063
13/16	0.8125	0.0012	0.0065	0.0038	0.0050	0.0029	0.0037	0.0084	0.0063
7/8	0.8750	0.0012	0.0065	0.0038	0.0050	0.0029	0.0037	0.0084	0.0063
15/16	0.9375	0.0012	0.0065	0.0040	0.0052	0.0030	0.0039	0.0084	0.0063
1	1.0000	0.0012	0.0065	0.0040	0.0052	0.0030	0.0039	0.0084	0.0063
1 1/16	1.0625	0.0012	0.0065	0.0040	0.0052	0.0030	0.0039	0.0084	0.0063
1 1/8	1.1250	0.0012	0.0065	0.0040	0.0052	0.0030	0.0039	0.0084	0.0063
1 3/16	1.1875	0.0012	0.0065	0.0041	0.0053	0.0031	0.0040	0.0084	0.0063
1 1/4	1.2500	0.0012	0.0065	0.0041	0.0053	0.0031	0.0040	0.0084	0.0063
1 5/16	1.3125	0.0012	0.0065	0.0041	0.0053	0.0031	0.0040	0.0084	0.0063
1 3/8	1.3750	0.0012	0.0065	0.0041	0.0053	0.0031	0.0040	0.0084	0.0063
1 7/16	1.4375	0.0013	0.0065	0.0042	0.0055	0.0031	0.0041	0.0084	0.0063
1 1/2	1.5000	0.0013	0.0065	0.0042	0.0055	0.0031	0.0041	0.0084	0.0063

GENERAL NOTE:
See Section 5 for application of allowances and tolerances.

NOTES:
(1) Asterisks denote standard sizes of the UNC, UNF, or UNEF thread series. See Note (4).
(2) Allowances apply to external thread Class 2A only and are taken from Table 32.
(3) Major diameter of internal threads may extend to a *P*/24 flat.
(4) Classes 2A, 2B, 3A, and 3B PD tolerances are based on a length of engagement of nine pitches and are taken from Tables 34, 35, 37, and 38, except that for the No. 12 and 1/4 in. sizes they are based on a length of engagement equal to the nominal diameter.
(5) Minor diameter of external threads may extend to a *P*/8 flat.
(6) Classes 2B and 3B minor diameter tolerances are based on a length of engagement of one diameter.

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TABLE 30 ALLOWANCES AND TOLERANCES FOR 32-THREAD SERIES (32-UN/32-UNR)

Nominal Size (1)	Basic Major Diameter *D*	Allowances (2)	Tolerances						
			Major Diameter, External Threads (3)	Pitch Diameter (4)				Minor Diameter, Internal Threads (5, 6)	
		Class 2A	Classes 2A, 3A	Class 2A	Class 2B	Class 3A	Class 3B	Class 2B	Class 3B
6 (0.138)*	0.1380	0.0008	0.0060	0.0028	0.0037	0.0021	0.0027	0.0098	0.0098
8 (0.164)*	0.1640	0.0009	0.0060	0.0029	0.0038	0.0022	0.0028	0.0087	0.0087
10 (0.190)*	0.1900	0.0009	0.0060	0.0030	0.0039	0.0023	0.0029	0.0079	0.0079
12 (0.216)*	0.2160	0.0009	0.0060	0.0031	0.0041	0.0024	0.0031	0.0074	0.0073
1/4*	0.2500	0.0010	0.0060	0.0032	0.0042	0.0024	0.0031	0.0074	0.0067
5/16*	0.3125	0.0010	0.0060	0.0032	0.0042	0.0024	0.0031	0.0074	0.0060
3/8*	0.3750	0.0010	0.0060	0.0034	0.0044	0.0025	0.0033	0.0074	0.0057
7/16	0.4375	0.0010	0.0060	0.0034	0.0044	0.0025	0.0033	0.0074	0.0057
1/2	0.5000	0.0010	0.0060	0.0035	0.0045	0.0026	0.0034	0.0074	0.0057
9/16	0.5625	0.0010	0.0060	0.0035	0.0045	0.0026	0.0034	0.0074	0.0057
5/8	0.6250	0.0011	0.0060	0.0036	0.0046	0.0027	0.0035	0.0074	0.0057
11/16	0.6875	0.0011	0.0060	0.0036	0.0046	0.0027	0.0035	0.0074	0.0057
3/4	0.7500	0.0011	0.0060	0.0036	0.0047	0.0027	0.0036	0.0074	0.0057
13/16	0.8125	0.0011	0.0060	0.0036	0.0047	0.0027	0.0036	0.0074	0.0057
7/8	0.8750	0.0011	0.0060	0.0036	0.0047	0.0027	0.0036	0.0074	0.0057
15/16	0.9375	0.0011	0.0060	0.0038	0.0049	0.0028	0.0037	0.0074	0.0057
1	1.0000	0.0011	0.0060	0.0038	0.0049	0.0028	0.0037	0.0074	0.0057

GENERAL NOTE:
See Section 5 for application of allowances and tolerances.

NOTES:
(1) Asterisks denote standard sizes of the UNC, UNF, or UNEF thread series. See Note (4).
(2) Allowances apply to external thread Class 2A only and are taken from Table 32.
(3) Major diameter of internal threads may extend to a *P*/24 flat.
(4) Classes 2A, 2B, 3A, and 3B PD tolerances are based on a length of engagement of nine pitches and are taken from Tables 34, 35, 37, and 38, except that for the Nos. 6, 8, and 10 sizes they are based on a length of engagement equal to the nominal diameter.
(5) Minor diameter of external threads may extend to a *P*/8 flat.
(6) Classes 2B and 3B minor diameter tolerances are based on a length of engagement of one diameter.

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TABLE 31 MAJOR DIAMETER TOLERANCES FOR EXTERNAL THREADS OF SPECIAL DIAMETERS, PITCHES, AND LENGTHS OF ENGAGEMENT (UNS/UNRS) — CLASSES 1A, 2A, AND 3A

	Major Diameter Tolerance	
Threads/in.	Class 1A $0.090\sqrt[3]{P^2}$	Class 2A and Class 3A $0.060\sqrt[3]{P^2}$
80	. . .	0.0032
72	. . .	0.0035
64	. . .	0.0038
56	. . .	0.0041
48	. . .	0.0045
44	. . .	0.0048
40	0.0077	0.0051
36	0.0083	0.0055
32	0.0089	0.0060
28	0.0098	0.0065
27	0.0100	0.0067
24	0.0108	0.0072
20	0.0122	0.0081
18	0.0131	0.0087
16	0.0142	0.0094
14	0.0155	0.0103
12	0.0172	0.0114
10	0.0194	0.0129
8	0.0225	0.0150
6	0.0273	0.0182
4	0.0357	0.0238
. . .	. . .	. . .

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TABLE 32 ALLOWANCES FOR EXTERNAL THREADS OF SPECIAL DIAMETERS AND PITCHES (UNS/UNRS) — CLASSES 1A AND 2A

Allowance based on basic major diameter of	0.0625	0.09375	0.125	0.1875	0.25	0.375	0.5	0.625	0.75	1	1.25	1.5
For diameter range above	0.0470	0.0781	0.1094	0.1562	0.2188	0.3125	0.4375	0.5625	0.6875	0.875	1.125	1.375
To and including	0.0781	0.1094	0.1562	0.2188	0.3125	0.4375	0.5625	0.6875	0.875	1.125	1.375	1.625
Threads/in.	Major, Pitch, and Minor Diameter Allowances, in.											
80	0.0006	0.0006	0.0006	0.0007	0.0007	...	...	...	...	...	...	...
72	0.0006	0.0006	0.0006	0.0007	0.0007	0.0007	...	...	...	...	...	...
64	0.0006	0.0007	0.0007	0.0007	0.0007	0.0008	0.0008	...	...	...	...	...
56	...	0.0007	0.0007	0.0007	0.0008	0.0008	0.0008	0.0009	0.0009	...	...	...
48	...	0.0007	0.0008	0.0008	0.0008	0.0009	0.0009	0.0009	0.0009	...	...	...
44	...	0.0008	0.0008	0.0008	0.0008	0.0009	0.0009	0.0009	0.0010	0.0010	...	...
40	...	...	0.0008	0.0009	0.0009	0.0009	0.0010	0.0010	0.0010	0.0010	...	...
36	...	...	0.0009	0.0009	0.0009	0.0010	0.0010	0.0010	0.0010	0.0011	0.0011	0.0012
32	...	...	0.0009	0.0009	0.0010	0.0010	0.0010	0.0011	0.0011	0.0011	0.0012	0.0012
28	...	...	...	0.0010	0.0010	0.0011	0.0011	0.0011	0.0012	0.0012	0.0012	0.0013
27	...	...	...	0.0010	0.0010	0.0011	0.0011	0.0011	0.0012	0.0012	0.0012	0.0013
24	...	...	...	0.0011	0.0011	0.0011	0.0012	0.0012	0.0012	0.0013	0.0013	0.0013
20	...	...	...	...	0.0012	0.0012	0.0013	0.0013	0.0013	0.0014	0.0014	0.0014
18	...	...	...	...	...	0.0013	0.0013	0.0014	0.0014	0.0014	0.0015	0.0015
16	...	...	...	...	...	0.0014	0.0014	0.0014	0.0015	0.0015	0.0015	0.0016
14	...	...	...	...	...	...	0.0015	0.0015	0.0015	0.0016	0.0016	0.0017
12	...	...	...	...	...	...	0.0016	0.0016	0.0017	0.0017	0.0017	0.0018
10	...	...	...	...	...	...	...	...	0.0018	0.0018	0.0019	0.0019
8	...	...	...	...	...	...	...	...	...	0.0021	0.0021	0.0021
6	...	...	...	...	...	...	...	...	...	...	...	0.0024
4	...	...	...	...	...	...	...	...	...	...	...	...

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TABLE 32 ALLOWANCES FOR EXTERNAL THREADS OF SPECIAL DIAMETERS AND PITCHES (UNS/UNRS) — CLASSES 1A AND 2A (CONT'D)

Allowance based on basic major diameter of	1.75	2	2.5	3	3.5	4	5	6	8	10	12
For diameter range above	1.625	1.875	2.25	2.75	3.25	3.75	4.5	5.5	7	9	11
To and including	1.875	2.25	2.75	3.25	3.75	4.5	5.5	7	9	11	13
Threads/in.	Major, Pitch, and Minor Diameter Allowances, in.										
80	...	...	...	...	...	...	...	...	...	...	...
72	...	...	...	...	...	...	...	...	...	...	...
64	...	...	...	...	...	...	...	...	...	...	...
56	...	...	...	...	Classes 1A and 2A allowances are determined by multiplying Class 2A pitch diameter tolerances (computed to six decimal places) by 0.3 and are based on lengths of engagement of nine pitches.						
48	...	...	...	...							
44	...	...	...	...							
40	...	...	...	...	...	...	...	...	...	...	...
36	...	...	...	...	...	...	...	...	...	...	...
32	0.0012	0.0013	0.0013	0.0013	...	...	...	...	...	...	...
28	0.0013	0.0013	0.0014	0.0014	0.0014	0.0015	...	...	...	...	...
27	0.0013	0.0013	0.0014	0.0014	0.0014	0.0015	0.0015	0.0016	...	...	...
24	0.0014	0.0014	0.0014	0.0015	0.0015	0.0015	0.0016	0.0016	...	...	...
20	0.0015	0.0015	0.0015	0.0016	0.0016	0.0016	0.0017	0.0017	...	...	...
18	0.0015	0.0015	0.0016	0.0016	0.0017	0.0017	0.0017	0.0018	0.0019	...	...
16	0.0016	0.0016	0.0017	0.0017	0.0017	0.0018	0.0018	0.0019	0.0019	0.0020	...
14	0.0017	0.0017	0.0017	0.0018	0.0018	0.0018	0.0019	0.0020	0.0020	0.0021	0.0022
12	0.0018	0.0018	0.0019	0.0019	0.0019	0.0020	0.0020	0.0021	0.0021	0.0022	0.0023
10	0.0019	0.0020	0.0020	0.0020	0.0021	0.0021	0.0022	0.0022	0.0023	0.0024	0.0024
8	0.0021	0.0022	0.0022	0.0023	0.0023	0.0023	0.0024	0.0024	0.0025	0.0026	0.0026
6	0.0025	0.0025	0.0025	0.0026	0.0026	0.0026	0.0027	0.0027	0.0028	0.0029	0.0029
4	...	0.0030	0.0031	0.0031	0.0031	0.0032	0.0032	0.0033	0.0034	0.0034	0.0035

Table 33 begins on the next page.

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TABLE 33 PITCH DIAMETER TOLERANCES FOR EXTERNAL THREADS OF SPECIAL DIAMETERS, PITCHES, AND LENGTHS OF ENGAGEMENT (UNS/UNRS) — CLASS 1A

Tolerance based on basic major diameter of			0.0625	0.09375	0.125	0.1875	0.25	0.375	0.5	0.625	0.75	1
For diameter range above			0.0470	0.0781	0.1094	0.1562	0.2188	0.3125	0.4375	0.5625	0.6875	0.875
To and including			0.0781	0.1094	0.1562	0.2188	0.3125	0.4375	0.5625	0.6875	0.875	1.125
	Length of Engagement											
Threads/In.	Number of Pitches	In.	Pitch Diameter Tolerances, in.									
80	5 to 15	0.06 to 0.19	...	...	...	...	...	...	...	...	...	...
	16 to 30	0.191 to 0.38	...	...	...	...	...	...	...	...	...	...
72	5 to 15	0.07 to 0.21	...	...	...	...	...	...	...	...	...	...
	16 to 30	0.211 to 0.42	...	...	...	...	...	...	...	...	...	...
64	5 to 15	0.08 to 0.23	...	...	...	...	...	...	...	...	...	...
	16 to 30	0.231 to 0.46	...	...	...	...	...	...	...	...	...	...
56	5 to 15	0.09 to 0.27	...	...	...	...	...	...	...	...	...	...
	16 to 30	0.271 to 0.54	...	...	...	...	...	...	...	...	...	...
48	5 to 15	0.10 to 0.31	...	...	...	...	...	...	...	...	...	...
	16 to 30	0.311 to 0.62	...	...	...	...	...	...	...	...	...	...
44	5 to 15	0.11 to 0.34	...	0.0038	0.0039	0.0041	0.0042	0.0044	0.0046	0.0047	0.0049	0.0051
	16 to 30	0.341 to 0.68	...	0.0048	0.0049	0.0051	0.0053	0.0056	0.0058	0.0059	0.0061	0.0063
40	5 to 15	0.12 to 0.38	...	...	0.0041	0.0043	0.0044	0.0046	0.0048	0.0049	0.0050	0.0052
	16 to 30	0.381 to 0.76	...	...	0.0051	0.0053	0.0055	0.0058	0.0060	0.0061	0.0063	0.0066
36	5 to 15	0.14 to 0.42	...	...	0.0043	0.0045	0.0046	0.0048	0.0050	0.0051	0.0052	0.0054
	16 to 30	0.421 to 0.84	...	...	0.0054	0.0056	0.0058	0.0060	0.0062	0.0064	0.0065	0.0068
32	5 to 15	0.16 to 0.47	...	...	0.0045	0.0047	0.0048	0.0050	0.0052	0.0053	0.0055	0.0057
	16 to 30	0.471 to 0.94	...	...	0.0057	0.0059	0.0061	0.0063	0.0065	0.0067	0.0068	0.0071
28	5 to 15	0.18 to 0.54	...	...	...	0.0050	0.0051	0.0053	0.0055	0.0056	0.0058	0.0060
	16 to 30	0.541 to 1.08	...	...	...	0.0063	0.0064	0.0067	0.0069	0.0070	0.0072	0.0075
27	5 to 15	0.19 to 0.56	...	...	...	0.0051	0.0052	0.0056	0.0056	0.0057	0.0058	0.0060
	16 to 30	0.561 to 1.12	...	...	...	0.0064	0.0065	0.0068	0.0070	0.0072	0.0073	0.0076
24	5 to 15	0.21 to 0.62	...	...	...	0.0054	0.0055	0.0057	0.0059	0.0060	0.0061	0.0063
	16 to 30	0.621 to 1.24	...	...	...	0.0067	0.0069	0.0071	0.0073	0.0075	0.0077	0.0079
20	5 to 15	0.25 to 0.75	...	...	...	...	0.0060	0.0062	0.0063	0.0065	0.0066	0.0068
	16 to 30	0.751 to 1.50	...	...	...	...	0.0075	0.0077	0.0079	0.0081	0.0083	0.0085
18	5 to 15	0.28 to 0.83	...	...	...	...	...	0.0065	0.0067	0.0068	0.0069	0.0071
	16 to 30	0.831 to 1.66	...	...	...	...	...	0.0081	0.0083	0.0085	0.0086	0.0089
16	5 to 15	0.31 to 0.94	...	...	...	...	...	0.0069	0.0070	0.0072	0.0073	0.0075
	16 to 30	0.941 to 1.88	...	...	...	...	...	0.0086	0.0088	0.0089	0.0091	0.0094
14	5 to 15	0.36 to 1.07	...	...	...	...	...	...	0.0075	0.0076	0.0077	0.0079
	16 to 30	1.071 to 2.14	...	...	...	...	...	...	0.0093	0.0095	0.0097	0.0099
12	5 to 15	0.42 to 1.25	...	...	...	...	...	...	0.0080	0.0082	0.0083	0.0085
	16 to 30	1.251 to 2.50	...	...	...	...	...	...	0.0100	0.0102	0.0104	0.0106
10	5 to 15	0.50 to 1.50	...	...	...	...	...	...	...	...	0.0090	0.0092
	16 to 30	1.501 to 3.00	...	...	...	...	...	...	...	...	0.0113	0.0115
8	5 to 15	0.62 to 1.88	...	...	...	...	...	...	...	...	...	0.0103
	16 to 30	1.881 to 3.76	...	...	...	...	...	...	...	...	...	0.0128
6	5 to 15	0.83 to 2.50	...	...	...	...	...	...	...	...	...	...
	16 to 30	2.501 to 5.00	...	...	...	...	...	...	...	...	...	...
4	5 to 15	1.25 to 3.75	...	...	...	...	...	...	...	...	...	...
	16 to 30	3.751 to 7.50	...	...	...	...	...	...	...	...	...	...

GENERAL NOTES:

(a) These values do not agree with and shall not be used in place of any tabulated values for the UNC, UNF, and 8-UN thread series.

(b) Class 1A tolerances in this Table for 5 to 15 pitches are based on 9 pitches and are obtained by multiplying the Class 2A (external thread) tolerances for 9 pitches taken to six decimal places (see Table 19) by a factor of 1.5.

(c) Class 1A tolerances in this Table for 16 to 30 pitches are obtained by multiplying the Class 2A (external thread) tolerances for 9 pitches taken to six decimal places by a factor of 1.875 (obtained by multiplying the 1.5 factor by 1.25). For lengths of engagement not tabulated, see Section 5.

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TABLE 33 PITCH DIAMETER TOLERANCES FOR EXTERNAL THREADS OF SPECIAL DIAMETERS, PITCHES, AND LENGTHS OF ENGAGEMENT (UNS/UNRS) — CLASS 1A

1.25	1.5	1.75	2	2.5	3	3.5	4	5	6	8	10	12	
1.125	1.375	1.625	1.875	2.25	2.75	3.25	3.75	4.5	5.5	7	9	11	
1.375	1.625	1.875	2.25	2.75	3.25	3.75	4.5	5.5	7	9	11	13	
Pitch Diameter Tolerances, in.													Threads/in.
...	...	...	...	...	...	...	...	...	...	...	...	...	80
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	72
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	64
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	56
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	48
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	44
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	40
...	...	...	...	...	...	...	...	...	...	...	...	...	
0.0056	0.0058	...	...	...	...	...	...	...	...	...	...	...	36
0.0070	0.0072	...	...	...	...	...	...	...	...	...	...	...	
0.0058	0.0060	0.0061	0.0063	0.0065	0.0067	...	...	...	...	...	...	...	32
0.0073	0.0075	0.0077	0.0078	0.0081	0.0083	...	...	...	...	...	...	...	
0.0061	0.0063	0.0064	0.0066	0.0068	0.0070	0.0071	0.0073	...	...	...	...	...	28
0.0077	0.0079	0.0080	0.0082	0.0085	0.0087	0.0089	0.0091	...	...	...	...	...	
0.0061	0.0064	0.0065	0.0066	0.0069	0.0070	0.0072	0.0074	0.0076	0.0079	...	...	...	27
0.0078	0.0080	0.0081	0.0083	0.0086	0.0088	0.0090	0.0092	0.0096	0.0099	...	...	...	
0.0065	0.0067	0.0068	0.0069	0.0071	0.0073	0.0075	0.0077	0.0079	0.0082	...	...	...	24
0.0081	0.0083	0.0085	0.0086	0.0089	0.0092	0.0094	0.0096	0.0099	0.0102	...	...	...	
0.0070	0.0071	0.0073	0.0074	0.0076	0.0078	0.0080	0.0081	0.0084	0.0087	...	...	...	20
0.0087	0.0089	0.0091	0.0092	0.0095	0.0098	0.0100	0.0102	0.0105	0.0108	...	...	...	
0.0073	0.0074	0.0076	0.0077	0.0079	0.0081	0.0083	0.0084	0.0087	0.0090	0.0094	...	...	18
0.0091	0.0093	0.0095	0.0096	0.0099	0.0101	0.0104	0.0105	0.0109	0.0112	0.0117	...	...	
0.0077	0.0078	0.0078	0.0081	0.0083	0.0085	0.0086	0.0088	0.0091	0.0093	0.0097	0.0101	...	16
0.0096	0.0098	0.0099	0.0101	0.0104	0.0106	0.0108	0.0110	0.0113	0.0116	0.0122	0.0126	...	
0.0081	0.0083	0.0084	0.0085	0.0087	0.0089	0.0091	0.0092	0.0095	0.0098	0.0102	0.0105	0.0108	14
0.0101	0.0103	0.0105	0.0106	0.0109	0.0112	0.0114	0.0116	0.0119	0.0122	0.0127	0.0132	0.0135	
0.0087	0.0088	0.0090	0.0091	0.0093	0.0095	0.0097	0.0098	0.0101	0.0103	0.0107	0.0111	0.0114	12
0.0108	0.0110	0.0112	0.0113	0.0116	0.0119	0.0121	0.0123	0.0126	0.0129	0.0134	0.0139	0.0142	
0.0094	0.0096	0.0097	0.0098	0.0100	0.0102	0.0104	0.0106	0.0108	0.0111	0.0115	0.0118	0.0121	10
0.0118	0.0119	0.0121	0.0123	0.0125	0.0128	0.0130	0.0132	0.0135	0.0138	0.0144	0.0148	0.0152	
0.0104	0.0106	0.0107	0.0108	0.0111	0.0113	0.0114	0.0116	0.0119	0.0121	0.0125	0.0129	0.0132	8
0.0130	0.0132	0.0134	0.0136	0.0138	0.0141	0.0143	0.0145	0.0148	0.0151	0.0156	0.0161	0.0165	
...	0.0121	0.0123	0.0124	0.0126	0.0128	0.0130	0.0131	0.0134	0.0137	0.0141	0.0144	0.0147	6
...	0.0152	0.0154	0.0155	0.0158	0.0160	0.0162	0.0164	0.0168	0.0171	0.0176	0.0180	0.0184	
...	...	...	0.0151	0.0154	0.0155	0.0157	0.0159	0.0162	0.0164	0.0168	0.0172	0.0175	4
...	...	...	0.0189	0.0192	0.0194	0.0196	0.0198	0.0202	0.0205	0.0210	0.0214	0.0214	

(d) Pitches listed are those used most commonly and are recommended. Where intermediate pitches are specified, the formula in Section 5 should be applied.

(e) Tolerances are tabulated only for combinations of diameter, pitch, and length of engagement that are considered to be generally used. For other combinations encountered, see Section 5.

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TABLE 34 PITCH DIAMETER TOLERANCES FOR EXTERNAL THREADS OF SPECIAL DIAMETERS, PITCHES, AND LENGTHS OF ENGAGEMENT (UNS/UNRS) — CLASS 2A

Tolerance based on basic major diameter of			0.0625	0.09375	0.125	0.1875	0.25	0.375	0.5	0.625	0.75	1
For diameter range above			0.0470	0.0781	0.1094	0.1562	0.2188	0.3125	0.4375	0.5625	0.6875	0.875
To and including			0.0781	0.1094	0.1562	0.2188	0.3125	0.4375	0.5625	0.6875	0.875	1.125
	Length of Engagement											
Threads/in.	Number of Pitches	in.	Pitch Diameter Tolerances, in.									
80	5 to 15	0.06 to 0.19	0.0019	0.0020	0.0021	0.0022	0.0023	...	...	...	...	...
	16 to 30	0.191 to 0.38	0.0024	0.0025	0.0026	0.0027	0.0028	...	...	...	...	...
72	5 to 15	0.07 to 0.21	0.0020	0.0021	0.0021	0.0023	0.0023	0.0025	...	...	...	...
	16 to 30	0.211 to 0.42	0.0025	0.0026	0.0027	0.0028	0.0029	0.0031	...	...	...	...
64	5 to 15	0.08 to 0.23	0.0021	0.0022	0.0022	0.0024	0.0024	0.0026	0.0027	...	...	...
	16 to 30	0.231 to 0.46	0.0026	0.0027	0.0028	0.0029	0.0031	0.0032	0.0034	...	...	...
56	5 to 15	0.09 to 0.27	...	0.0023	0.0024	0.0025	0.0026	0.0027	0.0028	0.0029	0.0030	...
	16 to 30	0.271 to 0.54	...	0.0029	0.0030	0.0031	0.0032	0.0034	0.0035	0.0036	0.0037	...
48	5 to 15	0.10 to 0.31	...	0.0025	0.0025	0.0026	0.0027	0.0029	0.0030	0.0031	0.0031	...
	16 to 30	0.311 to 0.62	...	0.0031	0.0032	0.0033	0.0034	0.0036	0.0037	0.0038	0.0039	...
44	5 to 15	0.11 to 0.34	...	0.0026	0.0026	0.0027	0.0028	0.0030	0.0031	0.0032	0.0032	0.0034
	16 to 30	0.341 to 0.68	...	0.0032	0.0033	0.0034	0.0035	0.0037	0.0038	0.0040	0.0041	0.0042
40	5 to 15	0.12 to 0.38	...	...	0.0027	0.0029	0.0029	0.0031	0.0032	0.0033	0.0034	0.0035
	16 to 30	0.381 to 0.76	...	...	0.0034	0.0036	0.0037	0.0038	0.0040	0.0041	0.0042	0.0044
36	5 to 15	0.14 to 0.42	...	...	0.0029	0.0030	0.0031	0.0032	0.0033	0.0034	0.0035	0.0036
	16 to 30	0.421 to 0.84	...	...	0.0036	0.0037	0.0038	0.0040	0.0041	0.0043	0.0044	0.0045
32	5 to 15	0.16 to 0.47	...	...	0.0030	0.0031	0.0032	0.0034	0.0035	0.0036	0.0036	0.0038
	16 to 30	0.471 to 0.94	...	...	0.0038	0.0039	0.0040	0.0042	0.0043	0.0045	0.0046	0.0047
28	5 to 15	0.18 to 0.54	...	...	...	0.0033	0.0034	0.0036	0.0037	0.0038	0.0038	0.0040
	16 to 30	0.541 to 1.08	...	...	...	0.0042	0.0043	0.0044	0.0046	0.0047	0.0048	0.0050
27	5 to 15	0.19 to 0.56	...	...	...	0.0034	0.0035	0.0036	0.0037	0.0038	0.0039	0.0040
	16 to 30	0.561 to 1.12	...	...	...	0.0042	0.0043	0.0045	0.0047	0.0048	0.0049	0.0050
24	5 to 15	0.21 to 0.62	...	...	...	0.0036	0.0037	0.0038	0.0039	0.0040	0.0041	0.0042
	16 to 30	0.621 to 1.24	...	...	...	0.0045	0.0046	0.0048	0.0049	0.0050	0.0051	0.0053
20	5 to 15	0.25 to 0.75	...	...	...	...	0.0040	0.0041	0.0042	0.0043	0.0044	0.0045
	16 to 30	0.751 to 1.50	...	...	...	...	0.0050	0.0052	0.0053	0.0054	0.0055	0.0057
18	5 to 15	0.28 to 0.83	...	...	...	...	...	0.0043	0.0044	0.0045	0.0046	0.0047
	16 to 30	0.831 to 1.66	...	...	...	...	...	0.0054	0.0055	0.0057	0.0058	0.0059
16	5 to 15	0.31 to 0.94	...	...	...	...	...	0.0046	0.0047	0.0048	0.0049	0.0050
	16 to 30	0.941 to 1.88	...	...	...	...	...	0.0057	0.0058	0.0060	0.0061	0.0062
14	5 to 15	0.36 to 1.07	...	...	...	...	...	...	0.0050	0.0051	0.0051	0.0053
	16 to 30	1.071 to 2.14	...	...	...	...	...	...	0.0062	0.0063	0.0064	0.0066
12	5 to 15	0.42 to 1.25	...	...	...	...	...	...	0.0054	0.0054	0.0055	0.0057
	16 to 30	1.251 to 2.50	...	...	...	...	...	...	0.0067	0.0068	0.0069	0.0071
10	5 to 15	0.50 to 1.50	...	...	...	...	...	...	...	...	0.0060	0.0062
	16 to 30	1.501 to 3.00	...	...	...	...	...	...	...	...	0.0075	0.0077
8	5 to 15	0.62 to 1.88	...	...	...	...	...	...	...	...	...	0.0068
	16 to 30	1.881 to 3.76	...	...	...	...	...	...	...	...	...	0.0086
6	5 to 15	0.83 to 2.50	...	...	...	...	...	...	...	...	...	...
	16 to 30	2.501 to 5.00	...	...	...	...	...	...	...	...	...	...
4	5 to 15	1.25 to 3.75	...	...	...	...	...	...	...	...	...	...
	16 to 30	3.751 to 7.50	...	...	...	...	...	...	...	...	...	...

GENERAL NOTES:

(a) These values do not agree with and shall not be used in place of any tabulated values for the UNC, UNF, and 8-UN thread series.

(b) Formula:

Class 2A tolerances $= 0.0015\sqrt[3]{D} + 0.0015\sqrt{LE} + 0.015\sqrt[3]{P^2}$, where

D = basic major diameter

LE = length of engagement

P = pitch

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TABLE 34 PITCH DIAMETER TOLERANCES FOR EXTERNAL THREADS OF SPECIAL DIAMETERS, PITCHES, AND LENGTHS OF ENGAGEMENT (UNS/UNRS)—CLASS 2A

1.25	1.5	1.75	2	2.5	3	3.5	4	5	6	8	10	12	
1.125	1.375	1.625	1.875	2.25	2.75	3.25	3.75	4.5	5.5	7	9	11	
1.375	1.625	1.875	2.25	2.75	3.25	3.75	4.5	5.5	7	9	11	13	
Pitch Diameter Tolerances, in.													Threads/in.
...	...	...	...	...	...	...	...	...	...	...	...	...	80
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	72
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	64
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	56
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	48
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	44
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	40
...	...	...	...	...	...	...	...	...	...	...	...	...	
0.0037	0.0038	...	...	...	...	...	...	...	...	...	...	...	36
0.0047	0.0048	...	...	...	...	...	...	...	...	...	...	...	
0.0039	0.0040	0.0041	0.0042	0.0043	0.0044	...	...	...	...	...	...	...	32
0.0049	0.0050	0.0051	0.0052	0.0054	0.0056	...	...	...	...	...	...	...	
0.0041	0.0042	0.0043	0.0044	0.0045	0.0046	0.0048	0.0049	...	...	...	...	...	28
0.0051	0.0052	0.0054	0.0055	0.0056	0.0058	0.0059	0.0061	...	...	...	...	...	
0.0041	0.0042	0.0043	0.0044	0.0046	0.0047	0.0048	0.0049	0.0051	0.0053	...	...	...	27
0.0052	0.0053	0.0054	0.0055	0.0057	0.0059	0.0060	0.0061	0.0064	0.0066	...	...	...	
0.0043	0.0044	0.0045	0.0046	0.0048	0.0049	0.0050	0.0051	0.0053	0.0054	...	...	...	24
0.0054	0.0055	0.0057	0.0058	0.0059	0.0061	0.0062	0.0064	0.0066	0.0068	...	...	...	
0.0047	0.0048	0.0048	0.0049	0.0051	0.0052	0.0053	0.0054	0.0056	0.0058	...	...	...	20
0.0058	0.0059	0.0061	0.0062	0.0063	0.0065	0.0066	0.0068	0.0070	0.0072	...	...	...	
0.0049	0.0050	0.0051	0.0051	0.0053	0.0054	0.0055	0.0056	0.0058	0.0060	0.0062	...	...	18
0.0061	0.0062	0.0063	0.0064	0.0066	0.0068	0.0069	0.0070	0.0073	0.0075	0.0078	...	...	
0.0051	0.0052	0.0053	0.0054	0.0055	0.0056	0.0058	0.0059	0.0061	0.0062	0.0065	0.0067	...	16
0.0064	0.0065	0.0066	0.0067	0.0069	0.0071	0.0072	0.0073	0.0076	0.0078	0.0081	0.0084	...	
0.0054	0.0055	0.0056	0.0057	0.0058	0.0059	0.0061	0.0062	0.0064	0.0065	0.0068	0.0070	0.0072	14
0.0068	0.0069	0.0070	0.0071	0.0073	0.0074	0.0076	0.0077	0.0079	0.0081	0.0085	0.0088	0.0090	
0.0058	0.0059	0.0060	0.0061	0.0062	0.0063	0.0064	0.0065	0.0067	0.0069	0.0072	0.0074	0.0076	12
0.0072	0.0073	0.0075	0.0076	0.0077	0.0079	0.0080	0.0082	0.0084	0.0086	0.0090	0.0092	0.0095	
0.0063	0.0064	0.0065	0.0065	0.0067	0.0068	0.0069	0.0070	0.0072	0.0074	0.0077	0.0079	0.0081	10
0.0078	0.0080	0.0081	0.0082	0.0084	0.0085	0.0087	0.0088	0.0090	0.0092	0.0096	0.0099	0.0101	
0.0070	0.0071	0.0071	0.0072	0.0074	0.0075	0.0076	0.0077	0.0079	0.0081	0.0083	0.0086	0.0088	8
0.0087	0.0088	0.0089	0.0090	0.0092	0.0094	0.0095	0.0097	0.0099	0.0101	0.0104	0.0107	0.0110	
...	0.0081	0.0082	0.0083	0.0084	0.0085	0.0087	0.0088	0.0089	0.0091	0.0094	0.0096	0.0098	6
...	0.0101	0.0102	0.0103	0.0105	0.0107	0.0108	0.0110	0.0112	0.0114	0.0117	0.0120	0.0123	
...	...	...	0.0101	0.0102	0.0104	0.0105	0.0106	0.0108	0.0109	0.0112	0.0114	0.0116	4
...	...	...	0.0126	0.0128	0.0130	0.0131	0.0132	0.0135	0.0137	0.0140	0.0143	0.0145	

(c) Length of engagement increments included in the tabulated tolerances for lengths of engagement of from 5 to 15 pitches are based on lengths of 9 pitches; those for lengths of engagement of from 16 to 30 pitches are obtained by multiplying the 9 pitch values taken to six decimal places by 1.25. For lengths of engagement not tabulated, the formula in (b) above should be applied except as modified.

(d) Pitches listed are those used most commonly and are recommended. When intermediate pitches are specified, the formula in (b) above should be applied.

(e) Tolerances are tabulated only for combinations of diameter, pitch, and length of engagement that are considered to be generally used. For other combinations encountered, see Section 5.

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TABLE 35 PITCH DIAMETER TOLERANCES FOR EXTERNAL THREADS OF SPECIAL DIAMETERS, PITCHES, AND LENGTHS OF ENGAGEMENT (UNS/UNRS)—CLASS 3A

Tolerance based on basic major diameter of			0.0625	0.09375	0.125	0.1875	0.25	0.375	0.5	0.625	0.75	1
For diameter range above			0.0470	0.0781	0.1094	0.1562	0.2188	0.3125	0.4375	0.5625	0.6875	0.875
To and including			0.0781	0.1094	0.1562	0.2188	0.3125	0.4375	0.5625	0.6875	0.875	1.125
	Length of Engagement											
Threads/in.	Number of Pitches	In.	Pitch Diameter Tolerances, In.									
80	5 to 15	0.06 to 0.19	0.0014	0.0015	0.0015	0.0016	0.0017	...	...	...	...	...
	16 to 30	0.191 to 0.38	0.0018	0.0019	0.0019	0.0020	0.0021	...	...	...	...	...
72	5 to 15	0.07 to 0.21	0.0015	0.0016	0.0016	0.0017	0.0018	0.0019	...	...	...	...
	16 to 30	0.211 to 0.42	0.0019	0.0019	0.0020	0.0021	0.0022	0.0023	...	...	...	...
64	5 to 15	0.08 to 0.23	0.0016	0.0016	0.0017	0.0018	0.0018	0.0019	0.0020	...	...	...
	16 to 30	0.231 to 0.46	0.0020	0.0020	0.0021	0.0022	0.0023	0.0024	0.0025	...	...	...
56	5 to 15	0.09 to 0.27	...	0.0017	0.0018	0.0019	0.0019	0.0020	0.0021	0.0022	0.0022	...
	16 to 30	0.271 to 0.54	...	0.0022	0.0022	0.0023	0.0024	0.0025	0.0026	0.0027	0.0028	...
48	5 to 15	0.10 to 0.31	...	0.0019	0.0019	0.0019	0.0020	0.0020	0.0022	0.0023	0.0024	...
	16 to 30	0.311 to 0.62	...	0.0022	0.0023	0.0024	0.0025	0.0026	0.0027	0.0029	0.0030	...
44	5 to 15	0.11 to 0.34	...	0.0019	0.0020	0.0021	0.0021	0.0022	0.0023	0.0024	0.0024	0.0025
	16 to 30	0.341 to 0.68	...	0.0024	0.0025	0.0026	0.0026	0.0028	0.0029	0.0030	0.0030	0.0032
40	5 to 15	0.12 to 0.38	...	...	0.0021	0.0021	0.0022	0.0023	0.0024	0.0025	0.0025	0.0026
	16 to 30	0.381 to 0.76	...	...	0.0026	0.0027	0.0028	0.0029	0.0030	0.0031	0.0031	0.0033
36	5 to 15	0.14 to 0.42	...	...	0.0022	0.0022	0.0023	0.0024	0.0025	0.0026	0.0026	0.0027
	16 to 30	0.421 to 0.84	...	...	0.0027	0.0028	0.0029	0.0030	0.0031	0.0032	0.0033	0.0034
32	5 to 15	0.16 to 0.47	...	...	0.0023	0.0024	0.0024	0.0025	0.0026	0.0027	0.0027	0.0028
	16 to 30	0.471 to 0.94	...	...	0.0028	0.0029	0.0030	0.0032	0.0033	0.0033	0.0034	0.0035
28	5 to 15	0.18 to 0.54	...	...	...	0.0025	0.0026	0.0027	0.0028	0.0028	0.0029	0.0030
	16 to 30	0.541 to 1.08	...	...	...	0.0031	0.0032	0.0033	0.0034	0.0035	0.0036	0.0037
27	5 to 15	0.19 to 0.56	...	...	...	0.0025	0.0026	0.0027	0.0028	0.0029	0.0029	0.0030
	16 to 30	0.561 to 1.12	...	...	...	0.0032	0.0033	0.0034	0.0035	0.0036	0.0037	0.0038
24	5 to 15	0.21 to 0.62	...	...	...	0.0027	0.0028	0.0029	0.0029	0.0030	0.0031	0.0032
	16 to 30	0.621 to 1.24	...	...	...	0.0034	0.0034	0.0036	0.0037	0.0038	0.0038	0.0040
20	5 to 15	0.25 to 0.75	...	...	...	...	0.0030	0.0031	0.0032	0.0032	0.0033	0.0034
	16 to 30	0.751 to 1.50	...	...	...	...	0.0037	0.0039	0.0040	0.0041	0.0041	0.0043
18	5 to 15	0.28 to 0.83	...	...	...	...	...	0.0032	0.0033	0.0034	0.0035	0.0036
	16 to 30	0.831 to 1.66	...	...	...	...	...	0.0041	0.0042	0.0042	0.0043	0.0044
16	5 to 15	0.31 to 0.94	...	...	...	...	...	0.0034	0.0035	0.0036	0.0036	0.0037
	16 to 30	0.941 to 1.88	...	...	...	...	...	0.0043	0.0044	0.0045	0.0045	0.0047
14	5 to 15	0.36 to 1.07	...	...	...	...	...	...	0.0037	0.0038	0.0039	0.0040
	16 to 30	1.071 to 2.14	...	...	...	...	...	...	0.0047	0.0048	0.0048	0.0050
12	5 to 15	0.42 to 1.25	...	...	...	...	...	...	0.0040	0.0041	0.0041	0.0042
	16 to 30	1.251 to 2.50	...	...	...	...	...	...	0.0050	0.0051	0.0052	0.0053
10	5 to 15	0.50 to 1.50	...	...	...	...	...	...	...	...	0.0045	0.0046
	16 to 30	1.501 to 3.00	...	...	...	...	...	...	...	...	0.0056	0.0058
8	5 to 15	0.62 to 1.88	...	...	...	...	...	...	...	...	...	0.0051
	16 to 30	1.881 to 3.76	...	...	...	...	...	...	...	...	...	0.0064
6	5 to 15	0.83 to 2.50	...	...	...	...	...	...	...	...	...	...
	16 to 30	2.501 to 5.00	...	...	...	...	...	...	...	...	...	...
4	5 to 15	1.25 to 3.75	...	...	...	...	...	...	...	...	...	...
	16 to 30	3.751 to 7.50	...	...	...	...	...	...	...	...	...	...

GENERAL NOTES:

(a) These values do not agree with and shall not be used in place of any tabulated values for the UNC, UNF, and 8-UN thread series.

(b) Class 3A tolerances in this Table for 5 to 15 pitches are based on 9 pitches and are obtained by multiplying the Class 2A (external thread) tolerances for 9 pitches taken to six decimal places by a factor of 0.75.

(c) Class 3A tolerances in this Table for 16 to 30 pitches are obtained by multiplying the Class 2A (external thread) tolerances for 9 pitches taken to six decimal places by a factor of 0.9375 (obtained by multiplying the 0.75 factor by 1.25). For lengths of engagement not tabulated, see Section 5.

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TABLE 35 PITCH DIAMETER TOLERANCES FOR EXTERNAL THREADS OF SPECIAL DIAMETERS, PITCHES, AND LENGTHS OF ENGAGEMENT (UNS/UNRS)—CLASS 3A

1.25	1.5	1.75	2	2.5	3	3.5	4	5	6	8	10	12	
1.125	1.375	1.625	1.875	2.25	2.75	3.25	3.75	4.5	5.5	7	9	11	
1.375	1.625	1.875	2.25	2.75	3.25	3.75	4.5	5.5	7	9	11	13	
Pitch Diameter Tolerances, in.													Threads/in.
...	...	...	...	...	...	...	...	...	...	...	...	...	80
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	72
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	64
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	56
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	48
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	44
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	40
...	...	...	...	...	...	...	...	...	...	...	...	...	
0.0028	0.0029	...	...	...	...	...	...	...	...	...	...	...	36
0.0035	0.0036	...	...	...	...	...	...	...	...	...	...	...	
0.0029	0.0030	0.0031	0.0031	0.0032	0.0033	...	...	...	...	...	...	...	32
0.0037	0.0038	0.0038	0.0039	0.0040	0.0042	...	...	...	...	...	...	...	
0.0031	0.0031	0.0032	0.0033	0.0034	0.0035	0.0036	0.0036	...	...	...	...	...	28
0.0038	0.0039	0.0040	0.0041	0.0042	0.0044	0.0045	0.0046	...	...	...	...	...	
0.0031	0.0032	0.0033	0.0033	0.0034	0.0035	0.0036	0.0037	0.0038	0.0039	...	...	...	27
0.0039	0.0040	0.0041	0.0041	0.0043	0.0044	0.0045	0.0046	0.0048	0.0049	...	...	...	
0.0033	0.0033	0.0034	0.0035	0.0036	0.0037	0.0037	0.0038	0.0040	0.0041	...	...	...	24
0.0041	0.0042	0.0042	0.0043	0.0045	0.0046	0.0047	0.0048	0.0050	0.0051	...	...	...	
0.0035	0.0036	0.0036	0.0037	0.0038	0.0039	0.0040	0.0041	0.0042	0.0043	...	...	...	20
0.0044	0.0045	0.0045	0.0046	0.0048	0.0049	0.0050	0.0051	0.0053	0.0054	...	...	...	
0.0036	0.0037	0.0038	0.0039	0.0040	0.0041	0.0041	0.0042	0.0044	0.0045	0.0047	...	...	18
0.0046	0.0047	0.0047	0.0048	0.0050	0.0051	0.0052	0.0053	0.0054	0.0056	0.0059	...	...	
0.0038	0.0039	0.0040	0.0040	0.0041	0.0042	0.0043	0.0045	0.0045	0.0047	0.0049	0.0050	...	16
0.0048	0.0049	0.0050	0.0050	0.0052	0.0053	0.0054	0.0055	0.0057	0.0058	0.0061	0.0063	...	
0.0041	0.0041	0.0042	0.0043	0.0044	0.0045	0.0045	0.0046	0.0048	0.0049	0.0051	0.0053	0.0054	14
0.0051	0.0052	0.0052	0.0053	0.0055	0.0056	0.0057	0.0058	0.0060	0.0061	0.0064	0.0066	0.0068	
0.0043	0.0044	0.0045	0.0045	0.0046	0.0047	0.0048	0.0049	0.0050	0.0052	0.0054	0.0055	0.0057	12
0.0054	0.0055	0.0056	0.0057	0.0058	0.0059	0.0060	0.0061	0.0063	0.0065	0.0067	0.0069	0.0071	
0.0047	0.0048	0.0048	0.0049	0.0050	0.0051	0.0052	0.0053	0.0054	0.0055	0.0057	0.0059	0.0061	10
0.0059	0.0060	0.0061	0.0061	0.0063	0.0064	0.0065	0.0066	0.0068	0.0069	0.0072	0.0074	0.0076	
0.0052	0.0053	0.0054	0.0054	0.0055	0.0056	0.0057	0.0058	0.0059	0.0061	0.0063	0.0064	0.0066	8
0.0065	0.0066	0.0067	0.0068	0.0069	0.0070	0.0071	0.0072	0.0074	0.0076	0.0078	0.0080	0.0082	
...	0.0061	0.0061	0.0062	0.0063	0.0064	0.0065	0.0066	0.0067	0.0068	0.0070	0.0072	0.0074	6
...	0.0076	0.0077	0.0078	0.0079	0.0080	0.0081	0.0082	0.0084	0.0085	0.0088	0.0090	0.0092	
...	...	...	0.0076	0.0077	0.0078	0.0079	0.0079	0.0081	0.0082	0.0084	0.0086	0.0087	4
...	...	...	0.0095	0.0096	0.0097	0.0098	0.0099	0.0101	0.0102	0.0105	0.0107	0.0109	

(d) Pitches listed are those used most commonly and are recommended. Where intermediate pitches are specified, the formula in Section 5 should be applied.

(e) Tolerances are tabulated only for combinations of diameter, pitch, and length of engagement that are considered to be generally used. For other combinations encountered, see Section 5.

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TABLE 36 PITCH DIAMETER TOLERANCES FOR INTERNAL THREADS OF SPECIAL DIAMETERS, PITCHES, AND LENGTHS OF ENGAGEMENT (UNS/UNRS) — CLASS 1B

Tolerance based on basic major diameter of			0.0625	0.09375	0.125	0.1875	0.25	0.375	0.5	0.625	0.75	1
For diameter range above			0.0470	0.0781	0.1094	0.1562	0.2188	0.3125	0.4375	0.5625	0.6875	0.875
To and including			0.0781	0.1094	0.1562	0.2188	0.3125	0.4375	0.5625	0.6875	0.875	1.125
	Length of Engagement											
Threads/In.	Number of Pitches	in.	Pitch Diameter Tolerances, in.									
80	5 to 15	0.06 to 0.19	...	...	...	...	...	...	...	...	...	...
	16 to 30	0.191 to 0.38	...	...	...	...	...	...	...	...	...	...
72	5 to 15	0.07 to 0.21	...	...	...	...	...	...	...	...	...	...
	16 to 30	0.211 to 0.42	...	...	...	...	...	...	...	...	...	...
64	5 to 15	0.08 to 0.23	...	...	...	...	...	...	...	...	...	...
	16 to 30	0.231 to 0.46	...	...	...	...	...	...	...	...	...	...
56	5 to 15	0.09 to 0.27	...	...	...	...	...	...	...	...	...	...
	16 to 30	0.271 to 0.54	...	...	...	...	...	...	...	...	...	...
48	5 to 15	0.10 to 0.31	...	...	...	...	...	...	...	...	...	...
	16 to 30	0.311 to 0.62	...	...	...	...	...	...	...	...	...	...
44	5 to 15	0.11 to 0.34	...	0.0050	0.0051	0.0053	0.0055	0.0058	0.0060	0.0062	0.0063	0.0066
	16 to 30	0.341 to 0.68	...	0.0062	0.0064	0.0067	0.0069	0.0072	0.0075	0.0077	0.0079	0.0082
40	5 to 15	0.12 to 0.38	...	...	0.0054	0.0056	0.0057	0.0060	0.0062	0.0064	0.0065	0.0068
	16 to 30	0.381 to 0.76	...	...	0.0067	0.0070	0.0072	0.0075	0.0078	0.0080	0.0082	0.0085
36	5 to 15	0.14 to 0.42	...	...	0.0056	0.0058	0.0060	0.0063	0.0065	0.0066	0.0068	0.0071
	16 to 30	0.421 to 0.84	...	...	0.0070	0.0073	0.0075	0.0078	0.0081	0.0083	0.0085	0.0088
32	5 to 15	0.16 to 0.47	...	...	0.0059	0.0061	0.0063	0.0066	0.0068	0.0070	0.0071	0.0074
	16 to 30	0.471 to 0.94	...	...	0.0074	0.0077	0.0079	0.0082	0.0085	0.0087	0.0089	0.0092
28	5 to 15	0.18 to 0.54	...	...	...	0.0065	0.0067	0.0069	0.0072	0.0073	0.0075	0.0078
	16 to 30	0.541 to 1.08	...	...	...	0.0081	0.0083	0.0087	0.0089	0.0092	0.0094	0.0097
27	5 to 15	0.19 to 0.56	...	...	...	0.0066	0.0068	0.0070	0.0073	0.0074	0.0076	0.0079
	16 to 30	0.561 to 1.12	...	...	...	0.0083	0.0085	0.0088	0.0091	0.0093	0.0095	0.0098
24	5 to 15	0.21 to 0.62	...	...	...	0.0070	0.0072	0.0074	0.0076	0.0078	0.0080	0.0082
	16 to 30	0.621 to 1.24	...	...	...	0.0087	0.0089	0.0093	0.0095	0.0098	0.0100	0.0103
20	5 to 15	0.25 to 0.75	...	...	...	...	0.0078	0.0080	0.0083	0.0084	0.0086	0.0089
	16 to 30	0.751 to 1.50	...	...	...	...	0.0097	0.0101	0.0103	0.0105	0.0107	0.0111
18	5 to 15	0.28 to 0.83	...	...	...	...	...	0.0084	0.0087	0.0088	0.0090	0.0093
	16 to 30	0.831 to 1.66	...	...	...	...	...	0.0105	0.0108	0.0110	0.0112	0.0116
16	5 to 15	0.31 to 0.94	...	...	...	...	...	0.0089	0.0091	0.0093	0.0095	0.0097
	16 to 30	0.941 to 1.88	...	...	...	...	...	0.0111	0.0114	0.0116	0.0118	0.0122
14	5 to 15	0.36 to 1.07	...	...	...	...	...	...	0.0097	0.0099	0.0100	0.0103
	16 to 30	1.071 to 2.14	...	...	...	...	...	...	0.0121	0.0124	0.0125	0.0129
12	5 to 15	0.42 to 1.25	...	...	...	...	...	...	0.0104	0.0106	0.0108	0.0109
	16 to 30	1.251 to 2.50	...	...	...	...	...	...	0.0130	0.0133	0.0135	0.0138
10	5 to 15	0.50 to 1.50	...	...	...	...	...	...	...	...	0.0117	0.0120
	16 to 30	1.501 to 3.00	...	...	...	...	...	...	...	...	0.0147	0.0150
8	5 to 15	0.62 to 1.88	...	...	...	...	...	...	...	...	...	0.0133
	16 to 30	1.881 to 3.76	...	...	...	...	...	...	...	...	...	0.0167
6	5 to 15	0.83 to 2.50	...	...	...	...	...	...	...	...	...	...
	16 to 30	2.501 to 5.00	...	...	...	...	...	...	...	...	...	...
4	5 to 15	1.25 to 3.75	...	...	...	...	...	...	...	...	...	...
	16 to 30	3.751 to 7.50	...	...	...	...	...	...	...	...	...	...

GENERAL NOTES:

(a) These values do not agree with and shall not be used in place of any tabulated values for the UNC, UNF, and 8-UN thread series.

(b) Class 1B (internal thread) tolerances in this Table for 5 to 15 pitches are based on 9 pitches and are obtained by multiplying the Class 2A (external thread) tolerances for 9 pitches taken to six decimal places by a factor of 1.95.

(c) Class 1B tolerances in this Table for 16 to 30 pitches are obtained by multiplying the Class 2A (external thread) tolerances for 9 pitches taken to six decimal places by a factor of 2.437 (obtained by multiplying the 1.95 factor by 1.25). For lengths of engagement not tabulated, see Section 5.

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TABLE 36 PITCH DIAMETER TOLERANCES FOR INTERNAL THREADS OF SPECIAL DIAMETERS, PITCHES, AND LENGTHS OF ENGAGEMENT (UNS/UNRS) — CLASS 1B

1.25	1.5	1.75	2	2.5	3	3.5	4	5	6	8	10	12	
1.125	1.375	1.625	1.875	2.25	2.75	3.25	3.75	4.5	5.5	7	9	11	
1.375	1.625	1.875	2.25	2.75	3.25	3.75	4.5	5.5	7	9	11	13	
Pitch Diameter Tolerances, in.													Threads/in.
...	...	...	...	...	...	...	...	...	...	...	...	...	80
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	72
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	64
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	56
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	48
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	44
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	40
...	...	...	...	...	...	...	...	...	...	...	...	...	
0.0073	0.0075	...	...	...	...	...	...	...	...	...	...	...	36
0.0091	0.0094	...	...	...	...	...	...	...	...	...	...	...	
0.0076	0.0078	0.0080	0.0081	0.0084	0.0087	...	...	...	...	...	...	...	32
0.0095	0.0098	0.0100	0.0102	0.0105	0.0108	...	...	...	...	...	...	...	
0.0080	0.0082	0.0084	0.0085	0.0088	0.0090	0.0093	0.0095	...	...	...	...	...	28
0.0100	0.0102	0.0104	0.0106	0.0110	0.0113	0.0116	0.0118	...	...	...	...	...	
0.0080	0.0083	0.0085	0.0085	0.0089	0.0092	0.0094	0.0096	0.0099	0.0103	...	...	...	27
0.0101	0.0104	0.0106	0.0108	0.0111	0.0114	0.0117	0.0120	0.0124	0.0128	...	...	...	
0.0085	0.0087	0.0088	0.0090	0.0093	0.0095	0.0097	0.0100	0.0103	0.0106	...	...	...	24
0.0106	0.0108	0.0110	0.0112	0.0116	0.0119	0.0122	0.0124	0.0129	0.0133	...	...	...	
0.0091	0.0093	0.0095	0.0096	0.0099	0.0101	0.0104	0.0106	0.0109	0.0112	...	...	...	20
0.0114	0.0116	0.0118	0.0120	0.0124	0.0127	0.0130	0.0132	0.0137	0.0141	...	...	...	
0.0095	0.0097	0.0099	0.0100	0.0103	0.0105	0.0108	0.0110	0.0113	0.0116	0.0122	...	...	18
0.0118	0.0121	0.0123	0.0125	0.0129	0.0132	0.0135	0.0137	0.0142	0.0146	0.0152	...	...	
0.0100	0.0101	0.0103	0.0105	0.0108	0.0110	0.0112	0.0114	0.0118	0.0121	0.0126	0.0131	...	16
0.0124	0.0127	0.0129	0.0131	0.0135	0.0138	0.0140	0.0143	0.0148	0.0151	0.0158	0.0164	...	
0.0105	0.0107	0.0109	0.0111	0.0114	0.0116	0.0118	0.0120	0.0124	0.0127	0.0132	0.0137	0.0141	14
0.0132	0.0134	0.0136	0.0138	0.0142	0.0145	0.0148	0.0150	0.0155	0.0159	0.0165	0.0171	0.0176	
0.0113	0.0115	0.0116	0.0118	0.0121	0.0123	0.0126	0.0128	0.0131	0.0134	0.0140	0.0144	0.0148	12
0.0141	0.0143	0.0145	0.0147	0.0151	0.0154	0.0157	0.0159	0.0164	0.0168	0.0175	0.0180	0.0185	
0.0122	0.0124	0.0126	0.0128	0.0130	0.0133	0.0135	0.0137	0.0141	0.0144	0.0149	0.0154	0.0158	10
0.0153	0.0155	0.0158	0.0160	0.0163	0.0166	0.0169	0.0172	0.0176	0.0180	0.0187	0.0192	0.0197	
0.0136	0.0138	0.0139	0.0141	0.0144	0.0146	0.0149	0.0151	0.0154	0.0157	0.0163	0.0167	0.0171	8
0.0170	0.0172	0.0174	0.0176	0.0180	0.0183	0.0186	0.0188	0.0193	0.0197	0.0203	0.0209	0.0214	
...	0.0158	0.0160	0.0161	0.0164	0.0167	0.0169	0.0171	0.0174	0.0178	0.0183	0.0187	0.0191	6
...	0.0197	0.0200	0.0202	0.0205	0.0208	0.0211	0.0214	0.0218	0.0222	0.0229	0.0234	0.0239	
...	...	...	0.0197	0.0200	0.0202	0.0204	0.0206	0.0210	0.0213	0.0218	0.0223	0.0227	4
...	...	...	0.0246	0.0250	0.0253	0.0255	0.0258	0.0262	0.0266	0.0273	0.0279	0.0284	

(d) Pitches listed are those used most commonly and are recommended. Where intermediate pitches are specified, the formula in Section 5 should be applied.

(e) Tolerances are tabulated only for combinations of diameter, pitch, and length of engagement that are considered to be generally used. For other combinations encountered, see Section 5.

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TABLE 37 PITCH DIAMETER TOLERANCES FOR INTERNAL THREADS OF SPECIAL DIAMETERS, PITCHES, AND LENGTHS OF ENGAGEMENT (UNS/UNRS) — CLASS 2B

Tolerance based on basic major diameter of			0.0625	0.09375	0.125	0.1875	0.25	0.375	0.5	0.625	0.75	1
For diameter range above			0.0470	0.0781	0.1094	0.1562	0.2188	0.3125	0.4375	0.5625	0.6875	0.875
To and Including			0.0781	0.1094	0.1562	0.2188	0.3125	0.4375	0.5625	0.6875	0.875	1.125
	Length of Engagement											
Threads/in.	Number of Pitches	In.	Pitch Diameter Tolerances, In.									
80	5 to 15	0.06 to 0.19	0.0025	0.0026	0.0027	0.0028	0.0029	...	...	...	...	...
	16 to 30	0.191 to 0.38	0.0031	0.0032	0.0033	0.0035	0.0037	...	...	...	...	...
72	5 to 15	0.07 to 0.21	0.0026	0.0027	0.0028	0.0029	0.0030	0.0032	...	...	...	...
	16 to 30	0.211 to 0.42	0.0032	0.0034	0.0035	0.0037	0.0038	0.0040	...	...	...	...
64	5 to 15	0.08 to 0.23	0.0027	0.0028	0.0029	0.0031	0.0032	0.0034	0.0035	...	...	...
	16 to 30	0.231 to 0.46	0.0034	0.0035	0.0037	0.0038	0.0040	0.0042	0.0044	...	...	...
56	5 to 15	0.09 to 0.27	...	0.0030	0.0031	0.0032	0.0033	0.0035	0.0037	0.0038	0.0039	...
	16 to 30	0.271 to 0.54	...	0.0037	0.0039	0.0040	0.0042	0.0044	0.0046	0.0047	0.0049	...
48	5 to 15	0.10 to 0.31	...	0.0032	0.0033	0.0034	0.0036	0.0037	0.0039	0.0040	0.0041	...
	16 to 30	0.311 to 0.62	...	0.0040	0.0041	0.0043	0.0044	0.0047	0.0048	0.0050	0.0051	...
44	5 to 15	0.11 to 0.34	...	0.0033	0.0034	0.0036	0.0037	0.0039	0.0040	0.0041	0.0042	0.0044
	16 to 30	0.341 to 0.68	...	0.0042	0.0043	0.0045	0.0046	0.0048	0.0050	0.0051	0.0053	0.0055
40	5 to 15	0.12 to 0.38	...	...	0.0036	0.0037	0.0038	0.0041	0.0041	0.0043	0.0044	0.0045
	16 to 30	0.381 to 0.76	...	...	0.0045	0.0046	0.0048	0.0050	0.0052	0.0053	0.0055	0.0057
36	5 to 15	0.14 to 0.42	...	...	0.0037	0.0039	0.0040	0.0042	0.0043	0.0044	0.0045	0.0047
	16 to 30	0.421 to 0.84	...	...	0.0047	0.0049	0.0050	0.0052	0.0054	0.0055	0.0057	0.0059
32	5 to 15	0.16 to 0.47	...	...	0.0030	0.0041	0.0042	0.0044	0.0045	0.0046	0.0047	0.0049
	16 to 30	0.471 to 0.94	...	...	0.0049	0.0051	0.0052	0.0055	0.0056	0.0058	0.0059	0.0061
28	5 to 15	0.18 to 0.54	...	...	...	0.0043	0.0044	0.0046	0.0048	0.0049	0.0050	0.0052
	16 to 30	0.541 to 1.08	...	...	...	0.0054	0.0056	0.0058	0.0060	0.0061	0.0062	0.0065
27	5 to 15	0.19 to 0.56	...	...	...	0.0044	0.0045	0.0047	0.0048	0.0050	0.0051	0.0052
	16 to 30	0.561 to 1.12	...	...	...	0.0055	0.0057	0.0059	0.0061	0.0062	0.0063	0.0066
24	5 to 15	0.21 to 0.62	...	...	...	0.0047	0.0048	0.0049	0.0051	0.0052	0.0053	0.0055
	16 to 30	0.621 to 1.24	...	...	...	0.0058	0.0060	0.0062	0.0064	0.0065	0.0066	0.0069
20	5 to 15	0.25 to 0.75	...	...	...	...	0.0052	0.0055	0.0056	0.0057	0.0057	0.0059
	16 to 30	0.751 to 1.50	...	...	...	...	0.0065	0.0067	0.0069	0.0072	0.0074	0.0074
18	5 to 15	0.28 to 0.83	...	...	...	...	...	0.0056	0.0059	0.0060	0.0060	0.0062
	16 to 30	0.831 to 1.66	...	...	...	...	...	0.0070	0.0072	0.0074	0.0075	0.0077
16	5 to 15	0.31 to 0.94	...	...	...	...	...	0.0059	0.0061	0.0062	0.0063	0.0065
	16 to 30	0.941 to 1.88	...	...	...	...	...	0.0074	0.0076	0.0077	0.0079	0.0081
14	5 to 15	0.36 to 1.07	...	...	...	...	...	...	0.0065	0.0066	0.0067	0.0069
	16 to 30	1.071 to 2.14	...	...	...	...	...	...	0.0081	0.0082	0.0084	0.0086
12	5 to 15	0.42 to 1.25	...	...	...	...	...	...	0.0070	0.0071	0.0072	0.0074
	16 to 30	1.251 to 2.50	...	...	...	...	...	...	0.0087	0.0088	0.0090	0.0092
10	5 to 15	0.50 to 1.50	...	...	...	...	...	...	...	...	0.0078	0.0080
	16 to 30	1.501 to 3.00	...	...	...	...	...	...	...	...	0.0098	0.0100
8	5 to 15	0.62 to 1.88	...	...	...	...	...	...	...	...	...	0.0089
	16 to 30	1.881 to 3.76	...	...	...	...	...	...	...	...	...	0.0111
6	5 to 15	0.83 to 2.50	...	...	...	...	...	...	...	...	...	...
	16 to 30	2.501 to 5.00	...	...	...	...	...	...	...	...	...	...
4	5 to 15	1.25 to 3.75	...	...	...	...	...	...	...	...	...	...
	16 to 30	3.751 to 7.50	...	...	...	...	...	...	...	...	...	...

GENERAL NOTES:

(a) These values do not agree with and shall not be used in place of any tabulated values for the UNC, UNF, and 8-UN thread series.

(b) Class 2B (internal thread) tolerances in this Table for 5 to 15 pitches are based on 9 pitches and are obtained by multiplying the Class 2A (external thread) tolerances for 9 pitches taken to six decimal places by a factor of 1.3.

(c) Class 2B tolerances in this Table for 16 to 30 pitches are obtained by multiplying the Class 2A (external thread) tolerances for 9 pitches taken to six decimal places by a factor of 1.625 (obtained by multiplying the 1.3 factor by 1.25). For lengths of engagement not tabulated, see Section 5.

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TABLE 37 PITCH DIAMETER TOLERANCES FOR INTERNAL THREADS OF SPECIAL DIAMETERS, PITCHES, AND LENGTHS OF ENGAGEMENT (UNS/UNRS) — CLASS 2B

1.25	1.5	1.75	2	2.5	3	3.5	4	5	6	8	10	12	
1.125	1.375	1.625	1.875	2.25	2.75	3.25	3.75	4.5	5.5	7	9	11	
1.375	1.625	1.875	2.25	2.75	3.25	3.75	4.5	5.5	7	9	11	13	
Pitch Diameter Tolerances, In.													Threads/in.
...	...	...	...	...	...	...	...	...	...	...	...	...	80
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	72
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	64
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	56
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	48
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	44
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	40
...	...	...	...	...	...	...	...	...	...	...	...	...	
0.0049	0.0050	...	...	...	...	...	...	...	...	...	...	...	36
0.0061	0.0062	...	...	...	...	...	...	...	...	...	...	...	
0.0051	0.0052	0.0053	0.0054	0.0056	0.0058	...	...	...	...	...	...	...	32
0.0063	0.0065	0.0066	0.0068	0.0070	0.0072	...	...	...	...	...	...	...	
0.0053	0.0055	0.0056	0.0057	0.0059	0.0060	0.0062	0.0063	...	...	...	...	...	28
0.0067	0.0068	0.0070	0.0071	0.0073	0.0075	0.0077	0.0079	...	...	...	...	...	
0.0053	0.0055	0.0056	0.0057	0.0059	0.0061	0.0063	0.0064	0.0066	0.0068	...	...	...	27
0.0067	0.0069	0.0071	0.0072	0.0074	0.0076	0.0078	0.0080	0.0083	0.0085	...	...	...	
0.0056	0.0058	0.0059	0.0060	0.0062	0.0064	0.0065	0.0066	0.0069	0.0071	...	...	...	24
0.0070	0.0072	0.0074	0.0075	0.0077	0.0079	0.0081	0.0083	0.0086	0.0089	...	...	...	
0.0061	0.0062	0.0063	0.0064	0.0066	0.0068	0.0069	0.0070	0.0073	0.0075	...	...	...	20
0.0076	0.0077	0.0079	0.0080	0.0083	0.0085	0.0086	0.0088	0.0091	0.0094	...	...	...	
0.0063	0.0065	0.0066	0.0067	0.0069	0.0070	0.0072	0.0073	0.0076	0.0078	0.0081	...	...	18
0.0079	0.0081	0.0082	0.0083	0.0086	0.0088	0.0090	0.0091	0.0094	0.0097	0.0101	...	...	
0.0066	0.0068	0.0069	0.0070	0.0072	0.0073	0.0075	0.0076	0.0079	0.0081	0.0084	0.0087	...	16
0.0083	0.0085	0.0086	0.0087	0.0090	0.0092	0.0094	0.0095	0.0098	0.0101	0.0105	0.0109	...	
0.0070	0.0072	0.0073	0.0074	0.0076	0.0077	0.0079	0.0080	0.0083	0.0085	0.0088	0.0091	0.0094	14
0.0088	0.0089	0.0091	0.0092	0.0095	0.0097	0.0099	0.0100	0.0103	0.0106	0.0110	0.0114	0.0117	
0.0075	0.0076	0.0078	0.0079	0.0081	0.0082	0.0084	0.0085	0.0087	0.0090	0.0093	0.0096	0.0099	12
0.0094	0.0096	0.0097	0.0098	0.0101	0.0103	0.0105	0.0106	0.0109	0.0112	0.0116	0.0120	0.0123	
0.0082	0.0083	0.0084	0.0085	0.0087	0.0089	0.0090	0.0091	0.0094	0.0096	0.0100	0.0103	0.0105	10
0.0102	0.0104	0.0105	0.0106	0.0109	0.0111	0.0113	0.0114	0.0117	0.0120	0.0124	0.0128	0.0131	
0.0090	0.0092	0.0093	0.0094	0.0096	0.0098	0.0099	0.0100	0.0103	0.0105	0.0108	0.0111	0.0114	8
0.0113	0.0115	0.0116	0.0118	0.0120	0.0122	0.0124	0.0125	0.0128	0.0131	0.0136	0.0139	0.0143	
...	0.0105	0.0106	0.0108	0.0109	0.0111	0.0113	0.0114	0.0116	0.0118	0.0122	0.0125	0.0128	6
...	0.0132	0.0133	0.0134	0.0137	0.0139	0.0141	0.0142	0.0145	0.0148	0.0152	0.0156	0.0159	
...	...	...	0.0131	0.0133	0.0135	0.0136	0.0138	0.0140	0.0142	0.0146	0.0149	0.0151	4
...	...	...	0.0164	0.0166	0.0168	0.0170	0.0172	0.0175	0.0178	0.0182	0.0186	0.0189	

(d) Pitches listed are those used most commonly and are recommended. Where intermediate pitches are specified, the formula in Section 5 should be applied.

(e) Tolerances are tabulated only for combinations of diameter, pitch, and length of engagement that are considered to be generally used. For other combinations encountered, see Section 5.

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TABLE 38 PITCH DIAMETER TOLERANCES FOR INTERNAL THREADS OF SPECIAL DIAMETERS, PITCHES, AND LENGTHS OF ENGAGEMENT (UNS/UNRS) — CLASS 3B

Tolerance based on basic major diameter of			0.0625	0.09375	0.125	0.1875	0.25	0.375	0.5	0.625	0.75	1
For diameter range above			0.0470	0.0781	0.1094	0.1562	0.2188	0.3125	0.4375	0.5625	0.6875	0.875
To and including			0.0781	0.1094	0.1562	0.2188	0.3125	0.4375	0.5625	0.6875	0.875	1.125
	Length of Engagement											
Threads/in.	Number of Pitches	In.	Pitch Diameter Tolerances, in.									
80	5 to 15	0.06 to 0.19	0.0019	0.0019	0.0020	0.0021	0.0022	...	...	...	...	...
	16 to 30	0.191 to 0.38	0.0023	0.0024	0.0025	0.0026	0.0027	...	...	...	...	...
72	5 to 15	0.07 to 0.21	0.0019	0.0020	0.0021	0.0022	0.0023	0.0024	...	...	...	...
	16 to 30	0.211 to 0.42	0.0024	0.0025	0.0026	0.0027	0.0029	0.0030	...	...	...	...
64	5 to 15	0.08 to 0.23	0.0020	0.0021	0.0022	0.0023	0.0024	0.0025	0.0026	...	...	...
	16 to 30	0.231 to 0.46	0.0026	0.0027	0.0027	0.0029	0.0030	0.0031	0.0033	...	...	...
56	5 to 15	0.09 to 0.27	...	0.0023	0.0023	0.0024	0.0025	0.0026	0.0027	0.0028	0.0029	...
	16 to 30	0.271 to 0.54	...	0.0028	0.0029	0.0030	0.0031	0.0033	0.0034	0.0036	0.0036	...
48	5 to 15	0.10 to 0.31	...	0.0024	0.0025	0.0026	0.0027	0.0028	0.0029	0.0030	0.0031	...
	16 to 30	0.311 to 0.62	...	0.0030	0.0031	0.0032	0.0033	0.0035	0.0036	0.0037	0.0038	...
44	5 to 15	0.11 to 0.34	...	0.0025	0.0026	0.0027	0.0028	0.0029	0.0030	0.0031	0.0032	0.0033
	16 to 30	0.341 to 0.68	...	0.0031	0.0032	0.0033	0.0034	0.0036	0.0037	0.0039	0.0040	0.0041
40	5 to 15	0.12 to 0.38	...	...	0.0027	0.0028	0.0029	0.0030	0.0031	0.0032	0.0033	0.0034
	16 to 30	0.381 to 0.76	...	...	0.0033	0.0035	0.0036	0.0037	0.0039	0.0040	0.0041	0.0043
36	5 to 15	0.14 to 0.42	...	...	0.0028	0.0029	0.0030	0.0031	0.0032	0.0033	0.0034	0.0035
	16 to 30	0.421 to 0.84	...	...	0.0035	0.0036	0.0037	0.0039	0.0040	0.0042	0.0043	0.0044
32	5 to 15	0.16 to 0.47	...	...	0.0030	0.0031	0.0031	0.0033	0.0034	0.0035	0.0036	0.0037
	16 to 30	0.471 to 0.94	...	...	0.0037	0.0038	0.0039	0.0041	0.0042	0.0043	0.0044	0.0046
28	5 to 15	0.18 to 0.54	...	...	...	0.0033	0.0033	0.0035	0.0036	0.0037	0.0037	0.0039
	16 to 30	0.541 to 1.08	...	...	...	0.0041	0.0042	0.0043	0.0045	0.0046	0.0047	0.0048
27	5 to 15	0.19 to 0.56	...	...	...	0.0033	0.0034	0.0035	0.0036	0.0037	0.0038	0.0039
	16 to 30	0.561 to 1.12	...	...	...	0.0041	0.0042	0.0044	0.0045	0.0046	0.0047	0.0049
24	5 to 15	0.21 to 0.62	...	...	...	0.0035	0.0036	0.0037	0.0038	0.0039	0.0040	0.0041
	16 to 30	0.621 to 1.24	...	...	...	0.0044	0.0045	0.0046	0.0048	0.0049	0.0050	0.0051
20	5 to 15	0.25 to 0.75	...	...	...	...	0.0039	0.0040	0.0041	0.0042	0.0043	0.0044
	16 to 30	0.751 to 1.50	...	...	...	...	0.0049	0.0050	0.0052	0.0053	0.0054	0.0055
18	5 to 15	0.28 to 0.83	...	...	...	...	...	0.0042	0.0043	0.0044	0.0045	0.0046
	16 to 30	0.831 to 1.66	...	...	...	...	...	0.0053	0.0054	0.0055	0.0056	0.0058
16	5 to 15	0.31 to 0.94	...	...	...	...	...	0.0045	0.0046	0.0046	0.0047	0.0049
	16 to 30	0.941 to 1.88	...	...	...	...	...	0.0056	0.0057	0.0058	0.0059	0.0061
14	5 to 15	0.36 to 1.07	...	...	...	...	...	...	0.0049	0.0049	0.0050	0.0052
	16 to 30	1.071 to 2.14	...	...	...	...	...	...	0.0061	0.0062	0.0063	0.0064
12	5 to 15	0.42 to 1.25	...	...	...	...	...	...	0.0052	0.0053	0.0054	0.0055
	16 to 30	1.251 to 2.50	...	...	...	...	...	...	0.0065	0.0066	0.0067	0.0069
10	5 to 15	0.50 to 1.50	...	...	...	...	...	...	...	...	0.0059	0.0060
	16 to 30	1.501 to 3.00	...	...	...	...	...	...	...	...	0.0073	0.0075
8	5 to 15	0.62 to 1.88	...	...	...	...	...	...	...	...	...	0.0067
	16 to 30	1.881 to 3.76	...	...	...	...	...	...	...	...	...	0.0083
6	5 to 15	0.83 to 2.50	...	...	...	...	...	...	...	...	...	...
	16 to 30	2.501 to 5.00	...	...	...	...	...	...	...	...	...	...
4	5 to 15	1.25 to 3.75	...	...	...	...	...	...	...	...	...	...
	16 to 30	3.751 to 7.50	...	...	...	...	...	...	...	...	...	...

GENERAL NOTES:

(a) These values do not agree with and shall not be used in place of any tabulated values for the UNC, UNF, and 8-UN thread series.

(b) Class 3B (internal thread) tolerances in this Table for 5 to 15 pitches are based on 9 pitches and are obtained by multiplying the Class 2A (external thread) tolerances for 9 pitches taken to six decimal places by a factor of 0.975.

(c) Class 3B tolerances in this Table for 16 to 30 pitches are obtained by multiplying the Class 2A (external thread) tolerances for 9 pitches taken to six decimal places by a factor of 1.21875 (obtained by multiplying the 0.975 factor by 1.25). For lengths of engagement not tabulated, see Section 5.

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TABLE 38 PITCH DIAMETER TOLERANCES FOR INTERNAL THREADS OF SPECIAL DIAMETERS, PITCHES, AND LENGTHS OF ENGAGEMENT (UNS/UNRS) — CLASS 3B

1.25	1.5	1.75	2	2.5	3	3.5	4	5	6	8	10	12	
1.125	1.375	1.625	1.875	2.25	2.75	3.25	3.75	4.5	5.5	7	9	11	
1.375	1.625	1.875	2.25	2.75	3.25	3.75	4.5	5.5	7	9	11	13	
Pitch Diameter Tolerances, in.													Threads/in.
...	...	...	...	...	...	...	...	...	...	...	...	...	80
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	72
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	64
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	56
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	48
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	44
...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	...	...	...	40
...	...	...	...	...	...	...	...	...	...	...	...	...	
0.0036	0.0037	...	...	...	...	...	...	...	...	...	...	...	36
0.0046	0.0047	...	...	...	...	...	...	...	...	...	...	...	
0.0038	0.0039	0.0040	0.0041	0.0042	0.0043	...	...	...	...	...	...	...	32
0.0048	0.0049	0.0050	0.0051	0.0053	0.0054	...	...	...	...	...	...	...	
0.0040	0.0041	0.0042	0.0043	0.0044	0.0045	0.0046	0.0047	...	...	...	...	...	28
0.0050	0.0051	0.0052	0.0053	0.0055	0.0057	0.0058	0.0059	...	...	...	...	...	
0.0040	0.0041	0.0042	0.0043	0.0045	0.0046	0.0047	0.0048	0.0050	0.0051	...	...	...	27
0.0051	0.0052	0.0053	0.0054	0.0056	0.0057	0.0059	0.0060	0.0062	0.0064	...	...	...	
0.0042	0.0043	0.0044	0.0045	0.0046	0.0048	0.0049	0.0050	0.0052	0.0053	...	...	...	24
0.0053	0.0054	0.0055	0.0056	0.0058	0.0060	0.0061	0.0062	0.0064	0.0066	...	...	...	
0.0045	0.0046	0.0047	0.0048	0.0050	0.0051	0.0052	0.0053	0.0055	0.0056	...	...	...	20
0.0057	0.0058	0.0059	0.0060	0.0062	0.0063	0.0065	0.0066	0.0068	0.0070	...	...	...	
0.0047	0.0048	0.0049	0.0050	0.0051	0.0053	0.0054	0.0055	0.0057	0.0058	0.0061	...	...	18
0.0059	0.0060	0.0062	0.0063	0.0064	0.0066	0.0067	0.0069	0.0071	0.0073	0.0076	...	...	
0.0050	0.0051	0.0052	0.0052	0.0054	0.0055	0.0056	0.0057	0.0059	0.0061	0.0063	0.0066	...	16
0.0062	0.0063	0.0065	0.0066	0.0067	0.0069	0.0070	0.0072	0.0074	0.0076	0.0079	0.0082	...	
0.0053	0.0054	0.0055	0.0055	0.0057	0.0058	0.0059	0.0060	0.0062	0.0063	0.0066	0.0068	0.0070	14
0.0066	0.0067	0.0068	0.0069	0.0071	0.0072	0.0074	0.0075	0.0077	0.0079	0.0083	0.0086	0.0088	
0.0056	0.0057	0.0058	0.0059	0.0060	0.0062	0.0063	0.0064	0.0066	0.0067	0.0070	0.0072	0.0074	12
0.0070	0.0072	0.0073	0.0074	0.0076	0.0077	0.0078	0.0080	0.0082	0.0084	0.0087	0.0090	0.0093	
0.0061	0.0062	0.0063	0.0064	0.0065	0.0066	0.0068	0.0069	0.0070	0.0072	0.0075	0.0077	0.0079	10
0.0076	0.0078	0.0079	0.0080	0.0082	0.0083	0.0084	0.0086	0.0088	0.0090	0.0093	0.0096	0.0099	
0.0068	0.0069	0.0070	0.0071	0.0072	0.0073	0.0074	0.0075	0.0077	0.0079	0.0081	0.0084	0.0086	8
0.0085	0.0086	0.0087	0.0088	0.0090	0.0091	0.0093	0.0094	0.0096	0.0098	0.0102	0.0104	0.0107	
...	0.0079	0.0080	0.0081	0.0082	0.0083	0.0084	0.0085	0.0087	0.0089	0.0091	0.0094	0.0096	6
...	0.0090	0.0100	0.0101	0.0103	0.0104	0.0106	0.0107	0.0109	0.0111	0.0114	0.0117	0.0120	
...	...	...	0.0098	0.0100	0.0101	0.0102	0.0103	0.0105	0.0107	0.0109	0.0111	0.0113	4
...	...	...	0.0123	0.0125	0.0126	0.0128	0.0129	0.0131	0.0133	0.0137	0.0139	0.0142	

(d) Pitches listed are those used most commonly and are recommended. Where intermediate pitches are specified, the formula in Section 5 should be applied.

(e) Tolerances are tabulated only for combinations of diameter, pitch, and length of engagement that are considered to be generally used. For other combinations encountered, see Section 5.

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TABLE 39 MINOR DIAMETER TOLERANCES FOR INTERNAL SPECIAL SCREW THREADS (UNS/UNRS) — CLASSES 1B AND 2B

Tolerance based on basic major diameter of	0.060	0.073	0.086	0.099	0.112	0.125	0.138	0.164	0.190	0.216	All Larger Diameters
For diameter range above	0.053	0.066	0.079	0.092	0.105	0.118	0.131	0.151	0.177	0.203	
To and including	0.066	0.079	0.092	0.105	0.118	0.131	0.151	0.177	0.203	0.233	

Threads/ in.	Tolerance Ratios	Length of Eng. in Terms of Diam. (1) Above	To and Incl.	Minor Diameter Tolerances, in. (2)										
80	0.5	0	0.33*D*	0.0035	0.0029	0.0025	0.0022	0.0020	0.0018	0.0017	0.0016	0.0016	0.0016	0.0016
	0.75	0.33*D*	0.67*D*	0.0049	0.0044	0.0038	0.0034	0.0030	0.0028	0.0026	0.0023	0.0023	0.0023	0.0023
	1.0	0.67*D*	1.5*D*	0.0049	0.0049	0.0049	0.0045	0.0040	0.0037	0.0034	0.0031	0.0031	0.0031	0.0031
	1.25	1.5*D*	3*D*	0.0049	0.0049	0.0049	0.0049	0.0049	0.0046	0.0043	0.0039	0.0039	0.0039	0.0039
72	0.5	0	0.33*D*	0.0039	0.0033	0.0029	0.0026	0.0023	0.0021	0.0020	0.0017	0.0017	0.0017	0.0017
	0.75	0.33*D*	0.67*D*	0.0055	0.0049	0.0043	0.0040	0.0035	0.0032	0.0029	0.0026	0.0026	0.0026	0.0026
	1.0	0.67*D*	1.5*D*	0.0055	0.0055	0.0055	0.0051	0.0046	0.0042	0.0039	0.0034	0.0034	0.0034	0.0034
	1.25	1.5*D*	3*D*	0.0055	0.0055	0.0055	0.0055	0.0055	0.0053	0.0049	0.0043	0.0042	0.0042	0.0042
64	0.5	0	0.33*D*	0.0045	0.0038	0.0033	0.0029	0.0027	0.0024	0.0023	0.0020	0.0019	0.0019	0.0019
	0.75	0.33*D*	0.67*D*	0.0062	0.0057	0.0049	0.0044	0.0040	0.0037	0.0034	0.0030	0.0028	0.0028	0.0028
	1.0	0.67*D*	1.5*D*	0.0062	0.0062	0.0062	0.0059	0.0053	0.0049	0.0045	0.0040	0.0038	0.0038	0.0038
	1.25	1.5*D*	3*D*	0.0062	0.0062	0.0062	0.0062	0.0062	0.0061	0.0057	0.0050	0.0048	0.0048	0.0048
56	0.5	0	0.33*D*	...	0.0044	0.0038	0.0034	0.0031	0.0029	0.0026	0.0023	0.0022	0.0022	0.0022
	0.75	0.33*D*	0.67*D*	...	0.0066	0.0057	0.0051	0.0046	0.0043	0.0040	0.0035	0.0032	0.0032	0.0032
	1.0	0.67*D*	1.5*D*	...	0.0070	0.0070	0.0068	0.0062	0.0057	0.0053	0.0047	0.0043	0.0043	0.0043
	1.25	1.5*D*	3*D*	...	0.0070	0.0070	0.0070	0.0070	0.0070	0.0066	0.0059	0.0054	0.0054	0.0054
48	0.5	0	0.33*D*	...	...	0.0045	0.0040	0.0037	0.0034	0.0032	0.0028	0.0025	0.0025	0.0025
	0.75	0.33*D*	0.67*D*	...	...	0.0068	0.0061	0.0055	0.0051	0.0047	0.0042	0.0038	0.0038	0.0038
	1.0	0.67*D*	1.5*D*	...	...	0.0082	0.0081	0.0074	0.0068	0.0063	0.0056	0.0051	0.0050	0.0050
	1.25	1.5*D*	3*D*	...	...	0.0082	0.0082	0.0082	0.0082	0.0079	0.0070	0.0063	0.0062	0.0062
44	0.5	0	0.33*D*	...	...	0.0050	0.0044	0.0040	0.0037	0.0035	0.0031	0.0028	0.0028	0.0028
	0.75	0.33*D*	0.67*D*	...	...	0.0075	0.0067	0.0061	0.0056	0.0052	0.0046	0.0042	0.0041	0.0041
	1.0	0.67*D*	1.5*D*	...	...	0.0090	0.0089	0.0081	0.0075	0.0070	0.0062	0.0056	0.0055	0.0055
	1.25	1.5*D*	3*D*	...	...	0.0090	0.0090	0.0090	0.0090	0.0087	0.0077	0.0070	0.0069	0.0069
40	0.5	0	0.33*D*	...	...	...	0.0049	0.0045	0.0041	0.0039	0.0034	0.0031	0.0030	0.0030
	0.75	0.33*D*	0.67*D*	...	...	...	0.0074	0.0067	0.0062	0.0058	0.0051	0.0047	0.0045	0.0045
	1.0	0.67*D*	1.5*D*	...	...	...	0.0098	0.0090	0.0083	0.0077	0.0068	0.0062	0.0060	0.0060
	1.25	1.5*D*	3*D*	...	...	...	0.0098	0.0098	0.0098	0.0096	0.0086	0.0078	0.0075	0.0075
36	0.5	0	0.33*D*	...	...	...	...	0.0050	0.0046	0.0043	0.0038	0.0035	0.0033	0.0033
	0.75	0.33*D*	0.67*D*	...	...	...	...	0.0075	0.0069	0.0065	0.0058	0.0052	0.0050	0.0050
	1.0	0.67*D*	1.5*D*	...	...	...	...	0.0100	0.0093	0.0086	0.0077	0.0070	0.0066	0.0066
	1.25	1.5*D*	3*D*	...	...	...	...	0.0109	0.0109	0.0108	0.0096	0.0087	0.0082	0.0082
32	0.5	0	0.33*D*	...	...	...	...	...	...	0.0049	0.0043	0.0039	0.0037	0.0037
	0.75	0.33*D*	0.67*D*	...	...	...	...	...	...	0.0073	0.0065	0.0059	0.0056	0.0056
	1.0	0.67*D*	1.5*D*	...	...	...	...	...	...	0.0098	0.0087	0.0079	0.0074	0.0074
	1.25	1.5*D*	3*D*	...	...	...	...	...	...	0.0122	0.0108	0.0099	0.0092	0.0092
28	0.5	0	0.33*D*	...	...	...	...	...	...	...	...	0.0045	0.0042	0.0042
	0.75	0.33*D*	0.67*D*	Tolerances in this range also apply to Class 3B threads							...	0.0068	0.0063	0.0063
	1.0	0.67*D*	1.5*D*								...	0.0091	0.0084	0.0084
	1.25	1.5*D*	3*D*								...	0.0113	0.0105	0.0105
27	0.5	0	0.33*D*	...	...	...	...	...	...	...	...	0.0047	0.0044	0.0044
	0.75	0.33*D*	0.67*D*	...	...	...	...	...	...	...	...	0.0071	0.0065	0.0065
	1.0	0.67*D*	1.5*D*	...	...	...	...	...	...	...	...	0.0094	0.0087	0.0087
	1.25	1.5*D*	3*D*	...	...	...	...	...	...	...	...	0.0118	0.0109	0.0109
24	0.5	0	0.33*D*	...	...	...	...	...	...	...	...	0.0053	0.0049	0.0048
	0.75	0.33*D*	0.67*D*	...	...	...	...	...	...	...	...	0.0079	0.0073	0.0073
	1.0	0.67*D*	1.5*D*	...	...	...	...	...	...	...	...	0.0106	0.0098	0.0097
	1.25	1.5*D*	3*D*	...	...	...	...	...	...	...	...	0.0132	0.0122	0.0121

Tolerance Ratios	Length of Eng. in Terms of Diam. Above	To and Including	Minor Diameter Tolerances, in. (Not applicable to diameters less than 0.25 in.) 20 TPI	18 TPI	16 TPI	14 TPI	13 TPI	12 TPI	11 TPI	10 TPI	9 TPI	8 TPI	7 TPI	6 TPI	5 TPI	4.5 TPI	4 TPI
0.5	0	0.33*D*	0.0058	0.0064	0.0070	0.0079	0.0085	0.0090	0.0097	0.0105	0.0114	0.0125	0.0138	0.0153	0.0170	0.0179	0.0188
0.75	0.33*D*	0.67*D*	0.0086	0.0095	0.0106	0.0118	0.0128	0.0135	0.0146	0.0158	0.0171	0.0188	0.0207	0.0230	0.0255	0.0268	0.0281
1.0	0.67*D*	1.5*D*	0.0115	0.0127	0.0141	0.0158	0.0170	0.0180	0.0194	0.0210	0.0228	0.0250	0.0276	0.0306	0.0340	0.0358	0.0375
1.25	1.5*D*	3*D*	0.0144	0.0159	0.0176	0.0198	0.0213	0.0225	0.0242	0.0262	0.0286	0.0312	0.0344	0.0382	0.0425	0.0448	0.0469

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NOTES TO TABLE 39

(1) Tolerances for lengths of engagement in terms of pitch should be selected from equivalent lengths of engagement in terms of diameter ranges.
(2) If the minor diameter tolerance as selected from this Table is less than the pitch diameter tolerance, use the latter.

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TABLE 40 MINOR DIAMETER TOLERANCES FOR INTERNAL SPECIAL SCREW THREADS (UNS/UNRS) — CLASS 3B

Tolerance based on basic major diameter of	...	0.161	0.190	0.216	0.250	0.3125	0.375	0.4375	0.500	0.5625	0.625	0.6875	All Larger Diameters
For diameter range above	0.053	0.151	0.177	0.203	0.233	0.281	0.344	0.406	0.469	0.531	0.594	0.656	
To and Including	0.151 (1)	0.177	0.203	0.233	0.281	0.344	0.406	0.469	0.531	0.594	0.656	0.719	

Threads/ in.	Tolerance Ratios	Length of Eng. in Terms of Diam. (2) Above	To and Including	Minor Diameter Tolerances, in. (3)												
80	0.5	0	0.33D	...	0.0015	0.0013	0.0013	0.0013	0.0013	...	...	...	...	...	...	...
	0.75	0.33D	0.67D	...	0.0022	0.0020	0.0020	0.0020	0.0020	...	...	...	...	...	...	...
	1.0	0.67D	1.5D	...	0.0030	0.0027	0.0026	0.0026	0.0026	...	...	...	...	...	...	...
	1.25	1.5D	3D	...	0.0037	0.0033	0.0033	0.0033	0.0033	...	...	...	...	...	...	...
72	0.5	0	0.33D	...	0.0017	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	...	...	...	...	...
	0.75	0.33D	0.67D	...	0.0026	0.0023	0.0022	0.0022	0.0022	0.0022	0.0022	...	...	...	...	...
	1.0	0.67D	1.5D	...	0.0034	0.0031	0.0029	0.0029	0.0029	0.0029	0.0029	...	...	...	...	...
	1.25	1.5D	3D	...	0.0043	0.0039	0.0036	0.0036	0.0036	0.0036	0.0036	...	...	...	...	...
64	0.5	0	0.33D	...	0.0020	0.0018	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	...	...	...
	0.75	0.33D	0.67D	...	0.0030	0.0027	0.0025	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	...	...	...
	1.0	0.67D	1.5D	...	0.0040	0.0036	0.0033	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	...	...	...
	1.25	1.5D	3D	...	0.0050	0.0045	0.0041	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	...	...	...
56	0.5	0	0.33D	...	0.0023	0.0021	0.0019	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
	0.75	0.33D	0.67D	...	0.0035	0.0032	0.0029	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027
	1.0	0.67D	1.5D	...	0.0047	0.0042	0.0039	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036
	1.25	1.5D	3D	...	0.0059	0.0053	0.0049	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045
48	0.5	0	0.33D	...	0.0028	0.0025	0.0023	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021
	0.75	0.33D	0.67D	...	0.0042	0.0038	0.0035	0.0032	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031
	1.0	0.67D	1.5D	...	0.0056	0.0051	0.0047	0.0043	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041
	1.25	1.5D	3D	...	0.0070	0.0063	0.0059	0.0054	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052
44	0.5	0	0.33D	...	0.0031	0.0028	0.0026	0.0024	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022
	0.75	0.33D	0.67D	...	0.0046	0.0042	0.0039	0.0036	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033
	1.0	0.67D	1.5D	...	0.0062	0.0056	0.0052	0.0047	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045
	1.25	1.5D	3D	...	0.0077	0.0070	0.0065	0.0059	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056
40	0.5	0	0.33D	...	0.0034	0.0031	0.0029	0.0026	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
	0.75	0.33D	0.67D	...	0.0051	0.0047	0.0043	0.0040	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036
	1.0	0.67D	1.5D	...	0.0068	0.0062	0.0057	0.0053	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048
	1.25	1.5D	3D	...	0.0086	0.0078	0.0072	0.0066	0.0062	0.0062	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060
36	0.5	0	0.33D	...	0.0038	0.0035	0.0032	0.0030	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026
	0.75	0.33D	0.67D	...	0.0058	0.0052	0.0048	0.0044	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039
	1.0	0.67D	1.5D	...	0.0077	0.0070	0.0064	0.0059	0.0053	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052
	1.25	1.5D	3D	...	0.0096	0.0087	0.0081	0.0074	0.0066	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065
32	0.5	0	0.33D	...	0.0043	0.0039	0.0036	0.0034	0.0030	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029
	0.75	0.33D	0.67D	...	0.0065	0.0059	0.0055	0.0050	0.0045	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043
	1.0	0.67D	1.5D	...	0.0087	0.0079	0.0073	0.0067	0.0060	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057
	1.25	1.5D	3D	...	0.0108	0.0099	0.0091	0.0084	0.0075	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072
28	0.5	0	0.33D	...	...	0.0045	0.0042	0.0039	0.0034	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032
	0.75	0.33D	0.67D	...	...	0.0068	0.0063	0.0058	0.0051	0.0047	0.0047	0.0047	0.0047	0.0047	0.0047	0.0047
	1.0	0.67D	1.5D	...	...	0.0091	0.0084	0.0077	0.0069	0.0063	0.0063	0.0063	0.0063	0.0063	0.0063	0.0063
	1.25	1.5D	3D	...	...	0.0113	0.0105	0.0096	0.0086	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079
27	0.5	0	0.33D	...	...	0.0047	0.0044	0.0040	0.0036	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032
	0.75	0.33D	0.67D	...	...	0.0071	0.0065	0.0060	0.0053	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048
	1.0	0.67D	1.5D	...	...	0.0094	0.0087	0.0080	0.0071	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065
	1.25	1.5D	3D	...	...	0.0118	0.0109	0.0100	0.0089	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081
24	0.5	0	0.33D	...	...	0.0053	0.0049	0.0045	0.0040	0.0037	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035
	0.75	0.33D	0.67D	...	...	0.0079	0.0073	0.0068	0.0060	0.0055	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052
	1.0	0.67D	1.5D	...	...	0.0106	0.0098	0.0090	0.0080	0.0073	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070
	1.25	1.5D	3D	...	...	0.0132	0.0122	0.0113	0.0100	0.0092	0.0087	0.0087	0.0087	0.0087	0.0087	0.0087
20	0.5	0	0.33D	...	...	...	...	0.0054	0.0048	0.0044	0.0041	0.0039	0.0039	0.0039	0.0039	0.0039
	0.75	0.33D	0.67D	...	...	...	...	0.0081	0.0072	0.0066	0.0062	0.0058	0.0058	0.0058	0.0058	0.0058
	1.0	0.67D	1.5D	...	...	...	...	0.0108	0.0096	0.0088	0.0082	0.0078	0.0078	0.0078	0.0078	0.0078
	1.25	1.5D	3D	...	...	...	...	0.0135	0.0120	0.0110	0.0103	0.0097	0.0097	0.0097	0.0097	0.0097
18	0.5	0	0.33D	...	...	...	...	...	0.0053	0.0049	0.0045	0.0043	0.0041	0.0041	0.0041	0.0041
	0.75	0.33D	0.67D	...	...	...	...	...	0.0080	0.0073	0.0068	0.0065	0.0062	0.0061	0.0061	0.0061
	1.0	0.67D	1.5D	...	...	...	...	...	0.0106	0.0097	0.0091	0.0086	0.0082	0.0081	0.0081	0.0081
	1.25	1.5D	3D	...	...	...	...	...	0.0133	0.0122	0.0114	0.0108	0.0103	0.0102	0.0102	0.0102
16	0.5	0	0.33D	...	...	...	...	...	...	0.0054	0.0051	0.0048	0.0046	0.0044	0.0043	0.0043
	0.75	0.33D	0.67D	...	...	...	...	...	...	0.0082	0.0076	0.0072	0.0069	0.0067	0.0064	0.0064
	1.0	0.67D	1.5D	...	...	...	...	...	...	0.0109	0.0102	0.0096	0.0092	0.0089	0.0086	0.0085
	1.25	1.5D	3D	...	...	...	...	...	...	0.0136	0.0127	0.0120	0.0115	0.0111	0.0108	0.0106

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TABLE 40 MINOR DIAMETER TOLERANCES FOR INTERNAL SPECIAL SCREW THREADS (UNS/UNRS) — CLASS 3B (CONT'D)

Tolerance based on basic major diameter of			0.375	0.4375	0.500	0.5625	0.625	0.6875	0.750	0.8125	0.875	0.9375	All Larger Diameters
For diameter range above			0.344	0.406	0.469	0.531	0.594	0.656	0.719	0.781	0.844	0.906	
To and including			0.406	0.469	0.531	0.594	0.656	0.719	0.781	0.844	0.906	0.969	
Threads/ in.	Tolerance Ratios	Length of Eng. in Terms of Diam. (2) Above	To and Including	Minor Diameter Tolerances, in. (3)									
14	0.5	0	0.33*D*	...	0.0058	0.0054	0.0052	0.0050	0.0049	0.0047	0.0046	0.0045	0.0044	0.0044
	0.75	0.33*D*	0.67*D*	...	0.0086	0.0082	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0067	0.0066
	1.0	0.67*D*	1.5*D*	...	0.0115	0.0109	0.0104	0.0100	0.0097	0.0095	0.0092	0.0091	0.0089	0.0088
	1.25	1.5*D*	3*D*	...	0.0144	0.0136	0.0130	0.0125	0.0122	0.0118	0.0116	0.0113	0.0111	0.0110
13	0.5	0	0.33*D*	...	...	0.0058	0.0056	0.0054	0.0052	0.0050	0.0050	0.0049	0.0048	0.0047
	0.75	0.33*D*	0.67*D*	...	...	0.0087	0.0083	0.0080	0.0078	0.0076	0.0074	0.0073	0.0071	0.0070
	1.0	0.67*D*	1.5*D*	...	...	0.0117	0.0111	0.0107	0.0104	0.0101	0.0099	0.0097	0.0095	0.0094
	1.25	1.5*D*	3*D*	...	...	0.0146	0.0139	0.0134	0.0130	0.0126	0.0124	0.0122	0.0119	0.0118
12	0.5	0	0.33*D*	...	...	0.0063	0.0060	0.0058	0.0056	0.0054	0.0053	0.0052	0.0051	0.0050
	0.75	0.33*D*	0.67*D*	...	...	0.0094	0.0090	0.0087	0.0084	0.0082	0.0080	0.0078	0.0077	0.0075
	1.0	0.67*D*	1.5*D*	...	...	0.0125	0.0120	0.0115	0.0112	0.0109	0.0106	0.0104	0.0102	0.0100
	1.25	1.5*D*	3*D*	...	...	0.0157	0.0150	0.0144	0.0140	0.0136	0.0133	0.0130	0.0128	0.0125
11	0.5	0	0.33*D*	...	...	...	...	0.0062	0.0060	0.0058	0.0058	0.0056	0.0055	0.0054
	0.75	0.33*D*	0.67*D*	...	...	...	...	0.0094	0.0091	0.0088	0.0086	0.0084	0.0082	0.0082
	1.0	0.67*D*	1.5*D*	...	...	...	...	0.0125	0.0121	0.0117	0.0115	0.0112	0.0110	0.0109
	1.25	1.5*D*	3*D*	...	...	...	...	0.0156	0.0151	0.0146	0.0144	0.0140	0.0138	0.0136
10	0.5	0	0.33*D*	...	...	...	...	...	0.0066	0.0064	0.0062	0.0061	0.0060	0.0060
	0.75	0.33*D*	0.67*D*	...	...	...	...	...	0.0099	0.0096	0.0093	0.0092	0.0090	0.0090
	1.0	0.67*D*	1.5*D*	...	...	...	...	...	0.0131	0.0128	0.0125	0.0122	0.0120	0.0120
	1.25	1.5*D*	3*D*	...	...	...	...	...	0.0164	0.0160	0.0156	0.0153	0.0150	0.0150
9	0.5	0	0.33*D*	...	...	...	...	...	...	...	0.0068	0.0067	0.0066	0.0066
	0.75	0.33*D*	0.67*D*	...	...	...	...	...	...	...	0.0103	0.0100	0.0100	0.0100
	1.0	0.67*D*	1.5*D*	...	...	...	...	...	...	...	0.0137	0.0134	0.0133	0.0133
	1.25	1.5*D*	3*D*	...	...	...	...	...	...	...	0.0171	0.0168	0.0166	0.0166
8	0.5	0	0.33*D*	...	...	...	...	...	...	...	0.0075	0.0075	0.0075	0.0075
	0.75	0.33*D*	0.67*D*	...	...	...	...	...	...	...	0.0112	0.0112	0.0112	0.0112
	1.0	0.67*D*	1.5*D*	...	...	...	...	...	...	...	0.0150	0.0150	0.0150	0.0150
	1.25	1.5*D*	3*D*	...	...	...	...	...	...	...	0.0188	0.0188	0.0188	0.0188
7	0.5	0	0.33*D*	...	...	...	...	...	...	...	...	...	0.0086	0.0086
	0.75	0.33*D*	0.67*D*	...	...	...	...	...	...	...	...	...	0.0129	0.0129
	1.0	0.67*D*	1.5*D*	...	...	...	...	...	...	...	...	...	0.0171	0.0171
	1.25	1.5*D*	3*D*	...	...	...	...	...	...	...	...	...	0.0214	0.0214
6	0.5	0	0.33*D*	...	...	...	...	...	...	...	...	...	...	0.0100
	0.75	0.33*D*	0.67*D*	...	...	...	...	...	...	...	...	...	...	0.0150
	1.0	0.67*D*	1.5*D*	...	...	...	...	...	...	...	...	...	...	0.0200
	1.25	1.5*D*	3*D*	...	...	...	...	...	...	...	...	...	...	0.0250
5	0.5	0	0.33*D*	...	...	...	...	...	...	...	...	...	...	0.0120
	0.75	0.33*D*	0.67*D*	...	...	...	...	...	...	...	...	...	...	0.0180
	1.0	0.67*D*	1.5*D*	...	...	...	...	...	...	...	...	...	...	0.0240
	1.25	1.5*D*	3*D*	...	...	...	...	...	...	...	...	...	...	0.0300
4.5	0.5	0	0.33*D*	...	...	...	...	...	...	...	...	...	...	0.0133
	0.75	0.33*D*	0.67*D*	...	...	...	...	...	...	...	...	...	...	0.0200
	1.0	0.67*D*	1.5*D*	...	...	...	...	...	...	...	...	...	...	0.0267
	1.25	1.5*D*	3*D*	...	...	...	...	...	...	...	...	...	...	0.0333
4	0.5	0	0.33*D*	...	...	...	...	...	...	...	...	...	...	0.0150
	0.75	0.33*D*	0.67*D*	...	...	...	...	...	...	...	...	...	...	0.0225
	1.0	0.67*D*	1.5*D*	...	...	...	...	...	...	...	...	...	...	0.0300
	1.25	1.5*D*	3*D*	...	...	...	...	...	...	...	...	...	...	0.0375

NOTES:
(1) For 0.151 in. diameter sizes and smaller, tolerance values for all three classes are the same. For smaller sizes, tolerance values are given in Table 39.
(2) Tolerances for lengths of engagement in terms of pitch should be selected from equivalent lengths of engagement in terms of diameter ranges.
(3) If the minor diameter tolerance as selected from this Table is less than the pitch diameter tolerance, use the latter.

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APPENDIX A
TERMINOLOGY AND IDENTIFICATION OF UNIFIED INCH SCREW THREADS

(This Appendix is not part of ASME B1.1-1989, and is included for information purposes only.)

A1 TERMINOLOGY

All terms relating to screw threads used in this Standard are defined in ANSI/ASME B1.7M.

A2 IDENTIFICATION

The various unified screw threads covered by B1 standards are compared in Fig. A1 and Table A1.

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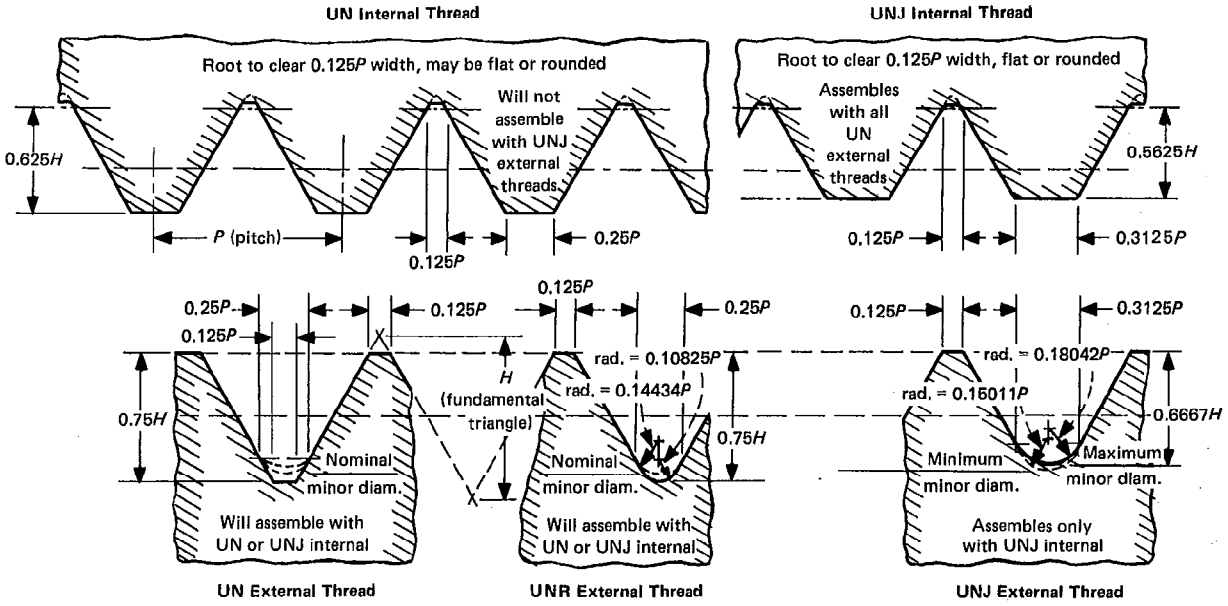

FIG. A1 IDENTIFICATION OF 60 DEG. INCH SCREW THREADS WITHIN THE SCOPE OF ASME COMMITTEE B1

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TABLE A1 IDENTIFICATION OF 60 DEG. INCH SCREW THREADS WITHIN THE SCOPE OF ASME COMMITTEE B1

Thread Identification	UN Threads, Internal and External	UNR Threads, External Only	UNJ Threads, Internal and External
ANSI standards documents	B1.1, Unified Inch Screw Threads; B1.2, Gages and Gaging for Unified Inch Screw Threads	B1.1, Unified Inch Screw Threads; B1.2, Gages and Gaging for Unified Inch Screw Threads	Draft of B1.15, Unified Inch Screw Threads — UNJ Thread Form; draft of B1.23, Gages and Gaging for Unified Inch Screw Threads — UNJ
External root	External thread root may be flat or rounded	Rounded root specified	Rounded root specified
External minor diameter	External thread minor diameter is not toleranced	External thread minor diameter is not toleranced	External thread minor diameter is toleranced
External threads	UN Classes 1A, 2A, and 3A	UNR Classes 1A, 2A, and 3A	UNJ Class 3A mates only with UNJ internal threads
Internal threads	UN Classes 1B, 2B, and 3B	No internal threads designated UNR; UNR mates with UN internal threads	UNJ Class 3B (no rounding required on internal thread root)

GENERAL NOTES:
(a) The above cannot be used as a working sheet. Refer to the appropriate standards, as listed, for complete thread details and conformance data.
(b) The appropriate current standard is the authoritative document for complete details and data and takes precedence over this sheet.
(c) These standards may be purchased from the ASME Order Department, 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300; telephone (201) 882-1167.

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APPENDIX B
THREAD STRENGTH DESIGN FORMULAS

(This Appendix is not part of ASME B1.1-1989, and is included for information purposes only.)

B1 THREAD TENSILE STRESS AREA

The following thread tensile stress area formulas are used for the purpose of product acceptance computations. Tensile stress area

$$A_s = 3.1416 \left[\frac{D_2}{2} - \frac{3H}{16}\right]^2$$

or

$$A_s = 0.7854 \left[D - \frac{0.9743}{1/P}\right]^2$$

where

D_2 = basic pitch diameter
D = basic major diameter
$1/P$ = number of threads per inch

For $3H/16$, see Table 6.

B2 THREAD SHEAR AREA

The following formulas for thread shear areas are geometric minimum values. Shear (thread stripping) strengths of screw threads under load are dependent, in addition, on mating component relative material strengths, nut geometry, and coefficient of friction between thread bearing surfaces. Effective shear areas are therefore somewhat less than the geometric values. Thread geometric shear areas

$$AS_n = 3.1416\ (1/P)\ (LE)\ (D \text{ min.}) \times \left[\frac{1}{2(1/P)} + 0.57735\ (D \text{ min.} - D_2 \text{ max.})\right]$$

$$AS_s = 3.1416\ (1/P)\ (LE)\ (D_1 \text{ max.}) \times \left[\frac{1}{2(1/P)} + 0.57735\ (d_2 \text{ min.} - D_1 \text{ max.})\right]$$

where

AS_n = minimum thread shear area for internal threads
AS_s = minimum thread shear area for external threads
$1/P$ = number of threads per inch
LE = length of engagement
D min. = minimum major diameter of external thread
D_2 max. = maximum pitch diameter of internal thread
D_1 max. = maximum minor diameter of internal thread
d_2 min. = minimum pitch diameter of external thread

B3 LENGTH OF THREAD ENGAGEMENT

In general, the length of engagement of mating threads is selected to utilize full tensile strength of a bolt prior to shearing of nut threads. Otner applications may require internal thread shear prior to failure of the externally threaded part. For noncritical design, the following formulas are often used for approximation:

$$\text{tensile strength of externally threaded part} = S_t A_s$$

$$\text{shear strength of threads} = 0.5 S_t\ (AS_n \text{ or } AS_s)$$

where

S_t = ultimate tensile strength of material, psi

An internationally accepted study on the subject was published in the 1977 Transactions of the Society of Automotive Engineers as paper number 770420, Analysis and Design of Threaded Assemblies, by E. M. Alexander.

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APPENDIX C
UNIFIED INCH SCREW THREADS — METRIC TRANSLATION

(This Appendix is not part of ASME B1.1-1989, and is included for information purposes only.)

C1 BACKGROUND

This Appendix presents a translation of unified inch screw threads into metric units of measurement. It is very important to recognize that this translation is not ISO metric screw threads. The tables of limiting dimensions of standard and UNS/UNRS series threads and the table of thread form data translated from inches to millimeters presented in this Appendix implement the decision of the B1 Committee that there should be official metric translations of inch screw thread standards to better fill communication needs in international exchange of technical data. This philosophy originated at the May 4, 1964, meeting of the Committee and was approved by a letter ballot of the Committee on November 2, 1966.

The tables in this Appendix were originally published as USAS B1.1a—1968 Supplement to USAS B1.1—1960, in the interest of meeting urgent needs of industry.

C2 DIMENSIONS

All dimensions in this Appendix are given in millimeters unless otherwise specified. Metric values in the limiting dimension tables are translations of the inch values tabulated in ASME B1.1.

In all cases, the metric values have been rounded toward the interior of the tolerance zone, that is, maximum limits have been rounded downward and minimum limits have been rounded upward. This method of rounding the translated values was selected to permit the use of existing gages. To avoid penalizing the producer excessively, gages should be based on the inch values rather than the metric translations.

Where it is necessary to use metric values of threads for which the metric limiting dimensions are not tabulated herein, the inch values should be determined in accordance with Section 8 of ASME B1.1 before translating to metric values and rounding by the method prescribed in the foregoing paragraph.

C3 DESIGNATIONS

Designation of unified inch screw threads expressed in metric dimensions shall be as prescribed in paras. C3.1 and C3.2.

C3.1 Metric Drawings or Documents

On metric drawings or documents, the designation shall specify, in sequence, the nominal size (expressed in decimal inches), the number of threads per inch, thread series symbol, and thread class symbol. All supplemental dimensions shall be as shown in metric units. The equivalent inch dimensions, as indicated and enclosed in parentheses, may be included if desired.

EXAMPLE (on metric drawing or metric document):
0.250-28 UNF-2A (22)
PD 5.735–5.652
(0.2258–0.2225 in.) (optional)

C3.2 Inch Drawings or Documents

On inch drawings or documents, the designation and supplemental dimensions expressed in inches may be further supplemented by inclusion of the equivalent metric dimensions, so indicated and enclosed in parentheses.

EXAMPLE:
0.250-28 UNF-2A (22)
PD 0.2258–0.2225
(5.735–5.652 mm) (optional)

C4 TABLES

Tables C1, C2, and C3 give limits of size for standard series and UNS/UNRS series threads and thread form data.

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
0-80 or 0.060-80	UNF	1.524	0.318	2A	0.014	1.511	1.431	...	1.305	1.260	0.045	1.133	2B	1.182	1.305	1.319	1.376	0.057	1.524
				3A	0.000	1.524	1.443	...	1.318	1.286	0.032	1.146	3B	1.182	1.305	1.319	1.361	0.042	1.524
1-64 or 0.073-64	UNC	1.854	0.397	2A	0.016	1.838	1.743	...	1.582	1.532	0.050	1.367	2B	1.425	1.582	1.598	1.663	0.065	1.855
				3A	0.000	1.854	1.758	...	1.597	1.560	0.037	1.382	3B	1.425	1.582	1.598	1.645	0.047	1.855
1-72 or 0.073-72	UNF	1.854	0.353	2A	0.016	1.838	1.751	...	1.610	1.563	0.047	1.420	2B	1.474	1.612	1.626	1.689	0.063	1.855
				3A	0.000	1.854	1.766	...	1.625	1.591	0.034	1.435	3B	1.474	1.612	1.626	1.673	0.047	1.855
2-56 or 0.086-56	UNC	2.184	0.454	2A	0.016	2.169	2.066	...	1.874	1.822	0.052	1.631	2B	1.695	1.871	1.890	1.960	0.070	2.185
				3A	0.000	2.184	2.081	...	1.889	1.850	0.039	1.646	3B	1.695	1.871	1.890	1.943	0.053	2.185
2-64 or 0.086-64	UNF	2.184	0.397	2A	0.016	2.169	2.073	...	1.912	1.862	0.050	1.697	2B	1.756	1.912	1.928	1.996	0.068	2.185
				3A	0.000	2.184	2.088	...	1.927	1.890	0.037	1.712	3B	1.756	1.912	1.928	1.978	0.050	2.185
3-48 or 0.099-48	UNC	2.514	0.529	2A	0.019	2.496	2.383	...	2.153	2.096	0.057	1.864	2B	1.941	2.146	2.172	2.247	0.075	2.515
				3A	0.000	2.514	2.401	...	2.171	2.129	0.042	1.882	3B	1.941	2.146	2.172	2.227	0.055	2.515
3-56 or 0.099-56	UNF	2.514	0.454	2A	0.018	2.496	2.393	...	2.202	2.147	0.055	1.958	2B	2.025	2.197	2.220	2.291	0.071	2.515
				3A	0.000	2.514	2.411	...	2.219	2.180	0.039	1.976	3B	2.025	2.197	2.220	2.273	0.053	2.515
4-40 or 0.112-40	UNC	2.844	0.635	2A	0.021	2.824	2.695	...	2.413	2.350	0.063	2.068	2B	2.157	2.385	2.434	2.517	0.083	2.845
				3A	0.000	2.844	2.716	...	2.433	2.386	0.047	2.088	3B	2.157	2.385	2.434	2.494	0.060	2.845
4-48 or 0.112-48	UNF	2.844	0.529	2A	0.018	2.827	2.713	...	2.484	2.424	0.060	2.195	2B	2.271	2.458	2.502	2.580	0.078	2.845
				3A	0.000	2.844	2.731	...	2.501	2.457	0.044	2.212	3B	2.271	2.458	2.502	2.560	0.058	2.845
5-40 or 0.125-40	UNC	3.175	0.635	2A	0.021	3.154	3.026	...	2.743	2.678	0.065	2.398	2B	2.487	2.697	2.764	2.847	0.083	3.175
				3A	0.000	3.175	3.046	...	2.763	2.716	0.047	2.418	3B	2.487	2.697	2.764	2.827	0.063	3.175
5-44 or 0.125-44	UNF	3.175	0.577	2A	0.019	3.157	3.036	...	2.781	2.718	0.063	2.469	2B	2.551	2.740	2.800	2.880	0.080	3.175
				3A	0.000	3.175	3.054	...	2.799	2.751	0.048	2.487	3B	2.551	2.740	2.800	2.860	0.060	3.175
6-32 or 0.138-32	UNC	3.505	0.794	2A	0.021	3.484	3.333	...	2.969	2.899	0.070	2.540	2B	2.642	2.895	2.990	3.083	0.093	3.506
				3A	0.000	3.505	3.353	...	2.989	2.937	0.052	2.560	3B	2.642	2.895	2.990	3.058	0.068	3.506
6-40 or 0.138-40	UNF	3.505	0.635	2A	0.021	3.484	3.356	...	3.073	3.008	0.065	2.728	2B	2.820	3.022	3.094	3.180	0.086	3.506
				3A	0.000	3.505	3.376	...	3.093	3.043	0.050	2.748	3B	2.820	3.012	3.094	3.157	0.063	3.506
8-32 or 0.164-32	UNC	4.165	0.794	2A	0.023	4.142	3.991	...	3.627	3.554	0.073	3.198	2B	3.302	3.530	3.650	3.746	0.096	4.166
				3A	0.000	4.165	4.014	...	3.649	3.595	0.054	3.221	3B	3.302	3.528	3.650	3.721	0.071	4.166
8-36 or 0.164-36	UNF	4.165	0.706	2A	0.021	4.145	4.006	...	3.688	3.617	0.071	3.305	2B	3.404	3.606	3.709	3.799	0.090	4.166
				3A	0.000	4.165	4.026	...	3.708	3.656	0.052	3.325	3B	3.404	3.596	3.709	3.776	0.067	4.166
10-24 or 0.190-24	UNC	4.826	1.058	2A	0.026	4.800	4.618	...	4.112	4.029	0.083	3.541	2B	3.683	3.962	4.138	4.246	0.108	4.826
				3A	0.000	4.826	4.644	...	4.137	4.075	0.062	3.566	3B	3.683	3.949	4.138	4.218	0.080	4.826
10-32 or 0.190-32	UNF	4.826	0.794	2A	0.024	4.803	4.651	...	4.287	4.212	0.075	3.858	2B	3.963	4.165	4.311	4.409	0.098	4.826
				3A	0.000	4.826	4.674	...	4.310	4.252	0.058	3.881	3B	3.963	4.165	4.311	4.384	0.073	4.826
12-24 or 0.216-24	UNC	5.486	1.058	2A	0.027	5.461	5.279	...	4.772	4.687	0.085	4.201	2B	4.344	4.597	4.799	4.909	0.110	5.487
				3A	0.000	5.486	5.304	...	4.798	4.733	0.065	4.227	3B	4.344	4.589	4.799	4.881	0.082	5.487
12-28 or 0.216-28	UNF	5.486	0.907	2A	0.027	5.461	5.296	...	4.871	4.791	0.080	4.379	2B	4.496	4.724	4.898	5.003	0.105	5.487
				3A	0.000	5.486	5.322	...	4.897	4.837	0.060	4.404	3B	4.496	4.716	4.898	4.975	0.077	5.487

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
12-32 or 0.216-32	UNEF	5.486	0.794	2A	0.024	5.463	5.312	...	4.947	4.870	0.077	4.519	2B	4.623	4.826	4.971	5.074	0.103	5.487
				3A	0.000	5.486	5.334	...	4.970	4.910	0.060	4.542	3B	4.623	4.813	4.971	5.049	0.078	5.487
1/4-20 or 0.250-20	UNC	6.350	1.270	1A	0.029	6.322	6.013	...	5.496	5.355	0.141	4.811	1B	4.979	5.257	5.525	5.709	0.184	6.350
				2A	0.029	6.322	6.117	6.013	5.496	5.403	0.093	4.811	2B	4.979	5.257	5.525	5.648	0.123	6.350
				3A	0.000	6.350	6.145	...	5.524	5.454	0.070	4.839	3B	4.979	5.250	5.525	5.615	0.090	6.350
1/4-28 or 0.250-28	UNF	6.350	0.907	1A	0.026	6.324	6.076	...	5.735	5.609	0.126	5.243	1B	5.360	5.588	5.761	5.925	0.164	6.350
				2A	0.026	6.324	6.160	...	5.735	5.652	0.083	5.243	2B	5.360	5.588	5.761	5.869	0.108	6.350
				3A	0.000	6.350	6.185	...	5.760	5.698	0.062	5.268	3B	5.360	5.562	5.761	5.842	0.081	6.350
1/4-32 or 0.250-32	UNEF	6.350	0.794	2A	0.027	6.324	6.173	...	5.808	5.728	0.080	5.380	2B	5.487	5.689	5.835	5.941	0.106	6.350
				3A	0.000	6.350	6.198	...	5.834	5.774	0.060	5.405	3B	5.487	5.661	5.835	5.913	0.078	6.350
5/16-18 or 0.3125-18	UNC	7.937	1.411	1A	0.031	7.907	7.575	...	6.990	6.836	0.154	6.228	1B	6.401	6.731	7.021	7.221	0.200	7.938
				2A	0.031	7.907	7.687	7.575	6.990	6.889	0.101	6.228	2B	6.401	6.731	7.021	7.155	0.134	7.938
				3A	0.000	7.937	7.717	...	7.020	6.945	0.075	6.259	3B	6.401	6.680	7.021	7.119	0.098	7.938
5/16-20 or 0.3125-20	UN	7.937	1.270	2A	0.031	7.907	7.702	...	7.081	6.980	0.101	6.396	2B	6.554	6.858	7.112	7.244	0.132	7.938
				3A	0.000	7.937	7.732	...	7.112	7.036	0.076	6.426	3B	6.554	6.807	7.112	7.211	0.099	7.938
5/16-24 or 0.3125-24	UNF	7.937	1.058	1A	0.029	7.909	7.636	...	7.221	7.082	0.139	6.650	1B	6.782	7.035	7.250	7.429	0.179	7.938
				2A	0.029	7.909	7.727	...	7.221	7.128	0.093	6.650	2B	6.782	7.035	7.250	7.371	0.121	7.938
				3A	0.000	7.937	7.755	...	7.249	7.181	0.068	6.678	3B	6.782	6.995	7.250	7.340	0.090	7.938
5/16-28 or 0.3125-28	UN	7.937	0.907	2A	0.027	7.912	7.747	...	7.322	7.237	0.085	6.830	2B	6.960	7.162	7.349	7.459	0.110	7.938
				3A	0.000	7.937	7.773	...	7.348	7.283	0.065	6.855	3B	6.960	7.129	7.349	7.432	0.033	7.938
5/16-32 or 0.3125-32	UNEF	7.937	0.794	2A	0.026	7.912	7.760	...	7.396	7.316	0.080	6.967	2B	7.087	7.264	7.422	7.528	0.106	7.938
				3A	0.000	7.937	7.786	...	7.421	7.361	0.060	6.993	3B	7.087	7.231	7.422	7.500	0.078	7.938
3/8-16 or 0.375-16	UNC	9.525	1.588	1A	0.034	9.491	9.132	...	8.460	8.296	0.164	7.600	1B	7.798	8.153	8.494	8.709	0.215	9.525
				2A	0.034	9.491	9.254	9.132	8.460	8.349	0.111	7.600	2B	7.798	8.153	8.494	8.638	0.144	9.525
				3A	0.000	9.525	9.287	...	8.493	8.410	0.083	7.633	3B	7.798	8.082	8.494	8.602	0.108	9.525
3/8-20 or 0.375-20	UN	9.525	1.270	2A	0.031	9.494	9.289	...	8.669	8.565	0.104	7.983	2B	8.154	8.432	8.700	8.836	0.136	9.525
				3A	0.000	9.525	9.320	...	8.699	8.621	0.078	8.014	3B	8.154	8.374	8.700	8.801	0.101	9.525
3/8-24 or 0.375-24	UNF	9.525	1.058	1A	0.029	9.497	9.223	...	8.808	8.664	0.144	8.237	1B	8.382	8.636	8.837	9.024	0.187	9.525
				2A	0.029	9.497	9.315	...	8.808	8.713	0.095	8.237	2B	8.382	8.636	8.837	8.961	0.124	9.525
				3A	0.000	9.525	9.343	...	8.836	8.763	0.073	8.265	3B	8.382	8.564	8.837	8.930	0.093	9.525
3/8-28 or 0.375-28	UN	9.525	0.907	2A	0.029	9.497	9.332	...	8.907	8.817	0.090	8.415	2B	8.535	8.763	8.936	9.052	0.116	9.525
				3A	0.000	9.525	9.360	...	8.935	8.868	0.067	8.443	3B	8.535	8.702	8.936	9.024	0.088	9.525
3/8-32 or 0.375-32	UNEF	9.525	0.794	2A	0.027	9.499	9.348	...	8.983	8.898	0.085	8.555	2B	8.662	8.864	9.010	9.121	0.111	9.525
				3A	0.000	9.525	9.373	...	9.009	8.946	0.063	8.580	3B	8.662	8.811	9.010	9.093	0.083	9.525
7/16-14 or 0.4375-14	UNC	11.112	1.814	1A	0.036	11.076	10.684	...	9.898	9.719	0.179	8.918	1B	9.144	9.550	9.934	10.167	0.233	11.113
				2A	0.036	11.076	10.816	10.684	9.898	9.779	0.119	8.918	2B	9.144	9.550	9.934	10.088	0.154	11.113
				3A	0.000	11.112	10.851	...	9.933	9.846	0.087	8.954	3B	9.144	9.441	9.934	10.050	0.116	11.113
7/16-16 or 0.4375-16	UN	11.112	1.588	2A	0.037	11.076	10.839	...	10.045	9.929	0.116	9.185	2B	9.398	9.753	10.082	10.231	0.149	11.113
				3A	0.000	11.112	10.874	...	10.081	9.995	0.086	9.220	3B	9.398	9.652	10.082	10.195	0.113	11.113

(Notes follow at end of table)

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
7/16-20 or 0.4375-20	UNF	11.112	1.270	1A	0.033	11.079	10.770	...	10.254	10.096	0.158	9.568	1B	9.729	10.033	10.287	10.492	0.205	11.113
				2A	0.033	11.079	10.874	...	10.254	10.147	0.107	9.568	2B	9.729	10.033	10.287	10.424	0.137	11.113
				3A	0.000	11.112	10.907	...	10.287	10.208	0.079	9.601	3B	9.729	9.946	10.287	10.391	0.104	11.113
7/16-28 or 0.4375-28	UNEF	11.112	0.907	2A	0.029	11.084	10.920	...	10.495	10.404	0.091	10.003	2B	10.135	10.337	10.524	10.640	0.116	11.113
				3A	0.000	11.112	10.948	...	10.523	10.455	0.068	10.030	3B	10.135	10.289	10.524	10.612	0.088	11.113
7/16-32 or 0.4375-32	UN	11.112	0.794	2A	0.026	11.087	10.935	...	10.571	10.485	0.086	10.142	2B	10.262	10.439	10.597	10.708	0.111	11.113
				3A	0.000	11.112	10.961	...	10.597	10.533	0.064	10.168	3B	10.262	10.398	10.597	10.680	0.083	11.113
1/2-13 or 0.500-13	UNC	12.700	1.954	1A	0.038	12.661	12.248	...	11.392	11.204	0.188	10.335	1B	10.592	11.023	11.430	11.676	0.246	12.700
				2A	0.038	12.661	12.386	12.248	11.392	11.265	0.127	10.335	2B	10.592	11.023	11.430	11.595	0.165	12.700
				3A	0.000	12.700	12.424	...	11.430	11.336	0.094	10.373	3B	10.592	10.881	11.430	11.551	0.121	12.700
1/2-16 or 0.500-16	UN	12.700	1.588	2A	0.036	12.664	12.426	...	11.633	11.514	0.119	10.772	2B	10.973	11.328	11.669	11.823	0.154	12.700
				3A	0.000	12.700	12.462	...	11.669	11.580	0.089	10.808	3B	10.973	11.224	11.669	11.785	0.116	12.700
1/2-20 or 0.500-20	UNF	12.700	1.270	1A	0.034	12.666	12.358	...	11.841	11.679	0.162	11.156	1B	11.329	11.607	11.875	12.087	0.212	12.700
				2A	0.034	12.666	12.462	...	11.841	11.732	0.109	11.156	2B	11.329	11.607	11.875	12.016	0.141	12.700
				3A	0.000	12.700	12.495	...	11.874	11.793	0.081	11.189	3B	11.329	11.523	11.875	11.981	0.106	12.700
1/2-28 or 0.500-28	UNEF	12.700	0.907	2A	0.028	12.672	12.507	...	12.083	11.989	0.094	11.590	2B	11.710	11.938	12.111	12.232	0.121	12.700
				3A	0.000	12.700	12.535	...	12.111	12.040	0.071	11.618	3B	11.710	11.877	12.111	12.202	0.091	12.700
1/2-32 or 0.500-32	UN	12.700	0.794	2A	0.026	12.674	12.523	...	12.159	12.070	0.089	11.730	2B	11.837	12.039	12.185	12.298	0.113	12.700
				3A	0.000	12.700	12.548	...	12.184	12.118	0.066	11.755	3B	11.837	11.986	12.185	12.270	0.085	12.700
9/16-12 or 0.5625-12	UNC	14.287	2.117	1A	0.041	14.246	13.810	...	12.873	12.675	0.198	11.727	1B	11.989	12.446	12.914	13.172	0.258	14.288
				2A	0.041	14.246	13.958	13.810	12.873	12.741	0.132	11.727	2B	11.989	12.446	12.914	13.086	0.172	14.288
				3A	0.000	14.287	13.998	...	12.913	12.814	0.099	11.768	3B	11.989	12.301	12.914	13.042	0.128	14.288
9/16-16 or 0.5625-16	UN	14.287	1.588	2A	0.036	14.251	14.014	...	13.221	13.101	0.120	12.360	2B	12.573	12.928	13.257	13.411	0.154	14.288
				3A	0.000	14.287	14.049	...	13.256	13.167	0.089	12.395	3B	12.573	12.801	13.257	13.373	0.116	14.288
9/16-18 or 0.5625-18	UNF	14.287	1.411	1A	0.036	14.251	13.920	...	13.335	13.163	0.172	12.573	1B	12.751	13.081	13.371	13.596	0.225	14.288
				2A	0.036	14.251	14.031	...	13.335	13.221	0.114	12.573	2B	12.751	13.081	13.371	13.520	0.149	14.288
				3A	0.000	14.287	14.067	...	13.370	13.285	0.085	12.609	3B	12.751	12.969	13.371	13.482	0.111	14.288
9/16-20 or 0.5625-20	UN	14.287	1.270	2A	0.034	14.254	14.049	...	13.428	13.323	0.105	12.743	2B	12.904	13.208	13.462	13.601	0.139	14.288
				3A	0.000	14.287	14.082	...	13.462	13.381	0.081	12.776	3B	12.904	13.111	13.462	13.566	0.104	14.288
9/16-24 or 0.5625-24	UNEF	14.287	1.058	2A	0.032	14.257	14.075	...	13.568	13.470	0.098	12.997	2B	13.132	13.385	13.600	13.728	0.128	14.288
				3A	0.000	14.287	14.105	...	13.599	13.526	0.073	13.028	3B	13.132	13.319	13.600	13.695	0.095	14.288
9/16-28 or 0.5625-28	UN	14.287	0.907	2A	0.029	14.259	14.095	...	13.670	13.577	0.093	13.178	2B	13.310	13.512	13.699	13.820	0.121	14.288
				3A	0.000	14.287	14.123	...	13.698	13.628	0.070	13.205	3B	13.310	13.464	13.699	13.789	0.090	14.288
9/16-32 or 0.5625-32	UN	14.287	0.794	2A	0.026	14.262	14.110	...	13.746	13.658	0.088	13.317	2B	13.437	13.614	13.772	13.886	0.114	14.288
				3A	0.000	14.287	14.136	...	13.771	13.706	0.065	13.342	3B	13.437	13.573	13.772	13.858	0.086	14.288
5/8-11 or 0.625-11	UNC	15.875	2.309	1A	0.042	15.834	15.373	...	14.335	14.125	0.210	13.086	1B	13.386	13.868	14.377	14.648	0.271	15.875
				2A	0.042	15.834	15.528	15.373	14.335	14.197	0.138	13.086	2B	13.386	13.868	14.377	14.559	0.182	15.875
				3A	0.000	15.875	15.568	...	14.376	14.273	0.103	13.127	3B	13.386	13.693	14.377	14.513	0.136	15.875
5/8-12 or 0.625-12	UN	15.875	2.117	2A	0.041	15.834	15.545	...	14.460	14.324	0.136	13.315	2B	13.589	14.046	14.501	14.681	0.180	15.875
				3A	0.000	15.875	15.586	...	14.500	14.397	0.103	13.355	3B	13.589	13.876	14.501	14.635	0.134	15.875

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
5/8-16 or 0.625-16	UN	15.875	1.588	2A	0.036	15.839	15.601	...	14.808	14.687	0.121	13.947	2B	14.148	14.503	14.844	15.001	0.157	15.875
				3A	0.000	15.875	15.637	...	14.843	14.753	0.090	13.983	3B	14.148	14.381	14.844	14.960	0.116	15.875
5/8-18 or 0.625-18	UNF	15.875	1.411	1A	0.037	15.839	15.507	...	14.922	14.745	0.177	14.161	1B	14.351	14.681	14.959	15.189	0.230	15.875
				2A	0.037	15.839	15.619	...	14.922	14.804	0.118	14.161	2B	14.351	14.681	14.959	15.110	0.151	15.875
				3A	0.000	15.875	15.655	...	14.958	14.870	0.088	14.196	3B	14.351	14.554	14.959	15.072	0.113	15.875
5/8-20 or 0.625-20	UN	15.875	1.270	2A	0.034	15.841	15.637	...	15.016	14.908	0.108	14.331	2B	14.504	14.782	15.050	15.191	0.141	15.875
				3A	0.000	15.875	15.670	...	15.049	14.969	0.080	14.364	3B	14.504	14.698	15.050	15.156	0.106	15.875
5/8-24 or 0.625-24	UNEF	15.875	1.058	2A	0.031	15.844	15.662	...	15.156	15.055	0.101	14.585	2B	14.732	14.986	15.187	15.318	0.131	15.875
				3A	0.000	15.875	15.693	...	15.186	15.111	0.075	14.615	3B	14.732	14.907	15.187	15.285	0.098	15.875
5/8-28 or 0.625-28	UN	15.875	0.907	2A	0.029	15.847	15.682	...	15.257	15.162	0.095	14.765	2B	14.885	15.113	15.286	15.410	0.124	15.875
				3A	0.000	15.875	15.710	...	15.285	15.215	0.070	14.793	3B	14.885	15.052	15.286	15.379	0.093	15.875
5/8-32 or 0.625-32	UN	15.875	0.794	2A	0.029	15.847	15.695	...	15.331	15.240	0.091	14.902	2B	15.012	15.214	15.360	15.476	0.116	15.875
				3A	0.000	15.875	15.723	...	15.359	15.291	0.068	14.930	3B	15.012	15.161	15.360	15.448	0.088	15.875
11/16-12 or 0.6875-12	UN	17.462	2.117	2A	0.042	17.421	17.133	...	16.047	15.911	0.136	14.902	2B	15.164	15.621	16.089	16.268	0.179	17.463
				3A	0.000	17.462	17.173	...	16.088	15.985	0.103	14.942	3B	15.164	15.455	16.089	16.222	0.133	17.463
11/16-16 or 0.6875-16	UN	17.462	1.588	2A	0.037	17.426	17.189	...	16.395	16.274	0.121	15.535	2B	15.748	16.103	16.432	16.588	0.156	17.463
				3A	0.000	17.462	17.224	...	16.431	16.340	0.091	15.570	3B	15.748	15.961	16.432	16.548	0.116	17.463
11/16-20 or 0.6875-20	UN	17.462	1.270	2A	0.034	17.429	17.224	...	16.603	16.495	0.108	15.918	2B	16.079	16.383	16.637	16.779	0.142	17.463
				3A	0.000	17.462	17.257	...	16.637	16.556	0.081	15.951	3B	16.079	16.286	16.637	16.743	0.106	17.463
11/16-24 or 0.6875-24	UNEF	17.462	1.058	2A	0.032	17.432	17.250	...	16.743	16.643	0.100	16.172	2B	16.307	16.560	16.775	16.906	0.131	17.463
				3A	0.000	17.462	17.280	...	16.774	16.698	0.076	16.203	3B	16.307	16.494	16.775	16.873	0.098	17.463
11/16-28 or 0.6875-28	UN	17.462	0.907	2A	0.029	17.434	17.270	...	16.845	16.749	0.096	16.353	2B	16.485	16.687	16.874	16.997	0.123	17.463
				3A	0.000	17.462	17.298	...	16.873	16.803	0.070	16.380	3B	16.485	16.639	16.874	16.967	0.093	17.463
11/16-32 or 0.6875-32	UN	17.462	0.794	2A	0.029	17.434	17.283	...	16.918	16.828	0.090	16.490	2B	16.612	16.789	16.947	17.063	0.116	17.463
				3A	0.000	17.462	17.311	...	16.946	16.879	0.067	16.518	3B	16.612	16.748	16.947	17.035	0.088	17.463
3/4-10 or 0.750-10	UNC	19.050	2.540	1A	0.046	19.004	18.512	...	17.353	17.130	0.223	15.979	1B	16.307	16.840	17.399	17.691	0.292	19.050
				2A	0.046	19.004	18.677	18.512	17.353	17.204	0.149	15.979	2B	16.307	16.840	17.399	17.594	0.195	19.050
				3A	0.000	19.050	18.273	...	17.399	17.288	0.111	16.025	3B	16.307	16.624	17.399	17.543	0.144	19.050
3/4-12 or 0.750-12	UN	19.050	2.117	2A	0.044	19.006	18.718	...	17.632	17.493	0.139	16.487	2B	16.764	17.221	17.676	17.858	0.182	19.050
				3A	0.000	19.050	18.761	...	17.675	17.572	0.103	16.530	3B	16.764	17.035	17.676	17.813	0.137	19.050
3/4-16 or 0.750-16	UNF	19.050	1.588	1A	0.039	19.011	18.652	...	17.980	17.791	0.189	17.120	1B	17.323	17.678	18.019	18.267	0.248	19.050
				2A	0.039	19.011	18.774	...	17.980	17.854	0.126	17.120	2B	17.323	17.678	18.019	18.183	0.164	19.050
				3A	0.000	19.050	18.812	...	18.018	17.923	0.095	17.158	3B	17.323	17.546	18.019	18.143	0.124	19.050
3/4-20 or 0.750-20	UNEF	19.050	1.270	2A	0.034	19.016	18.812	...	18.191	18.080	0.111	17.506	2B	17.679	17.957	18.225	18.369	0.144	19.050
				3A	0.000	19.050	18.845	...	18.224	18.141	0.083	17.539	3B	17.679	17.873	18.225	18.333	0.108	19.050
3/4-28 or 0.750-28	UN	19.050	0.907	2A	0.031	19.019	18.855	...	18.430	18.334	0.096	17.937	2B	18.060	18.288	18.461	18.587	0.126	19.050
				3A	0.000	19.050	18.885	...	18.460	18.388	0.072	17.968	3B	18.060	18.227	18.461	18.554	0.093	19.050
3/4-32 or 0.750-32	UN	19.050	0.794	2A	0.029	19.022	18.870	...	18.506	18.415	0.091	18.077	2B	18.187	18.389	18.535	18.653	0.118	19.050
				3A	0.000	19.050	18.898	...	18.534	18.466	0.068	18.105	3B	18.187	18.336	18.535	18.625	0.090	19.050

(Notes follow at end of table)

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
13/16-12 or 0.8125-12	UN	20.637	2.117	2A	0.044	20.594	20.305	...	19.220	19.081	0.139	18.075	2B	18.339	18.796	19.264	19.446	0.182	20.638
				3A	0.000	20.637	20.348	...	19.263	19.160	0.103	18.118	3B	18.339	18.615	19.264	19.400	0.136	20.638
13/16-16 or 0.8125-16	UN	20.637	1.588	2A	0.039	20.599	20.361	...	19.568	19.444	0.124	18.707	2B	18.923	19.278	19.607	19.766	0.159	20.638
				3A	0.000	20.637	20.399	...	19.606	19.515	0.091	18.745	3B	18.923	19.133	19.607	19.725	0.118	20.638
13/16-20 or 0.8125-20	UNEF	20.637	1.270	2A	0.034	20.604	20.399	...	19.778	19.668	0.110	19.093	2B	19.254	19.558	19.812	19.956	0.144	20.638
				3A	0.000	20.637	20.432	...	19.812	19.729	0.083	19.126	3B	19.254	19.461	19.812	19.921	0.109	20.638
13/16-28 or 0.8125-28	UN	20.637	0.907	2A	0.032	20.607	20.442	...	20.017	19.922	0.095	19.525	2B	19.660	19.862	20.049	20.175	0.126	20.638
				3A	0.000	20.637	20.473	...	20.048	19.975	0.073	19.555	3B	19.660	19.814	20.049	20.142	0.093	20.638
13/16-32 or 0.8125-32	UN	20.637	0.794	2A	0.029	20.609	20.458	...	20.093	20.003	0.090	19.665	2B	19.787	19.964	20.122	20.241	0.119	20.638
				3A	0.000	20.637	20.486	...	20.121	20.054	0.067	19.693	3B	19.787	19.923	20.122	20.213	0.091	20.638
7/8-9 or 0.875-9	UNC	22.225	2.822	1A	0.050	22.176	21.649	...	20.342	20.102	0.240	18.816	1B	19.177	19.761	20.392	20.703	0.311	22.225
				2A	0.050	22.176	21.824	21.649	20.342	20.183	0.159	18.816	2B	19.177	19.761	20.392	20.599	0.207	22.225
				3A	0.000	22.225	21.872	...	20.391	20.272	0.119	18.865	3B	19.177	19.509	20.392	20.546	0.154	22.225
7/8-12 or 0.875-12	UN	22.225	2.117	2A	0.044	22.181	21.893	...	20.807	20.668	0.139	19.662	2B	19.939	20.396	20.851	21.033	0.182	22.225
				3A	0.000	22.225	21.936	...	20.850	20.747	0.103	19.705	3B	19.939	20.187	20.851	20.988	0.137	22.225
7/8-14 or 0.875-14	UNF	22.225	1.814	1A	0.042	22.184	21.791	...	21.005	20.801	0.204	20.025	1B	20.270	20.675	21.047	21.315	0.268	22.225
				2A	0.042	22.184	21.923	...	21.005	20.869	0.136	20.025	2B	20.270	20.675	21.047	21.224	0.177	22.225
				3A	0.000	22.225	21.964	...	21.046	20.943	0.103	20.066	3B	20.270	20.492	21.047	21.181	0.134	22.225
7/8-16 or 0.875-16	UN	22.225	1.588	2A	0.039	22.186	21.949	...	21.155	21.032	0.123	20.295	2B	20.498	20.853	21.194	21.353	0.159	22.225
				3A	0.000	22.225	21.987	...	21.193	21.103	0.090	20.333	3B	20.498	20.721	21.194	21.313	0.119	22.225
7/8-20 or 0.875-20	UNEF	22.225	1.270	2A	0.034	22.191	21.987	...	21.366	21.255	0.111	20.681	2B	20.854	21.132	21.400	21.544	0.144	22.225
				3A	0.000	22.225	22.020	...	21.399	21.316	0.083	20.714	3B	20.854	21.048	21.400	21.508	0.108	22.225
7/8-28 or 0.875-28	UN	22.225	0.907	2A	0.031	22.194	22.030	...	21.605	21.509	0.096	21.112	2B	21.235	21.463	21.636	21.762	0.126	22.225
				3A	0.000	22.225	22.060	...	21.635	21.563	0.072	21.143	3B	21.235	21.402	21.636	21.729	0.093	22.225
7/8-32 or 0.875-32	UN	22.225	0.794	2A	0.029	22.197	22.045	...	21.681	21.590	0.091	21.252	2B	21.362	21.564	21.710	21.828	0.118	22.225
				3A	0.000	22.225	22.073	...	21.709	21.641	0.068	21.280	3B	21.362	21.511	21.710	21.800	0.090	22.225
15/16-12 or 0.9375-12	UN	23.812	2.117	2A	0.044	23.769	23.480	...	22.395	22.251	0.144	21.250	2B	21.514	21.971	22.439	22.626	0.187	23.813
				3A	0.000	23.812	23.523	...	22.438	22.332	0.106	21.293	3B	21.514	21.780	22.439	22.578	0.139	23.813
15/16-16 or 0.9375-16	UN	23.812	1.588	2A	0.039	23.774	23.536	...	22.743	22.617	0.126	21.882	2B	22.098	22.453	22.782	22.946	0.164	23.813
				3A	0.000	23.812	23.574	...	22.781	22.688	0.093	21.920	3B	22.098	22.308	22.782	22.905	0.123	23.813
15/16-20 or 0.9375-20	UNEF	23.812	1.270	2A	0.036	23.776	23.572	...	22.951	22.838	0.113	22.266	2B	22.429	22.733	22.987	23.136	0.149	23.813
				3A	0.000	23.812	23.607	...	22.987	22.901	0.086	22.301	3B	22.429	22.636	22.987	23.098	0.111	23.813
15/16-28 or 0.9375-28	UN	23.812	0.907	2A	0.032	23.782	23.617	...	23.192	23.092	0.100	22.700	2B	22.835	23.037	23.224	23.355	0.131	23.813
				3A	0.000	23.812	23.648	...	23.223	23.148	0.095	22.730	3B	22.835	22.989	23.224	23.322	0.098	23.813
15/16-32 or 0.9375-32	UN	23.812	0.794	2A	0.029	23.784	23.633	...	23.268	23.173	0.095	22.840	2B	22.962	23.139	23.297	23.421	0.124	23.813
				3A	0.000	23.812	23.661	...	23.296	23.226	0.070	22.868	3B	22.962	23.098	23.297	23.390	0.093	23.813
1-8 or 1.000-8	UNC	25.400	3.175	1A	0.052	25.349	24.778	...	23.286	23.031	0.255	21.570	1B	21.971	22.606	23.338	23.672	0.334	25.400
				2A	0.052	25.349	24.969	24.778	23.286	23.114	0.172	21.570	2B	21.971	22.606	23.338	23.561	0.223	25.400
				3A	0.000	25.400	25.019	...	23.337	23.208	0.129	21.620	3B	21.971	22.344	23.338	23.505	0.167	25.400

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)								Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
1-12 or 1.000-12	UNF	25.400	2.117	1A	0.046	25.354	24.918	...	23.980	23.757	0.223	22.835	1B	23.114	23.571	24.026	24.315	0.289	25.400
				2A	0.046	25.354	25.065	...	23.980	23.831	0.149	22.835	2B	23.114	23.571	24.026	24.218	0.192	25.400
				3A	0.000	25.400	25.111	...	24.025	23.915	0.110	22.880	3B	23.114	23.362	24.026	24.170	0.144	25.400
1-16 or 1.000-16	UN	25.400	1.588	2A	0.039	25.361	25.124	...	24.330	24.204	0.126	23.470	2B	23.673	24.028	24.369	24.533	0.164	25.400
				3A	0.000	25.400	25.162	...	24.368	24.275	0.093	23.508	3B	23.673	23.896	24.369	24.493	0.124	25.400
1-20 or 1.000-20	UNEF	25.400	1.270	2A	0.037	25.364	25.159	...	24.538	24.425	0.113	23.853	2B	24.029	24.307	24.575	24.724	0.149	25.400
				3A	0.000	25.400	25.195	...	24.574	24.489	0.085	23.889	3B	24.029	24.223	24.575	24.686	0.111	25.400
1-28 or 1.000-28	UN	25.400	0.907	2A	0.031	25.369	25.205	...	24.780	24.679	0.101	24.287	2B	24.410	24.638	24.811	24.942	0.131	25.400
				3A	0.000	25.400	25.235	...	24.810	24.735	0.075	24.318	3B	24.410	24.577	24.811	24.909	0.098	25.400
1-32 or 1.000-32	UN	25.400	0.794	2A	0.029	25.372	25.220	...	24.856	24.760	0.096	24.427	2B	24.537	24.739	24.885	25.008	0.123	25.400
				3A	0.000	25.400	25.248	...	24.884	24.814	0.070	24.455	3B	24.537	24.686	24.885	24.978	0.093	25.400
1 1/16-8 or 1.0625-8	UN	26.987	3.175	2A	0.052	26.936	26.556	...	24.874	24.702	0.172	23.157	2B	23.546	24.180	24.926	25.151	0.225	26.988
				3A	0.000	26.987	26.607	...	24.925	24.796	0.129	23.208	3B	23.546	23.931	24.926	25.095	0.169	26.988
1 1/16-12 or 1.0625-12	UN	26.987	2.117	2A	0.044	26.944	26.655	...	25.570	25.426	0.144	24.425	2B	24.689	25.146	25.614	25.801	0.187	26.988
				3A	0.000	26.987	26.698	...	25.613	25.507	0.106	24.468	3B	24.689	24.950	25.614	25.753	0.139	26.988
1 1/16-16 or 1.0625-16	UN	26.987	1.588	2A	0.039	26.949	26.711	...	25.918	25.792	0.126	25.057	2B	25.273	25.628	25.957	26.121	0.164	26.988
				3A	0.000	26.987	26.749	...	25.956	25.863	0.093	25.092	3B	25.273	25.483	25.957	26.080	0.123	26.988
1 1/16-18 or 1.0625-18	UNEF	26.987	1.411	2A	0.036	26.951	26.731	...	26.035	25.916	0.119	25.273	2B	25.451	25.781	26.071	26.228	0.157	26.988
				3A	0.000	26.987	26.767	...	26.070	25.980	0.090	25.309	3B	25.451	25.666	26.071	26.187	0.116	26.988
1 1/16-20 or 1.0625-20	UN	26.987	1.270	2A	0.036	26.951	26.747	...	26.126	26.013	0.113	25.441	2B	25.604	25.908	26.162	26.311	0.149	26.988
				3A	0.000	26.987	26.782	...	26.162	26.076	0.086	25.476	3B	25.604	25.811	26.162	26.273	0.111	26.988
1 1/16-28 or 1.0625-28	UN	26.987	0.907	2A	0.032	26.957	26.792	...	26.367	26.267	0.100	25.875	2B	26.010	26.212	26.399	26.530	0.131	26.988
				3A	0.000	26.987	26.823	...	26.398	26.323	0.075	25.905	3B	26.010	26.164	26.399	26.497	0.098	26.988
1 1/8-7 or 1.125-7	UNC	28.575	3.629	1A	0.056	28.519	27.895	...	26.162	25.886	0.276	24.199	1B	24.638	25.349	26.218	26.576	0.358	28.575
				2A	0.056	28.519	28.103	27.895	26.162	25.980	0.182	24.199	2B	24.638	25.349	26.218	26.456	0.238	28.575
				3A	0.000	28.575	28.159	...	26.217	26.081	0.136	24.254	3B	24.638	25.082	26.218	26.398	0.180	28.575
1 1/8-8 or 1.125-8	UN	28.575	3.175	2A	0.054	28.521	28.141	27.951	26.459	26.284	0.175	24.742	2B	25.146	25.781	26.513	26.741	0.228	28.575
				3A	0.000	28.575	28.194	...	26.512	26.381	0.131	24.795	3B	25.146	25.519	26.513	26.682	0.169	28.575
1 1/8-12 or 1.125-12	UNF	28.575	2.117	1A	0.046	28.529	28.093	...	27.155	26.927	0.228	26.010	1B	26.289	26.746	27.201	27.498	0.297	28.575
				2A	0.046	28.529	28.240	...	27.155	27.003	0.152	26.010	2B	26.289	26.746	27.201	27.398	0.197	28.575
				3A	0.000	28.575	28.286	...	27.200	27.087	0.113	26.055	3B	26.289	26.537	27.201	27.350	0.149	28.575
1 1/8-16 or 1.125-16	UN	28.575	1.588	2A	0.039	28.536	28.299	...	27.505	27.379	0.126	26.645	2B	26.848	27.203	27.544	27.708	0.164	28.575
				3A	0.000	28.575	28.337	...	27.543	27.450	0.093	26.683	3B	26.848	27.071	27.544	27.668	0.124	28.575
1 1/8-18 or 1.125-18	UNEF	28.575	1.411	2A	0.037	28.539	28.319	...	27.622	27.504	0.118	26.860	2B	27.051	27.381	27.659	27.815	0.156	28.575
				3A	0.000	28.575	28.355	...	27.658	27.567	0.091	26.896	3B	27.051	27.254	27.659	27.774	0.115	28.575
1 1/8-20 or 1.125-20	UN	28.575	1.270	2A	0.037	28.539	28.334	...	27.713	27.600	0.113	27.028	2B	27.204	27.482	27.750	27.899	0.149	28.575
				3A	0.000	28.575	28.370	...	27.749	27.664	0.085	27.064	3B	27.204	27.398	27.750	27.861	0.111	28.575
1 1/8-28 or 1.125-28	UN	28.575	0.907	2A	0.031	28.544	28.380	...	27.955	27.854	0.101	27.462	2B	27.585	27.813	27.986	28.117	0.131	28.575
				3A	0.000	28.575	28.410	...	27.985	27.910	0.075	27.493	3B	27.585	27.752	27.986	28.084	0.098	28.575

(Notes follow at end of table)

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
1 3/16-8 or 1.1875-8	UN	30.162	3.175	2A	0.055	30.109	29.729	...	28.046	27.869	0.177	26.330	2B	26.721	27.355	28.101	28.331	0.230	30.163
				3A	0.000	30.162	29.782	...	28.100	27.968	0.132	26.383	3B	26.721	27.106	28.101	28.272	0.171	30.163
1 3/16-12 or 1.1875-12	UN	30.162	2.117	2A	0.044	30.119	29.830	...	28.745	28.598	0.147	27.600	2B	27.864	28.321	28.789	28.978	0.189	30.163
				3A	0.000	30.162	29.873	...	28.788	28.680	0.108	27.642	3B	27.864	28.125	28.789	28.930	0.141	30.163
1 3/16-16 or 1.1875-16	UN	30.162	1.588	2A	0.039	30.124	29.886	...	29.093	28.964	0.129	28.232	2B	28.448	28.808	29.132	29.298	0.166	30.163
				3A	0.000	30.162	29.924	...	29.131	29.035	0.096	28.270	3B	28.448	28.658	29.132	29.258	0.126	30.163
1 3/16-18 or 1.1875-18	UNEF	30.162	1.411	2A	0.039	30.124	29.904	...	29.207	29.083	0.124	28.445	2B	28.626	28.956	29.246	29.405	0.159	30.163
				3A	0.000	30.162	29.942	...	29.245	29.155	0.090	28.484	3B	28.626	28.841	29.246	29.364	0.118	30.163
1 3/16-20 or 1.1875-20	UN	30.162	1.270	2A	0.036	30.126	29.922	...	29.301	29.183	0.118	28.616	2B	28.779	29.083	29.337	29.491	0.154	30.163
				3A	0.000	30.162	29.957	...	29.337	29.249	0.088	28.651	3B	28.779	28.986	29.337	29.451	0.114	30.163
1 3/16-28 or 1.1875-28	UN	30.162	0.907	2A	0.032	30.132	29.967	...	29.542	29.439	0.103	29.050	2B	29.185	29.387	29.574	29.707	0.133	30.163
				3A	0.000	30.162	29.998	...	29.573	29.495	0.078	29.080	3B	29.185	29.339	29.574	29.674	0.100	30.163
1 1/4-7 or 1.250-7	UNC	31.750	3.629	1A	0.056	31.694	31.070	...	29.337	29.056	0.281	27.374	1B	27.813	28.524	29.393	29.758	0.365	31.750
				2A	0.056	31.694	31.278	31.070	29.337	29.150	0.187	27.374	2B	27.813	28.524	29.393	29.636	0.243	31.750
				3A	0.000	31.750	31.334	...	29.392	29.254	0.138	27.429	3B	27.813	28.257	29.393	29.575	0.182	31.750
1 1/4-8 or 1.250-8	UN	31.750	3.175	2A	0.054	31.696	31.316	31.126	29.634	29.457	0.177	27.917	2B	28.321	28.956	29.688	29.921	0.233	31.750
				3A	0.000	31.750	31.369	...	29.687	29.553	0.134	27.970	3B	28.321	28.694	29.688	29.862	0.174	31.750
1 1/4-12 or 1.250-12	UNF	31.750	2.117	1A	0.046	31.704	31.268	...	30.330	30.097	0.233	29.185	1B	29.464	29.921	30.376	30.680	0.304	31.750
				2A	0.046	31.704	31.415	...	30.330	30.173	0.157	29.185	2B	29.464	29.921	30.376	30.579	0.203	31.750
				3A	0.000	31.750	31.461	...	30.375	30.260	0.115	29.230	3B	29.464	29.712	30.376	30.528	0.152	31.750
1 1/4-16 or 1.250-16	UN	31.750	1.588	2A	0.039	31.711	31.474	...	30.680	30.552	0.128	29.820	2B	30.023	30.378	30.719	30.886	0.167	31.750
				3A	0.000	31.750	31.512	...	30.718	30.623	0.095	29.858	3B	30.023	30.246	30.719	30.845	0.126	31.750
1 1/4-18 or 1.250-18	UNEF	31.750	1.411	2A	0.040	31.711	31.491	...	30.794	30.671	0.123	30.033	2B	30.226	30.556	30.834	30.993	0.159	31.750
				3A	0.000	31.750	31.530	...	30.833	30.742	0.091	30.071	3B	30.226	30.429	30.834	30.952	0.118	31.750
1 1/4-20 or 1.250-20	UN	31.750	1.270	2A	0.037	31.714	31.509	...	30.888	30.770	0.118	30.203	2B	30.379	30.657	30.925	31.079	0.154	31.750
				3A	0.000	31.750	31.545	...	30.924	30.836	0.088	30.239	3B	30.379	30.573	30.925	31.038	0.113	31.750
1 1/4-28 or 1.250-28	UN	31.750	0.907	2A	0.031	31.719	31.555	...	31.130	31.027	0.103	30.637	2B	30.760	30.988	31.161	31.295	0.134	31.750
				3A	0.000	31.750	31.585	...	31.160	31.082	0.078	30.668	3B	30.760	30.927	31.161	31.262	0.101	31.750
1 5/16-8 or 1.3125-8	UN	33.337	3.175	2A	0.055	33.284	32.904	...	31.221	31.042	0.179	29.505	2B	29.896	30.530	31.276	31.508	0.232	33.338
				3A	0.000	33.337	32.957	...	31.275	31.141	0.134	29.558	3B	29.896	30.281	31.276	31.450	0.174	33.338
1 5/16-12 or 1.3125-12	UN	33.337	2.117	2A	0.044	33.294	33.005	...	31.920	31.773	0.147	30.775	2B	31.039	31.496	31.964	32.153	0.189	33.338
				3A	0.000	33.337	33.048	...	31.963	31.855	0.108	30.818	3B	31.039	31.300	31.964	32.105	0.141	33.338
1 5/16-16 or 1.3125-16	UN	33.337	1.588	2A	0.039	33.299	33.061	...	32.268	32.139	0.129	31.407	2B	31.623	31.978	32.307	32.473	0.166	33.338
				3A	0.000	33.337	33.099	...	32.306	32.210	0.096	31.445	3B	31.623	31.833	32.307	32.433	0.126	33.338
1 5/16-18 or 1.3125-18	UNEF	33.337	1.411	2A	0.039	33.299	33.079	...	32.382	32.258	0.124	31.620	2B	31.801	32.131	32.421	32.580	0.159	33.338
				3A	0.000	33.337	33.117	...	32.420	32.330	0.090	31.659	3B	31.801	32.016	32.421	32.539	0.118	33.338
1 5/16-20 or 1.3125-20	UN	33.337	1.270	2A	0.036	33.301	33.097	...	32.476	32.358	0.118	31.791	2B	31.954	32.258	32.512	32.666	0.154	33.338
				3A	0.000	33.337	33.132	...	32.512	32.424	0.088	31.826	3B	31.954	32.161	32.512	32.626	0.114	33.338
1 5/16-28 or 1.3125-28	UN	33.337	0.907	2A	0.032	33.307	33.142	...	32.717	32.614	0.103	32.225	2B	32.360	32.562	32.749	32.882	0.133	33.338
				3A	0.000	33.337	33.173	...	32.748	32.670	0.078	32.255	3B	32.360	32.514	32.749	32.849	0.100	33.338

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
1⅜-6 or 1.375-6	UNC	34.925	4.233	1A	0.062	34.864	34.171	...	32.113	31.809	0.304	29.825	1B	30.353	31.115	32.175	32.567	0.392	34.925
				2A	0.062	34.864	34.402	34.171	32.113	31.911	0.202	29.825	2B	30.353	31.115	32.175	32.438	0.263	34.925
				3A	0.000	34.925	34.463	...	32.174	32.022	0.152	29.886	3B	30.353	30.850	32.175	32.372	0.197	34.925
1⅜-8 or 1.375-8	UN	34.925	3.175	2A	0.057	34.869	34.489	34.298	32.806	32.624	0.182	31.090	2B	31.496	32.131	32.863	33.098	0.235	34.925
				3A	0.000	34.925	34.544	...	32.862	32.726	0.136	31.145	3B	31.496	31.869	32.863	33.040	0.177	34.925
1⅜-12 or 1.375-12	UNF	34.925	2.117	1A	0.049	34.876	34.440	...	33.502	33.264	0.238	32.357	1B	32.639	33.096	33.551	33.863	0.312	34.925
				2A	0.049	34.876	34.588	...	33.502	33.343	0.159	32.357	2B	32.639	33.096	33.551	33.759	0.208	34.925
				3A	0.000	34.925	34.636	...	33.550	33.432	0.118	32.405	3B	32.639	32.887	33.551	33.705	0.154	34.925
1⅜-16 or 1.375-16	UN	34.925	1.588	2A	0.039	34.886	34.649	...	33.855	33.727	0.128	32.995	2B	33.198	33.553	33.894	34.061	0.167	34.925
				3A	0.000	34.925	34.687	...	33.893	33.798	0.095	33.033	3B	33.198	33.421	33.894	34.020	0.126	34.925
1⅜-18 or 1.375-18	UNEF	34.925	1.411	2A	0.040	34.886	34.666	...	33.969	33.846	0.123	33.208	2B	33.401	33.731	34.009	34.168	0.159	34.925
				3A	0.000	34.925	34.705	...	34.008	33.917	0.091	33.246	3B	33.401	33.604	34.009	34.127	0.118	34.925
1⅜-20 or 1.375-20	UN	34.925	1.270	2A	0.037	34.889	34.684	...	34.063	33.945	0.118	33.378	2B	33.554	33.832	34.100	34.254	0.154	34.925
				3A	0.000	34.925	34.720	...	34.099	34.011	0.088	33.414	3B	33.554	33.748	34.100	34.213	0.113	34.925
1⅜-28 or 1.375-28	UN	34.925	0.907	2A	0.031	34.894	34.730	...	34.305	34.202	0.103	33.812	2B	33.935	34.163	34.336	34.470	0.134	34.925
				3A	0.000	34.925	34.760	...	34.335	34.257	0.078	33.843	3B	33.935	34.102	34.336	34.437	0.101	34.925
1⅞-6 or 1.4375-6	UN	36.512	4.233	2A	0.062	36.451	35.990	...	33.700	33.498	0.202	31.412	2B	31.928	32.715	33.762	34.025	0.263	36.513
				3A	0.000	36.512	36.051	...	33.761	33.610	0.151	31.473	3B	31.928	32.438	33.762	33.959	0.197	36.513
1⅞-8 or 1.4375-8	UN	36.512	3.175	2A	0.057	36.456	36.076	...	34.394	34.212	0.182	32.677	2B	33.071	33.705	34.451	34.688	0.237	36.513
				3A	0.000	36.512	36.132	...	34.450	34.313	0.137	32.739	3B	33.071	33.456	34.451	34.630	0.179	36.513
1⅞-12 or 1.4375-12	UN	36.512	2.117	2A	0.047	36.466	36.178	...	35.092	34.943	0.149	33.947	2B	34.214	34.671	35.139	35.331	0.192	36.513
				3A	0.000	36.512	36.223	...	35.138	35.027	0.111	33.993	3B	34.214	34.475	35.139	35.283	0.144	36.513
1⅞-16 or 1.4375-16	UN	36.512	1.588	2A	0.042	36.471	36.234	...	35.440	35.309	0.131	34.580	2B	34.798	35.153	35.482	35.653	0.171	36.513
				3A	0.000	36.512	36.274	...	35.481	35.383	0.098	34.620	3B	34.798	35.008	35.482	35.610	0.128	36.513
1⅞-18 or 1.4375-18	UNEF	36.512	1.411	2A	0.039	36.474	36.254	...	35.557	35.431	0.126	34.795	2B	34.976	35.306	35.596	35.760	0.164	36.513
				3A	0.000	36.512	36.292	...	35.595	35.502	0.093	34.834	3B	34.976	35.191	35.596	35.717	0.121	36.513
1⅞-20 or 1.4375-20	UN	36.512	1.270	2A	0.036	36.476	36.272	...	35.651	35.530	0.121	34.966	2B	35.129	35.433	35.687	35.844	0.157	36.513
				3A	0.000	36.512	36.307	...	35.687	35.596	0.091	35.001	3B	35.129	35.336	35.687	35.803	0.116	36.513
1⅞-28 or 1.4375-28	UN	36.512	0.907	2A	0.034	36.479	36.315	...	35.890	35.784	0.106	35.397	2B	35.535	35.737	35.924	36.062	0.138	36.513
				3A	0.000	36.512	36.348	...	35.923	35.845	0.078	35.430	3B	35.535	35.689	35.924	36.027	0.103	36.513
1½-6 or 1.500-6	UNC	38.100	4.233	1A	0.062	38.039	37.346	...	35.288	34.981	0.307	33.000	1B	33.528	34.290	35.350	35.750	0.400	38.100
				2A	0.062	38.039	37.577	37.346	35.288	35.083	0.205	33.000	2B	33.528	34.290	35.350	35.615	0.265	38.100
				3A	0.000	38.100	37.638	...	35.349	35.195	0.154	33.061	3B	33.528	34.025	35.350	35.549	0.199	38.100
1½-8 or 1.500-8	UN	38.100	3.175	2A	0.057	38.044	37.664	37.473	35.981	35.797	0.184	34.265	2B	34.671	35.306	36.038	36.278	0.240	38.100
				3A	0.000	38.100	37.719	...	36.037	35.898	0.139	34.320	3B	34.671	35.044	36.038	36.217	0.179	38.100
1½-12 or 1.500-12	UNF	38.100	2.117	1A	0.049	38.051	37.615	...	36.677	36.434	0.243	35.532	1B	35.814	36.271	36.726	37.043	0.317	38.100
				2A	0.049	38.051	37.763	...	36.677	36.516	0.161	35.532	2B	35.814	36.271	36.726	36.936	0.210	38.100
				3A	0.000	38.100	37.811	...	36.725	36.604	0.121	35.580	3B	35.814	36.062	36.726	36.885	0.159	38.100
1½-16 or 1.500-16	UN	38.100	1.588	2A	0.041	38.059	37.821	...	37.028	36.897	0.131	36.167	2B	36.373	36.728	37.069	37.241	0.172	38.100
				3A	0.000	38.100	37.862	...	37.068	36.970	0.098	36.208	3B	36.373	36.596	37.069	37.198	0.129	38.100

(Notes follow at end of table)

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
1½-18 or 1.500-18	UNEF	38.100	1.411	2A	0.040	38.061	37.841	...	37.144	37.018	0.126	36.383	2B	36.576	36.880	37.184	37.348	0.164	38.100
				3A	0.000	38.100	37.880	...	37.183	37.090	0.093	36.421	3B	36.576	36.779	37.184	37.304	0.120	38.100
1½-20 or 1.500-20	UN	38.100	1.270	2A	0.037	38.064	37.859	...	37.238	37.118	0.120	36.553	2B	36.729	37.007	37.275	37.431	0.156	38.100
				3A	0.000	38.100	37.895	...	37.274	37.184	0.090	36.589	3B	36.729	36.923	37.275	37.391	0.116	38.100
1½-28 or 1.500-28	UN	38.100	0.907	2A	0.034	38.066	37.902	...	37.477	37.372	0.105	36.985	2B	37.110	37.338	37.511	37.650	0.139	38.100
				3A	0.000	38.100	37.935	...	37.510	37.432	0.078	37.018	3B	37.110	37.277	37.511	37.614	0.103	38.100
1 9/16-6 or 1.5625-6	UN	39.687	4.233	2A	0.062	39.626	39.165	...	36.875	36.668	0.207	34.587	2B	35.103	35.890	36.937	37.205	0.268	39.688
				3A	0.000	39.687	39.226	...	36.936	36.782	0.154	34.648	3B	35.103	35.613	36.937	37.139	0.202	39.688
1 9/16-8 or 1.5625-8	UN	39.687	3.175	2A	0.057	39.631	39.251	...	37.569	37.382	0.187	35.852	2B	36.246	36.880	37.626	37.868	0.242	39.688
				3A	0.000	39.687	39.307	...	37.625	37.486	0.139	35.908	3B	36.246	36.631	37.626	37.807	0.181	39.688
1 9/16-12 or 1.5625-12	UN	39.687	2.117	2A	0.047	39.641	39.353	...	38.267	38.118	0.149	37.122	2B	37.389	37.846	38.314	38.506	0.192	39.688
				3A	0.000	39.687	39.398	...	38.313	38.202	0.111	37.168	3B	37.389	37.650	38.314	38.458	0.144	39.688
1 9/16-16 or 1.5625-16	UN	39.687	1.588	2A	0.042	39.646	39.409	...	38.615	38.484	0.131	37.755	2B	37.973	38.328	38.657	38.828	0.171	39.688
				3A	0.000	39.687	39.449	...	38.656	38.558	0.098	37.795	3B	37.973	38.183	38.657	38.785	0.128	39.688
1 9/16-18 or 1.5625-18	UNEF	39.687	1.411	2A	0.039	39.649	39.429	...	38.732	38.606	0.126	37.970	2B	38.151	38.481	38.771	38.935	0.164	39.688
				3A	0.000	39.687	39.467	...	38.770	38.677	0.093	38.009	3B	38.151	38.366	38.771	38.892	0.121	39.688
1 9/16-20 or 1.5625-20	UN	39.687	1.270	2A	0.036	39.651	39.447	...	38.826	38.705	0.121	38.141	2B	38.304	38.608	38.862	39.019	0.157	39.688
				3A	0.000	39.687	39.482	...	38.862	38.771	0.091	38.176	3B	38.304	38.511	38.862	38.979	0.116	39.688
1⅝-6 or 1.625-6	UN	41.275	4.233	2A	0.065	41.211	40.750	...	38.460	38.253	0.207	36.185	2B	36.703	37.465	38.525	38.795	0.270	41.275
				3A	0.000	41.275	40.813	...	38.524	38.367	0.157	36.248	3B	36.703	37.200	38.525	38.727	0.202	41.275
1⅝-8 or 1.625-8	UN	41.275	3.175	2A	0.057	41.219	40.839	40.648	39.156	38.969	0.187	37.551	2B	37.846	38.481	39.213	39.458	0.245	41.275
				3A	0.000	41.275	40.894	...	39.212	39.071	0.141	37.607	3B	37.846	38.219	39.213	39.395	0.182	41.275
1⅝-12 or 1.625-12	UN	41.275	2.117	2A	0.046	41.229	40.940	...	39.855	39.706	0.149	38.710	2B	38.989	39.446	39.901	40.093	0.192	41.275
				3A	0.000	41.275	40.986	...	39.900	39.790	0.110	38.755	3B	38.989	39.237	39.901	40.045	0.144	41.275
1⅝-16 or 1.625-16	UN	41.275	1.588	2A	0.041	41.234	40.996	...	40.203	40.072	0.131	39.342	2B	39.548	39.903	40.244	40.416	0.172	41.275
				3A	0.000	41.275	41.037	...	40.243	40.145	0.098	39.383	3B	39.548	39.771	40.244	40.373	0.129	41.275
1⅝-18 or 1.625-18	UNEF	41.275	1.411	2A	0.040	41.236	41.016	...	40.319	40.193	0.126	39.558	2B	39.751	40.081	40.359	40.523	0.164	41.275
				3A	0.000	41.275	41.055	...	40.358	40.265	0.093	39.596	3B	39.751	39.954	40.359	40.479	0.120	41.275
1⅝-20 or 1.625-20	UN	41.275	1.270	2A	0.037	41.239	41.034	...	40.413	40.293	0.120	39.728	2B	39.904	40.182	40.450	40.606	0.156	41.275
				3A	0.000	41.275	41.070	...	40.449	40.359	0.090	39.764	3B	39.904	40.098	40.450	40.566	0.116	41.275
1 11/16-6 or 1.6875-6	UN	42.862	4.233	2A	0.064	42.799	42.337	...	40.048	39.838	0.210	37.760	2B	38.278	39.065	40.112	40.386	0.274	42.863
				3A	0.000	42.862	42.401	...	40.111	39.955	0.156	37.823	3B	38.278	38.788	40.112	40.317	0.205	42.863
1 11/16-8 or 1.6875-8	UN	42.862	3.175	2A	0.057	42.806	42.426	...	40.744	40.554	0.190	39.027	2B	39.421	40.055	40.801	41.046	0.245	42.863
				3A	0.000	42.862	42.482	...	40.800	40.658	0.142	39.083	3B	39.421	39.806	40.801	40.985	0.184	42.863
1 11/16-12 or 1.6875-12	UN	42.862	2.117	2A	0.047	42.816	42.528	...	41.442	41.291	0.151	40.297	2B	40.564	41.021	41.489	41.686	0.197	42.863
				3A	0.000	42.862	42.573	...	41.488	41.375	0.113	40.343	3B	40.564	40.825	41.489	41.635	0.146	42.863
1 11/16-16 or 1.6875-16	UN	42.862	1.588	2A	0.042	42.821	42.584	...	41.790	41.656	0.134	40.930	2B	41.148	41.503	41.832	42.006	0.174	42.863
				3A	0.000	42.862	42.624	...	41.831	41.730	0.101	40.970	3B	41.148	41.358	41.832	41.963	0.131	42.863
1 11/16-18 or 1.6875-18	UNEF	42.862	1.411	2A	0.039	42.824	42.604	...	41.907	41.778	0.129	41.145	2B	41.326	41.656	41.946	42.113	0.167	42.863
				3A	0.000	42.862	42.642	...	41.945	41.850	0.095	41.184	3B	41.326	41.541	41.946	42.070	0.124	42.863

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
$1\frac{11}{16}$-20 or 1.6875-20	UN	42.862	1.270	2A	0.039	42.824	42.619	...	41.998	41.877	0.121	41.313	2B	41.479	41.783	42.037	42.197	0.160	42.863
				3A	0.000	42.862	42.657	...	42.037	41.946	0.091	41.351	3B	41.479	41.686	42.037	42.156	0.119	42.863
$1\frac{3}{4}$-5 or 1.750-5	UNC	44.450	5.080	1A	0.070	44.381	43.600	...	41.081	40.742	0.339	38.334	1B	38.964	39.827	41.151	41.592	0.441	44.450
				2A	0.070	44.381	43.861	43.600	41.081	40.856	0.225	38.334	2B	38.964	39.827	41.151	41.445	0.294	44.450
				3A	0.000	44.450	43.930	...	41.150	40.981	0.169	38.403	3B	38.964	39.560	41.151	41.371	0.220	44.450
$1\frac{3}{4}$-6 or 1.750-6	UN	44.450	4.233	2A	0.065	44.386	43.925	...	41.635	41.425	0.210	39.347	2B	39.878	40.640	41.700	41.973	0.273	44.450
				3A	0.000	44.450	43.988	...	41.699	41.540	0.159	39.411	3B	39.878	40.375	41.700	41.904	0.204	44.450
$1\frac{3}{4}$-8 or 1.750-8	UN	44.450	3.175	2A	0.059	44.391	44.011	43.821	42.329	42.139	0.190	40.612	2B	41.021	41.656	42.388	42.636	0.248	44.450
				3A	0.000	44.450	44.069	...	42.387	42.243	0.144	40.670	3B	41.021	41.394	42.388	42.575	0.187	44.450
$1\frac{3}{4}$-12 or 1.750-12	UN	44.450	2.117	2A	0.046	44.404	44.115	...	43.030	42.878	0.152	41.885	2B	42.164	42.621	43.076	43.273	0.197	44.450
				3A	0.000	44.450	44.161	...	43.075	42.962	0.113	41.930	3B	42.164	42.412	43.076	43.223	0.147	44.450
$1\frac{3}{4}$-16 or 1.750-16	UN	44.450	1.588	2A	0.041	44.409	44.171	...	43.378	43.244	0.134	42.517	2B	42.723	43.078	43.419	43.594	0.175	44.450
				3A	0.000	44.450	44.212	...	43.418	43.318	0.100	42.558	3B	42.723	42.946	43.419	43.550	0.131	44.450
$1\frac{3}{4}$-20 or 1.750-20	UN	44.450	1.270	2A	0.039	44.411	44.207	...	43.586	43.465	0.121	42.901	2B	43.079	43.357	43.625	43.784	0.159	44.450
				3A	0.000	44.450	44.245	...	43.624	43.534	0.090	42.939	3B	43.079	43.273	43.625	43.743	0.118	44.450
$1\frac{13}{16}$-6 or 1.8125-6	UN	46.037	4.233	2A	0.064	45.974	45.512	...	43.223	43.010	0.213	40.935	2B	41.453	42.240	43.287	43.563	0.276	46.038
				3A	0.000	46.037	45.576	...	43.286	43.127	0.159	40.998	3B	41.453	41.963	43.287	43.494	0.207	46.038
$1\frac{13}{16}$-8 or 1.8125-8	UN	46.037	3.175	2A	0.060	45.979	45.599	...	43.916	43.724	0.192	42.200	2B	42.596	43.230	43.976	44.226	0.250	46.038
				3A	0.000	46.037	45.657	...	43.975	43.831	0.144	42.258	3B	42.596	42.981	43.976	44.162	0.186	46.038
$1\frac{13}{16}$-12 or 1.8125-12	UN	46.037	2.117	2A	0.047	45.991	45.703	...	44.617	44.466	0.151	43.472	2B	43.739	44.196	44.664	44.861	0.197	46.038
				3A	0.000	46.037	45.748	...	44.663	44.550	0.113	43.518	3B	43.739	44.000	44.664	44.810	0.146	46.038
$1\frac{13}{16}$-16 or 1.8125-16	UN	46.037	1.588	2A	0.042	45.996	45.759	...	44.965	44.831	0.134	44.105	2B	44.323	44.678	45.007	45.181	0.174	46.038
				3A	0.000	46.037	45.799	...	45.006	44.905	0.101	44.145	3B	44.323	44.533	45.007	45.138	0.131	46.038
$1\frac{13}{16}$-20 or 1.8125-20	UN	46.037	1.270	2A	0.039	45.999	45.794	...	45.173	45.052	0.121	44.488	2B	44.654	44.958	45.212	45.372	0.160	46.038
				3A	0.000	46.037	45.832	...	45.212	45.121	0.091	44.526	3B	44.654	44.861	45.212	45.331	0.119	46.038
$1\frac{7}{8}$-6 or 1.875-6	UN	47.625	4.233	2A	0.065	47.561	47.100	...	44.810	44.598	0.212	42.522	2B	43.053	43.815	44.875	45.153	0.278	47.625
				3A	0.000	47.625	47.163	...	44.874	44.715	0.159	42.586	3B	43.053	43.550	44.875	45.082	0.207	47.625
$1\frac{7}{8}$-8 or 1.875-8	UN	47.625	3.175	2A	0.059	47.566	47.186	46.996	45.504	45.309	0.195	43.787	2B	44.196	44.831	45.563	45.816	0.253	47.625
				3A	0.000	47.625	47.244	...	45.562	45.418	0.144	43.845	3B	44.196	44.569	45.563	45.753	0.190	47.625
$1\frac{7}{8}$-12 or 1.875-12	UN	47.625	2.117	2A	0.046	47.579	47.290	...	46.205	46.053	0.152	45.060	2B	45.339	45.796	46.251	46.448	0.197	47.625
				3A	0.000	47.625	47.336	...	46.250	46.137	0.113	45.105	3B	45.339	45.587	46.251	46.398	0.147	47.625
$1\frac{7}{8}$-16 or 1.875-16	UN	47.625	1.588	2A	0.041	47.584	47.346	...	46.553	46.419	0.134	45.692	2B	45.898	46.253	46.594	46.769	0.175	47.625
				3A	0.000	47.625	47.387	...	46.593	46.493	0.100	45.733	3B	45.898	46.121	46.594	46.725	0.131	47.625
$1\frac{7}{8}$-20 or 1.875-20	UN	47.625	1.270	2A	0.039	47.586	47.382	...	46.761	46.640	0.121	46.076	2B	46.254	46.532	46.800	46.959	0.159	47.625
				3A	0.000	47.625	47.420	...	46.799	46.709	0.090	46.114	3B	46.254	46.448	46.800	46.918	0.118	47.625
$1\frac{15}{16}$-6 or 1.9375-6	UN	49.212	4.233	2A	0.067	49.146	48.685	...	46.395	46.180	0.215	44.107	2B	44.628	45.415	46.462	46.743	0.281	49.213
				3A	0.000	49.212	48.751	...	46.461	46.300	0.161	44.173	3B	44.628	45.138	46.462	46.672	0.210	49.213
$1\frac{15}{16}$-8 or 1.9375-8	UN	49.212	3.175	2A	0.060	49.154	48.774	...	47.091	46.897	0.194	45.375	2B	45.771	46.405	47.151	47.404	0.253	49.213
				3A	0.000	49.212	48.832	...	47.150	47.003	0.147	45.433	3B	45.771	46.156	47.151	47.340	0.189	49.213

(Notes follow at end of table)

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
$1\frac{15}{16}$-12 or 1.9375-12	UN	49.212	2.117	2A	0.047	49.166	48.878	...	47.792	47.638	0.154	46.647	2B	46.914	47.371	47.839	48.039	0.200	49.213
				3A	0.000	49.212	48.923	...	47.838	47.725	0.113	46.693	3B	46.914	47.175	47.839	47.988	0.149	49.213
$1\frac{15}{16}$-16 or 1.9375-16	UN	49.212	1.588	2A	0.042	49.171	48.934	...	48.140	48.004	0.136	47.280	2B	47.498	47.853	48.182	48.359	0.177	49.213
				3A	0.000	49.212	48.974	...	48.181	48.080	0.101	47.320	3B	47.498	47.708	48.182	48.313	0.131	49.213
$1\frac{15}{16}$-20 or 1.9375-20	UN	49.212	1.270	2A	0.039	49.174	48.969	...	48.348	48.225	0.123	47.663	2B	47.829	48.133	48.387	48.549	0.162	49.213
				3A	0.000	49.212	49.007	...	48.387	48.294	0.093	47.701	3B	47.829	48.036	48.387	48.508	0.121	49.213
2-4½ or 2.000-4.5	UNC	50.800	5.644	1A	0.074	50.726	49.889	...	47.061	46.698	0.363	44.003	1B	44.679	45.593	47.135	47.607	0.472	50.800
				2A	0.074	50.726	50.168	49.889	47.061	46.820	0.241	44.003	2B	44.679	45.593	47.135	47.449	0.314	50.800
				3A	0.000	50.800	50.242	...	47.134	46.955	0.179	44.077	3B	44.679	45.366	47.135	47.371	0.236	50.800
2-6 or 2.000-6	UN	50.800	4.233	2A	0.067	50.733	50.272	...	47.983	47.765	0.218	45.695	2B	46.228	46.990	48.050	48.331	0.281	50.800
				3A	0.000	50.800	50.338	...	48.049	47.887	0.162	45.761	3B	46.228	46.725	48.050	48.260	0.210	50.800
2-8 or 2.000-8	UN	50.800	3.175	2A	0.059	50.741	50.361	50.171	48.679	48.481	0.198	46.962	2B	47.371	48.006	48.738	48.994	0.256	50.800
				3A	0.000	50.800	50.419	...	48.737	48.591	0.146	47.020	3B	47.371	47.744	48.738	48.930	0.192	50.800
2-12 or 2.000-12	UN	50.800	2.117	2A	0.046	50.754	50.465	...	49.380	49.226	0.154	48.235	2B	48.514	48.971	49.426	49.626	0.200	50.800
				3A	0.000	50.800	50.511	...	49.425	49.312	0.113	48.280	3B	48.514	48.762	49.426	49.575	0.149	50.800
2-16 or 2.000-16	UN	50.800	1.588	2A	0.041	50.759	50.521	...	49.728	49.591	0.137	48.867	2B	49.073	49.428	49.769	49.946	0.177	50.800
				3A	0.000	50.800	50.562	...	49.768	49.668	0.100	48.908	3B	49.073	49.296	49.769	49.900	0.131	50.800
2-20 or 2.000-20	UN	50.800	1.270	2A	0.039	50.761	50.557	...	49.936	49.812	0.124	49.251	2B	49.429	49.707	49.975	50.137	0.162	50.800
				3A	0.000	50.800	50.595	...	49.974	49.881	0.093	49.289	3B	49.429	49.623	49.975	50.096	0.121	50.800
2⅛-6 or 2.125-6	UN	53.975	4.233	2A	0.067	53.908	53.447	...	51.158	50.938	0.220	48.870	2B	49.403	50.165	51.225	51.511	0.286	53.975
				3A	0.000	53.975	53.513	...	51.224	51.060	0.164	48.936	3B	49.403	49.900	51.225	51.437	0.212	53.975
2⅛-8 or 2.125-8	UN	53.975	3.175	2A	0.062	53.914	53.534	53.343	51.851	51.651	0.200	50.135	2B	50.546	51.181	51.913	52.171	0.258	53.975
				3A	0.000	53.975	53.594	...	51.912	51.763	0.149	50.195	3B	50.546	50.919	51.913	52.108	0.195	53.975
2⅛-12 or 2.125-12	UN	53.975	2.117	2A	0.046	53.929	53.640	...	52.555	52.401	0.154	51.410	2B	51.689	52.146	52.601	52.801	0.200	53.975
				3A	0.000	53.975	53.686	...	52.600	52.487	0.113	51.455	3B	51.689	51.937	52.601	52.750	0.149	53.975
2⅛-16 or 2.125-16	UN	53.975	1.588	2A	0.041	53.934	53.696	...	52.903	52.766	0.137	52.042	2B	52.248	52.603	52.944	53.121	0.177	53.975
				3A	0.000	53.975	53.737	...	52.943	52.843	0.100	52.083	3B	52.248	52.471	52.944	53.075	0.131	53.975
2⅛-20 or 2.125-20	UN	53.975	1.270	2A	0.039	53.936	53.732	...	53.111	52.987	0.124	52.426	2B	52.604	52.882	53.150	53.312	0.162	53.975
				3A	0.000	53.975	53.770	...	53.149	53.056	0.093	52.464	3B	52.604	52.798	53.150	53.271	0.121	53.975
2¼-4½ or 2.250-4.5	UNC	57.150	5.644	1A	0.074	57.076	56.239	...	53.411	53.041	0.370	50.353	1B	51.029	51.943	53.485	53.967	0.482	57.150
				2A	0.074	57.076	56.518	56.239	53.411	53.165	0.246	50.353	2B	51.029	51.943	53.485	53.804	0.419	57.150
				3A	0.000	57.150	56.592	...	53.484	53.300	0.184	50.427	3B	51.029	51.716	53.485	53.726	0.241	57.150
2¼-6 or 2.250-6	UN	57.150	4.233	2A	0.067	57.083	56.622	...	54.333	54.110	0.223	52.045	2B	52.578	53.340	54.400	54.688	0.288	57.150
				3A	0.000	57.150	56.688	...	54.399	54.232	0.167	52.111	3B	52.578	53.075	54.400	54.615	0.215	57.150
2¼-8 or 2.250-8	UN	57.150	3.175	2A	0.062	57.089	56.709	56.518	55.026	54.824	0.202	53.310	2B	53.721	54.356	55.088	55.351	0.263	57.150
				3A	0.000	57.150	56.769	...	55.087	54.936	0.151	53.370	3B	53.721	54.094	55.088	55.285	0.197	57.150
2¼-12 or 2.250-12	UN	57.150	2.117	2A	0.046	57.104	56.815	...	55.730	55.576	0.154	54.585	2B	54.864	55.321	55.776	55.976	0.200	57.150
				3A	0.000	57.150	56.861	...	55.775	55.662	0.113	54.630	3B	54.864	55.112	55.776	55.925	0.149	57.150
2¼-16 or 2.250-16	UN	57.150	1.588	2A	0.041	57.109	56.871	...	56.078	55.941	0.137	55.217	2B	55.423	55.778	56.119	56.296	0.177	57.150
				3A	0.000	57.150	56.912	...	56.118	56.018	0.100	55.258	3B	55.423	55.646	56.119	56.250	0.131	57.150

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
2¼-20 or 2.250-20	UN	57.150	1.270	2A	0.039	57.111	56.907	...	56.286	56.162	0.124	55.601	2B	55.779	56.057	56.325	56.487	0.162	57.150
				3A	0.000	57.150	56.945	...	56.324	56.231	0.093	55.639	3B	55.779	55.973	56.325	56.446	0.121	57.150
2⅜-6 or 2.375-6	UN	60.325	4.233	2A	0.070	60.256	59.795	...	57.505	57.280	0.225	55.217	2B	55.753	56.540	57.575	57.866	0.291	60.325
				3A	0.000	60.325	59.863	...	57.574	57.407	0.167	55.286	3B	55.753	56.250	57.575	57.792	0.217	60.325
2⅜-8 or 2.375-8	UN	60.325	3.175	2A	0.062	60.264	59.884	...	58.201	57.996	0.205	56.485	2B	56.896	57.531	58.263	58.529	0.266	60.325
				3A	0.000	60.325	59.944	...	58.262	58.111	0.151	56.545	3B	56.896	57.269	58.263	58.463	0.200	60.325
2⅜-12 or 2.375-12	UN	60.325	2.117	2A	0.049	60.276	59.988	...	58.902	58.746	0.156	57.757	2B	58.039	58.496	58.951	59.156	0.205	60.325
				3A	0.000	60.325	60.036	...	58.950	58.835	0.115	57.805	3B	58.039	58.287	58.951	59.103	0.152	60.325
2⅜-16 or 2.375-16	UN	60.325	1.588	2A	0.044	60.281	60.044	...	59.250	59.111	0.139	58.390	2B	58.598	58.953	59.294	59.476	0.182	60.325
				3A	0.000	60.325	60.087	...	59.293	59.190	0.103	58.433	3B	58.598	58.821	59.294	59.430	0.136	60.325
2⅜-20 or 2.375-20	UN	60.325	1.270	2A	0.039	60.286	60.082	...	59.461	59.332	0.129	58.776	2B	58.954	59.232	59.500	59.667	0.167	60.325
				3A	0.000	60.325	60.120	...	59.499	59.403	0.096	58.814	3B	58.954	59.148	59.500	59.626	0.126	60.325
2½-4 or 2.500-4	UNC	63.500	6.350	1A	0.080	63.421	62.515	...	59.296	58.903	0.393	55.860	1B	56.617	57.581	59.376	59.888	0.512	63.500
				2A	0.080	63.421	62.817	62.515	59.296	59.033	0.263	55.860	2B	56.617	57.581	59.376	59.717	0.341	63.500
				3A	0.000	63.500	62.896	...	59.375	59.177	0.198	55.938	3B	56.617	57.388	59.376	59.631	0.255	63.500
2½-6 or 2.500-6	UN	63.500	4.233	2A	0.070	63.431	62.970	...	60.680	60.452	0.228	58.392	2B	58.928	59.690	60.750	61.043	0.293	63.500
				3A	0.000	63.500	63.038	...	60.749	60.579	0.170	58.461	3B	58.928	59.425	60.750	60.970	0.220	63.500
2½-8 or 2.500-8	UN	63.500	3.175	2A	0.062	63.439	63.059	62.868	61.376	61.169	0.207	59.660	2B	60.071	60.706	61.438	61.706	0.368	63.500
				3A	0.000	63.500	63.119	...	61.437	61.283	0.154	59.720	3B	60.071	60.444	61.438	61.640	0.202	63.500
2½-12 or 2.500-12	UN	63.500	2.117	2A	0.049	63.451	63.163	...	62.077	61.921	0.156	60.932	2B	61.214	61.671	62.126	62.331	0.205	63.500
				3A	0.000	63.500	63.211	...	62.125	62.010	0.115	60.980	3B	61.214	61.462	62.126	62.278	0.152	63.500
2½-16 or 2.500-16	UN	63.500	1.588	2A	0.044	63.456	63.219	...	62.425	62.286	0.139	61.565	2B	61.773	62.128	62.469	62.651	0.182	63.500
				3A	0.000	63.500	63.262	...	62.468	62.365	0.103	61.608	3B	61.773	61.996	62.469	62.605	0.136	63.500
2½-20 or 2.500-20	UN	63.500	1.270	2A	0.039	63.461	63.257	...	62.636	62.507	0.129	61.951	2B	62.129	62.407	62.675	62.842	0.167	63.500
				3A	0.000	63.500	63.295	...	62.674	62.578	0.096	61.989	3B	62.129	62.323	62.675	62.801	0.126	63.500
2⅝-6 or 2.625-6	UN	66.675	4.233	2A	0.070	66.606	66.145	...	63.855	63.627	0.228	61.567	2B	62.103	62.865	63.925	64.223	0.298	66.675
				3A	0.000	66.675	66.213	...	63.924	63.752	0.172	61.636	3B	62.103	62.600	63.925	64.147	0.222	66.675
2⅝-8 or 2.625-8	UN	66.675	3.175	2A	0.064	66.611	66.231	...	64.549	64.341	0.208	62.832	2B	63.246	63.881	64.613	64.884	0.271	66.675
				3A	0.000	66.675	66.294	...	64.612	64.456	0.156	62.895	3B	63.246	63.619	64.613	64.815	0.202	66.675
2⅝-12 or 2.625-12	UN	66.675	2.117	2A	0.049	66.626	66.338	...	65.252	65.096	0.156	64.107	2B	64.389	64.846	65.301	65.506	0.205	66.675
				3A	0.000	66.675	66.386	...	65.300	65.185	0.115	64.155	3B	64.389	64.637	65.301	65.453	0.152	66.675
2⅝-16 or 2.625-16	UN	66.675	1.588	2A	0.044	66.631	66.394	...	65.600	65.461	0.139	64.740	2B	64.948	65.303	65.644	65.826	0.182	66.675
				3A	0.000	66.675	66.437	...	65.643	65.540	0.103	64.783	3B	64.948	65.171	65.644	65.780	0.136	66.675
2⅝-20 or 2.625-20	UN	66.675	1.270	2A	0.039	66.636	66.432	...	65.811	65.682	0.129	65.126	2B	65.304	65.582	65.850	66.017	0.167	66.675
				3A	0.000	66.675	66.470	...	65.849	65.753	0.096	65.164	3B	65.304	65.498	65.850	65.976	0.126	66.675
2¾-4 or 2.750-4	UNC	69.850	6.350	1A	0.083	69.768	68.862	...	65.643	65.243	0.400	62.207	1B	62.967	63.931	65.726	66.248	0.522	69.850
				2A	0.083	69.768	69.165	68.862	65.643	65.378	0.265	62.207	2B	62.967	63.931	65.726	66.073	0.347	69.850
				3A	0.000	69.850	69.246	...	65.725	65.525	0.200	62.288	3B	62.967	63.738	65.726	65.986	0.260	69.850
2¾-6 or 2.750-6	UN	69.850	4.233	2A	0.070	69.781	69.320	...	67.030	66.800	0.230	64.742	2B	65.278	66.040	67.100	67.401	0.301	69.850
				3A	0.000	69.850	69.388	...	67.099	66.927	0.172	64.811	3B	65.278	65.775	67.100	67.325	0.225	69.850

(Notes follow at end of table)

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
2¾-8 or 2.750-8	UN	69.850	3.175	2A	0.064	69.786	69.406	69.215	67.724	67.514	0.210	66.007	2B	66.421	67.056	67.788	68.061	0.273	69.850
				3A	0.000	69.850	69.469	...	67.787	67.628	0.159	66.070	3B	66.421	66.794	67.788	67.993	0.205	69.850
2¾-12 or 2.750-12	UN	69.850	2.117	2A	0.049	69.801	69.513	...	68.427	68.271	0.156	67.282	2B	67.564	68.021	68.476	68.681	0.205	69.850
				3A	0.000	69.850	69.561	...	68.475	68.360	0.115	67.330	3B	67.564	67.812	68.476	68.628	0.152	69.850
2¾-16 or 2.750-16	UN	69.850	1.588	2A	0.044	69.806	69.569	...	68.775	68.636	0.139	67.915	2B	68.123	68.478	68.819	69.001	0.182	69.850
				3A	0.000	69.850	69.612	...	68.818	68.715	0.103	67.958	3B	68.123	68.346	68.819	68.955	0.136	69.850
2¾-20 or 2.750-20	UN	69.850	1.270	2A	0.039	69.811	69.607	...	68.986	68.857	0.129	68.301	2B	68.479	68.757	69.025	69.192	0.167	69.850
				3A	0.000	69.850	69.645	...	69.024	68.928	0.096	68.339	3B	68.479	68.673	69.025	69.151	0.126	69.850
2⅞-6 or 2.875-6	UN	73.025	4.233	2A	0.072	72.953	72.492	...	70.203	69.970	0.233	67.915	2B	68.453	69.215	70.275	70.578	0.303	73.025
				3A	0.000	73.025	72.563	...	70.274	70.099	0.175	67.986	3B	68.453	68.950	70.275	70.502	0.227	73.025
2⅞-8 or 2.875-8	UN	73.025	3.175	2A	0.064	72.961	72.581	...	70.899	70.686	0.213	69.182	2B	69.596	70.231	70.963	71.241	0.278	73.025
				3A	0.000	73.025	72.644	...	70.962	70.803	0.159	69.245	3B	69.596	69.969	70.963	71.170	0.207	73.025
2⅞-12 or 2.875-12	UN	73.025	2.117	2A	0.049	72.976	72.688	...	71.602	71.443	0.159	70.457	2B	70.739	71.196	71.651	71.859	0.208	73.025
				3A	0.000	73.025	72.736	...	71.650	71.532	0.118	70.505	3B	70.739	70.987	71.651	71.808	0.157	73.025
2⅞-16 or 2.875-16	UN	73.025	1.588	2A	0.044	72.981	72.744	...	71.950	71.809	0.141	71.090	2B	71.298	71.653	71.994	72.179	0.185	73.025
				3A	0.000	73.025	72.787	...	71.993	71.888	0.105	71.133	3B	71.298	71.521	71.994	72.133	0.139	73.025
2⅞-20 or 2.875-20	UN	73.025	1.270	2A	0.042	72.984	72.779	...	72.158	72.027	0.131	71.473	2B	71.654	71.932	72.200	72.372	0.172	73.025
				3A	0.000	73.025	72.820	...	72.199	72.101	0.098	71.514	3B	71.654	71.848	72.200	72.329	0.129	73.025
3-4 or 3.000-4	UNC	76.200	6.350	1A	0.083	76.118	75.212	...	71.993	71.585	0.408	68.557	1B	69.317	70.281	72.076	72.605	0.529	76.200
				2A	0.083	76.118	75.515	75.212	71.993	71.722	0.271	68.557	2B	69.317	70.281	72.076	72.428	0.352	76.200
				3A	0.000	76.200	75.596	...	72.075	71.872	0.203	68.638	3B	69.317	70.088	72.076	72.339	0.263	76.200
3-6 or 3.000-6	UN	76.200	4.233	2A	0.072	76.128	75.667	...	73.378	73.142	0.236	71.090	2B	71.628	72.390	73.450	73.756	0.306	76.200
				3A	0.000	76.200	75.738	...	73.449	73.272	0.177	71.161	3B	71.628	72.125	73.450	73.680	0.230	76.200
3-8 or 3.000-8	UN	76.200	3.175	2A	0.067	76.133	75.753	75.563	74.071	73.856	0.215	72.354	2B	72.771	73.406	74.138	74.419	0.281	76.200
				3A	0.000	76.200	75.819	...	74.137	73.975	0.162	72.420	3B	72.771	73.144	74.138	74.348	0.210	76.200
3-12 or 3.000-12	UN	76.200	2.117	2A	0.049	76.151	75.863	...	74.777	74.618	0.159	73.632	2B	73.914	74.371	74.826	75.034	0.208	76.200
				3A	0.000	76.200	75.911	...	74.825	74.707	0.118	73.680	3B	73.914	74.162	74.826	74.983	0.157	76.200
3-16 or 3.000-16	UN	76.200	1.588	2A	0.044	76.156	75.919	...	75.125	74.984	0.141	74.265	2B	74.473	74.828	75.169	75.354	0.185	76.200
				3A	0.000	76.200	75.962	...	75.168	75.063	0.105	74.308	3B	74.473	74.696	75.169	75.308	0.139	76.200
3-20 or 3.000-20	UN	76.200	1.270	2A	0.042	76.159	75.954	...	75.333	75.202	0.131	74.648	2B	74.829	75.107	75.375	75.547	0.172	76.200
				3A	0.000	76.200	75.995	...	75.374	75.276	0.098	74.689	3B	74.829	75.023	75.375	75.504	0.129	76.200
3⅛-6 or 3.125-6	UN	79.375	4.233	2A	0.072	79.303	78.842	...	76.553	76.315	0.238	74.265	2B	74.803	75.565	76.625	76.934	0.309	79.375
				3A	0.000	79.375	79.913	...	76.624	76.447	0.177	74.336	3B	74.803	75.300	76.625	76.857	0.232	79.375
3⅛-8 or 3.125-8	UN	79.375	3.175	2A	0.067	79.308	78.928	...	77.246	77.029	0.217	75.529	2B	75.946	76.581	77.313	77.597	0.284	79.375
				3A	0.000	79.375	78.994	...	77.312	77.150	0.162	75.595	3B	75.946	76.319	77.313	77.525	0.212	79.375
3⅛-12 or 3.125-12	UN	79.375	2.117	2A	0.049	79.326	79.038	...	77.952	77.793	0.159	76.807	2B	77.089	77.546	78.001	78.209	0.208	79.375
				3A	0.000	79.375	79.086	...	78.000	77.882	0.118	76.855	3B	77.089	77.337	78.001	78.158	0.157	79.375
3⅛-16 or 3.125-16	UN	79.375	1.588	2A	0.044	79.331	79.094	...	78.300	78.159	0.141	77.440	2B	77.648	78.003	78.344	78.529	0.185	79.375
				3A	0.000	79.375	79.137	...	78.343	78.238	0.105	77.483	3B	77.648	77.871	78.344	78.483	0.139	79.375

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)								Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
3¼-4 or 3.250-4	UNC	82.550	6.350	1A	0.085	82.466	81.560	...	78.341	77.928	0.413	74.905	1B	75.667	76.631	78.426	78.963	0.537	82.550
				2A	0.085	82.466	81.862	81.560	78.341	78.065	0.276	74.905	2B	75.667	76.631	78.426	78.783	0.357	82.550
				3A	0.000	82.550	81.946	...	78.425	78.217	0.208	74.988	3B	75.667	76.438	78.426	78.694	0.268	82.550
3¼-6 or 3.250-6	UN	82.550	4.233	2A	0.072	82.478	82.017	...	79.728	79.487	0.241	77.440	2B	77.978	78.740	79.800	80.111	0.311	82.550
				3A	0.000	82.550	82.088	...	79.799	79.619	0.180	77.511	3B	77.978	78.475	79.800	80.032	0.232	82.550
3¼-8 or 3.250-8	UN	82.550	3.175	2A	0.067	82.483	82.103	81.913	80.421	80.201	0.220	78.704	2B	79.121	79.756	80.488	80.774	0.286	82.550
				3A	0.000	82.550	82.169	...	80.487	80.323	0.164	78.770	3B	79.121	79.494	80.488	80.703	0.215	82.550
3¼-12 or 3.250-12	UN	82.550	2.117	2A	0.049	82.501	82.213	...	81.127	80.968	0.159	79.982	2B	80.264	80.721	81.176	81.384	0.208	82.550
				3A	0.000	82.550	82.261	...	81.175	81.057	0.118	80.030	3B	80.264	80.512	81.176	81.333	0.157	82.550
3¼-16 or 3.250-16	UN	82.550	1.588	2A	0.044	82.506	82.269	...	81.475	81.334	0.141	80.615	2B	80.823	81.178	81.519	81.704	0.185	82.550
				3A	0.000	82.550	82.312	...	81.518	81.413	0.105	80.658	3B	80.823	81.046	81.519	81.658	0.139	82.550
3⅜-6 or 3.375-6	UN	85.725	4.233	2A	0.075	85.651	85.190	...	82.900	82.660	0.240	80.612	2B	81.153	81.915	82.975	83.289	0.314	85.725
				3A	0.000	85.725	85.263	...	82.974	82.792	0.182	80.686	3B	81.153	81.650	82.975	83.210	0.235	85.725
3⅜-8 or 3.375-8	UN	85.725	3.175	2A	0.067	85.658	85.278	...	83.596	83.373	0.223	81.879	2B	82.296	82.931	83.663	83.952	0.289	85.725
				3A	0.000	85.725	85.344	...	83.662	83.495	0.167	81.945	3B	82.296	82.669	83.663	83.878	0.215	85.725
3⅜-12 or 3.375-12	UN	85.725	2.117	2A	0.049	85.676	85.388	...	84.302	84.141	0.161	83.157	2B	83.439	83.896	84.351	84.564	0.213	85.725
				3A	0.000	85.725	85.436	...	84.350	84.229	0.121	83.205	3B	83.439	83.687	84.351	84.510	0.159	85.725
3⅜-16 or 3.375-16	UN	85.725	1.588	2A	0.044	85.681	85.444	...	84.650	84.504	0.146	83.790	2B	83.998	84.353	84.694	84.884	0.190	85.725
				3A	0.000	85.725	85.487	...	84.693	84.585	0.108	83.833	3B	83.998	84.221	84.694	84.836	0.142	85.725
3½-4 or 3.500-4	UNC	88.900	6.350	1A	0.085	88.816	87.910	...	84.691	84.270	0.421	81.255	1B	82.017	82.981	84.776	85.321	0.545	88.900
				2A	0.085	88.816	88.212	87.910	84.691	84.412	0.279	81.255	2B	82.017	82.981	84.776	85.138	0.362	88.900
				3A	0.000	88.900	88.296	...	84.775	84.565	0.210	81.338	3B	82.017	82.788	84.776	85.049	0.273	88.900
3½-6 or 3.500-6	UN	88.900	4.233	2A	0.075	88.826	88.365	...	86.075	85.832	0.243	83.787	2B	84.328	85.090	86.150	86.466	0.316	88.900
				3A	0.000	88.900	88.438	...	86.149	85.967	0.182	83.861	3B	84.328	84.825	86.150	86.387	0.237	88.900
3½-8 or 3.500-8	UN	88.900	3.175	2A	0.067	88.833	88.453	88.263	86.771	86.548	0.223	85.054	2B	85.471	86.106	86.838	87.129	0.291	88.900
				3A	0.000	88.900	88.519	...	86.837	86.670	0.167	85.120	3B	85.471	85.844	86.838	87.055	0.217	88.900
3½-12 or 3.500-12	UN	88.900	2.117	2A	0.049	88.851	88.563	...	87.477	87.316	0.161	86.332	2B	86.614	87.071	87.526	87.739	0.213	88.900
				3A	0.000	88.900	88.611	...	87.525	87.404	0.124	86.380	3B	86.614	86.862	87.526	87.685	0.159	88.900
3½-16 or 3.500-16	UN	88.900	1.588	2A	0.044	88.856	88.619	...	87.825	87.679	0.146	86.965	2B	87.173	87.528	87.869	88.059	0.190	88.900
				3A	0.000	88.900	88.662	...	87.868	87.760	0.108	87.008	3B	87.173	87.396	87.869	88.011	0.142	88.900
3⅝-6 or 3.625-6	UN	92.075	4.233	2A	0.075	92.001	91.540	...	89.250	89.005	0.245	86.962	2B	87.503	88.265	89.325	89.644	0.319	92.075
				3A	0.000	92.075	91.613	...	89.324	89.139	0.185	87.036	3B	87.503	88.000	89.325	89.565	0.240	92.075
3⅝-8 or 3.625-8	UN	92.075	3.175	2A	0.070	92.006	91.626	...	89.943	89.718	0.225	88.227	2B	88.646	89.281	90.013	90.307	0.294	92.075
				3A	0.000	92.075	91.694	...	90.012	89.843	0.169	88.295	3B	88.646	89.019	90.013	90.233	0.220	92.075
3⅝-12 or 3.625-12	UN	92.075	2.117	2A	0.049	92.026	91.738	...	90.652	90.491	0.161	89.507	2B	89.789	90.246	90.701	90.914	0.213	92.075
				3A	0.000	92.075	91.786	...	90.700	90.579	0.121	89.555	3B	89.789	90.037	90.701	90.860	0.159	92.075
3⅝-16 or 3.625-16	UN	92.075	1.588	2A	0.044	92.031	91.794	...	91.000	90.854	0.146	90.140	2B	90.348	90.703	91.044	91.234	0.190	92.075
				3A	0.000	92.075	91.837	...	91.043	90.935	0.108	90.183	3B	90.348	90.571	91.044	91.186	0.142	92.075

(Notes follow at end of table)

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
3¾-4 or 3.750-4	UNC	95.250	6.350	1A	0.088	95.163	94.257	...	91.038	90.612	0.426	87.602	1B	88.367	89.331	91.126	91.678	0.552	95.250
				2A	0.088	95.163	94.560	94.257	91.038	90.755	0.283	87.602	2B	88.367	89.331	91.126	91.493	0.367	95.250
				3A	0.000	95.250	94.646	...	91.125	90.912	0.213	87.688	3B	88.367	89.138	91.126	91.401	0.275	95.250
3¾-6 or 3.750-6	UN	95.250	4.233	2A	0.075	95.176	94.715	...	92.425	92.177	0.248	90.137	2B	90.678	91.440	92.500	92.821	0.321	95.250
				3A	0.000	95.250	94.788	...	92.499	92.314	0.185	90.211	3B	90.678	91.175	92.500	92.740	0.240	95.250
3¾-8 or 3.750-8	UN	95.250	3.175	2A	0.070	95.181	94.801	94.610	93.118	92.891	0.227	91.402	2B	91.821	92.456	93.188	93.484	0.296	95.250
				3A	0.000	95.250	94.869	...	93.187	93.018	0.169	91.470	3B	91.821	92.194	93.188	93.411	0.223	95.250
3¾-12 or 3.750-12	UN	95.250	2.117	2A	0.049	95.201	94.913	...	93.827	93.666	0.161	92.682	2B	92.964	93.421	93.876	94.089	0.213	95.250
				3A	0.000	95.250	94.961	...	93.875	93.754	0.121	92.730	3B	92.964	93.212	93.876	94.035	0.159	95.250
3¾-16 or 3.750-16	UN	95.250	1.588	2A	0.044	95.206	94.969	...	94.175	94.029	0.146	93.315	2B	93.523	93.878	94.219	94.409	0.190	95.250
				3A	0.000	95.250	95.012	...	94.218	94.110	0.108	93.358	3B	93.523	93.746	94.219	94.361	0.142	95.250
3⅞-6 or 3.875-6	UN	98.425	4.233	2A	0.078	98.348	97.887	...	95.597	95.347	0.250	93.309	2B	93.853	94.615	95.675	95.999	0.324	98.425
				3A	0.000	98.425	97.963	...	95.674	95.487	0.187	93.386	3B	93.853	94.350	95.675	95.918	0.243	98.425
3⅞-8 or 3.875-8	UN	98.425	3.175	2A	0.070	98.356	97.976	...	96.293	96.063	0.230	94.577	2B	94.996	95.631	96.363	96.662	0.299	98.425
				3A	0.000	98.425	98.044	...	96.362	96.190	0.172	94.645	3B	94.996	95.369	96.363	96.586	0.223	98.425
3⅞-12 or 3.875-12	UN	98.425	2.117	2A	0.051	98.374	98.085	...	97.000	96.835	0.165	95.855	2B	96.139	96.596	97.051	97.266	0.215	98.425
				3A	0.000	98.425	98.136	...	97.050	96.927	0.123	95.905	3B	96.139	96.387	97.051	97.213	0.162	98.425
3⅞-16 or 3.875-16	UN	98.425	1.588	2A	0.046	98.379	98.141	...	97.348	97.199	0.149	96.487	2B	96.698	97.053	97.394	97.586	0.192	98.425
				3A	0.000	98.425	98.187	...	97.393	97.282	0.111	96.533	3B	96.698	96.921	97.394	97.538	0.144	98.425
4-4 or 4.000-4	UNC	101.600	6.350	1A	0.088	101.513	100.607	...	97.388	96.957	0.431	93.952	1B	94.717	95.681	97.476	98.036	0.560	101.600
				2A	0.088	101.513	100.910	100.607	97.388	97.102	0.286	93.952	2B	94.717	95.681	97.476	97.848	0.372	101.600
				3A	0.000	101.600	100.996	...	97.475	97.260	0.215	94.038	3B	94.717	95.488	97.476	97.756	0.280	101.600
4-6 or 4.000-6	UN	101.600	4.233	2A	0.078	101.523	101.062	...	98.772	98.522	0.250	96.484	2B	97.028	97.790	98.850	99.176	0.326	101.600
				3A	0.000	101.600	101.138	...	98.849	98.662	0.187	96.561	3B	97.028	97.525	98.850	99.095	0.245	101.600
4-8 or 4.000-8	UN	101.600	3.175	2A	0.070	101.531	101.151	100.960	99.468	99.238	0.230	97.752	2B	98.171	98.806	99.538	99.839	0.301	101.600
				3A	0.000	101.600	101.219	...	99.537	99.365	0.172	97.820	3B	98.171	98.544	99.538	99.763	0.225	101.600
4-12 or 4.000-12	UN	101.600	2.117	2A	0.051	101.549	101.260	...	100.175	100.010	0.165	99.030	2B	99.314	99.771	100.226	100.441	0.215	101.600
				3A	0.000	101.600	101.311	...	100.225	100.102	0.123	99.080	3B	99.314	99.562	100.226	100.388	0.162	101.600
4-16 or 4.000-16	UN	101.600	1.588	2A	0.046	101.554	101.316	...	100.523	100.374	0.149	99.662	2B	99.873	100.228	100.569	100.761	0.192	101.600
				3A	0.000	101.600	101.362	...	100.568	100.457	0.111	99.708	3B	99.873	100.096	100.569	100.713	0.144	101.600
4⅛-6 or 4.125-6	UN	104.775	4.233	2A	0.078	104.698	104.237	...	101.947	101.694	0.253	99.659	2B	100.203	100.965	102.025	102.354	0.329	104.775
				3A	0.000	104.775	104.313	...	102.024	101.834	0.190	99.736	3B	100.203	100.700	102.025	102.270	0.245	104.775
4⅛-12 or 4.125-12	UN	104.775	2.117	2A	0.051	104.724	104.435	...	103.350	103.185	0.165	102.205	2B	102.489	102.946	103.401	103.616	0.215	104.775
				3A	0.000	104.775	104.486	...	103.400	103.277	0.123	102.255	3B	102.489	102.737	103.401	103.563	0.162	104.775
4⅛-16 or 4.125-16	UN	104.775	1.588	2A	0.046	104.729	104.491	...	103.698	103.549	0.149	102.837	2B	103.048	103.403	103.744	103.936	0.192	104.775
				3A	0.000	104.775	104.537	...	103.743	103.632	0.111	102.883	3B	103.048	103.271	103.744	103.888	0.144	104.775
4¼-4 or 4.250-4	UN	107.950	6.350	2A	0.088	107.863	107.260	...	103.738	103.447	0.291	100.302	2B	101.067	102.031	103.826	104.203	0.377	107.950
				3A	0.000	107.950	107.346	...	103.825	103.607	0.218	100.388	3B	101.067	101.838	103.826	104.109	0.283	107.950
4¼-6 or 4.250-6	UN	107.950	4.233	2A	0.078	107.873	107.412	...	105.122	104.867	0.255	102.834	2B	103.378	104.140	105.200	105.531	0.331	107.950
				3A	0.000	107.950	107.488	...	105.199	105.009	0.190	102.911	3B	103.378	103.875	105.200	105.448	0.248	107.950

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
4¼-12 or 4.250-12	UN	107.950	2.117	2A	0.051	107.899	107.610	...	106.525	106.360	0.165	105.380	2B	105.664	106.121	106.576	106.791	0.215	107.950
				3A	0.000	107.950	107.661	...	106.575	106.452	0.123	105.430	3B	105.664	105.912	106.576	106.738	0.162	107.950
4¼-16 or 4.250-16	UN	107.950	1.588	2A	0.046	107.904	107.666	...	106.873	106.724	0.149	106.012	2B	106.223	106.578	106.919	107.111	0.192	107.950
				3A	0.000	107.950	107.712	...	106.918	106.807	0.111	106.058	3B	106.223	106.446	106.919	107.063	0.144	107.950
4⅜-6 or 4.375-6	UN	111.125	4.233	2A	0.078	111.048	110.587	...	108.297	108.042	0.255	106.009	2B	106.553	107.315	108.375	108.709	0.334	111.125
				3A	0.000	111.125	110.663	...	108.374	108.182	0.192	106.086	3B	106.553	107.050	108.375	108.625	0.250	111.125
4⅜-12 or 4.375-12	UN	111.125	2.117	2A	0.051	111.074	110.785	...	109.700	109.535	0.165	108.555	2B	108.839	109.296	109.751	109.966	0.215	111.125
				3A	0.000	111.125	110.836	...	109.750	109.627	0.123	108.605	3B	108.839	109.087	109.751	109.913	0.162	111.125
4⅜-16 or 4.375-16	UN	111.125	1.588	2A	0.046	111.079	110.841	...	110.048	109.899	0.149	109.187	2B	109.398	109.753	110.094	110.286	0.192	111.125
				3A	0.000	111.125	110.887	...	110.093	109.982	0.111	109.233	3B	109.398	109.621	110.094	110.238	0.144	111.125
4½-4 or 4.500-4	UN	114.300	6.350	2A	0.090	114.211	113.607	...	110.086	109.792	0.294	106.650	2B	107.417	108.381	110.176	110.558	0.382	114.300
				3A	0.000	114.300	113.696	...	110.175	109.955	0.220	106.738	3B	107.417	108.188	110.176	110.462	0.286	114.300
4½-6 or 4.500-6	UN	114.300	4.233	2A	0.080	114.221	113.759	...	111.470	111.212	0.258	109.182	2B	109.728	110.490	111.550	111.887	0.337	114.300
				3A	0.000	114.300	113.838	...	111.549	111.354	0.195	109.261	3B	109.728	110.225	111.550	111.800	0.250	114.300
4½-12 or 4.500-12	UN	114.300	2.117	2A	0.051	114.249	113.960	...	112.875	112.710	0.165	111.730	2B	112.014	112.471	112.926	113.141	0.215	114.300
				3A	0.000	114.300	114.011	...	112.925	112.802	0.123	111.780	3B	112.014	112.262	112.926	113.088	0.162	114.300
4½-16 or 4.500-16	UN	114.300	1.588	2A	0.046	114.254	114.016	...	113.223	113.074	0.149	112.362	2B	112.573	112.928	113.269	113.461	0.192	114.300
				3A	0.000	114.300	114.062	...	113.268	113.157	0.111	112.408	3B	112.573	112.796	113.269	113.413	0.144	114.300
4⅝-6 or 4.625-6	UN	117.475	4.233	2A	0.080	117.396	116.934	...	114.645	114.384	0.261	112.357	2B	112.903	113.665	114.725	115.062	0.337	117.475
				3A	0.000	117.475	117.013	...	114.724	114.529	0.195	112.436	3B	112.903	113.400	114.725	114.978	0.253	117.475
4⅝-12 or 4.625-12	UN	117.475	2.117	2A	0.051	117.424	117.135	...	116.050	115.880	0.170	114.905	2B	115.189	115.646	116.101	116.321	0.220	117.475
				3A	0.000	117.475	117.186	...	116.100	115.974	0.126	114.955	3B	115.189	115.437	116.101	116.268	0.167	117.475
4⅝-16 or 4.625-16	UN	117.475	1.588	2A	0.046	117.429	117.191	...	116.398	116.244	0.154	115.537	2B	115.748	116.103	116.444	116.644	0.200	117.475
				3A	0.000	117.475	117.237	...	116.443	116.330	0.113	115.583	3B	115.748	115.971	116.444	116.593	0.149	117.475
4¾-4 or 4.750-4	UN	120.650	6.350	2A	0.090	120.561	119.957	...	116.436	116.139	0.297	113.000	2B	113.767	114.731	116.526	116.913	0.387	120.650
				3A	0.000	120.650	120.046	...	116.525	116.302	0.223	113.088	3B	113.767	114.538	116.526	116.814	0.288	120.650
4¾-6 or 4.750-6	UN	120.650	4.233	2A	0.080	120.571	120.109	...	117.820	117.559	0.261	115.532	2B	116.078	116.840	117.900	118.239	0.339	120.650
				3A	0.000	120.650	120.188	...	117.899	117.704	0.195	115.611	3B	116.078	116.575	117.900	118.155	0.255	120.650
4¾-12 or 4.750-12	UN	120.650	2.117	2A	0.051	120.599	120.310	...	119.225	119.055	0.170	118.080	2B	118.364	118.821	119.276	119.496	0.220	120.650
				3A	0.000	120.650	120.361	...	119.275	119.149	0.126	118.130	3B	118.364	118.612	119.276	119.443	0.167	120.650
4¾-16 or 4.750-16	UN	120.650	1.588	2A	0.046	120.604	120.366	...	119.573	119.419	0.154	118.712	2B	118.923	119.278	119.619	119.819	0.200	120.650
				3A	0.000	120.650	120.412	...	119.618	119.505	0.113	118.758	3B	118.923	119.146	119.619	119.768	0.149	120.650
4⅞-6 or 4.875-6	UN	123.825	4.233	2A	0.080	123.746	123.284	...	120.995	120.732	0.263	118.707	2B	119.253	120.015	121.075	121.417	0.342	123.825
				3A	0.000	123.825	123.363	...	121.074	120.877	0.197	118.786	3B	119.253	119.750	121.075	121.330	0.255	123.825
4⅞-12 or 4.875-12	UN	123.825	2.117	2A	0.051	123.774	123.485	...	122.400	122.230	0.170	121.255	2B	121.539	121.996	122.451	122.671	0.220	123.825
				3A	0.000	123.825	123.536	...	122.450	122.324	0.126	121.305	3B	121.539	121.787	122.451	122.618	0.167	123.825
4⅞-16 or 4.875-16	UN	123.825	1.588	2A	0.046	123.779	123.541	...	122.748	122.594	0.154	121.887	2B	122.098	122.453	122.794	122.994	0.200	123.825
				3A	0.000	123.825	123.587	...	122.793	122.680	0.113	121.933	3B	122.098	122.321	122.794	122.943	0.149	123.825

(Notes follow at end of table)

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance	Max. (4) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
5-4 or 5.000-4	UN	127.000	6.350	2A	0.093	126.908	126.305	...	122.783	122.482	0.301	119.347	2B	120.117	121.081	122.876	123.266	0.390	127.000
				3A	0.000	127.000	126.396	...	122.875	122.649	0.226	119.438	3B	120.117	120.888	122.876	123.169	0.293	127.000
5-6 or 5.000-6	UN	127.000	4.233	2A	0.080	126.921	126.459	...	124.170	123.904	0.266	121.882	2B	122.428	123.190	124.250	124.594	0.344	127.000
				3A	0.000	127.000	126.538	...	124.249	124.052	0.197	121.961	3B	122.428	122.925	124.250	124.508	0.258	127.000
5-12 or 5.000-12	UN	127.000	2.117	2A	0.051	126.949	126.660	...	125.575	125.405	0.170	124.430	2B	124.714	125.171	125.626	125.846	0.220	127.000
				3A	0.000	127.000	126.711	...	125.625	125.499	0.126	124.480	3B	124.714	124.962	125.626	125.793	0.167	127.000
5-16 or 5.000-16	UN	127.000	1.588	2A	0.046	126.954	126.716	...	125.923	125.769	0.154	125.062	2B	125.273	125.628	125.969	126.169	0.200	127.000
				3A	0.000	127.000	126.762	...	125.968	125.855	0.113	125.108	3B	125.273	125.496	125.969	126.118	0.149	127.000
5⅛-12 or 5.125-12	UN	130.175	2.117	2A	0.051	130.124	129.835	...	128.750	128.580	0.170	127.605	2B	127.889	128.346	128.801	129.021	0.220	130.175
				3A	0.000	130.175	129.886	...	128.800	128.674	0.126	127.655	3B	127.889	128.137	128.801	128.968	0.167	130.175
5⅛-16 or 5.125-16	UN	130.175	1.588	2A	0.046	130.129	129.891	...	129.098	128.944	0.154	128.237	2B	128.448	128.803	129.144	129.344	0.200	130.175
				3A	0.000	130.175	129.937	...	129.143	129.030	0.113	128.283	3B	128.448	128.671	129.144	129.293	0.149	130.175
5¼-4 or 5.250-4	UN	133.350	6.350	2A	0.093	133.258	132.655	...	129.133	128.829	0.304	125.697	2B	126.467	127.431	129.226	129.621	0.395	133.350
				3A	0.000	133.350	132.746	...	129.225	128.997	0.228	125.788	3B	126.467	127.238	129.226	129.522	0.296	133.350
5¼-12 or 5.250-12	UN	133.350	2.117	2A	0.051	133.299	133.010	...	131.925	131.755	0.170	130.780	2B	131.064	131.521	131.976	132.196	0.220	133.350
				3A	0.000	133.350	133.061	...	131.975	131.849	0.126	130.830	3B	131.064	131.312	131.976	132.143	0.167	133.350
5¼-16 or 5.250-16	UN	133.350	1.588	2A	0.046	133.304	133.066	...	132.273	132.119	0.154	131.412	2B	131.623	131.978	132.319	132.519	0.200	133.350
				3A	0.000	133.350	133.112	...	132.318	132.205	0.113	131.458	3B	131.623	131.846	132.319	132.468	0.149	133.350
5⅜-12 or 5.375-12	UN	136.525	2.117	2A	0.051	136.474	136.185	...	135.100	134.930	0.170	133.955	2B	134.239	134.696	135.151	135.371	0.220	136.525
				3A	0.000	136.525	136.236	...	135.150	135.024	0.126	134.005	3B	134.239	134.487	135.151	135.318	0.167	136.525
5⅜-16 or 5.375-16	UN	136.525	1.588	2A	0.046	136.479	136.241	...	135.448	135.294	0.154	134.587	2B	134.798	135.153	135.494	135.694	0.200	136.525
				3A	0.000	136.525	136.287	...	135.493	135.380	0.113	134.633	3B	134.798	135.021	135.494	135.643	0.149	136.525
5½-4 or 5.500-4	UN	139.700	6.350	2A	0.093	139.608	139.005	...	135.483	135.177	0.306	132.047	2B	132.817	133.781	135.576	135.976	0.400	139.700
				3A	0.000	139.700	139.096	...	135.575	135.344	0.231	132.138	3B	132.817	133.588	135.576	135.874	0.298	139.700
5½-12 or 5.500-12	UN	139.700	2.117	2A	0.051	139.649	139.360	...	138.275	138.105	0.170	137.130	2B	137.414	137.871	138.326	138.546	0.220	139.700
				3A	0.000	139.700	139.411	...	138.325	138.199	0.126	137.180	3B	137.414	137.662	138.326	138.493	0.167	139.700
5½-16 or 5.500-16	UN	139.700	1.588	2A	0.046	139.654	139.416	...	138.623	138.469	0.154	137.762	2B	137.973	138.328	138.669	138.869	0.200	139.700
				3A	0.000	139.700	139.462	...	138.668	138.555	0.113	137.808	3B	137.973	138.196	138.669	138.818	0.149	139.700
5⅝-12 or 5.625-12	UN	142.875	2.117	2A	0.054	142.821	142.533	...	141.447	141.273	0.174	140.302	2B	140.589	141.046	141.501	141.729	0.228	142.875
				3A	0.000	142.875	142.586	...	141.500	141.369	0.131	140.355	3B	140.589	140.837	141.501	141.671	0.170	142.875
5⅝-16 or 5.625-16	UN	142.875	1.588	2A	0.049	142.826	142.588	...	141.795	141.639	0.156	140.934	2B	141.148	141.503	141.844	142.049	0.205	142.875
				3A	0.000	142.875	142.637	...	141.843	141.725	0.118	140.983	3B	141.148	141.371	141.844	141.998	0.154	142.875
5¾-4 or 5.750-4	UN	146.050	6.350	2A	0.095	145.956	145.352	...	141.831	141.522	0.309	138.394	2B	139.167	140.131	141.926	142.328	0.402	146.050
				3A	0.000	146.050	145.446	...	141.925	141.692	0.233	138.488	3B	139.167	139.938	141.926	142.227	0.301	146.050
5¾-12 or 5.750-12	UN	146.050	2.117	2A	0.054	145.996	145.708	...	144.622	144.448	0.174	143.477	2B	143.764	144.221	144.676	144.904	0.228	146.050
				3A	0.000	146.050	145.761	...	144.675	144.544	0.131	143.530	3B	143.764	144.012	144.676	144.846	0.170	146.050
5¾-16 or 5.750-16	UN	146.050	1.588	2A	0.049	146.001	145.763	...	144.970	144.814	0.156	144.109	2B	144.323	144.678	145.019	145.224	0.205	146.050
				3A	0.000	146.050	145.812	...	145.018	144.900	0.118	144.158	3B	144.323	144.546	145.019	145.173	0.154	146.050

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TABLE C1 LIMITS OF SIZE FOR STANDARD SERIES (UN/UNR) THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)									Internal (1)						
						Major Diameter			Pitch Diameter			UNR Minor Diam. Max. (4) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Min. (3)	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
5⅞-12 or 5.875-12	UN	149.225	2.117	2A	0.054	149.171	148.883	...	147.797	147.623	0.174	146.652	2B	146.939	147.396	147.851	148.079	0.228	149.225
				3A	0.000	149.225	148.936	...	147.850	147.719	0.131	146.705	3B	146.939	147.187	147.851	148.021	0.170	149.225
5⅞-16 or 5.875-16	UN	149.225	1.588	2A	0.049	149.176	148.938	...	148.145	147.989	0.156	147.284	2B	147.498	147.853	148.194	148.399	0.205	149.225
				3A	0.000	149.225	148.987	...	148.193	148.075	0.118	147.333	3B	147.498	147.721	148.194	148.348	0.154	149.225
6-4 or 6.000-4	UN	152.400	6.350	2A	0.095	152.306	151.702	...	148.181	147.867	0.314	144.744	2B	145.517	146.481	148.276	148.683	0.407	152.400
				3A	0.000	152.400	151.796	...	148.275	148.039	0.236	144.838	3B	145.517	146.288	148.276	148.579	0.303	152.400
6-12 or 6.000-12	UN	152.400	2.117	2A	0.054	152.346	152.058	...	150.972	150.798	0.174	149.827	2B	150.114	150.571	151.026	151.254	0.228	152.400
				3A	0.000	152.400	152.111	...	151.025	150.894	0.131	149.880	3B	150.114	150.362	151.026	151.196	0.170	152.400
6-16 or 6.000-16	UN	152.400	1.588	2A	0.049	152.351	152.113	...	151.320	151.164	0.156	150.459	2B	150.673	151.028	151.369	151.574	0.205	152.400
				3A	0.000	152.400	152.162	...	151.368	151.250	0.118	150.508	3B	150.673	150.896	151.369	151.523	0.154	152.400

GENERAL NOTE:
Series designation shown indicates the UN thread form; however, the UNR thread form may be specified by substituting UNR in place of UN in all designations for external use only.

NOTES:
(1) Thread classes may be combined. See para. 4.2 of ASME B1.1.
(2) For Class 2A threads having an additive finish, the maximum major and pitch diameters, after coating, may equal the basic sizes, whose values are the same as the maximum values shown for Class 3A in these columns. See paras. 4.1.1 and 4.1.3 of ASME B1.1.
(3) For unfinished hot material, not including standard fasteners with rolled threads.
(4) UN series external thread maximum minor diameter is basic (D_1 in Section 11) for Class 3A and basic minus allowance for Classes 1A and 2A.

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TABLE C2 LIMITS OF SIZE FOR SELECTED COMBINATIONS OF UNS/UNRS SERIES THREADS, mm

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)								Internal (1)						
						Major Diameter		Pitch Diameter			UNR Minor Diam.		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Max. (2)	Min.	Tolerance	Max. (3) (Ref.)	Class	Min.	Max.	Min.	Max.	Tolerance	Min.
10-28 or 0.1900-28	UNS	4.826	0.907	2A	0.026	4.800	4.636	4.211	4.128	0.083	3.719	2B	3.836	4.064	4.237	4.345	0.108	4.826
10-36 or 0.1900-36	UNS	4.826	0.706	2A	0.024	4.803	4.664	4.345	4.270	0.075	3.962	2B	4.064	4.216	4.369	4.467	0.098	4.826
10-40 or 0.1900-40	UNS	4.826	0.635	2A	0.024	4.803	4.674	4.391	4.318	0.073	4.044	2B	4.141	4.292	4.415	4.508	0.093	4.826
10-48 or 0.1900-48	UNS	4.826	0.529	2A	0.022	4.805	4.692	4.462	4.397	0.065	4.176	2B	4.242	4.368	4.484	4.569	0.085	4.826
10-56 or 0.1900-56	UNS	4.826	0.454	2A	0.019	4.808	4.705	4.513	4.451	0.062	4.270	2B	4.344	4.445	4.532	4.612	0.080	4.826
12-36 or 0.2160-36	UNS	5.486	0.706	2A	0.024	5.463	5.324	5.006	4.931	0.075	4.625	2B	4.725	4.876	5.030	5.128	0.098	5.487
12-40 or 0.2160-40	UNS	5.486	0.635	2A	0.023	5.463	5.334	5.052	4.979	0.073	4.661	2B	4.801	4.953	5.075	5.168	0.093	5.487
12-48 or 0.2160-48	UNS	5.486	0.529	2A	0.021	5.466	5.352	5.123	5.058	0.065	4.836	2B	4.903	5.029	5.144	5.229	0.085	5.487
12-56 or 0.2160-56	UNS	5.486	0.454	2A	0.019	5.468	5.365	5.173	5.111	0.062	4.930	2B	5.004	5.105	5.192	5.273	0.081	5.487
1/4-24 or 0.2500-24	UNS	6.350	1.058	2A	0.029	6.322	6.140	5.633	5.540	0.093	5.062	2B	5.207	5.461	5.662	5.783	0.121	6.350
1/4-27 or 0.2500-27	UNS	6.350	0.941	2A	0.026	6.324	6.155	5.712	5.624	0.088	5.204	2B	5.334	5.562	5.738	5.852	0.114	6.350
1/4-36 or 0.2500-36	UNS	6.350	0.706	2A	0.024	6.327	6.188	5.869	5.792	0.077	5.489	2B	5.588	5.740	5.893	5.994	0.101	6.350
1/4-40 or 0.2500-40	UNS	6.350	0.635	2A	0.024	6.327	6.198	5.915	5.842	0.073	5.570	2B	5.665	5.816	5.939	6.035	0.096	6.350
1/4-48 or 0.2500-48	UNS	6.350	0.529	2A	0.022	6.329	6.216	5.986	5.919	0.067	5.697	2B	5.766	5.892	6.008	6.098	0.090	6.350
1/4-56 or 0.2500-56	UNS	6.350	0.454	2A	0.021	6.329	6.226	6.035	5.969	0.066	5.791	2B	5.868	5.969	6.056	6.139	0.083	6.350
5/16-27 or 0.3125-27	UNS	7.937	0.941	2A	0.027	7.912	7.742	7.299	7.212	0.087	6.792	2B	6.909	7.137	7.326	7.439	0.113	7.938
5/16-36 or 0.3125-36	UNS	7.937	0.706	2A	0.024	7.914	7.775	7.457	7.379	0.078	7.074	2B	7.163	7.340	7.481	7.581	0.100	7.938
5/16-40 or 0.3125-40	UNS	7.937	0.635	2A	0.024	7.914	7.786	7.503	7.430	0.073	7.158	2B	7.239	7.391	7.527	7.622	0.095	7.938
5/16-48 or 0.3125-48	UNS	7.937	0.529	2A	0.021	7.917	7.803	7.574	7.506	0.068	7.287	2B	7.366	7.493	7.595	7.686	0.091	7.938
3/8-18 or 0.3750-18	UNS	9.525	1.411	2A	0.034	9.491	9.271	8.575	8.466	0.109	7.813	2B	8.001	8.331	8.609	8.750	0.141	9.525
3/8-27 or 0.3750-27	UNS	9.525	0.941	2A	0.029	9.497	9.327	8.884	8.794	0.090	8.377	2B	8.509	8.737	8.913	9.032	0.119	9.525
3/8-36 or 0.3750-36	UNS	9.525	0.706	2A	0.026	9.499	9.360	9.042	8.962	0.080	8.659	2B	8.763	8.940	9.068	9.174	0.106	9.525
3/8-40 or 0.3750-40	UNS	9.525	0.635	2A	0.024	9.502	9.373	9.090	9.012	0.078	8.745	2B	8.840	8.991	9.114	9.215	0.101	9.525
0.390-27	UNS	9.906	0.941	2A	0.029	9.878	9.708	9.265	9.175	0.090	8.758	2B	8.890	9.118	9.294	9.413	0.119	9.906
7/16-18 or 0.4375-18	UNS	11.112	1.411	2A	0.034	11.079	10.859	10.162	10.054	0.108	9.401	2B	9.576	9.906	10.196	10.337	0.141	11.113
7/16-24 or 0.4375-24	UNS	11.112	1.058	2A	0.029	11.084	10.902	10.396	10.300	0.096	9.825	2B	9.957	10.210	10.425	10.548	0.123	11.113
7/16-27 or 0.4375-27	UNS	11.112	0.941	2A	0.029	11.084	10.915	10.472	10.381	0.091	9.964	2B	10.084	10.312	10.501	10.619	0.118	11.113
1/2-12 or 0.5000-12	UNS	12.700	2.117	2A	0.041	12.659	12.370	11.285	11.149	0.136	10.140	2B	10.414	10.871	11.326	11.503	0.177	12.700
				3A	0.000	12.700	12.411	11.325	11.225	0.100	10.180	3B	10.414	10.726	11.326	11.457	0.131	12.700
1/2-14 or 0.5000-14	UNS	12.700	1.814	2A	0.039	12.661	12.401	11.483	11.357	0.126	10.503	2B	10.745	11.125	11.522	11.686	0.164	12.700
1/2-18 or 0.5000-18	UNS	12.700	1.411	2A	0.034	12.666	12.446	11.750	11.639	0.111	10.988	2B	11.176	11.506	11.784	11.930	0.146	12.700
1/2-24 or 0.5000-24	UNS	12.700	1.058	2A	0.031	12.669	12.487	11.981	11.883	0.098	11.410	2B	11.557	11.811	12.012	12.141	0.129	12.700
1/2-27 or 0.5000-27	UNS	12.700	0.941	2A	0.029	12.672	12.502	12.059	11.966	0.093	11.552	2B	11.684	11.912	12.088	12.209	0.121	12.700
9/16-14 or 0.5625-14	UNS	14.287	1.814	2A	0.039	14.249	13.988	13.070	12.944	0.126	12.090	2B	12.319	12.725	13.109	13.274	0.165	14.288
9/16-27 or 0.5625-27	UNS	14.287	0.941	2A	0.029	14.259	14.090	13.647	13.554	0.093	13.139	2B	13.259	13.487	13.676	13.797	0.121	14.288
5/8-14 or 0.6250-14	UNS	15.875	1.814	2A	0.039	15.836	15.576	14.658	14.529	0.129	13.678	2B	13.920	14.325	14.697	14.864	0.167	15.875
5/8-27 or 0.6250-27	UNS	15.875	0.941	2A	0.029	15.847	15.677	15.234	15.139	0.095	14.727	2B	14.859	15.087	15.263	15.389	0.126	15.875
3/4-14 or 0.7500-14	UNS	19.050	1.814	2A	0.039	19.011	18.751	17.833	17.704	0.129	16.853	2B	17.095	17.475	17.872	18.041	0.169	19.050
3/4-18 or 0.7500-18	UNS	19.050	1.411	2A	0.037	19.014	18.794	18.097	17.981	0.116	17.355	2B	17.526	17.856	18.134	18.285	0.151	19.050
3/4-24 or 0.7500-24	UNS	19.050	1.058	2A	0.031	19.019	18.837	18.331	18.228	0.103	17.760	2B	17.907	18.161	18.362	18.496	0.134	19.050
3/4-27 or 0.7500-27	UNS	19.050	0.941	2A	0.030	19.019	18.850	18.407	18.309	0.098	17.900	2B	18.034	18.262	18.438	18.567	0.129	19.050

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TABLE C2 LIMITS OF SIZE FOR SELECTED COMBINATIONS OF UNS/UNRS SERIES THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)								Internal (1)						
						Major Diameter		Pitch Diameter			UNR Minor Diam. Max. (3) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
7/8-10 or 0.8750-10	UNS	22.225	2.540	2A	0.046	22.179	21.852	20.528	20.376	0.152	19.157	2B	19.482	20.015	20.574	20.772	0.198	22.225
7/8-18 or 0.8750-18	UNS	22.225	1.411	2A	0.037	22.189	21.969	21.272	21.156	0.116	20.511	2B	20.701	21.031	21.309	21.460	0.151	22.225
7/8-24 or 0.8750-24	UNS	22.225	1.058	2A	0.031	22.194	22.012	21.506	21.403	0.103	20.935	2B	21.082	21.336	21.537	21.671	0.134	22.225
7/8-27 or 0.8750-27	UNS	22.225	0.941	2A	0.031	22.194	22.025	21.582	21.484	0.098	21.074	2B	21.209	21.437	21.613	21.742	0.129	22.225
1-10 or 1.0000-10	UNS	25.400	2.540	2A	0.046	25.354	25.027	23.703	23.546	0.157	22.332	2B	22.657	23.190	23.749	23.952	0.203	25.400
1-14 or 1.0000-14	UNS	25.400	1.814	1A	0.044	25.356	24.964	24.178	23.965	0.213	23.195	1B	23.445	23.825	24.222	24.498	0.276	25.400
				2A	0.044	25.356	25.096	24.178	24.037	0.141	23.195	2B	23.445	23.825	24.222	24.406	0.184	25.400
				3A	0.000	25.400	25.139	24.221	24.115	0.106	23.238	3B	23.445	23.660	24.222	24.358	0.136	25.400
1-18 or 1.0000-18	UNS	25.400	1.411	2A	0.037	25.364	25.144	24.447	24.329	0.118	23.686	2B	23.876	24.206	24.484	24.640	0.156	25.400
1-24 or 1.0000-24	UNS	25.400	1.058	2A	0.034	25.366	25.185	24.678	24.572	0.106	24.107	2B	24.257	24.511	24.712	24.851	0.139	25.400
1-27 or 1.0000-27	UNS	25.400	0.941	2A	0.031	25.369	25.200	24.757	24.656	0.101	24.249	2B	24.384	24.612	24.788	24.919	0.131	25.400
1 1/8-10 or 1.1250-10	UNS	28.575	2.540	2A	0.046	28.529	28.202	26.878	26.721	0.157	25.507	2B	25.832	26.365	26.924	27.127	0.203	28.575
1 1/8-14 or 1.1250-14	UNS	28.575	1.814	2A	0.042	28.534	28.273	27.355	27.222	0.133	26.375	2B	26.620	27.025	27.397	27.571	0.174	28.575
1 1/8-24 or 1.1250-24	UNS	28.575	1.058	2A	0.034	28.541	28.360	27.853	27.747	0.106	27.285	2B	27.432	27.686	27.887	28.026	0.139	28.575
1 1/4-10 or 1.2500-10	UNS	31.750	2.540	2A	0.049	31.701	31.375	30.050	29.891	0.159	28.679	2B	29.007	29.540	30.099	30.307	0.208	31.750
1 1/4-14 or 1.2500-14	UNS	31.750	1.814	2A	0.042	31.709	31.448	30.530	30.394	0.136	29.550	2B	29.795	30.175	30.572	30.749	0.177	31.750
1 1/4-24 or 1.2500-24	UNS	31.750	1.058	2A	0.034	31.716	31.535	31.028	30.920	0.108	30.457	2B	30.607	30.861	31.062	31.203	0.141	31.750
1 3/8-10 or 1.3750-10	UNS	34.925	2.540	2A	0.049	34.876	34.550	33.225	33.066	0.159	31.854	2B	32.182	32.715	33.274	33.482	0.208	34.925
1 3/8-14 or 1.3750-14	UNS	34.925	1.814	2A	0.042	34.884	34.623	33.705	33.569	0.136	32.725	2B	32.970	33.375	33.747	33.924	0.177	34.925
1 3/8-24 or 1.3750-24	UNS	34.925	1.058	2A	0.034	34.891	34.710	34.203	34.095	0.208	33.632	2B	33.782	34.036	34.237	34.378	0.141	34.925
1 1/2-10 or 1.5000-10	UNS	38.100	2.540	2A	0.049	38.051	37.725	36.400	36.239	0.161	35.029	2B	35.357	35.890	36.449	36.659	0.210	38.100
1 1/2-14 or 1.5000-14	UNS	38.100	1.814	2A	0.044	38.056	37.796	36.878	36.739	0.139	35.898	2B	36.145	36.525	36.922	37.104	0.182	38.100
1 1/2-24 or 1.5000-24	UNS	38.100	1.058	2A	0.034	38.066	37.885	37.378	37.267	0.111	36.807	2B	36.957	37.211	37.412	37.558	0.146	38.100
1 5/8-10 or 1.6250-10	UNS	41.275	2.540	2A	0.049	41.226	40.900	39.575	39.414	0.161	38.204	2B	38.532	39.065	39.624	39.834	0.210	41.275
1 5/8-14 or 1.6250-14	UNS	41.275	1.814	2A	0.044	41.231	40.971	40.053	39.914	0.139	39.073	2B	39.320	39.725	40.097	40.279	0.182	41.275
1 5/8-24 or 1.6250-24	UNS	41.275	1.058	2A	0.034	41.241	41.060	40.553	40.442	0.111	39.982	2B	40.132	40.386	40.587	40.733	0.146	41.275
1 3/4-10 or 1.7500-10	UNS	44.450	2.540	2A	0.049	44.401	44.075	42.750	42.586	0.164	41.379	2B	41.707	42.240	42.799	43.012	0.213	44.450
1 3/4-14 or 1.7500-14	UNS	44.450	1.814	2A	0.044	44.406	44.146	43.228	43.087	0.141	42.245	2B	42.495	42.875	43.272	43.456	0.184	44.450
1 3/4-18 or 1.7500-18	UNS	44.450	1.411	2A	0.040	44.411	44.191	43.494	43.366	0.128	42.733	2B	42.926	43.256	43.534	43.700	0.166	44.450
1 7/8-10 or 1.8750-10	UNS	47.625	2.540	2A	0.049	47.576	47.250	45.925	45.761	0.164	44.554	2B	44.882	45.415	45.974	46.187	0.213	47.625
1 7/8-14 or 1.8750-14	UNS	47.625	1.814	2A	0.044	47.581	47.321	46.403	46.262	0.141	45.423	2B	45.670	46.075	46.447	46.631	0.184	47.625
1 7/8-18 or 1.8750-18	UNS	47.625	1.411	2A	0.040	47.586	47.366	46.669	46.541	0.128	45.908	2B	46.101	46.431	46.709	46.875	0.166	47.625
2-10 or 2.0000-10	UNS	50.800	2.540	2A	0.051	50.749	50.422	49.098	48.934	0.164	47.727	2B	48.057	48.590	49.149	49.364	0.215	50.800
2-14 or 2.0000-14	UNS	50.800	1.814	2A	0.044	50.756	50.496	49.578	49.434	0.144	48.598	2B	48.845	49.225	49.622	49.809	0.187	50.800
2-18 or 2.0000-18	UNS	50.800	1.411	2A	0.040	50.761	50.541	49.844	49.716	0.128	49.083	2B	49.276	49.606	49.884	50.053	0.169	50.800
2 1/16-16 or 2.0625-16	UNS	52.387	1.588	2A	0.042	52.346	52.109	51.315	51.179	0.136	50.455	2B	50.673	51.028	51.357	51.534	0.177	52.388
				3A	0.000	52.387	52.149	51.356	51.255	0.101	50.495	3B	50.673	50.883	51.357	51.488	0.131	52.388
2 3/16-16 or 2.1875-16	UNS	55.562	1.588	2A	0.042	55.521	55.284	54.490	54.354	0.136	53.630	2B	53.848	54.203	54.532	54.709	0.177	55.563
				3A	0.000	55.562	55.324	54.531	54.428	0.103	53.670	3B	53.848	54.058	54.532	54.663	0.131	55.563

(Notes follow at end of table)

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TABLE C2 LIMITS OF SIZE FOR SELECTED COMBINATIONS OF UNS/UNRS SERIES THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)								Internal (1)						
						Major Diameter		Pitch Diameter			UNR Minor Diam. Max. (3) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
2¼-10 or 2.2500-10	UNS	57.150	2.540	2A	0.051	57.099	56.772	55.448	55.284	0.164	54.077	2B	54.407	54.940	55.499	55.714	0.215	57.150
2¼-14 or 2.2500-14	UNS	57.150	1.814	2A	0.044	57.106	56.846	55.928	55.784	0.144	54.948	2B	55.195	55.575	55.972	56.159	0.187	57.150
2¼-18 or 2.2500-18	UNS	57.150	1.411	2A	0.040	57.111	56.891	56.194	56.066	0.128	55.433	2B	55.626	55.956	56.234	56.403	0.169	57.150
2⅝-16 or 2.3125-16	UNS	58.737	1.588	2A	0.044	58.694	58.456	57.663	57.524	0.139	56.802	2B	57.023	57.378	57.707	57.889	0.182	58.738
				3A	0.000	58.737	58.499	57.706	57.603	0.103	56.845	3B	57.023	57.233	57.707	57.843	0.136	58.738
2⅞-16 or 2.4375-16	UNS	61.912	1.588	2A	0.044	61.869	61.631	60.838	60.699	0.139	59.977	2B	60.198	60.553	60.882	61.064	0.182	61.913
				3A	0.000	61.912	61.674	60.881	60.778	0.103	60.020	3B	60.198	60.408	60.882	61.018	0.136	61.913
2½-10 or 2.5000-10	UNS	63.500	2.540	2A	0.051	63.449	63.122	61.798	61.629	0.169	60.427	2B	60.757	61.290	61.849	62.069	0.220	63.500
2½-14 or 2.5000-14	UNS	63.500	1.814	2A	0.044	63.456	63.196	62.278	62.131	0.147	61.298	2B	61.545	61.925	62.322	62.514	0.192	63.500
2½-18 or 2.5000-18	UNS	63.500	1.411	2A	0.042	63.459	63.239	62.542	62.408	0.134	61.780	2B	61.976	62.306	62.584	62.758	0.174	63.500
2¾-10 or 2.7500-10	UNS	69.850	2.540	2A	0.051	69.799	69.472	68.148	67.979	0.169	66.777	2B	67.107	67.640	68.199	68.419	0.220	69.850
2¾-14 or 2.7500-14	UNS	69.850	1.814	2A	0.044	69.806	69.546	68.628	68.481	0.147	67.648	2B	67.895	68.275	68.672	68.864	0.192	69.850
2¾-18 or 2.7500-18	UNS	69.850	1.411	2A	0.042	69.809	69.589	68.892	68.758	0.134	68.130	2B	68.326	68.656	68.934	69.108	0.174	69.850
3-10 or 3.0000-10	UNS	76.200	2.540	2A	0.051	76.149	75.822	74.498	74.326	0.172	73.127	2B	73.457	73.990	74.549	74.775	0.226	76.200
3-14 or 3.0000-14	UNS	76.200	1.814	2A	0.047	76.154	75.893	74.975	74.826	0.149	73.995	2B	74.245	74.625	75.022	75.217	0.195	76.200
3-18 or 3.0000-18	UNS	76.200	1.411	2A	0.042	76.159	75.939	75.242	75.106	0.136	74.480	2B	74.676	75.006	75.284	75.460	0.176	76.200
3¼-10 or 3.2500-10	UNS	82.550	2.540	2A	0.051	82.499	82.172	80.848	80.676	0.172	79.477	2B	79.807	80.340	80.899	81.125	0.226	82.550
3¼-14 or 3.2500-14	UNS	82.550	1.814	2A	0.047	82.504	82.243	81.325	81.176	0.149	80.345	2B	80.595	80.975	81.372	81.567	0.195	82.550
3¼-18 or 3.2500-18	UNS	82.550	1.411	2A	0.042	82.509	82.289	81.592	81.456	0.136	80.830	2B	81.026	81.356	81.634	81.810	0.176	82.550
3½-10 or 3.5000-10	UNS	88.900	2.540	2A	0.054	88.846	88.519	87.195	87.021	0.174	85.824	2B	86.157	86.690	87.249	87.477	0.228	88.900
3½-14 or 3.5000-14	UNS	88.900	1.814	2A	0.047	88.854	88.593	87.675	87.521	0.154	86.695	2B	86.945	87.325	87.722	87.922	0.200	88.900
3½-18 or 3.5000-18	UNS	88.900	1.411	2A	0.045	88.856	88.636	87.939	87.801	0.138	87.178	2B	87.376	87.706	87.984	88.165	0.181	88.900
3¾-10 or 3.7500-10	UNS	95.250	2.540	2A	0.054	95.196	94.869	93.545	93.371	0.174	92.174	2B	92.507	93.040	93.599	93.827	0.228	95.250
3¾-14 or 3.7500-14	UNS	95.250	1.814	2A	0.047	95.204	94.943	94.025	93.871	0.154	93.045	2B	93.295	93.675	94.072	94.272	0.200	95.250
3¾-18 or 3.7500-18	UNS	95.250	1.411	2A	0.045	95.206	94.986	94.289	94.151	0.138	93.528	2B	93.726	94.056	94.334	94.515	0.181	95.250
4-10 or 4.0000-10	UNS	101.600	2.540	2A	0.054	101.546	101.219	99.895	99.718	0.177	98.471	2B	98.857	99.390	99.949	100.180	0.231	101.600
4-14 or 4.0000-14	UNS	101.600	1.814	2A	0.047	101.554	101.293	100.375	100.219	0.156	99.395	2B	99.645	100.025	100.422	100.624	0.202	101.600
4¼-10 or 4.2500-10	UNS	107.950	2.540	2A	0.054	107.896	107.569	106.245	106.068	0.177	104.874	2B	105.207	105.740	106.299	106.530	0.231	107.950
4¼-14 or 4.2500-14	UNS	107.950	1.814	2A	0.047	107.904	107.643	106.725	106.569	0.156	105.745	2B	105.995	106.375	106.772	106.974	0.202	107.950
4½-10 or 4.5000-10	UNS	114.300	2.540	2A	0.054	114.246	113.919	112.595	112.418	0.177	111.224	2B	111.557	112.090	112.649	112.880	0.231	114.300
4½-14 or 4.5000-14	UNS	114.300	1.814	2A	0.047	114.254	113.993	113.075	112.919	0.156	112.095	2B	112.345	112.725	113.122	113.324	0.202	114.300
4¾-10 or 4.7500-10	UNS	120.650	2.540	2A	0.056	120.594	120.267	118.943	118.761	0.182	117.572	2B	117.907	118.440	118.999	119.237	0.238	120.650
4¾-14 or 4.7500-14	UNS	120.650	1.814	2A	0.049	120.601	120.341	119.423	119.261	0.162	118.443	2B	118.695	119.075	119.472	119.682	0.210	120.650
5-10 or 5.0000-10	UNS	127.000	2.540	2A	0.056	126.944	126.617	125.293	125.111	0.182	123.922	2B	124.257	124.790	125.349	125.587	0.238	127.000
5-14 or 5.0000-14	UNS	127.000	1.814	2A	0.049	126.951	126.691	125.773	125.611	0.162	124.793	2B	125.045	125.425	125.822	126.032	0.210	127.000
5¼-10 or 5.2500-10	UNS	133.350	2.540	2A	0.056	133.294	132.967	131.643	131.461	0.182	130.272	2B	130.607	131.140	131.699	131.937	0.238	133.350
5¼-14 or 5.2500-14	UNS	133.350	1.814	2A	0.049	133.301	133.041	132.123	131.961	0.162	131.143	2B	131.395	131.775	132.172	132.382	0.210	133.350
5½-10 or 5.5000-10	UNS	139.700	2.540	2A	0.056	139.644	139.317	137.993	137.811	0.182	136.622	2B	136.957	137.490	138.049	138.287	0.238	139.700
5½-14 or 5.5000-14	UNS	139.700	1.814	2A	0.049	139.651	139.391	138.473	138.311	0.162	137.493	2B	137.745	138.125	138.522	138.732	0.210	139.700

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TABLE C2 LIMITS OF SIZE FOR SELECTED COMBINATIONS OF UNS/UNRS SERIES THREADS, mm (CONT'D)

Nominal Size (in.) and Threads/in.	Series Designation	Metric Equivalents		External (1)								Internal (1)						
						Major Diameter		Pitch Diameter			UNR Minor Diam. Max. (3) (Ref.)		Minor Diameter		Pitch Diameter			Major Diameter
		Diameter	Pitch	Class	Allowance	Max. (2)	Min.	Max. (2)	Min.	Tolerance		Class	Min.	Max.	Min.	Max.	Tolerance	Min.
5¾-10 or 5.7500-10	UNS	146.050	2.540	2A	0.056	145.994	145.667	144.343	144.156	0.187	142.972	2B	143.307	143.840	144.399	144.642	0.243	146.050
5¾-14 or 5.7500-14	UNS	146.050	1.814	2A	0.052	145.999	145.738	144.820	144.656	0.164	143.840	2B	144.095	144.475	144.872	145.087	0.215	146.050
6-10 or 6.0000-10	UNS	152.400	2.540	2A	0.056	152.344	152.017	150.693	150.506	0.187	149.322	2B	149.657	150.190	150.749	150.992	0.243	152.400
6-14 or 6.0000-14	UNS	152.400	1.814	2A	0.052	152.349	152.088	151.170	151.006	0.164	150.190	2B	150.445	150.825	151.222	151.437	0.215	152.400

GENERAL NOTE:
Series designation shown indicates the UN thread form; however, the UNR thread form may be specified by substituting UNR in place of UN in all designations for external use only.

NOTES:
(1) Thread classes may be combined. See para. 4.2 of ASME B1.1.
(2) For Class 2A threads having an additive finish, the maximum major and pitch diameters, after coating, may equal the basic sizes, whose values are the same as the maximum values shown for Class 3A in these columns. See paras. 4.1.1 and 4.1.3.
(3) UN series external thread maximum minor diameter is basic (D_1 in Section 11) for Class 3A and basic minus allowance for Classes 1A and 2A.

TABLE C3 THREAD FORM DATA, mm

Threads/in. n	Pitch $P = 25.4/n$	Basic Flat at Internal Thread Crest and External UN Thread Root, $F_{rs} = F_{cn} = P/4 = 0.25P$	Flat at Internal Thread Root and External Thread Crest, $F_{rn} = F_{cs} = P/8 = 0.125P$	Height of Sharp V-Thread, $H = 0.866025P$	Truncation of Internal Thread Root and External Thread Crest, $f_{rn} = f_{es} = 0.125H = 0.10825P$ (1)	External Thread Root Radius Max., $r_{rs} = 0.166667H = 0.14434P$	Truncation of UNR Design Profile External Thread Root and Half Addendum of External Thread, $S_{rs} = 0.1875H = 0.16238P$	External Thread Root and Truncation of Internal Thread Crest, $f_{rs} = f_{cn} = 0.250H = 0.21651P$ (2)
1	2	3	4	5	6	7	8	9
80	0.31750	0.0794	0.0397	0.2750	0.0344	0.0458	0.0516	0.0687
72	0.35278	0.0882	0.0441	0.3055	0.0382	0.0509	0.0573	0.0764
64	0.39688	0.0992	0.0496	0.3437	0.0430	0.0573	0.0644	0.0859
56	0.45357	0.1134	0.0567	0.3928	0.0491	0.0655	0.0736	0.0982
48	0.52916	0.1323	0.0661	0.4583	0.0573	0.0764	0.0859	0.1146
44	0.57727	0.1443	0.0722	0.4999	0.0625	0.0833	0.0937	0.1250
40	0.63500	0.1588	0.0794	0.5499	0.0687	0.0917	0.1031	0.1375
36	0.70556	0.1764	0.0882	0.6110	0.0764	0.1018	0.1146	0.1528
32	0.79375	0.1984	0.0992	0.6874	0.0859	0.1146	0.1289	0.1719
28	0.90714	0.2268	0.1134	0.7856	0.0982	0.1309	0.1473	0.1964
27	0.94074	0.2352	0.1176	0.8147	0.1018	0.1358	0.1528	0.2037
24	1.05834	0.2646	0.1323	0.9166	0.1146	0.1528	0.1719	0.2291
20	1.27000	0.3175	0.1588	1.0999	0.1375	0.1833	0.2062	0.2750
18	1.41112	0.3528	0.1764	1.2221	0.1528	0.2037	0.2291	0.3055
16	1.58750	0.3969	0.1984	1.3748	0.1718	0.2291	0.2578	0.3437
14	1.81430	0.4536	0.2268	1.5712	0.1964	0.2619	0.2946	0.3928
13	1.95384	0.4885	0.2442	1.6921	0.2115	0.2820	0.3173	0.4230
12	2.11666	0.5292	0.2646	1.8331	0.2291	0.3055	0.3437	0.4583
11½	2.20871	0.5522	0.2761	1.9128	0.2391	0.3188	0.3586	0.4782
11	2.30909	0.5773	0.2886	1.9997	0.2500	0.3333	0.3749	0.4999
10	2.54000	0.6350	0.3175	2.1997	0.2750	0.3666	0.4124	0.5499
9	2.82222	0.7056	0.3528	2.4441	0.3055	0.4074	0.4583	0.6110
8	3.17500	0.7938	0.3969	2.7496	0.3437	0.4583	0.5156	0.6874
7	3.62857	0.9071	0.4536	3.1424	0.3928	0.5237	0.5892	0.7856
6	4.23334	1.0583	0.5292	3.6662	0.4583	0.6110	0.6874	0.9166
5	5.08000	1.2700	0.6350	4.3994	0.5499	0.7332	0.8249	1.0999
4½	5.64444	1.4111	0.7056	4.8882	0.6110	0.8147	0.9165	1.2221
4	6.35000	1.5875	0.7938	5.4993	0.6874	0.9166	1.0311	1.3748

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TABLE C3 THREAD FORM DATA, mm

Addendum of External Thread, h_{as} = 0.375H = 0.32476P (3)	Height of Internal Thread, UN External Thread, and Depth of Thread Engagement, $h_s = h_n = h_e$ = 0.625H = 0.54127P	Height of UNR External Thread, h_s = 0.6875H = 0.59539P	Twice the External Thread Addendum, $h_b = 2h_{as}$ = 0.750H = 0.649519P	Difference Between Max. Major and Pitch Diameters of Internal Thread, 0.916667H = 0.79386P	Double Height of Internal Thread and External UN Thread, $2h_n$ = 1.250H = 1.08253P	Double Height of External UNR Thread, $2h_s$ = 1.375H = 1.19078P	$H/2$ = 0.43301P	Threads/in. n
10	11	12	13	14	15	16	17	1
0.1031	0.1719	0.1890	0.2062	0.2520	0.3437	0.3782	0.1374	80
0.1146	0.1909	0.2101	0.2291	0.2801	0.3819	0.4201	0.1527	72
0.1289	0.2148	0.2362	0.2578	0.3151	0.4296	0.4727	0.1720	64
0.1473	0.2455	0.2700	0.2946	0.3601	0.4910	0.5400	0.1963	56
0.1718	0.2864	0.3150	0.3437	0.4201	0.5728	0.6302	0.2291	48
0.1875	0.3125	0.3437	0.3749	0.4583	0.6249	0.6873	0.2499	44
0.2062	0.3437	0.3780	0.4124	0.5041	0.6874	0.7562	0.2751	40
0.2291	0.3819	0.4201	0.4583	0.5601	0.7638	0.8402	0.3056	36
0.2578	0.4296	0.4727	0.5156	0.6301	0.8593	0.9451	0.3437	32
0.2946	0.4910	0.5400	0.5892	0.7201	0.9820	1.0803	0.3927	28
0.3055	0.5092	0.5601	0.6110	0.7468	1.0184	1.1201	0.4074	27
0.3437	0.5728	0.6302	0.6874	0.8402	1.1457	1.2603	0.4582	24
0.4124	0.6874	0.7562	0.8249	1.0082	1.3748	1.5123	0.5499	20
0.4583	0.7638	0.8402	0.9166	1.1202	1.5276	1.6802	0.6111	18
0.5156	0.8593	0.9451	1.0311	1.2603	1.7185	1.8903	0.6873	16
0.5892	0.9820	1.0803	1.1784	1.4403	1.9640	2.1605	0.7856	14
0.6345	1.0576	1.1633	1.2691	1.5511	2.1151	2.3266	0.8461	13
0.6874	1.1457	1.2603	1.3748	1.6803	2.2913	2.5204	0.9164	12
0.7173	1.1955	1.3150	1.4346	1.7534	2.3910	2.6302	0.9563	11½
0.7499	1.2498	1.3749	1.4998	1.8331	2.4997	2.7500	0.9997	11
0.8249	1.3748	1.5123	1.6498	2.0164	2.7496	3.0246	1.0998	10
0.9165	1.5276	1.6802	1.8331	2.2404	3.0551	3.3607	1.2220	9
1.0311	1.7185	1.8903	2.0622	2.5205	3.4370	3.7808	1.3749	8
1.1784	1.9640	2.1605	2.3568	2.8806	3.9280	4.3208	1.5712	7
1.3748	2.2914	2.5204	2.7496	3.3607	4.5827	5.0409	1.8331	6
1.6498	2.7497	3.0246	3.2996	4.0328	5.4993	6.0493	2.1885	5
1.8331	3.0552	3.3607	3.6662	4.4809	6.1103	6.7213	2.4442	4½
2.0622	3.4371	3.7808	4.1245	5.0410	6.8741	7.5616	2.7496	4

GENERAL NOTE:
Metric conversion given for comparative reference only.

NOTES:
(1) The values tabulated in column 6 also pertain to the minimum root radius of UNR screw threads. See paras. 2.3.1 and 2.3.1(a) of ASME B1.1.
(2) $h_{gn} = f_{cn} = 0.25H$.
(3) $h_{dn} = h_{as} = 0.375H$.

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AMERICAN NATIONAL STANDARDS FOR SCREW THREADS

(Published by The American Society of Mechanical Engineers)

TITLE OF STANDARD

Unified Inch Screw Threads (UN and UNR Thread Form) B1.1-1989
Gages and Gaging for Unified Inch Screw Threads B1.2-1983
Screw Thread Gaging Systems for Dimensional Acceptability — Inch and Metric Screw Threads (UN, UNR, UNJ, M, and MJ) B1.3M-1986
Acme Screw Threads B1.5-1988
Nomenclature, Definitions, and Letter Symbols for Screw Threads B1.7M-1984
Stub Acme Screw Threads B1.8-1988
Buttress Inch Screw Threads 7°/45° Form With 0.6 Pitch Basic Height of Thread Engagement ..... B1.9-1973(R1985)
Unified Miniature Screw Threads ..... B1.10-1958(R1988)
Microscope Objective Thread ..... B1.11-1958(R1989)
Class 5 Interference-Fit Thread ..... B1.12 -1987
Metric Screw Threads — M Profile ..... B1.13M-1983(R1989)
Gages and Gaging for Metric M Screw Threads B1.16M-1984
Metric Screw Threads for Commercial Mechanical Fasteners — Boundary Profile Defined ..... B1.18M-1982(R1987)
Gages for Metric Screw Threads for Commercial Mechanical Fasteners — Boundary Profile Defined B1.19M-1984
Pipe Threads, General Purpose (Inch) B1.20.1-1983
Dryseal Pipe Threads (Inch) ..... B1.20.3-1976(R1982)
Dryseal Pipe Threads (Metric Translation of B1.20.3-1976) ..... B1.20.4-1976(R1982)
Gaging for Dryseal Pipe Threads (Inch) B1.20.5-1978
Gaging for Dryseal Pipe Threads (Metric Translation of B1.20.5-1978) B1.20.6M-1984
Hose Coupling Screw Threads ..... B1.20.7-1966(R1983)
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AN AMERICAN NATIONAL STANDARD

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ANSI/ASME B1.20.1 - 1983

(REVISION AND REDESIGNATION OF ANSI B2.1–1968)

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FOREWORD

(This Foreword is not part of American National Standard, Pipe Threads, General Purpose (Inch) ANSI/ASME B1.20.1-1983.)

In 1973 American National Standards Committee B2, which had formerly been responsible for pipe thread standards, was absorbed by ANSI Standards Committee B1 and reorganized as subcommittee 20. A complete rewrite of the B2.2-1968 standard on Dryseal Pipe Threads has been completed, with the product thread data in separate documents from the gaging standards for Dryseal Pipe Threads. The system of numbering, to include metric conversions, is as follows:

ANSI B1.20.3-1976 Dryseal Pipe Threads (Inch)
ANSI B1.20.4-1976 Dryseal Pipe Threads (Metric Translation)
ANSI B1.20.5-1978 Gaging for Dryseal Pipe Threads (Inch)
In preparation, B1.20.6M Gaging for Dryseal Pipe Threads (Metric Translation)

A complete rewrite of the B2.1-1968 standard on Pipe Threads (Except Dryseal) was then undertaken. The system of numbering, to include metric conversions, is as follows:

ANSI/ASME B1.20.1 Pipe Threads, General Purpose (Inch)
In preparation, B1.20.2M Pipe Threads, General Purpose (Metric Translation)

These standards, ANSI/ASME B1.20.1 and B1.20.2M, have product thread dimensions and gaging in the same document. Thread inspection specifies the use of L_1 taper thread plug and ring gages similar to B2.1-1968. In addition, emphasis is given to the requirement that all basic thread design dimensions are to be met within the specified tolerances.

The data in this Standard supersede those given in ANSI B2.1-1968.

The ANSI/ASME B1.20.1 was approved by ASME Standards Committee B1 on December 1, 1982 for publication as an official ANSI standard.

The proposed standard was submitted by standards committee B1 to the Secretariat and the American National Standards Institute. It was approved and formally designated as an American National Standard on February 4, 1983.

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Standardization and Unification of Screw Threads

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Appendix 23

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AN AMERICAN NATIONAL STANDARD

PIPE THREADS, GENERAL PURPOSE (INCH)

1 INTRODUCTION

1.1 Scope

This American National Standard covers dimensions and gaging of pipe threads for general purpose applications.

1.2 Thread Designations

1.2.1 The types of pipe threads included in this Standard are designated by specifying in sequence the nominal pipe size,[1] number of threads per inch and the thread series symbol as follows:

3/8 - 18 NPT
1/8 - 27 NPSC
1/2 - 14 NPTR
1/8 - 27 NPSM
1/8 - 27 NPSL
1 - 11.5 NPSH

For left hand threads add LH to the designation, otherwise right hand threads will be understood. For example:

3/8 - 18 NPT - LH

1.2.2 Each of these letters in the symbols has a definite significance as follows:

N = National (American) Standard
P = Pipe
T = Taper
C = Coupling
S = Straight
M = Mechanical
L = Locknut
H = Hose Coupling
R = Railing Fittings

[1]Where it is necessary to use decimal notation for the size designation (as when inserting such in a computer or electronic accounting machine) the decimal equivalent of nominal pipe size may be substituted for fractional pipe sizes.

1.2.3 Coated or Plated Threads. The threaded product specifications covered in this Standard do not include an allowance for coatings or plating.

1.3 Sealing

1.3.1 Where pressure-tight joints are required, it is intended that taper pipe threads conforming to this Standard be made up wrench-tight with a sealant. To prevent galling on certain piping materials such as stainless steels, the sealant usually contains a lubricant.

1.3.2 Pipe threads designed for pressure-tight joints that may be used without sealing compounds (Dryseal Threads) are covered in ANSI B1.20.3 (Inch) and ANSI B1.20.4 (Metric Translation).

1.4 Inspection

A gaging method and tolerances are prescribed in this Standard to effect a functional inspection of the handtight L_1 engagement threads. However, conformance to this Standard requires that all basic design dimensions be met (within applicable tolerances) including extension of the thread elements to provide for wrench-tight makeup. Therefore, additional methods of gaging may be employed to evaluate conformance to the basic design dimensions. When additional methods of gaging are employed, they shall be agreed upon by the supplier and the purchaser.

1.5 Appendix

Useful and supplementary information which is not a part of this Standard is presented in the Appendix. Specifically, the Appendix gives Suggested Twist Drill Diameters for Drilled Hole Sizes for Pipe Threads.

1.6 Related Standard

Definitions of terms and symbols for thread dimensions are given in ANSI B1.7, Nomenclature, Definitions and Letter Symbols for Screw Threads.

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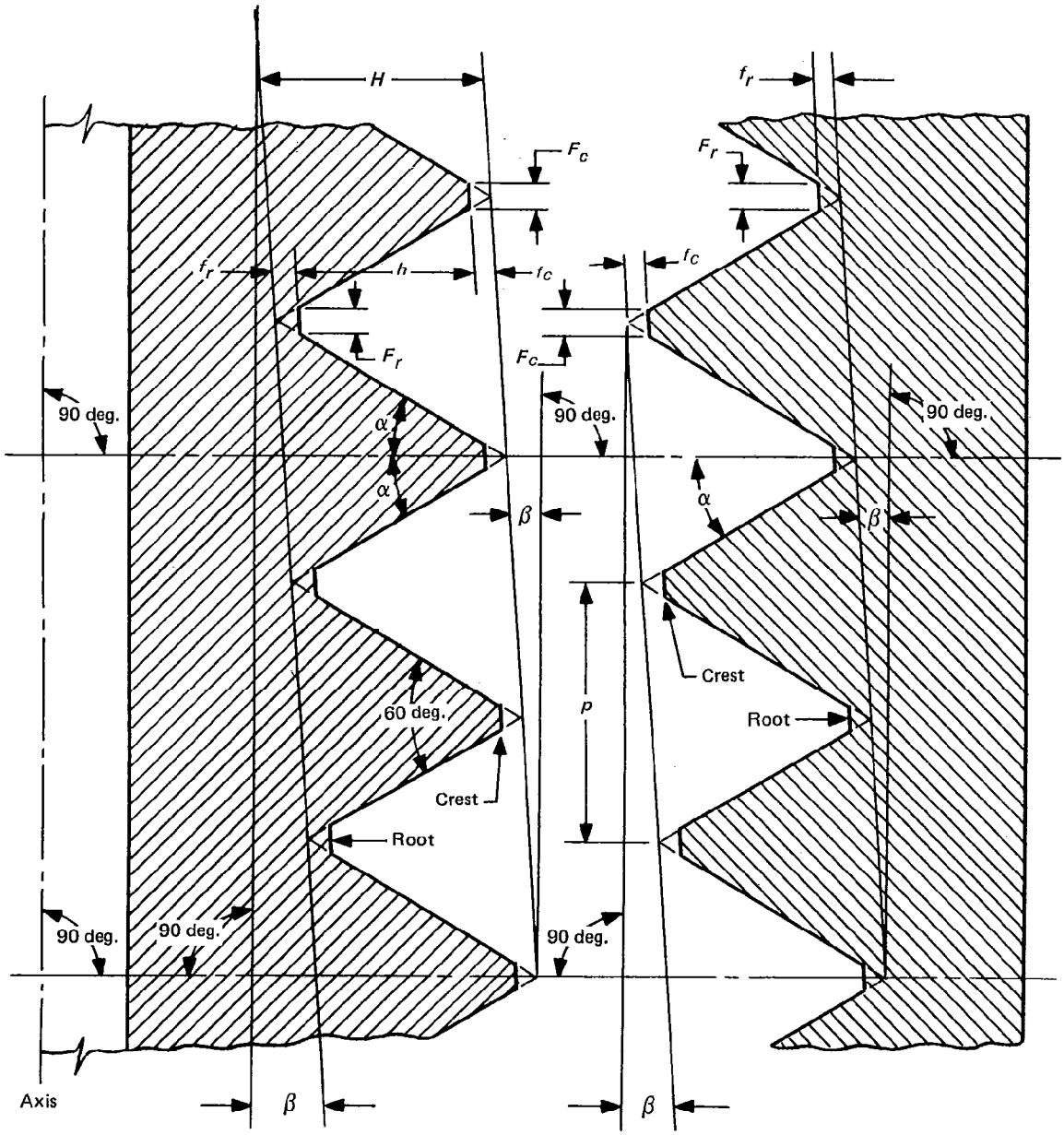

NOTATION

H	= 0.866025p = height of 60 deg. sharp V thread	β	= 1 deg. 47 min. = thread taper angle for 1/16 taper
h	= 0.800000p = height of thread on product	f_c	= depth of truncation at crest
p	= $1/n$ = pitch (measured parallel to axis)	f_r	= depth of truncation at root
n	= number of threads per inch	F_c	= width of flat at crest
α	= 30 deg. = thread flank angle	F_r	= width of flat at root

GENERAL NOTE: For a symmetrical straight screw thread, $H = \cot \alpha/2n$. For a symmetrical taper screw thread, $H = (\cot \alpha - \tan^2 \beta \tan \alpha)/2n$, so that the exact value for an American National Standard taper pipe thread is $H = 0.865743p$ as against $H = 0.866025p$, the value given above. For an 8-pitch thread, which is the coarsest standard taper pipe thread pitch, the corresponding values of H are 0.108218 and 0.108253 respectively, the difference being 0.000035 inch. This difference being too small to be significant, the value of $H = 0.866025p$ continues in use for threads of 0.750 in., or less, taper/ft on the diameter.

FIG. 1 BASIC FORM OF AMERICAN NATIONAL STANDARD TAPER PIPE THREAD

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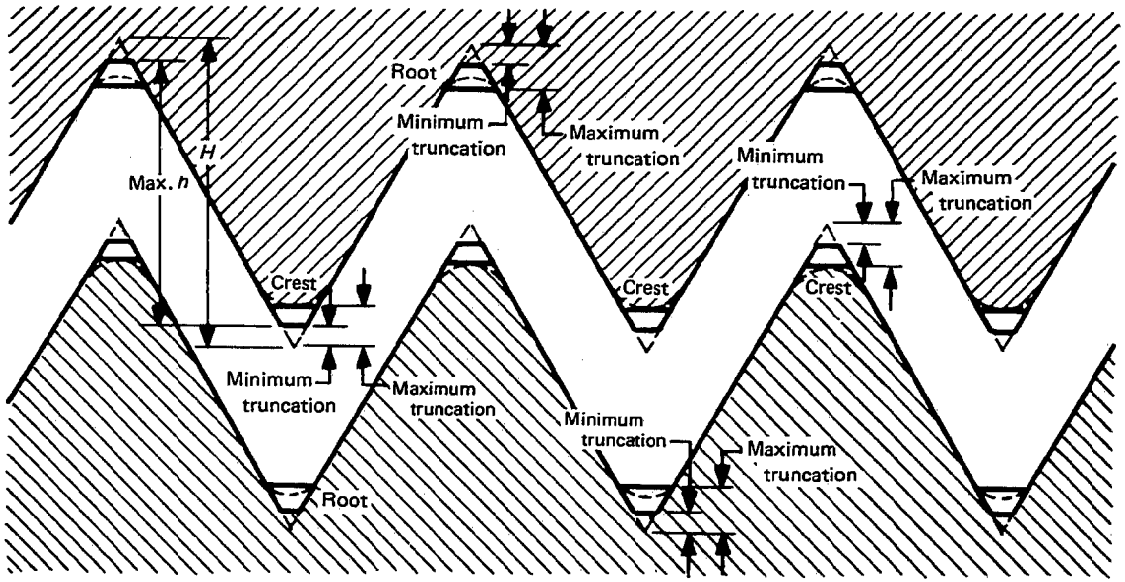
Internal Thread



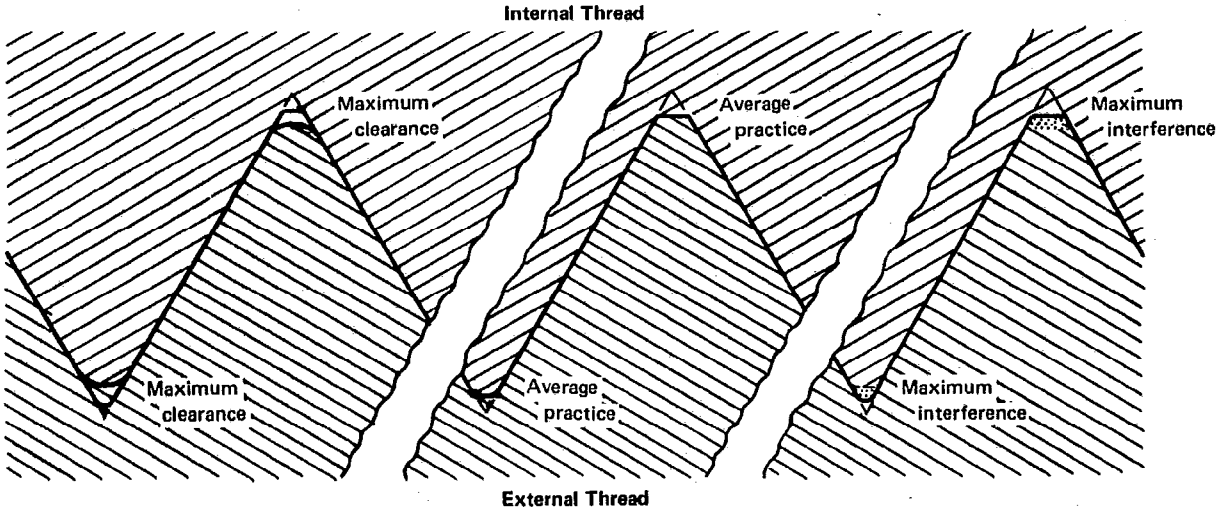
External Thread

TABLE 1 LIMITS ON CREST AND ROOT TRUNCATION OF AMERICAN NATIONAL STANDARD EXTERNAL AND INTERNAL TAPER PIPE THREADS, NPT[1]

Threads/ in. (n)	Height of Sharp V Thread (H)	Height of Thread (h)		Truncation (f)					Equivalent Width of Flat (F)				
				Minimum		Maximum		Tolerance	Minimum		Maximum		Tolerance
		Maximum	Minimum	Formula	in.	Formula	in.		Formula	in.	Formula	in.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
27	0.03208	0.02963	0.02496	0.033*p*	0.0012	0.096*p*	0.0036	0.0024	0.038*p*	0.0014	0.111*p*	0.0041	0.0027
18	0.04811	0.04444	0.03833	0.033*p*	0.0018	0.088*p*	0.0049	0.0031	0.038*p*	0.0021	0.102*p*	0.0057	0.0036
14	0.06186	0.05714	0.05071	0.033*p*	0.0024	0.078*p*	0.0056	0.0032	0.038*p*	0.0027	0.090*p*	0.0064	0.0037
11.5	0.07531	0.06957	0.06261	0.033*p*	0.0029	0.073*p*	0.0063	0.0034	0.038*p*	0.0033	0.084*p*	0.0073	0.0040
8	0.10825	0.10000	0.09275	0.033*p*	0.0041	0.062*p*	0.0078	0.0037	0.038*p*	0.0048	0.072*p*	0.0090	0.0042

NOTE:

(1) The basic dimensions of the American National Standard Taper Pipe Thread are given in inches to four and five decimal places. While this implies a greater degree of precision than is ordinarily attained, these dimensions are so expressed for the purpose of eliminating errors in computations.



GENERAL NOTE:
When threaded joints are made up wrench-tight with lubricant or sealer, it is intended that the flanks shall be in contact.

FIG. 2. AMERICAN NATIONAL STANDARD TAPER PIPE THREADS FOR PRESSURE-TIGHT JOINTS, NPT

2 AMERICAN NATIONAL STANDARD PIPE THREAD FORM

2.1 Thread Form

The form of thread profile specified in this Standard shall be known as the American National Standard Pipe Thread Form. The relations as specified herein, for form of thread and general notation are shown in Fig. 1.

2.2 Angle of Thread

The angle between the sides of the thread is 60 deg when measured in an axial plane. The line bisecting this angle is perpendicular to the axis.

2.3 Truncation and Thread Height

The height of the sharp V thread, H, is

$$H = 0.866025p = 0.866025/n$$

where

p = pitch of thread
n = threads per inch

The basic maximum depth of the truncated thread, h (see Fig. 1), is based on factors entering into the manufacture of cutting tools and the making of tight joints.

$$h = 0.800p = 0.800/n$$

The crest and root of pipe threads are truncated a minimum of $0.033p$. The maximum depth of truncation for the crest and root of these pipe threads will be found in Table 1. The crests and roots of the external and internal threads may be truncated either parallel to the pitch line or parallel to the axis.

The sketch in Table 2, giving a sectional view of this Standard thread form, represents the truncated thread form by a straight line. However, when closely examined, the crests and roots of commercially manufactured pipe threads appear slightly rounded. When crests and roots of threading tools or chasers lie within the limits shown in Table 1, the pipe threads of products produced by such means are acceptable on the basis of in-process control.

3 SPECIFICATION FOR GENERAL PURPOSE TAPER PIPE THREADS, NPT

3.1 Taper Pipe Threads

Threads made in accordance with these specifications consist of an external taper and an internal taper thread, to form the normal type of joint having general application on pipe and fittings. See Fig. 2.

NPT taper pipe threads are intended to be made up wrench-tight and with a sealant whenever a pressure-tight joint is required.

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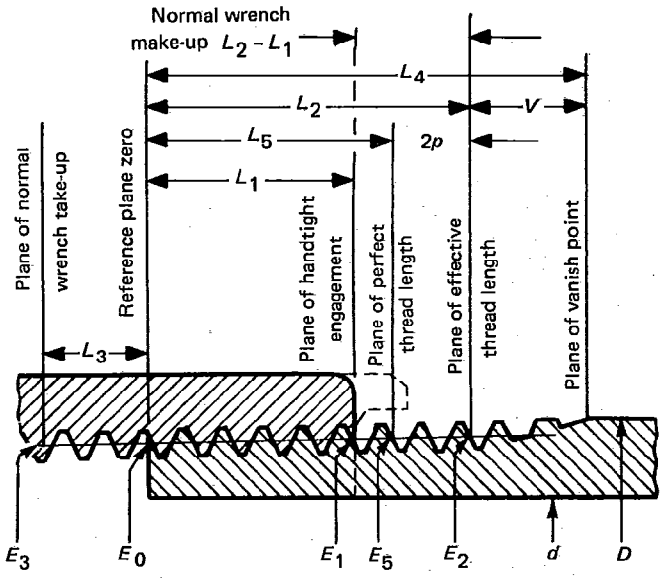

FIG. 3 AMERICAN NATIONAL STANDARD TAPER PIPE THREAD NOTATION

Sealing is affected by out-of-roundness which is possible between the wrench-tight mated parts in final assembly. This will vary depending on the method for producing the thread in conjunction with the elasticity and/or ductility of the mating parts and the resultant conformance at final assembly.

3.1.1 Thread Designation and Notation. American National Standard Taper Pipe Threads are designated in accordance with 1.2.1 as follows:

3/8 - 18 NPT

Standard notation applicable to American National Standard Taper Pipe Threads is shown in Fig. 3.

3.1.2 Designation of Plated Threads. The product specifications of this Standard do not include an allowance for plating. If plating is desired, it may be necessary to modify the threads since the same final gaging requirements must be satisfied for plated and unplated parts. This may be emphasized by adding the words AFTER PLATING to the designation. For manufacturing purposes, notes for plated taper pipe threads may specify the gage limits (turns or threads engagement) before plating followed by the words BEFORE PLATING. These should be followed by the standard gage limits (turns or threads engagement) after plating and the words AFTER PLATING.

3.1.3 Form of Thread. The form of the thread for American National Standard Taper Pipe Threads is that specified in 2.1.

3.1.4 Taper of Thread. The taper of the thread is 1 in 16 or 0.75 in./ft measured on the diameter and along the axis.

3.1.5 Diameter of Thread. The basic pitch diameters of the taper thread are determined by the following formulas[2] based on the outside diameter of the pipe and the pitch of the thread:

$$E_0 = D - (0.05D + 1.1)\,1/n$$
$$= D - (0.05D + 1.1)\,p$$
$$E_1 = E_0 + 0.0625L_1$$

where

D = outside diameter of pipe
E_0 = pitch diameter of thread at end of pipe or small end of external thread
E_1 = pitch diameter of thread at the gaging notch or large end of internal thread
L_1 = normal engagement by hand between external and internal threads
n = threads per inch

[2]For the 1/8-27 and 1/4-18 sizes, E_1 approx. $= D - (0.05D + 0.827)\,p$.

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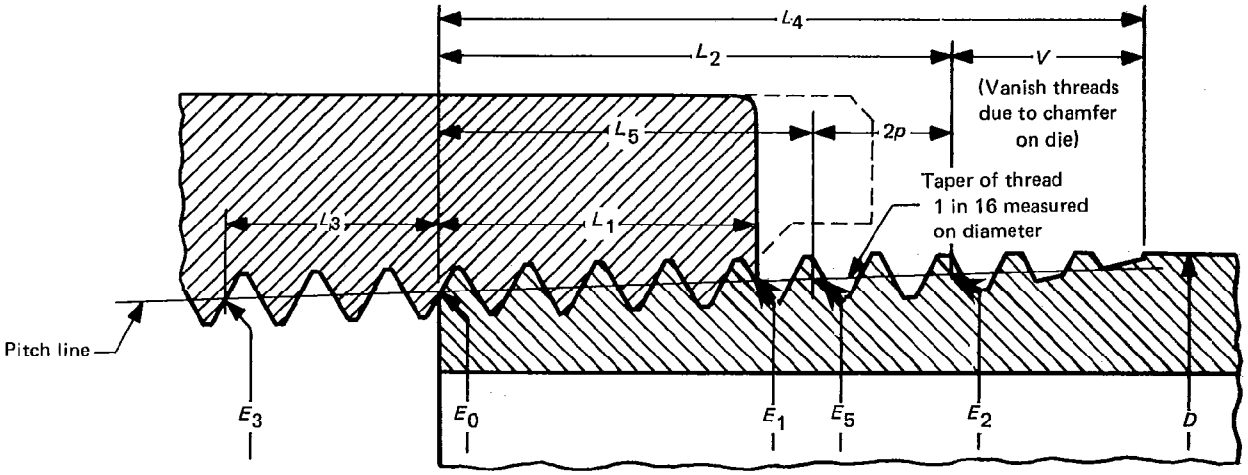

TABLE 2 BASIC DIMENSIONS OF AMERICAN NATIONAL STANDARD TAPER PIPE THREAD, NPT[1]

Nominal Pipe Size	O.D. of Pipe (D)	Threads/in. (n)	Pitch of Thread (P)	Pitch Diam. at Beginning of External Thread (E_0)	Handtight Engagement			Effective Thread, External		
					Length[2] (L_1)		Diam.[3] (E_1)	Length[4] (L_2)		Diam. (E_2)
					inch	Threads		inch	Threads	
1	2	3	4	5	6	7	8	9	10	11
1/16	0.3125	27	0.03704	0.27118	0.160	4.32	0.28118	0.2611	7.05	0.28750
1/8	0.405	27	0.03704	0.36351	0.1615	4.36	0.37360	0.2639	7.12	0.38000
1/4	0.540	18	0.05556	0.47739	0.2278	4.10	0.49163	0.4018	7.23	0.50250
3/8	0.675	18	0.05556	0.61201	0.240	4.32	0.62701	0.4078	7.34	0.63750
1/2	0.840	14	0.07143	0.75843	0.320	4.48	0.77843	0.5337	7.47	0.79179
3/4	1.050	14	0.07143	0.96768	0.339	4.75	0.98887	0.5457	7.64	1.00179
1	1.315	11.5	0.08696	1.21363	0.400	4.60	1.23863	0.6828	7.85	1.25630
1 1/4	1.660	11.5	0.08686	1.55713	0.420	4.83	1.58338	0.7068	8.13	1.60130
1 1/2	1.900	11.5	0.08696	1.79609	0.420	4.83	1.82234	0.7235	8.32	1.84130
2	2.375	11.5	0.08696	2.26902	0.436	5.01	2.29627	0.7565	8.70	2.31630
2 1/2	2.875	8	0.12500	2.71953	0.682	5.46	2.76216	1.1375	9.10	2.79062
3	3.500	8	0.12500	3.34062	0.766	6.13	3.38850	1.2000	9.60	3.41562
3 1/2	4.000	8	0.12500	3.83750	0.821	6.57	3.88881	1.2500	10.00	3.91562
4	4.500	8	0.12500	4.33438	0.844	6.75	4.38712	1.3000	10.40	4.41562
5	5.563	8	0.12500	5.39073	0.937	7.50	5.44929	1.4063	11.25	5.47862
6	6.625	8	0.12500	6.44609	0.958	7.66	6.50597	1.5125	12.10	6.54062
8	8.625	8	0.12500	8.43359	1.063	8.50	8.50003	1.7125	13.70	8.54062
10	10.750	8	0.12500	10.54531	1.210	9.68	10.62094	1.9250	15.40	10.66562
12	12.750	8	0.12500	12.53281	1.360	10.88	12.61781	2.1250	17.00	12.66562
14 O.D.	14.000	8	0.12500	13.77500	1.562	12.50	13.87262	2.2500	18.00	13.91562
16 O.D.	16.000	8	0.12500	15.76250	1.812	14.50	15.87575	2.4500	19.60	15.91562
18 O.D.	18.000	8	0.12500	17.75000	2.000	16.00	17.87500	2.6500	21.20	17.91562
20 O.D.	20.000	8	0.12500	19.73750	2.125	17.00	19.87031	2.8500	22.80	19.91562
24 O.D.	24.000	8	0.12500	23.71250	2.375	19.00	23.86094	3.2500	26.00	23.91562

NOTES:

(1) The basic dimensions of the American National Standard Taper Pipe Thread are given in inches to four or five decimal places. While this implies a greater degree of precision than is ordinarily attained, these dimensions are the basis of gage dimensions and are so expressed for the purpose of eliminating errors in computations.

(2) Also length of thin ring gage and length from gaging notch to small end of plug gage.

(3) Also pitch diameter at gaging notch (handtight plane).

(4) Also length of plug gage.

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TABLE 2 BASIC DIMENSIONS OF AMERICAN NATIONAL STANDARD TAPER PIPE THREAD, NPT[1] (CONT'D)

Nominal Pipe Size	Length, L_1 Plane to L_2 Plane External Thread ($L_2 - L_1$)		Wrench Makeup Length for Internal Thread[7]			Vanish Thread (V)		Overall[8] Length External Thread (L_4)	Nominal Complete External Threads[5]		Height of Thread (h)	Increase in Diam./ Thread ($0.0625/n$)	Basic[6] Minor Diam. at Small End of Pipe (K_0)
			Length (L_3)		Diam. (E_3)				Length (L_5)	Diam. (E_5)			
	in.	Thread	in.	Thread		in.	Thread						
1	12	13	14	15	16	17	18	19	20	21	22	23	24
1/16	0.1011	2.73	0.1111	3	0.26424	0.1285	3.47	0.3896	0.1870	0.28287	0.02963	0.00231	0.2416
1/8	0.1024	2.76	0.1111	3	0.35656	0.1285	3.47	0.3924	0.1898	0.37537	0.02963	0.00231	0.3339
1/4	0.1740	3.13	0.1667	3	0.46697	0.1928	3.47	0.5946	0.2907	0.49556	0.04444	0.00347	0.4329
3/8	0.1678	3.02	0.1667	3	0.60160	0.1928	3.47	0.6006	0.2967	0.63056	0.04444	0.00347	0.5676
1/2	0.2137	2.99	0.2143	3	0.74504	0.2478	3.47	0.7815	0.3909	0.78286	0.05714	0.00446	0.7013
3/4	0.2067	2.89	0.2143	3	0.95429	0.2478	3.47	0.7935	0.4029	0.99286	0.05714	0.00446	0.9105
1	0.2828	3.25	0.2609	3	1.19733	0.3017	3.47	0.9845	0.5089	1.24543	0.06957	0.00543	1.1441
1 1/4	0.2868	3.30	0.2609	3	1.54083	0.3017	3.47	1.0085	0.5329	1.59043	0.06957	0.00543	1.4876
1 1/2	0.3035	3.49	0.2609	3	1.77978	0.3017	3.47	1.0252	0.5496	1.83043	0.06957	0.00543	1.7265
2	0.3205	3.69	0.2609	3	2.25272	0.3017	3.47	1.0582	0.5826	2.30543	0.06957	0.00543	2.1995
2 1/2	0.4555	3.64	0.2500	2	2.70391	0.4337	3.47	1.5712	0.8875	2.77500	0.100000	0.00781	2.6195
3	0.4340	3.47	0.2500	2	3.32500	0.4337	3.47	1.6337	0.9500	3.40000	0.100000	0.00781	3.2406
3 1/2	0.4290	3.43	0.2500	2	3.82188	0.4337	3.47	1.6837	1.0000	3.90000	0.100000	0.00781	3.7375
4	0.4560	3.65	0.2500	2	4.31875	0.4337	3.47	1.7337	1.0500	4.40000	0.100000	0.00781	4.2344
5	0.4693	3.75	0.2500	2	5.37511	0.4337	3.47	1.8400	1.1563	5.46300	0.100000	0.00781	5.2907
6	0.5545	4.44	0.2500	2	6.43047	0.4337	3.47	1.9462	1.2625	6.52500	0.100000	0.00781	6.3461
8	0.6495	5.20	0.2500	2	8.41797	0.4337	3.47	2.1462	1.4625	8.52500	0.100000	0.00781	8.3336
10	0.7150	5.72	0.2500	2	10.52969	0.4337	3.47	2.3587	1.6750	10.65000	0.100000	0.00781	10.4453
12	0.7650	6.12	0.2500	2	12.51719	0.4337	3.47	2.5587	1.8750	12.65000	0.100000	0.00781	12.4328
14 O.D.	0.6880	5.50	0.2500	2	13.75938	0.4337	3.47	2.6837	2.0000	13.90000	0.100000	0.00781	13.6750
16 O.D.	0.6380	5.10	0.2500	2	15.74688	0.4337	3.47	2.8837	2.2000	15.90000	0.100000	0.00781	15.6625
18 O.D.	0.6500	5.20	0.2500	2	17.73438	0.4337	3.47	3.0837	2.4000	17.90000	0.100000	0.00781	17.6500
20 O.D.	0.7250	5.80	0.2500	2	19.72188	0.4337	3.47	3.2837	2.6000	19.90000	0.100000	0.00781	19.6375
24 O.D.	0.8750	7.00	0.2500	2	23.69688	0.4337	3.47	3.6837	3.0000	23.90000	0.100000	0.00781	23.6125

(5) The length L_5 from the end of the pipe determines the plane beyond which the thread form is incomplete at the crest. The next two threads are complete at the root. At this plane the cone formed by the crests of the thread intersects the cylinder forming the external surface of the pipe. $L_5 = L_2 - 2p$.

(6) Given as information for use in selecting tap drills. (See Appendix).

(7) Military Specification MIL—P—7105 gives the wrench makeup as three threads for sizes 3 and smaller. The E_3 dimensions are as follows: Nominal pipe size 2½ = 2.69609 and size 3 = 3.31719; sizes 2 and smaller same as above, col. 16.

(8) Reference dimension.

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TABLE 3 TOLERANCES ON TAPER, LEAD, AND ANGLE OF PIPE THREADS, NPT

Nominal Pipe Size	Threads/in. (n)	Tolerances			
		Taper on Pitch Line (3/4 in./ft)		Lead in Length of Effective Threads (±)	60 deg. Angle of Threads, degrees (±)
		Maximum	Minimum		
1	2	3	4	5	6
1/16, 1/8	27	+ 1/8	- 1/16	0.003	2 1/2
1/4, 3/8	18	+ 1/8	- 1/16	0.003	2
1/2, 3/4	14	+ 1/8	- 1/16	0.003[1]	2
1, 1 1/4, 1 1/2, 2	11.5	+ 1/8	- 1/16	0.003[1]	1 1/2
2 1/2 and larger	8	+ 1/8	- 1/16	0.003[1]	1 1/2

GENERAL NOTE:
For tolerances on depth of thread see Table 1, and for tolerances on functional size, see 3.2.1.
NOTE:
(1) The tolerance on lead shall be ±0.003 in./in. on any size threaded to an effective thread length greater than 1 in.

TABLE 4 DIMENSIONS, INTERNAL STRAIGHT THREADS IN PIPE COUPLING, NPSC
(Pressure-tight Joints With Lubricant or Sealant)

Nominal Pipe Size	O.D. of Pipe (D)	Threads/in. (n)	Minor Diameter, Minimum	Pitch Diameter[1]	
				Minimum	Maximum
1	2	3	4	5	6
1/8	0.405	27	0.340	0.3701	0.3771
1/4	0.540	18	0.442	0.4864	0.4968
3/8	0.675	18	0.577	0.6218	0.6322
1/2	0.840	14	0.715	0.7717	0.7851
3/4	1.050	14	0.925	0.9822	0.9956
1	1.315	11.5	1.161	1.2305	1.2468
1 1/4	1.660	11.5	1.506	1.5752	1.5915
1 1/2	1.900	11.5	1.745	1.8142	1.8305
2	2.375	11.5	2.219	2.2881	2.3044
2 1/2	2.875	8	2.650	2.7504	2.7739
3	3.500	8	3.277	3.3768	3.4002
3 1/2	4.000	8	3.777	3.8771	3.9005
4	4.500	8	4.275	4.3754	4.3988

NOTE:
(1) Attention is called to the fact that the actual pitch diameter of the straight tapped hole will be slightly smaller than the value given when gaged with a taper plug gage as specified in 9.1.2.

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3.1.6 Length of Thread. The basic length of the effective external taper thread L_2, is determined by the following formula based on the outside diameter of the pipe and the pitch of the thread:

$$L_2 = (0.80D + 6.8)\,1/n$$
$$= (0.80D + 6.8)\,p$$

where

D = outside diameter of pipe
n = threads per inch

This formula determines directly the length of effective thread which includes two usable threads slightly incomplete at the crest.

3.1.7 Engagement Between External and Internal Taper Threads. The normal length of engagement between external and internal taper threads when screwed together handtight is shown in col. 6, Table 2. This length is controlled by the construction and use of the gages. It is recognized that in special applications, such as flanges for high pressure work, longer thread engagement is used, in which case the pitch diameter (dimension E_1, Table 2) is maintained and the pitch diameter E_0 at the end of the pipe is proportionately smaller.

3.1.8 Basic Dimensions. The basic dimensions of taper pipe threads, derived from the above specifications, are given in Table 2. All dimensions are given in inches unless otherwise specified.

3.2 Tolerances

3.2.1 Manufacturing Tolerance on Product. The maximum allowable deviation in the commercial product is one turn large or small from gages made to the basic dimensions. See 8.2 and 8.3.

3.2.2 Tolerances on Thread Elements. The permissible deviations in thread elements are given in Table 3. This table is a guide for establishing limits of the thread elements of taps, dies, and thread chasers. Conformance to these limits may be required on product threads, in which case specifications shall require control and checking of thread elements.

On pipe fittings and valves (not steel or high grade alloys used in critical services) for steam pressures 300 lb and below, it is intended that plug and ring gage practices as established in this Standard be used in conjunction with tooling control of thread elements, e.g., taps and dies, to provide satisfactory control of functional size. Therefore, no tolerances on thread elements have been established for this class.

For service conditions, where more exact checks are required, procedures have been developed by industry to supplement the standard plug and ring gage method of gaging.

4 SPECIFICATIONS FOR INTERNAL STRAIGHT THREADS IN PIPE COUPLINGS, NPSC

4.1 Straight Pipe Threads in Pipe Couplings

Threads in pipe couplings made in accordance with these specifications are straight (parallel) threads of the same thread form as the American National Standard Taper Pipe Thread specified in 2.1. They are used to form pressure-tight joints when assembled with an American National Standard external taper pipe thread and made up wrench-tight with lubricant or sealant.

4.1.1 Thread Designation. The American National Standard Coupling Straight Pipe Threads are designated in accordance with 1.2.1 as follows:

1/8 - 27 NPSC

4.1.2 Dimensions and Limits of Size. The dimensions and pitch diameter limits of size are specified in Table 4. The pitch diameter limits of size correspond to one and one-half turns large or small of the standard taper pipe thread. The major and minor diameters vary with the pitch diameter, as the American National Standard Pipe Thread form is maintained within the truncation tolerances shown in Table 1.

5 SPECIFICATIONS FOR RAILING JOINT TAPER PIPE THREADS, NPTR

5.1 Railing Joints

Railing joints that require a rigid mechanical thread joint may be made with external and internal taper threads.

The external thread is basically the same as the American National Standard Taper Pipe Thread, except that it is shortened to permit the use of the

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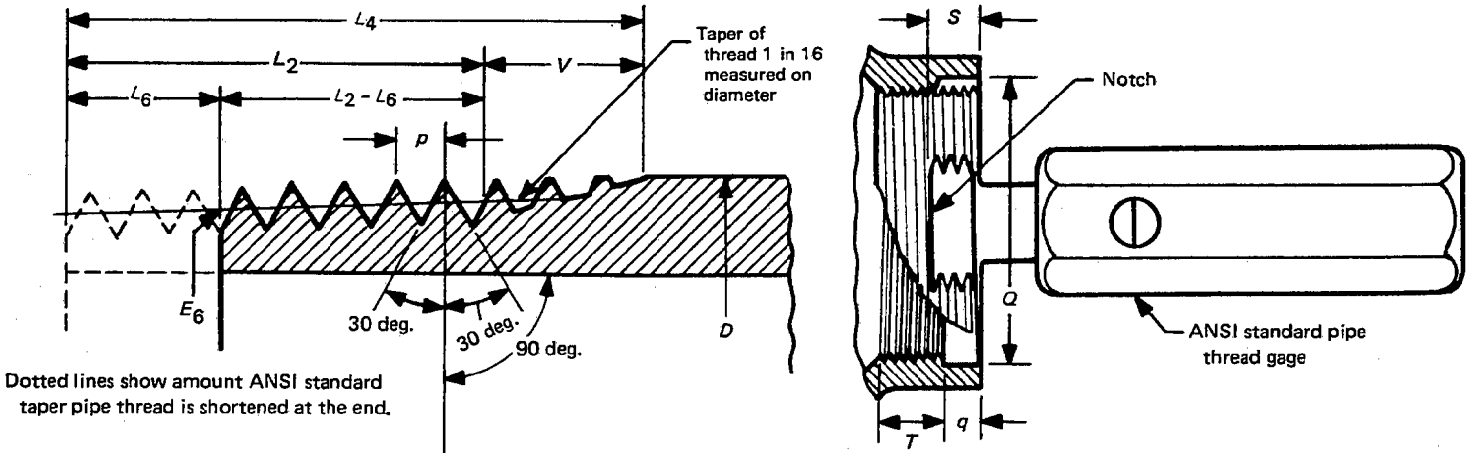

TABLE 5 DIMENSIONS OF EXTERNAL AND INTERNAL TAPER PIPE THREADS FOR RAILING JOINTS, NPTR[1]
(Mechanical Joints)

Nom. Pipe Size	O.D. of Pipe (D)	Threads/ in. (n)	Height of Thread (h)	Pitch Diameter at End of External Thread (E_6)	Shortening of Thread (L_6)		Length of Effective Thread ($L_2 - L_6$)		Total Length of External Thread, max. ($L_4 - L_6$)		Incomplete Threads due to Chamfer of Die, max. (V)		Depth of Recess in Fitting (q)	Dia. of Recess in Fitting (Q)	Length (T)	Distance Gage[2] Notch comes below Face of Fitting (S)	
					in.	Threads	in.	Threads	in.	Threads	in.	Threads	Minimum	Minimum	Minimum	in.	Threads
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
½	0.840	14	0.0571	0.7718	0.214	3	0.320	4.47	0.499	6.98	0.179	2½	0.18	0.86	0.25	0.286	4
¾	1.050	14	0.0571	0.9811	0.214	3	0.332	4.64	0.510	7.15	0.179	2½	0.18	1.07	0.25	0.286	4
1	1.315	11.5	0.0696	1.2299	0.261	3	0.422	4.85	0.639	7.35	0.217	2½	0.22	1.34	0.30	0.348	4
1¼	1.660	11.5	0.0696	1.5734	0.261	3	0.446	5.13	0.707	8.13	0.261	3	0.26	1.68	0.39	0.348	4
1½	1.900	11.5	0.0696	1.8124	0.261	3	0.463	5.32	0.724	8.33	0.261	3	0.26	1.92	0.43	0.348	4
2	2.375	11.5	0.0696	2.2853	0.261	3	0.496	5.70	0.757	8.70	0.261	3	0.26	2.40	0.43	0.348	4
2½	2.875	8	0.1000	2.7508	0.500	4	0.638	5.10	1.013	8.10	0.375	3	0.38	2.90	0.63	0.625	5
3	3.500	8	0.1000	3.3719	0.500	4	0.700	5.60	1.075	8.60	0.375	3	0.38	3.53	0.63	0.625	5
3½	4.000	8	0.1000	3.8688	0.500	4	0.750	6.00	1.125	9.00	0.375	3	0.38	4.04	0.63	0.625	5
4	4.500	8	0.1000	4.3656	0.500	4	0.800	6.40	1.175	9.40	0.375	3	0.38	4.54	0.63	0.625	5

NOTES:
(1) These dimensions agree with those developed by the Manufacturers Standardization Society of the Valve and Fittings Industry. Thread lengths are specified to three decimal places for convenience.
(2) American National Standard Taper Pipe Thread Plug Gage. See Section 7.

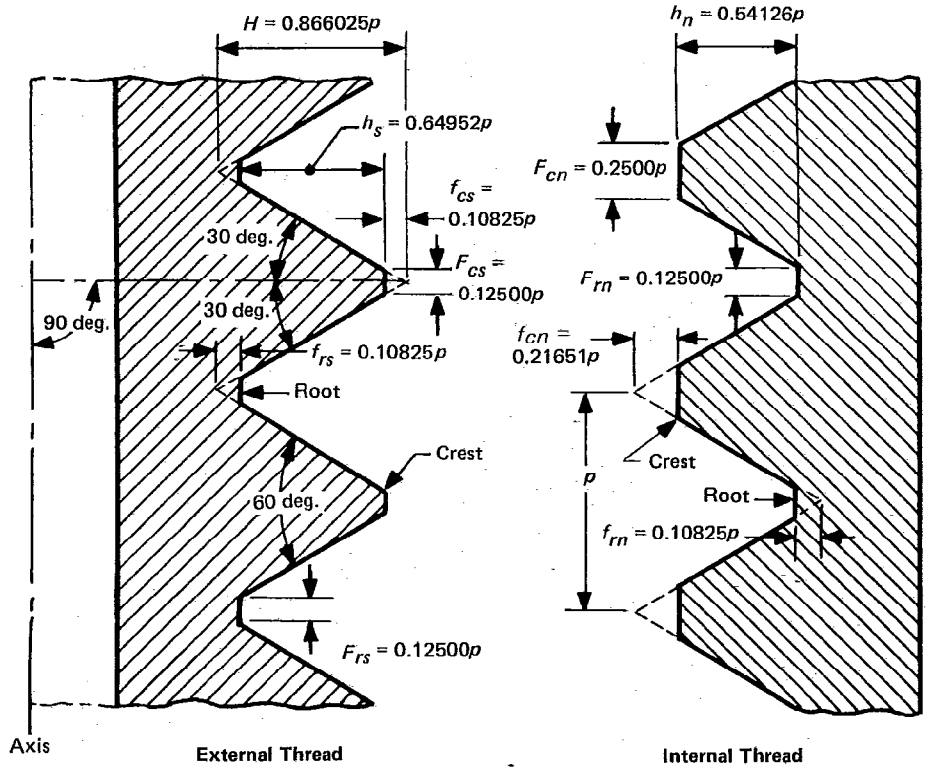

TABLE 6 DIMENSIONS OF EXTERNAL AND INTERNAL STRAIGHT PIPE THREADS FOR FIXTURES, NPSM
(Free Fitting Mechanical Joints)

Nom. Pipe Size	O.D. of Pipe (*D*)	Threads/ in.	Allow-ance	External Thread, Class 2A				Internal Thread, Class 2B			
				Major Diameter		Pitch Diameter		Minor Diameter		Pitch Diameter	
				Maximum	Minimum	Maximum	Minimum	Minimum	Maximum	Minimum[1]	Maximum
1	2	3	4	5	6	7	8	9	10	11	12
1/8	0.405	27	0.0011	0.397	0.390	0.3725	0.3689	0.358	0.364	0.3736	0.3783
1/4	0.540	18	0.0013	0.526	0.517	0.4903	0.4859	0.468	0.481	0.4916	0.4974
3/8	0.675	18	0.0014	0.662	0.653	0.6256	0.6211	0.603	0.612	0.6270	0.6329
1/2	0.840	14	0.0015	0.823	0.813	0.7769	0.7718	0.747	0.759	0.7784	0.7851
3/4	1.050	14	0.0016	1.034	1.024	0.9873	0.9820	0.958	0.970	0.9889	0.9958
1	1.315	11.5	0.0017	1.293	1.281	1.2369	1.2311	1.201	1.211	1.2386	1.2462
1 1/4	1.660	11.5	0.0018	1.638	1.626	1.5816	1.5756	1.546	1.555	1.5834	1.5912
1 1/2	1.900	11.5	0.0018	1.877	1.865	1.8205	1.8144	1.785	1.794	1.8223	1.8302
2	2.375	11.5	0.0019	2.351	2.339	2.2944	2.2882	2.259	2.268	2.2963	2.3044
2 1/2	2.875	8	0.0022	2.841	2.826	2.7600	2.7526	2.708	2.727	2.7622	2.7720
3	3.500	8	0.0023	3.467	3.452	3.3862	3.3786	3.334	3.353	3.3885	3.3984
3 1/2	4.000	8	0.0023	3.968	3.953	3.8865	3.8788	3.835	3.848	3.8888	3.8988
4	4.500	8	0.0023	4.466	4.451	4.3848	4.3771	4.333	4.346	4.3871	4.3971
5	5.563	8	0.0024	5.528	5.513	5.4469	5.4390	5.395	5.408	5.4493	5.4598
6	6.625	8	0.0024	6.585	6.570	6.5036	6.4955	6.452	6.464	6.5060	6.5165

GENERAL NOTES:

(a) NPSM threads are of Unified screw thread form to Classes 2A/2B tolerances, having the minimum pitch diameter of the internal thread basic and equal to E_1 of NPT threads.

(b) The minor diameters of external threads and major diameters of internal threads are those as produced by commercial straight pipe dies and commercial ground straight pipe taps.

The major diameter of the external thread has been calculated on the basis of a truncation of 0.10825*p*, and the minor diameter of the internal thread has been calculated on the basis of a truncation of 0.21651*p*, to provide no interference at crest and root when product is gaged with gages made in accordance with 9.2.

NOTE:

(1) Column 11 is the same as the pitch diameter at the large end of internal thread, E_1, *Basic*. (See Table 2, col. 8.)

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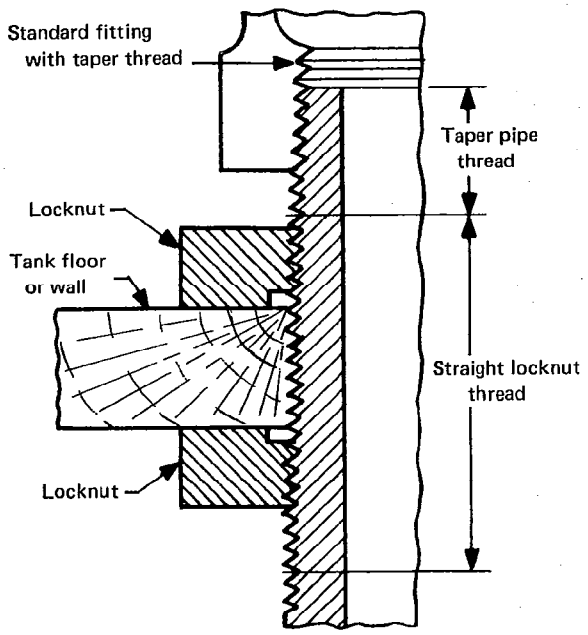

TABLE 7 DIMENSIONS, EXTERNAL AND INTERNAL STRAIGHT PIPE THREAD FOR LOCKNUT CONNECTIONS, NPSL (Loose Fitting Mechanical Joints)

Nominal Pipe Size	O.D. of Pipe (*D*)	Threads/ inch	External Threads			Internal Threads		
			Maximum[1] Major Diameter	Pitch Diameter		Minimum[1] Minor Diameter	Pitch Diameter	
				Maximum	Minimum		Minimum	Maximum
1	2	3	4	5	6	7	8	9
1/8	0.405	27	0.409	0.3840	0.3805	0.362	0.3863	0.3989
1/4	0.540	18	0.541	0.5038	0.4986	0.470	0.5073	0.5125
3/8	0.675	18	0.678	0.6409	0.6357	0.607	0.6444	0.6496
1/2	0.840	14	0.844	0.7963	0.7896	0.753	0.8008	0.8075
3/4	1.050	14	1.054	1.0067	1.0000	0.964	1.0112	1.0179
1	1.315	11.5	1.318	1.2604	1.2523	1.208	1.2658	1.2739
1 1/4	1.660	11.5	1.663	1.6051	1.5970	1.553	1.6106	1.6187
1 1/2	1.900	11.5	1.902	1.8441	1.8360	1.792	1.8495	1.8576
2	2.375	11.5	2.376	2.3180	2.3099	2.265	2.3234	2.3315
2 1/2	2.875	8	2.877	2.7934	2.7817	2.718	2.8012	2.8129
3	3.500	8	3.503	3.4198	3.4081	3.344	3.4276	3.4393
3 1/2	4.000	8	4.003	3.9201	3.9084	3.845	3.9279	3.9396
4	4.500	8	4.502	4.4184	4.4067	4.343	4.4262	4.4379
5	5.563	8	5.564	5.4805	5.4688	5.405	5.4884	5.5001
6	6.625	8	6.620	6.5372	6.5255	6.462	6.5450	6.5567
8	8.625	8	8.615	8.5313	8.5196	8.456	8.5391	8.5508
10	10.750	8	10.735	10.6522	10.6405	10.577	10.6600	10.6717
12	12.750	8	12.732	12.6491	12.6374	12.574	12.6569	12.6686

NOTE:

(1) NPSL threads are standard pipe thread form where the pitch diameters of the external threads are fixed at 2.5 and 4 turns larger than basic E_1, and where the pitch diameters of the internal threads are fixed at 5 and 6.5 turns larger than basic E_1, thus providing an allowance equivalent to one turn of the standard taper pipe thread.

As the American National Standard Straight Pipe Thread form of thread is produced by a single tool, the major and the minor diameters of the internal thread and the minor diameter of the external thread are presumed to vary with the pitch diameter. The major diameter of the external thread is usually determined by the diameter of the pipe. These theoretical diameters result from adding the depth of the truncated thread (0.666025 X p) to the maximum pitch diameters in col. 5, and it should be understood that commercial pipe will not always have these maximum major diameters.

The locknut thread is established on the basis of retaining the greatest possible amount of metal thickness between the bottom of the thread and the inside of the pipe.

In order that a locknut may fit loosely on the externally threaded part, an allowance equal to the *increase in pitch diameter per turn* is provided, with a tolerance of 1.5 turns for both external and internal threads.

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larger end of the pipe thread. See Table 5. The dimensions of these external and internal threads are shown in Table 5. A recess in the fitting provides a covering for the last scratch or sharp edges of incomplete threads on the pipe.

5.1.1 Thread Designation. American National Standard Railing Joint Taper Pipe Threads are designated in accordance with 1.2.1 as follows:

1/2 - 14 NPTR

5.1.2 Form of Thread. The form of the thread is the same as the form of the American National Standard Taper Pipe Thread shown in Fig. 1.

5.1.3 Tolerances on Thread Elements. The gaging of these threads is specified in Table 5. The maximum allowable deviation in the external thread is no turns large and one turn small. The maximum allowable deviation in the internal thread is one turn large, no turns small.

6 SPECIFICATIONS FOR STRAIGHT PIPE THREADS FOR MECHANICAL JOINTS; NPSM, NPSL, NPSH

6.1 Straight Pipe Threads

In addition to pressure-tight pipe joints, for which taper external threads and either taper or straight internal threads are used, there are mechanical joints where straight pipe threads are used to advantage on both external and internal threads. Three of these straight pipe thread joints are covered by this Standard, all of which are based on the pitch diameter of the American National Standard Taper Pipe Thread at the gaging notch (dimension E_1 of Table 2) but have various truncations at crest and root as described below. These three types of joints are as follows:

(*a*) free-fitting mechanical joints for fixtures, Table 6, both external and internal, NPSM.

(*b*) loose-fitting mechanical joints with locknuts, Table 7, both external and internal, NPSL.

(*c*) loose-fitting mechanical joints for hose couplings (ANSI B2.4), NPSH.

6.1.1 Thread Designations. The above types of straight pipe threads for mechanical joints are designated in accordance with 1.2.1 as follows:

1/8 - 27 NPSM
1/8 - 27 NPSL
1 - 11.5 NPSH

6.1.2 Pitch and Flank Angle. The pitch and flank angle are the same as the corresponding dimensions of the taper pipe thread described in Section 3.

6.1.3 Diameter of Thread. The basic pitch diameter for both the external and internal straight pipe threads is equal to the pitch diameter of the American National Standard Taper Pipe Thread at the gaging notch (dimension E_1 of Table 2), which is the same as at the large end of the internal taper pipe thread.

6.2 Free-Fitting Mechanical Joints for Fixtures, NPSM

Pipe is often used for special applications where there are no internal pressures. Where straight thread joints are required for mechanical assemblies, straight pipe threads are often found more suited or convenient.

The dimensions of these threads, as given in Table 6, are for pipe thread connections where reasonably close fit of the mating parts is desired.

6.3 Loose-Fitting Mechanical Joints With Locknuts, NPSL

The American National Standard External Locknut thread is designed to produce a pipe thread having the largest diameter that it is possible to cut on standard pipe. Ordinarily Straight Internal Threads are used with these Straight External Threads, providing a loose fit. The dimensions of these threads are given in Table 7. It will be noted that the maximum major diameter of the external thread is slightly greater than the nominal outside diameter of the pipe. The normal manufacturer's variation in pipe diameter provides for this increase.

One application of a taper pipe thread in combination with a locknut thread which has been in use for some time is that shown in Table 7. It consists of the nipple threaded joint used to connect standpipes with the floor or wall of a water supply tank.

Gaging information for these threads is given in Section 7.

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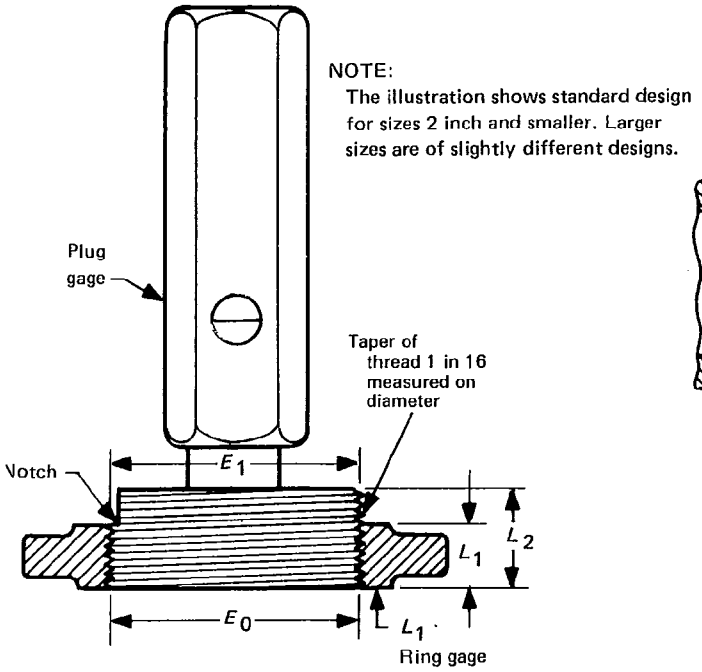

FIG. 4 NPT STANDARD TAPER PIPE THREAD PLUG AND RING GAGES

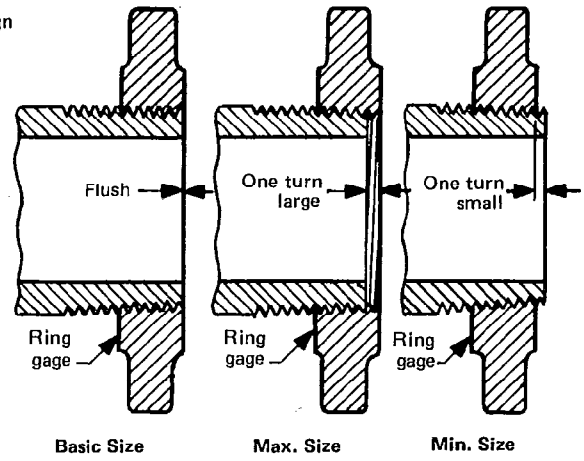

FIG. 6 GAGING EXTERNAL TAPER THREADS WITH RING GAGE

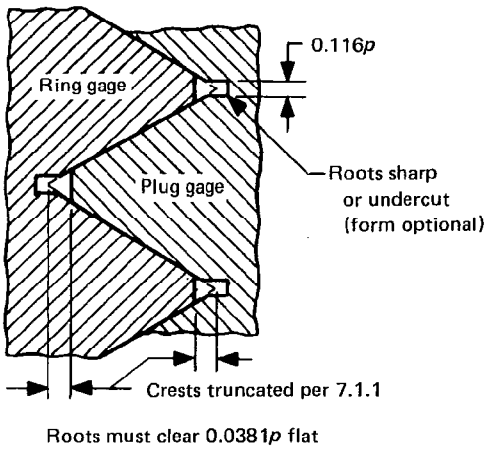

FIG. 5 SUGGESTED FORM OF GAGE THREAD

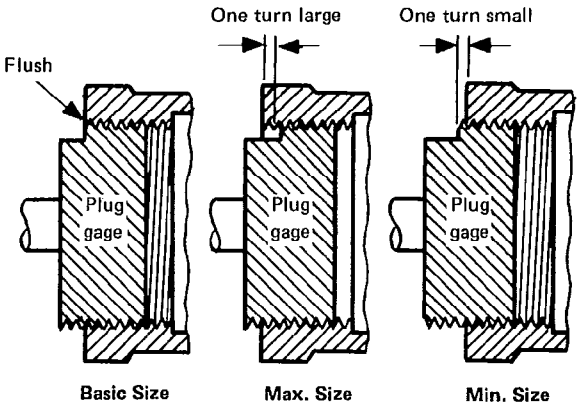

FIG. 7 GAGING INTERNAL TAPER THREADS

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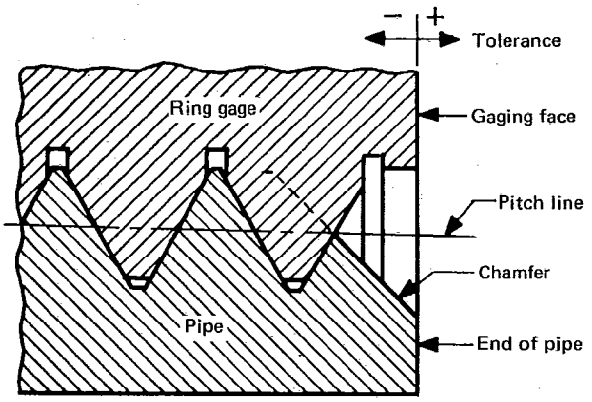
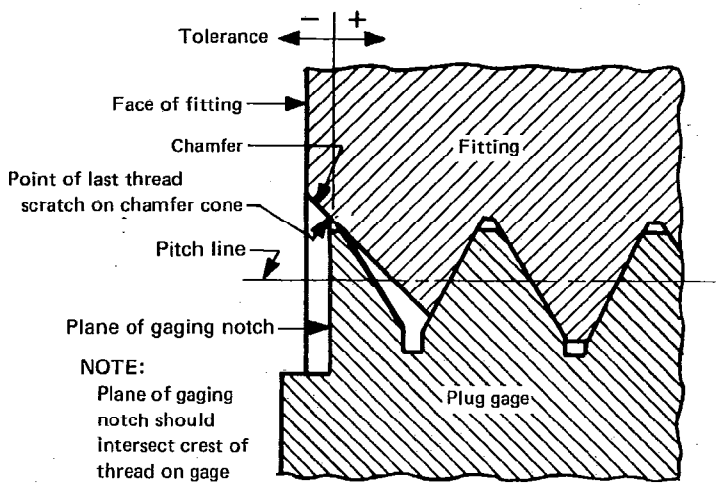


(A) Enlarged view showing chamfered external thread of basic size



(B) Enlarged view showing chamfered internal thread of basic size with chamfer exceeding the major diameter

GENERAL NOTE:
The chamfer illustrated is at 45 deg. angle and is approximately ½ pitch in depth. However, these details are not requirements and are given only for information on the illustration shown. The chamfered portion of thread and the full chamfer cone are indicated by dotted lines.

The reference point for the internal product thread is the starting end of the fitting, providing the chamfer does not exceed the major diameter of the internal thread. When a chamfer on the product thread exceeds this limit, the reference point becomes the last thread scratch on the chamfer cone, as illustrated. Allowance must be made for depth of counterbore on counterbored fittings.

FIG. 8 GAGING OF CHAMFERED THREADS
(See 8.4)

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6.4 Loose-Fitting Mechanical Joints for Hose Couplings, NPSH

Hose coupling joints are ordinarily made with straight internal and external loose-fitting threads. There are several standards of hose threads having various diameters and pitches, one of which is based on the American National Standard Pipe Thread. By the use of this thread series, it is possible to join small hose couplings in sizes ½ to 4, inclusive, to ends of standard pipe having American National Standard External Pipe Threads, using a gasket to seal the joint. For dimensions and tolerances, see ANSI B2.4.

7 GAGES AND GAGE TOLERANCES FOR AMERICAN NATIONAL STANDARD PIPE THREADS

7.1 Design of Gages

Gages for American National Standard Pipe Threads provide a functional check and are of the standard type as described below. Gages should conform to the designs recommended in ANSI Standard B47.1, Gage Blanks.

7.1.1 Standard Type Gages. A set of standard or basic type gages consists of a taper-threaded plug gage and a taper-threaded ring gage. See Figs. 4 and 5. The plug gages are made to dimensions given in Table 8 with a gaging notch located a distance L_1 from the small end. The L_1 ring gage has a length equal to dimension L_1. The roots of the threads on these gages shall clear $0.0381p$ width. A sharp V or undercut clearance is acceptable. The crests are to be truncated an amount equal to $0.140p$ for 27 threads per inch (tpi), $0.109p$ for 18 tpi, and $0.100p$ for 14 tpi, 11-1/2 tpi and 8 tpi threads (see Fig. 5). In locating the basic gaging notch, the plane of the notch should intersect the crest of the gage thread.

The ring gage shall be fitted to the plug so that, when assembled handtight, the gaging notch of the plug gage will be flush with the large end face of the ring gage within tolerances as given in Table 9.

Partial end threads shall be removed on both ends of the ring gage and on the small end of the plug gage to full-form profile in order to avoid possible seating error from bent or malformed feathered edge.

7.1.2 Marking of Gages. Each gage shall be marked so as to indicate clearly the nominal size of pipe, threads per inch, and the proper thread series designation as given in the respective section of this Standard.

7.2 Classes of Gages

Gages of the following types may be used to completely cover gage requirements:

(*a*) master gages used to check working gages.

(*b*) working gages used to check threads during manufacture and for conformance inspection.

7.2.1 Master Gages. The set of master gages consists of an L_1 taper threaded plug gage and an L_1 taper threaded ring gage (see Figs. 4 and 5). The plug gage is made to dimensions specified in Table 8. It is constructed of hardened steel with a gaging notch located a distance L_1 (Table 2) from the small end. The ring gage has a length equal to dimension L_1 specified in Table 8. This ring is fitted to its mating plug - seating flush at the notch within ± 0.002 in. for sizes 1/16 through 2, within ± 0.003 in. for sizes 2-1/2 through 12, and within ± 0.005 in. for sizes 14 and larger. The roots of the threads on these ring gages shall clear a $0.0381p$ flat or may be undercut beyond a sharp V. The crests of the plug and ring gage are truncated $0.100p$. The set of master gages is used for checking working gages (see 7.3.2). A supplementary check by optical means should be made of flank angle and form.

CAUTION: It should be understood that only a specifically matched set of masters (L_1 plug and L_1 ring) can be expected to mate with each other within the tolerance specified. There are many characteristics or deviations in gage elements that may combine to cause a significant standoff difference between master gages which are not specifically matched.

7.2.2 Working Gages. Each set of working gages consists of an L_1 taper threaded plug gage and an L_1 taper threaded ring gage and is used for checking the product. These gages are made of hardened steel or equivalent material to dimensions given in Table 8. (See 7.3.2 for tolerance.) In locating the basic notch of the plug gage the plane of the notch should intersect the crest of the thread.

It is to be noted that these gages are truncated at the crest so that they bear only on the flanks of the thread. Thus, although they do not check the crest or root truncations specified in Table 1, they are a satisfactory functional check for the general run of product. When it is deemed necessary to determine

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TABLE 8 BASIC DIMENSIONS OF THREADED PLUG AND RING GAGES FOR NATIONAL AMERICAN NATIONAL STANDARD TAPER PIPE THREADS, NPT

Nominal Pipe Size	O.D. of Pipe (D)	Threads/ in. (n)	Pitch (p)	Major Diameters of Plug Gages			Pitch Diameters of Plug and Ring Gages			Minor Diameters of Ring Gages		Increase in Diam./ Thread (0.0625/ n)	Thickness of Ring (L_1)
				At Small End (E_0) Plane	At Gaging Notch (E_1) Plane	At Large End (E_2) Plane	At Small End (E_0)	At Gaging Notch (E_1)	At Large End, Plug Gage (E_2)	At Small End, (E_0) Plane	At Gaging Notch (E_1) Plane		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1/16	0.3125	27	0.03704	0.29289	0.30289	0.30921	0.27118	0.28118	0.28750	0.24947	0.25947	0.00231	0.160
1/8	0.405	27	0.03704	0.38522	0.39531	0.40171	0.36351	0.37360	0.38000	0.34180	0.35189	0.00231	0.1615
1/4	0.540	18	0.05556	0.51339	0.52763	0.53850	0.47739	0.49163	0.50250	0.44139	0.45563	0.00347	0.2278
3/8	0.675	18	0.05556	0.64801	0.66301	0.67350	0.61201	0.62701	0.63750	0.57601	0.59101	0.00347	0.240
1/2	0.840	14	0.07143	0.80600	0.82600	0.83936	0.75843	0.77843	0.79179	0.71086	0.73086	0.00446	0.320
3/4	1.050	14	0.07143	1.01525	1.03644	1.04936	0.96768	0.98887	1.00179	0.92011	0.94129	0.00446	0.339
1	1.315	11.5	0.08696	1.27154	1.29654	1.31422	1.21363	1.23863	1.25630	1.15572	1.18072	0.00543	0.400
1 1/4	1.660	11.5	0.08696	1.61504	1.64129	1.65922	1.55713	1.58338	1.60130	1.49922	1.52547	0.00543	0.420
1 1/2	1.900	11.5	0.08696	1.85400	1.88025	1.89922	1.79609	1.82234	1.84130	1.73817	1.76442	0.00543	0.420
2	2.375	11.5	0.08696	2.32693	2.35418	2.37422	2.26902	2.29627	2.31630	2.21111	2.23836	0.00543	0.436
2 1/2	2.875	8	0.12500	2.80278	2.84541	2.87388	2.71953	2.76216	2.79062	2.63628	2.67891	0.00781	0.682
3	3.500	8	0.12500	3.42388	3.47175	3.49888	3.34062	3.38850	3.41562	3.25737	3.30525	0.00781	0.766
3 1/2	4.000	8	0.12500	3.92075	3.97207	3.99888	3.83750	3.88881	3.91562	3.75425	3.80556	0.00781	0.821
4	4.500	8	0.12500	4.41762	4.47038	4.49888	4.33438	4.38712	4.41562	4.25112	4.30387	0.00781	0.844
5	5.563	8	0.12500	5.47398	5.53255	5.56188	5.39073	5.44929	5.47862	5.30748	5.36604	0.00781	0.937
6	6.625	8	0.12500	6.52935	6.58922	6.62388	6.44609	6.50597	6.54062	6.36284	6.42272	0.00781	0.958
8	8.625	8	0.12500	8.51685	8.58328	8.62388	8.43359	8.50003	8.54062	8.35034	8.41678	0.00781	1.063
10	10.750	8	0.12500	10.62857	10.70419	10.74888	10.54531	10.62094	10.66562	10.46206	10.53768	0.00781	1.210
12	12.750	8	0.12500	12.61607	12.70107	12.74888	12.53281	12.61781	12.66562	12.44956	12.53456	0.00781	1.360
14 O.D.	14.000	8	0.12500	13.85825	13.95588	13.99888	13.77500	13.87262	13.91562	13.69175	13.78937	0.00781	1.562
16 O.D.	16.000	8	0.12500	15.84575	15.95900	15.99888	15.76250	15.87575	15.91562	15.67925	15.79250	0.00781	1.812
18 O.D.	18.000	8	0.12500	17.83325	17.95825	17.99888	17.75000	17.87500	17.91562	17.66675	17.79175	0.00781	2.000
20 O.D.	20.000	8	0.12500	19.82075	19.95357	19.99888	19.73750	19.87031	19.91562	19.65425	19.78706	0.00781	2.125
24 O.D.	24.000	8	0.12500	23.79575	23.94419	23.99888	23.71250	23.86094	23.91562	23.62925	23.77768	0.00781	2.375

GENERAL NOTE: Gage blanks shall conform to dimensions given in ANSI B47.1. The major diameters of the plug gages and the minor diameters of the ring gages are based upon the truncations specified in 7.1.1.

whether or not such truncations are within the limits specified, or particularly to see that maximum truncation is not exceeded, it is necessary to make further inspection. For this inspection, optics or optical projection is suggested.

7.3 Gage Tolerances

In the manufacture of gages, variations from basic dimensions are unavoidable. Furthermore, gages will wear in use. In order to fix the maximum allowable variations of gages, tolerances have been established. See Table 9 and 7.3.2.

7.3.1 Master Gage Tolerances. The set of master gages should be made to the basic dimensions as accurately as possible, but in no case shall the cumulative deviation exceed one-half of the total cumulative tolerance specified in cols. 13 and 14 of Table 9. Each master gage should be accompanied by a record of the measurements of all elements of the thread and the standoff of master plug to master ring (large end of ring gage to basic notch of plug gage).

7.3.2 Working Gage Tolerances. All gages applied to the product thread, whether in manufacture or inspection, are designated as working gages. All working gages should be made to the basic dimensions specified in Table 8 and within tolerances specified in Table 9. The maximum wear on a working gage shall not be more than the equivalent of one-quarter turn from its original dimensions.

7.4 Relation of Lead and Angle Deviations to Pitch Diameter Tolerances of Gages

When it is necessary to compute from measurements the decimal part of a turn that a gage varies from the basic dimensions, Tables 10 and 11 should be used. Table 10 gives the correction in diameter for angle deviations and Table 11 gives the correction in diameter for lead deviations. These corrections are always added to the pitch diameter in the case of external threads and subtracted in the case of internal threads regardless of whether the lead or angle deviations are either plus or minus.

The diameter equivalent for lead and angle deviations plus the pitch diameter deviation multiplied by 16 gives the longitudinal deviation from basic at the gaging notch. This longitudinal deviation divided by the pitch equals the decimal part of a turn that the gage varies from basic at the gaging notch.

8 GAGING OF TAPER PIPE THREADS

8.1 Gaging External Taper Threads

In gaging external taper threads, the L_1 ring gage, Fig. 6, is screwed handtight on the pipe or external thread. The thread is within the permissible tolerance when the gaging face of the working ring gage is not more than one turn, large or small, from being flush with the end of the thread, as indicated in Fig. 6.

8.2 Gaging Internal Taper Threads

In gaging internal taper threads, the L_1 plug gage, Fig. 4, is screwed handtight into the fitting or coupling. The thread is within the permissible tolerance when the gaging notch of the working plug gage is not more than 1 turn, large or small, from being flush with the end of the thread, as indicated in Fig. 7.

8.3 Gaging Practice

8.3.1 Precautions. In gaging pipe threads it is common practice to tap or rap the part to assure proper seating of the gage in or on the product thread. However, it is first necessary to clean both the gage and the product threads so that they are free of chips, burrs, abrasives, or other foreign materials.

8.3.2 Supplemental Gaging. Gaging of both internal and external threads by use of the L_1 plug and ring gages, illustrated by Figs. 6 and 7, serves to assure conformance to the L_1 elements of the design dimensions. However, conformance to this Standard requires that all basic design dimensions be met within applicable tolerances including extension of the thread elements to provide for wrench-tight make-up. Therefore, in controlling manufacturing practices or as otherwise required, additional methods of measuring or gaging may be employed to supplement L_1 gaging.

8.4 Gaging Chamfered, Countersunk, or Recessed Threads

The reference point for gaging internal product threads depends upon the chamfer diameter. When the internal chamfer diameter exceeds the major diameter of the internal thread, the reference point is the last thread scratch on the chamfer cone. See Fig. 8B. Otherwise, when the internal chamfer diameter does not exceed the major diameter of the internal thread, the reference point is the end of the

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TABLE 9 TOLERANCES FOR AMERICAN NATIONAL STANDARD WORKING TAPER PIPE THREAD PLUG AND RING GAGES, NPT

Nominal Pipe Size	O.D. of Pipe, (D)	Threads/ in.	Tolerance on Pitch Diam.[1] (±)	Tolerance on Lead[2,4]		Tolerance on Half Angle,[3] Minutes		Tolerance on Taper[4,5]		Tolerance on Major Diam.	Tolerance on Minor Diam.	Total Cumulative Tolerances on Pitch Diam.		Standoff between Plug and Ring Gages at Gaging Notch for Dimensions at Opposite Extreme Tolerance Limits[6]
				Plugs	Rings	Plugs (±)	Rings (±)	Plugs (+)	Rings (−)	Plugs (−)	Rings (+)	Plugs	Rings	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1/16	0.3125	27	0.0002	0.0002	0.0003	15	20	0.0003	0.0006	0.0004	0.0004	0.00080	0.00118	0.032
1/8	0.405	27	0.0002	0.0002	0.0003	15	20	0.0003	0.0006	0.0004	0.0004	0.00080	0.00118	0.032
1/4	0.540	18	0.0002	0.0002	0.0003	15	20	0.0004	0.0007	0.0006	0.0006	0.00092	0.00134	0.036
3/8	0.675	18	0.0002	0.0002	0.0003	15	20	0.0004	0.0007	0.0006	0.0006	0.00092	0.00134	0.036
1/2	0.840	14	0.0003	0.0002	0.0003	10	15	0.0006	0.0009	0.0010	0.0010	0.00097	0.00142	0.038
3/4	1.050	14	0.0003	0.0002	0.0003	10	15	0.0006	0.0009	0.0010	0.0010	0.00097	0.00142	0.038
1	1.315	11.5	0.0003	0.0003	0.0004	10	15	0.0008	0.0012	0.0010	0.0010	0.00121	0.00170	0.047
1 1/4	1.660	11.5	0.0003	0.0003	0.0004	10	15	0.0008	0.0012	0.0010	0.0010	0.00121	0.00170	0.047
1 1/2	1.900	11.5	0.0003	0.0003	0.0004	10	15	0.0008	0.0012	0.0010	0.0010	0.00121	0.00170	0.047
2	2.375	11.5	0.0003	0.0003	0.0004	10	15	0.0008	0.0012	0.0010	0.0010	0.00121	0.00170	0.047
2 1/2	2.875	8	0.0005	0.0004	0.0005	7	10	0.0010	0.0014	0.0016	0.0016	0.00158	0.00211	0.059
3	3.500	8	0.0005	0.0004	0.0005	7	10	0.0010	0.0014	0.0016	0.0016	0.00158	0.00211	0.059
3 1/2	4.000	8	0.0005	0.0004	0.0005	7	10	0.0010	0.0014	0.0016	0.0016	0.00158	0.00211	0.059
4	4.500	8	0.0005	0.0004	0.0005	7	10	0.0010	0.0014	0.0016	0.0016	0.00158	0.00211	0.059
5	5.563	8	0.0005	0.0004	0.0005	7	10	0.0010	0.0014	0.0016	0.0016	0.00158	0.00211	0.059
6	6.625	8	0.0005	0.0004	0.0005	7	10	0.0010	0.0014	0.0016	0.0016	0.00158	0.00211	0.059
8	8.625	8	0.0005	0.0004	0.0005	7	10	0.0010	0.0014	0.0020	0.0020	0.00158	0.00211	0.059
10	10.750	8	0.0005	0.0004	0.0005	7	10	0.0010	0.0014	0.0020	0.0020	0.00158	0.00211	0.059
12	12.750	8	0.0005	0.0004	0.0005	7	10	0.0010	0.0014	0.0020	0.0020	0.00158	0.00211	0.059
14 O.D.	14.000	8	0.0008	0.0005	0.0006	7	10	0.0010	0.0014	0.0030	0.0030	0.00206	0.00271	0.076
16 O.D.	16.000	8	0.0008	0.0005	0.0006	7	10	0.0010	0.0014	0.0030	0.0030	0.00206	0.00271	0.076
18 O.D.	18.000	8	0.0008	0.0005	0.0006	7	10	0.0010	0.0014	0.0030	0.0030	0.00206	0.00271	0.076
20 O.D.	20.000	8	0.0008	0.0005	0.0006	7	10	0.0010	0.0014	0.0030	0.0030	0.00206	0.00271	0.076
24 O.D.	24.000	8	0.0008	0.0005	0.0006	7	10	0.0010	0.0014	0.0020	0.0020	0.00206	0.00271	0.076

GENERAL NOTES:

(a) The large end of the master ring gage shall be flush with the gaging notch of its master plug when assembled handtight within ±0.002 for sizes 1/16 to 2 inclusive, within ±0.003 for sizes 2 1/2 to 12, inclusive, and within ±0.005 for sizes 14 and larger.

(b) The tolerances for the length L_1 from small end to gaging notch of the plug gaged (Fig. 4) shall be + 0.000 and − 0.001 for sizes 1/16 to 2, inclusive, and + 0.000 and − 0.002 for sizes 2 1/2 and larger.

(c) The tolerances for the over-all thread length L_2 of the plug gage (Fig. 4) shall be + 0.050 and − 0.000 for all sizes.

(d) Tolerances for the thickness L_1 of the ring gage (Fig. 4) shall be − 0.000 and + 0.001 for sizes 1/16 to 2, inclusive, and − 0.000 and + 0.002 for sizes 2 1/2 and larger.

NOTES:

(1) To be measured at the gaging notch of plug gage.

(2) Allowable variation in lead between any two threads in L_1 length of gage (Fig. 4).

(3) In solving for the correction in diameter for angle deviations, the average deviation in half angle for the two sides of thread regardless of their signs should be taken.

(4) The lead and taper on plug and ring gages shall be measured along the pitch line omitting the imperfect threads at each end.

(5) Allowable variation in taper in L_1 length of gage (Fig. 4).

(6) Maximum possible interchange standoff, any ring against any plug other than its master plug, may occur when taper deviations are zero and all other dimensions are at opposite extreme tolerance limits. Average standoff should be well within these maximum limits.

TABLE 10 DIAMETER EQUIVALENT OF DEVIATION[1] IN HALF INCLUDED ANGLE OF THREAD FOR TOOLS AND GAGES[3]

Deviation[2] ($\delta\alpha$) Minutes	8 Threads/in.	11.5 Threads/in.	14 Threads/in.	18 Threads/in.	27 Threads/in.
1	2	3	4	5	6
1	0.00006	0.00004	0.00003	0.00002	0.00002
2	0.00011	0.00008	0.00006	0.00005	0.00003
3	0.00017	0.00012	0.00010	0.00007	0.00005
4	0.00022	0.00016	0.00013	0.00010	0.00007
5	0.00028	0.00019	0.00016	0.00012	0.00008
6	0.00034	0.00023	0.00019	0.00015	0.00010
7	0.00039	0.00027	0.00022	0.00017	0.00012
8	0.00045	0.00031	0.00026	0.00020	0.00013
9	0.00050	0.00035	0.00029	0.00022	0.00015
10	0.00056	0.00039	0.00032	0.00025	0.00017
11	0.00062	0.00043	0.00035	0.00027	0.00018
12	0.00067	0.00047	0.00038	0.00030	0.00020
13	0.00073	0.00051	0.00042	0.00032	0.00022
14	0.00078	0.00054	0.00045	0.00035	0.00023
15	0.00084	0.00058	0.00048	0.00037	0.00025
16	0.00089	0.00062	0.00051	0.00040	0.00027
17	0.00095	0.00066	0.00054	0.00042	0.00028
18	0.00101	0.00070	0.00058	0.00045	0.00030
19	0.00106	0.00074	0.00061	0.00047	0.00031
20	0.00112	0.00078	0.00064	0.00050	0.00033
21	0.00117	0.00082	0.00067	0.00052	0.00035
22	0.00123	0.00086	0.00070	0.00055	0.00036
23	0.00129	0.00089	0.00074	0.00057	0.00038
24	0.00134	0.00093	0.00077	0.00060	0.00040
25	0.00140	0.00097	0.00080	0.00062	0.00041
26	0.00145	0.00101	0.00083	0.00065	0.00043
27	0.00151	0.00105	0.00086	0.00067	0.00045
28	0.00157	0.00109	0.00089	0.00070	0.00046
29	0.00162	0.00113	0.00093	0.00072	0.00048
30	0.00168	0.00117	0.00096	0.00075	0.00050
45	0.00252	0.00175	0.00144	0.00112	0.00075
50	0.00336	0.00233	0.00192	0.00149	0.00099

GENERAL NOTE: Values given in inches at 68°F.

NOTES:

(1) In solving for the diameter equivalent of angle deviations the average deviation in half included angle for the two sides of the thread regardless of their signs should be taken.

(2) Diameter equivalent = $0.53812p$ tan $\delta\alpha$, where $\delta\alpha$ = deviation in half included angle of thread expressed in minutes.

(3) Table is based upon an NPT gage with $0.1p$ root/crest Truncations with equal half-angle deviations. For other gages with equal truncations, multiply by

$$\frac{0.866p - 2(\text{truncation})}{0.6667p}$$

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TABLE 11 DIAMETER EQUIVALENT OF DEVIATION IN LEAD FOR TOOLS AND GAGES[1]

Deviation (δp)	0.00000	0.00001	0.00002	0.00003	0.00004	0.00005	0.00006	0.00007	0.00008	0.00009
1	2	3	4	5	6	7	8	9	10	11
0.00000	0.00000	0.00002	0.00003	0.00005	0.00007	0.00009	0.00010	0.00012	0.00014	0.00016
0.00010	0.00017	0.00019	0.00021	0.00023	0.00024	0.00026	0.00028	0.00029	0.00031	0.00033
0.00020	0.00035	0.00036	0.00038	0.00040	0.00042	0.00043	0.00045	0.00047	0.00048	0.00050
0.00030	0.00052	0.00054	0.00055	0.00057	0.00059	0.00061	0.00062	0.00064	0.00066	0.00068
0.00040	0.00069	0.00071	0.00073	0.00074	0.00076	0.00078	0.00080	0.00081	0.00083	0.00085
0.00050	0.00087	0.00088	0.00090	0.00092	0.00094	0.00095	0.00097	0.00099	0.00100	0.00102
0.00060	0.00104	0.00106	0.00107	0.00109	0.00111	0.00113	0.00114	0.00116	0.00118	0.00120
0.00070	0.00121	0.00123	0.00125	0.00126	0.00128	0.00130	0.00132	0.00133	0.00135	0.00137
0.00080	0.00139	0.00140	0.00142	0.00144	0.00145	0.00147	0.00149	0.00151	0.00152	0.00154
0.00090	0.00156	0.00158	0.00159	0.00161	0.00163	0.00165	0.00166	0.00168	0.00170	0.00171
0.00100	0.00173	0.00175	0.00177	0.00178	0.00180	0.00182	0.00184	0.00185	0.00187	0.00189
0.00110	0.00191	0.00192	0.00194	0.00196	0.00197	0.00199	0.00201	0.00203	0.00204	0.00206
0.00120	0.00208	0.00210	0.00211	0.00213	0.00215	0.00217	0.00218	0.00220	0.00222	0.00223
0.00130	0.00225	0.00227	0.00229	0.00230	0.00232	0.00234	0.00236	0.00237	0.00239	0.00241
0.00140	0.00242	0.00244	0.00246	0.00248	0.00249	0.00251	0.00253	0.00255	0.00256	0.00258
0.00150	0.00260	0.00262	0.00263	0.00265	0.00267	0.00268	0.00270	0.00272	0.00274	0.00275
0.00160	0.00277	0.00279	0.00281	0.00282	0.00284	0.00286	0.00288	0.00289	0.00291	0.00293
0.00170	0.00294	0.00296	0.00298	0.00300	0.00301	0.00303	0.00305	0.00307	0.00308	0.00310
0.00180	0.00312	0.00313	0.00315	0.00317	0.00319	0.00320	0.00322	0.00324	0.00326	0.00327
0.00190	0.00329	0.00331	0.00333	0.00334	0.00336	0.00338	0.00339	0.00341	0.00343	0.00345
0.00200	0.00346	0.00348	0.00350	0.00352	0.00353	0.00355	0.00357	0.00359	0.00360	0.00362

GENERAL NOTE: Values given in inches at 68° F.

NOTE:

(1) Diameter equivalent = $1.732\delta p$, where δp = deviation in lead between any two threads.

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fitting. An allowance must be made for the depth of counterbore on counterbored fittings.

The reference point for gaging or measuring the length of external product threads is the end of the pipe.

8.4.1 Turns-Engagement Method of Gaging. The turns-engagement method of gaging taper threads with plug and ring pipe thread gages, determines that an adequate number of threads is available at hand engagement, thus avoiding possible complications resulting from gage chamfer and product chamfer. See Table 2, col. 7, for the basic number of turns in the absence of chamfers (e.g., 4.32 turns for 27 tpi), the applicable tolerance being plus or minus one turn (or limits 3.32 to 5.32 turns for 27 tpi).

9 GAGING OF STRAIGHT PIPE THREADS

9.1 Types of Gages

Gages to properly control the production of these straight threads should be either straight GO and HI (Internal) and GO and LO (External) gages or the regular American National Standard Taper Pipe Thread gages as indicated below.

9.1.1 Use of Straight and Taper Gages. Straight GO and HI/LO gages should be used for all types of threaded joints where both the external and internal threads are straight. Taper plug gages should be used for the internal threads of all types of mechanical joints where the external thread is tapered and the internal thread is straight. Taper plug gages used for this purpose should be checked periodically by direct measurement.

9.1.2 Gaging Pressure-tight Joints. Taper thread gages shall be used to gage straight internal pipe threads forming part of pressure-tight joints where the external thread is tapered.

The plane of the gaging notch on the American National Standard Taper Pipe Thread plug gage shall come flush with the end of the American National Standard Coupling Straight Pipe Thread (NPSC) (Table 4) or flush with the last thread scratch on the chamfer cone if chamfered with an internal chamfer diameter in excess of the major diameter of the internal thread (see Fig. 8B). A tolerance of one and one-half turns large or small to gage shall be allowed.

CAUTION: When using a tapered thread plug gage, nonuniformity of gage wear is a particular problem; therefore, taper plug gages used for this application should be checked by direct measurement of thread form and size in addition to checking against a master.

9.2 Gage Dimensions

The straight GO and HI plug gages and the straight GO and LO ring gages used for checking mechanical joint threads, Tables 6 and 7, shall be made to the pitch diameter limits specified in the product tables in accordance with standard practice for straight thread gages as outlined in ANSI B1.2, Gages and Gaging for Unified Screw Threads.

The minimum major diameter of the GO thread plug gage shall be equal to the minimum pitch diameter of the internal thread plus an amount equal to 0.75H (0.649519p). The maximum major diameter of the HI thread plug gage shall be equal to the maximum pitch diameter of the internal thread plus an amount equal to 0.50H (0.433013p).

The maximum minor diameter of the GO thread ring gage shall be equal to the maximum pitch diameter of the external thread minus an amount equal to 0.50H (0.433013p). The minimum minor diameter of the LO thread ring gage shall be equal to the minimum pitch diameter of the external thread minus an amount equal to 0.25H (0.216506p).

See ANSI B1.2 for further details and tolerances for these straight thread gages.

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APPENDIX

(This Appendix is not part of American National Standard, Pipe Threads, General Purpose (Inch) ANSI/ASME B1.20.1-198x, but is included for information purposes only.)

Suggested Twist Drill Diameters for Drilled Hole Sizes for Pipe Threads

The drill diameters given in Table 1 are the diameters of the standard and stock drills which are the closest to the minimum minor diameters shown in Table 2, col. 24.

They represent the diameters of the holes which would be cut with a twist drill correctly ground when drilling a material without tearing or flow of metal. This is approximately the condition that exists when a correctly sharpened twist drill is cutting a hole in a homogeneous block of cast iron.

When flat drills are used, the width of the cutting edge may have to be adjusted to produce a hole of the required diameter.

When nonferrous metals and other similar materials are to be drilled and tapped, it may be found necessary to use a drill of slightly larger or smaller diameter to produce a hole of a size that will make it possible for the tap to cut an acceptable pipe thread with the required thread height.

It should be understood that this table of twist drill diameters is intended to help only the occasional user of drills in the application of this Standard. When internal pipe threads are produced in larger quantities in a particular type of material and with specially designed machinery it may be found to be more advantageous to use a drill size not given in the table, even one having a nonstandard diameter.

TABLE A1 SUGGESTED TWIST DRILL DIAMETERS (INCHES) FOR DRILLED HOLE SIZES FOR PIPE THREADS

Nom. Pipe Size	O.D. of Pipe (*D*)	Taper Thread		Straight Pipe Thread (NPSC)[2]
		With use of Reamer	Without use of Reamer	
1	2	3	4	5
1/16	0.3125	A 0.234[1]	C 0.242[1]	1/4 0.250[1]
1/8	0.405	21/64 0.328[1]	Q 0.332[1]	11/32 0.344[1]
1/4	0.540	27/64 0.422[1]	7/16 0.438[1]	7/16 0.438[1]
3/8	0.675	9/16 0.562[1]	9/16 0.562[1]	37/64 0.578[1]
1/2	0.840	11/16 0.688[1]	45/64 0.703[1]	23/32 0.719[1]
3/4	1.050	57/64 0.891[1]	29/32 0.906[1]	59/64 0.922[1]
1	1.315	1 1/8 1.125[1]	1 9/64 1.141[1]	1 5/32 1.156[1]
1 1/4	1.660	1 15/32 1.469	1 31/64 1.484	1 1/2 1.500
1 1/2	1.900	1 45/64 1.703	1 23/32 1.719	1 3/4 1.750
2	2.375	2 11/64 2.172	2 3/16 2.188	2 7/32 2.219
2 1/2	2.875	2 37/64 2.578	2 39/64 2.609	2 21/32 2.656

GENERAL NOTE: The use of twist drills of the diameters listed will not assure completely formed threads over the entire L_1 length.

NOTES:

(1) American National Standard twist drill sizes in accordance with ANSI B94.11, applicable to commercial threads only.

(2) Twist drill diameters for NPSM, NPSL and NPSH threads may be larger to suit the increased internal minor diameters established for these threads. Refer to Tables 6 and 7 in this Standard and Table 3 in ANSI B2.4, Hose Coupling Screw Threads.

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CAST IRON PIPE FLANGES AND FLANGED FITTINGS

Classes 25, 125, and 250

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CAST IRON PIPE FLANGES AND FLANGED FITTINGS

Classes 25, 125, and 250

ASME B16.1-1998
(Revision of ASME/ANSI B16.1-1989)

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FOREWORD

(This Foreword is not part of ASME B16.1-1998.)

In 1894, the American Society of Mechanical Engineers (ASME) adopted a standard flange template ("ASME Standard") for low-pressure service. A "Manufacturers Standard" for pressures up to 250 psi followed in 1901. Around 1910, a group of fittings manufacturers formed an organization that was the forerunner of the present Manufacturers Standardization Society of the Valve and Fittings Industry (MSS) and undertook the design of a line of flanged fittings. A document covering this work was published in 1912.

During the years 1912–1914, a Joint Committee of the ASME and the Manufacturers Committee formulated compromise standard dimensions for pipe flanges and flanged fittings for use under saturated steam pressures of 125 psi and 250 psi pressure ranges. The Joint Committee's report was accepted at a conference attended by representatives of ASME, the Manufacturers Committee, the U.S. government, and the National Association of Master Steam and Hot Water Fitters. ASME published this report as the "American Standard for Pipe Flanges, Fittings and Their Bolting" in 1914. In 1918, work was started on standards for 50 lb steam flanges and for 800 lb, 1200 lb, and 3000 lb hydraulic flanges, which were subsequently approved by this group.

In 1921, the American Engineering Standards Committee, later known as the American Standards Association (ASA), United States of America Standards Institute (USAS), and more recently, the American National Standards Institute (ANSI), organized Sectional Committee B16 to unify and further develop national standards for pipe flanges and fittings (and later for valves and gaskets). Cosponsors of the B16 Committee were ASME, MSS, and the Heating and Piping Contractors Association [now the Mechanical Contractors Association of America (MCAA)]. Work already in progress on flanges and flanged fittings was assigned to Subcommittee 1 (now Subcommittee A). Following approval by the Subcommittee, the B16 Committee, the cosponsors, and ASA, the standards were published in 1928.

In later work, Subcommittee 1 developed the 25 lb Flange and Flanged Fitting Standard (approved in 1931 as ASA B16b2), which replaced the 50 lb standard that had been originally approved in 1918. Work on the 800 lb Hydraulic Flange Standard was published as ASA B16b1 in 1931. Revision of thicknesses, tolerances, and service pressure ratings of the 125 lb and 250 lb flanges and flanged fittings led to approval and publication of ASA B16a-1939.

An American War Standard entitled "Pressure Ratings for Cast Iron Flanges and Flanged Fittings, 125 lb" (ASA B16a1) was published in 1943. A complete review of the 125 lb and 250 lb standards resulted in new editions of each: ASA B16.1-1948 and ASA B16.2-1948. In 1960, editions of B16.1 and B16.2 were issued in which ratings were presented in graphic form and special requirements were added for testing flanges.

A review of all cast iron flange and flanged fittings standards initiated in 1962 resulted in the withdrawal of B16.16, "300 lb Refrigerant Flanges and Flanged Fittings" and the combining of the remaining standards into a single document, with B16.1 and B16.2 coming together as USAS B16.1-1967. In this edition, the presentation of ratings was restored to tabular form.

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The increasing use of higher grades of cast iron necessitated the establishment of a second set of ratings for the smaller sizes. A revised edition published as ANSI B16.1-1975 incorporated these new ratings along with metric (SI) equivalents for dimensions and minor corrections to the 1967 edition text.

In 1982, American National Standards Committee B16 was recognized as an ASME Committee operating under procedures accredited by ANSI. Following approval by the ASME B16 Subcommittee A and B16 Committee, ANSI approved ASME/ANSI B16.1-1989 on March 8, 1989. Changes included revised marking requirements, revised bolt length increments ($\frac{1}{2}$ in. rather than $\frac{1}{4}$ in.), elimination of metric equivalents, a correction of the Class 800 flange raised face height to 0.25 in. from the 0.06 in. shown previously, and editorial changes to the text.

In the 1998 edition of ASME B16.1, Reference Standards have been updated, a Quality System Program Annex has been added, Class 800 has been deleted, and several editorial revisions have been made. Following approval by ASME B16 Subcommittee B and B16 Main Committee, ANSI approved this American National Standard on November 20, 1998.

Requests for interpretation or suggestions for revision should be sent to the Secretary, B16 Committee, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

RATINGS OF ASME B16.1 VERSUS ANSI/AWWA A21.10

Attention is directed to an apparent conflict in ambient temperature pressure ratings for flanged fittings between ASME B16.1 and ANSI/AWWA A21.10, Gray Iron and Ductile Iron Fittings, 2 in. through 48 in. for Water and Other Liquids.

The scope of ANSI/AWWA A21.10 limits that standard to fittings for use with gray iron and ductile iron pipe for water and other liquids at rated working pressures of 150 psi and 250 psi. The ratings of these fittings were established on the basis of hydrostatic testing of fittings to bursting, and do provide a factor of safety of at least 3.0 at the rated working pressure and at ambient temperature.

ASME B16.1 covers both separate flanges and flanged fittings for more general service at ambient and elevated temperatures. The pressure ratings set forth are not based upon burst strength, but have evolved over an extended period of time of satisfactory performance in a wide range of general service conditions. The ratings encompass pressure combined with elevated temperature, stresses imposed by piping, thermal stresses due to temperature variations, and many other conditions causing stress in the flange or fitting.

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Standardization of Valves, Flanges, Fittings, Gaskets, and Valve Actuators

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CAST IRON PIPE FLANGES AND FLANGED FITTINGS
Classes 25, 125, and 250

1 SCOPE

1.1 General

This Standard for Classes 25, 125, and 250 Cast Iron Pipe Flanges and Flanged Fittings covers:

(a) pressure–temperature ratings

(b) sizes and method of designating openings of reducing fittings

(c) marking

(d) minimum requirements for materials

(e) dimensions and tolerances

(f) bolt, nut, and gasket dimensions

(g) tests

1.2 References

Standards and specifications adopted by reference in this Standard are shown in Annex I, which is part of this Standard.

1.3 Quality Systems

Requirements relating to the product manufacturer's Quality System Programs are described in Annex A.

2 PRESSURE–TEMPERATURE RATINGS

2.1 General

Pressure ratings for various temperatures (including limitations) are shown in Table 1.

2.2 Ratings

Ratings are independent of the contained fluid and are the maximum nonshock pressures at the tabulated temperatures. Intermediate ratings may be obtained by linear interpolation between the temperatures shown.

2.3 Rating Temperature

Temperatures shown for the corresponding pressure rating shall be the material temperature of the pressure-retaining structure. It may be assumed that the material temperature is the same as the fluid temperature. Use of a pressure rating at a material temperature other than that of the contained fluid is the responsibility of the user and subject to the requirements of any applicable code.

2.4 Low-Temperature Ratings

Pressure ratings for temperatures below −20°F should be determined in accordance with low-temperature properties of cast iron (ASTM A 126) as governed by applicable codes.

3 SIZE

3.1 Nominal Pipe Size

The sizes of the flanges and fittings shown in Figs. 2 through 9 and scheduled in Tables 2 through 9 are identified by the corresponding nominal pipe sizes. NPS as used in this document means the nominal pipe size.

3.2 Reducing Fittings

Reducing fittings shall be designated by the size of the openings in their proper sequence as indicated in the sketches of Fig. 1.

4 MARKING

4.1 Fittings

The manufacturer's name or trademark and numerals as shown below for each rating shall be cast on the exterior surface of all fittings.

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Rating Class	Size	Numeral
25	All	25
125	1 to 12	125
	14 to 24	100
	30 to 48	50
250	1 to 12	250
	14 to 24	200
	30 to 48	100

4.2 Flanges

The manufacturer's name or trademark shall be cast on all loose flanges. In addition, numerals 25 shall be cast on Class 25 flanges. Rating numerals for other classes shall be cast on loose flanges that are subject to the requirements of para. 4.3.

4.3 Material Class

In those sizes and classes where both Classes A and B iron can be used, the letter A or B shall be cast on both flanges and fittings adjacent to the rating numerals. Flanges and fittings with no A or B Class iron marking shall be considered as Class A iron for rating purposes.

5 MATERIALS

5.1 Castings

The castings shall meet the requirements of ASTM A 126 as listed in para. 5.1.1.

5.1.1 The material requirements for flanges and flanged fittings shall be as follows:

Rating Class	Size	Class of Iron ASTM A 126
25	All	A
125	1 to 12	A or B
	14 and above	B
250	1 to 12	A or B
	14 and above	B

5.2 Bolting

The bolting used with these flanges and fittings shall be made of carbon steel that conforms to the requirements of ASTM A 307 Grade B[1] and used with ring-type gaskets.

6 FITTING DIMENSIONS AND TOLERANCES

6.1 Wall Thickness

It is recognized that some variations are absolutely unavoidable in the making of patterns and castings. Equipment shall be designed to produce wall thicknesses given in the tables. Wall thickness at no point shall be less than 87.5% of the thickness given in the tables.

6.2 Facing

6.2.1 Classes 25 and 125 cast iron flanges and flanged fittings shall be flat faced (i.e., without projection or raised face) and finished in accordance with MSS SP-6.

6.2.2 Class 250 flanges and flanged fittings shall have a raised face 0.06 in. high of the diameters given in Table 6 and finished in accordance with MSS SP-6. The raised face is included in the minimum flange thickness and center-to-face dimension.

6.3 Center-to-Face Dimensions

6.3.1 Side Outlet Fittings. Side outlet elbows, side outlet tees, and side outlet crosses shall have all openings on intersecting centerlines. Long-radius elbows with side outlet shall have the side outlet on the radial centerline of the elbow.

6.3.2 Elbows

(a) The center-to-face dimensions for straight-size 90 deg. elbows, 90 deg. long-radius elbows, 45 deg. elbows, side-outlet 90 deg. elbows, and double-branch elbows are shown in Tables 3, 5, and 7.

(b) Reducing 90 deg. elbows, reducing 90 deg. long-radius elbows, reducing side-outlet 90 deg. elbows, and reducing double-branch elbows shall have the same center-to-face dimensions as straight-size fittings shown in Tables 3, 5, and 7 corresponding to the size of the largest opening.

[1] For Classes 25 and 125 flanges: The carbon steel bolts prescribed for the flanges in this Standard are based on the use of a flat "ring" gasket that extends to the bolts.

Where cast iron to cast iron flanges or cast iron to steel flanges are used with full-face gaskets, higher strength bolts may properly be used.

Where cast iron flanges are bolted to steel flanges and flat ring gaskets are used, carbon steel bolts prescribed in this Standard shall be employed.

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(c) For 90 deg. long-radius elbows with side outlet, the center-to-face dimensions of the side outlet shall be the same as dimension *A* in Tables 3, 5, and 7 for a straight-size 90 deg. elbow corresponding to the size of the largest opening.

(d) Special-degree elbows ranging from 1 deg. to 45 deg., inclusive, shall have the same center-to-face dimensions as those for 45 deg. elbows; those over 45 deg. and up to 90 deg., inclusive, shall have the same center-to-face dimensions as those for 90 deg. elbows. The angle designation of an elbow is the angle between the flange faces.

6.3.3 Tees, Crosses, and Laterals

(a) The center-to-face dimensions for straight-size tees and crosses, with or without side outlet, and laterals are shown in Tables 3, 5, and 7.

(b) Reducing tees and reducing crosses, with or without side outlet, and reducing laterals, NPS 16 and smaller, shall have the same center-to-face dimensions as straight-size fittings shown in Tables 3, 5, and 7 corresponding to the size of the largest opening. For NPS 18 and larger, if the outlet of a reducing tee; the branch of a reducing lateral; or the largest outlet of a reducing side outlet tee, reducing cross, and reducing side outlet cross is the same size or smaller than given in Tables 3, 5, and 7 (short body pattern), the center-to-face dimensions shown in these Tables shall be used. If a branch or any outlet is larger than shown in Tables 3, 5, and 7, the center-to-face dimensions shall be the same as for the straight-size fitting shown in Tables 3, 5, and 7 corresponding to the size of the largest opening. Tees, crosses, and laterals, reducing on the run only, shall have the same center-to-face dimensions as straight-size fittings shown in Tables 3, 5, and 7 corresponding to the size of the largest opening.

(c) Tees reducing on both runs are generally known as bull-head tees and have the same center-to-face dimensions as straight-size fittings corresponding to the size of the outlet.

6.3.4 True Ys. Center-to-face dimensions for straight-size true Ys are shown in Tables 5 and 7. Reducing sizes are considered special and should be made to suit conditions.

6.3.5 Reducers and Eccentric Reducers. The face-to-face dimensions for all reductions of reducers and eccentric reducers shall be the same as given in Tables 5 and 7 for the largest opening.

6.4 Center-to-Face Tolerances

The following tolerances shall be permitted on all center-to-contact surface dimensions of fittings: Tolerances for contact surface-to-contact surface dimensions shall be twice those given below. The largest opening in the fitting governs the tolerance to be applied to all openings.

Nominal Pipe Size	Tolerance Plus or Minus, in.
10 and smaller	0.03
12 and larger	0.06

6.5 Threaded Flanges

6.5.1 General. Flanges shall have a Standard Taper Pipe Thread in accordance with ASME B1.20.1. The thread shall be concentric with the axis of the flange, and variations in alignment shall not exceed 0.06 in./ft. The gaging notch of working gage should come flush with the bottom of chamfer, and the maximum allowable thread variations are one turn large or one turn small from the gaging notch.

6.5.2 Class 125. Threads shall be countersunk a distance not less than one-half of the pitch of the thread at an angle approximately 45 deg. with the axis of the thread, for the purpose of easy entrance in making the joint and protection of the threads. Countersinking shall be concentric with the threads. The length of the threads shall be measured to include the countersink.

6.5.3 Class 250. Hub may be recessed. When not recessed, threads shall be countersunk a distance not less than one-half of the pitch of the thread at an angle approximately 45 deg. with the axis of the thread at the back of the flange. If hub is recessed, threads shall be 45 deg. countersunk to diameter of recess. The purpose is for easier entrance in making a joint and for the protection of the threads. Countersinking shall be concentric with the threads. The length of threads shall be measured to include the countersink.

6.6 Flange Bolt Holes

Flange bolt holes shall be in accordance with the dimensions shown in Tables 2, 4, and 6. Pairs of bolt holes shall straddle the centerline.

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6.7 Spot Facing

All flanges and flanged fittings covered by this Standard shall have bearing surfaces for bolting that are parallel to the flange face within 3 deg. Any back facing or spot facing required to accomplish parallelism shall not reduce the flange thickness Q below the dimensions given in Tables 2 through 7. Flange thickness at any point within the spot face area, as defined in MSS SP-9, shall not exceed the required minimum thickness by more than the following amounts.

Nominal Pipe Size	Excess Thickness, Max., in.
2 to 12	0.12
14 to 24	0.18
30 to 96	0.25

When required, all spot facing shall be done in accordance with MSS SP-9. Sharp corners shall be avoided in back facing.

6.8 Crosses and Lateral Reinforcement

Crosses and laterals (Y-branches) both straight and reducing shall be reinforced where necessary to compensate for the inherent weakness in the shape of these fittings.

6.9 Drain Tappings

Holes may be tapped in the wall of fittings if the metal thickness is sufficient to provide the effective length of thread as shown in Fig. 10 and as specified in Table 10. Where thread length is insufficient due to metal thickness or size of tapping is such that reinforcement of opening is necessary, an integral boss should be added. In no case shall the effective length of thread A be less than that shown in Table 10. These lengths are equal to the effective thread lengths as shown in ASME B1.20.1.

The method of designating the locations of the tapped holes for drains is shown in Fig. 11. Each possible location is designated by a letter so that desired locations for the various types of fittings may be definitely specified without the use of further sketches or description. For further detail in applying tappings, see MSS SP-45.

7 BOLT, NUT, AND GASKET DIMENSIONS

7.1 Bolting

Carbon steel bolts smaller than 0.75 in. shall have (ASME B18.2.1) square heads or (ASME B18.2.1) heavy hex heads, and shall have (ASME B18.2.2) heavy hex nuts.

Carbon steel bolts 0.75 in. and larger shall have (ASME B18.2.1) square heads or (ASME B18.2.1) hex heads and shall have (ASME B18.2.2) hex nuts or (ASME B18.2.2) heavy hex nuts or (ASME B18.2.2) square nuts. For bolt sizes 1.5 in. and larger, stud bolts with a nut on each end are recommended.

All bolts or (stud bolts) and all nuts shall be threaded in accordance with the Unified Screw Threads, standard coarse thread series (ASME B1.1) with Class 2A for bolts and Class 2B for nuts.

7.2 Gaskets[1]

Flat ring gaskets shall be in accordance with dimensions given in ASME B16.21 for nonmetallic gaskets for pipe flanges.

8 HYDROSTATIC TESTS

Tests are not required unless specified by the user.

(a) Fittings. Fittings shall be capable of withstanding, without showing leaks, the hydrostatic test pressures listed in Table 1 for the material and maximum working pressure of the item tested. These test pressures are 1.5 times the cold working pressure rate rounded to the next higher 10 psi in Table 1.

(b) Flanges. Flanges integral with or attached to equipment may be hydrostatically tested by the purchaser at his responsibility at pressures higher than specified herein.

9 CERTIFICATIONS

The manufacturer shall be able to certify that products are in conformance with the requirements of this Standard when required on the purchase order.

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TABLE 1 NONSHOCK GAGE PRESSURE–TEMPERATURE RATINGS

Temperature, °F	Class 25 [Note (1)] ASTM A 126		Class 125 ASTM A 126				Class 250 [Note (1)] ASTM A 126			
	Class A		Class A	Class B			Class A	Class B		
	NPS 4–36	NPS 42–96	NPS 1–12	NPS 1–12	NPS 14–24	NPS 30–48	NPS 1–12	NPS 1–12	NPS 14–24	NPS 30–48
–20 to 150	45	25	175	200	150	150	400	500	300	300
200	40	25	165	190	135	115	370	460	280	250
225	35	25	155	180	130	100	355	440	270	225
250	30	25	150	175	125	85	340	415	260	200
275	25	25	145	170	120	65	325	395	250	175
300	...	...	140	165	110	50	310	375	240	150
325	...	...	130	155	105	...	295	355	230	125
353 [Note (2)]	...	...	125	150	100	...	280	335	220	100
375	...	...	...	145	...	...	265	315	210	...
406 [Note (3)]	...	...	...	140	...	...	250	290	200	...
425	...	...	...	130	...	...	...	270	...	...
450	...	...	...	125	...	...	...	250	...	...
Hydrostatic Shell Test Pressures [Note (4)]										
100	70	40	270	300	230	230	600	750	450	450

GENERAL NOTES:
(a) Pressure is in lb/sq in. gage.
(b) NPS is nominal pipe size.

NOTES:
(1) Limitations:
  (a) Class 25. When Class 25 cast iron flanges and flanged fittings are used for gaseous service, the maximum pressure shall be limited to 25 psig. Tabulated pressure–temperature ratings above 25 psig for Class 25 cast iron flanges and flanged fittings are applicable for nonshock hydraulic service only.
  (b) Class 250. When used for liquid service, the tabulated pressure–temperature ratings in NPS 14 and larger are applicable to Class 250 flanges only and not to Class 250 fittings.
(2) 353°F (max.) to reflect the temperature of saturated steam at 125 psig.
(3) 406°F (max.) to reflect the temperature of saturated steam at 250 psig.
(4) Hydrostatic tests are not required unless specified by the user.

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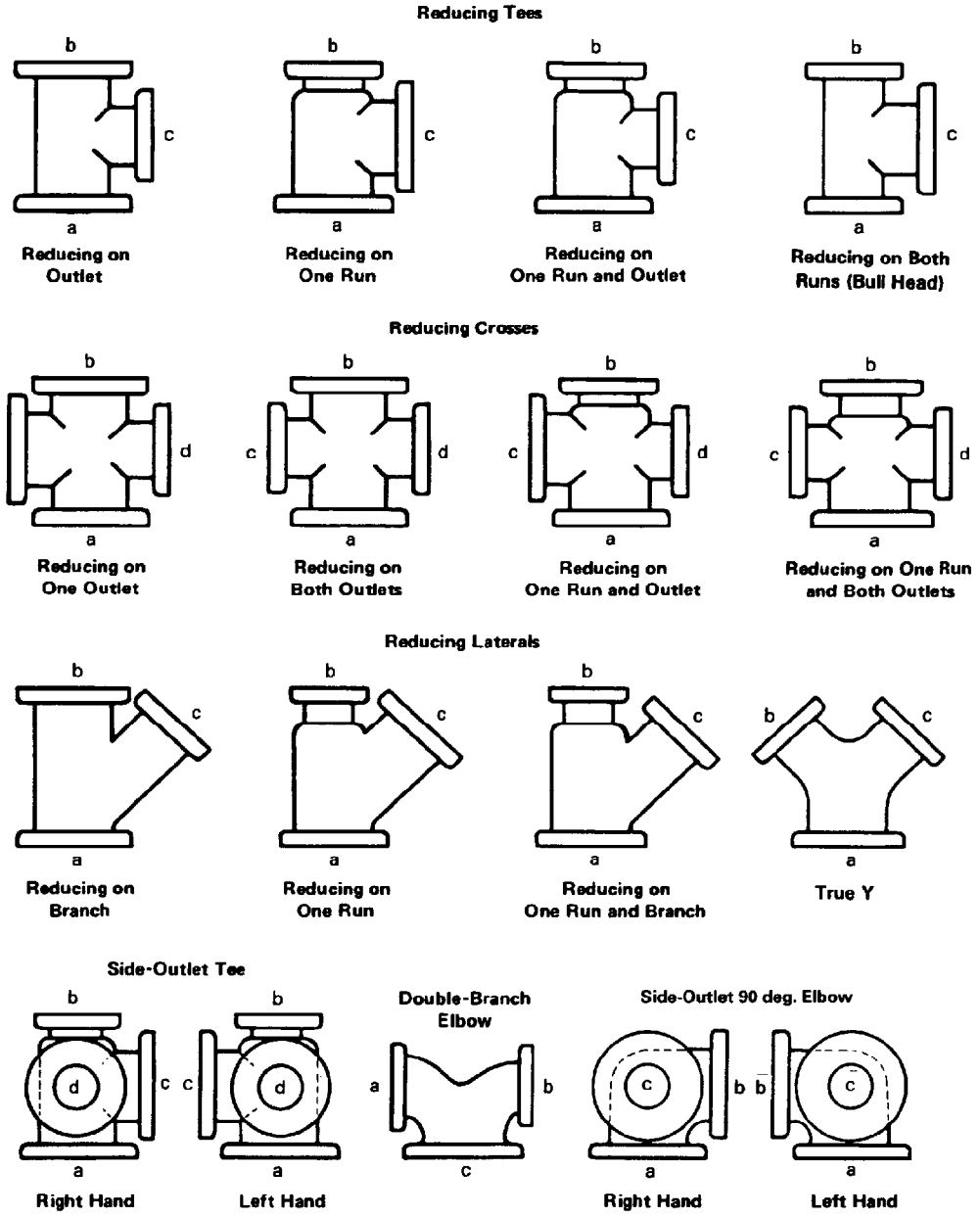

GENERAL NOTE:
The largest opening establishes the basic size of a reducing fitting. The largest opening is named first, except for bull-head tees, which are reducing on both runs, and double-branch elbows where both branches are reducing; the outlet is the largest opening and named last in both cases.

In designating the openings of reducing fittings, they should be read in the order indicated by the sequence of the letters a, b, c, and d. In designating the outlets of side-outlet reducing fittings, the side outlet is named last; and in the case of the cross (which is not shown), the side outlet is designated by the letter e.

FIG. 1 METHOD OF DESIGNATING OUTLETS OF REDUCING FITTINGS IN SPECIFICATIONS

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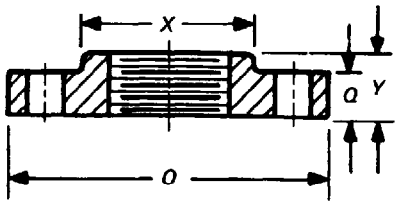

FIG. 2 CLASS 25 FLANGE

TABLE 2 FLANGES, BOLT HOLES, AND BOLTING DIMENSIONS OF CLASS 25 CAST IRON FLANGES

	Flanges				Bolt Holes		Bolting [Note (6)]		
			Hub						
Nominal Pipe Size	Diameter O	Thickness, Min. Q [Notes (1) and (2)]	Diameter, Min. X	Length, Min. Y	Diameter of Bolt Circle [Note (3)]	Diameter of Bolt Holes [Notes (3)–(5)]	Number of Bolts	Diameter of Bolts [Note (3)]	Length of Bolts
4	9.00	0.75	5.31	1.31	7.50	0.75	8	0.62	2.50
5	10.00	0.75	6.44	1.44	8.50	0.75	8	0.62	2.50
6	11.00	0.75	7.56	1.56	9.50	0.75	8	0.62	2.50
8	13.50	0.75	9.69	1.75	11.75	0.75	8	0.62	2.50
10	16.00	0.88	11.94	1.94	14.25	0.75	12	0.62	3.00
12	19.00	1.00	14.06	2.19	17.00	0.75	12	0.62	3.00
14	21.00	1.12	15.37	2.25	18.75	0.88	12	0.75	3.50
16	23.50	1.12	17.50	2.50	21.25	0.88	16	0.75	3.50
18	25.00	1.25	19.62	2.69	22.75	0.88	16	0.75	4.00
20	27.50	1.25	21.75	2.88	25.00	0.88	20	0.75	4.00
24	32.00	1.38	26.00	3.25	29.50	0.88	20	0.75	4.00
30	38.75	1.50	...	...	36.00	1.00	28	0.88	4.50
36	46.00	1.62	...	...	42.75	1.00	32	0.88	5.00
42	53.00	1.75	...	...	49.50	1.12	36	1.00	5.50
48	59.50	2.00	...	...	56.00	1.12	44	1.00	6.00
54	66.25	2.25	...	...	62.75	1.12	44	1.00	6.50
60	73.00	2.25	...	...	69.25	1.25	52	1.12	6.50
72	86.50	2.50	...	...	82.50	1.25	60	1.12	7.00
84	99.75	2.75	...	...	95.50	1.38	64	1.25	7.50
96	113.25	3.00	...	...	108.50	1.38	68	1.25	8.00

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) For facing, see para. 6.2.1.

(2) Threaded companion flanges should not be thinner than the Class 125 thickness on NPS 24 and smaller. Other types of flanges may have thicknesses as given above.

(3) The flange diameter, bolt circle, and number of bolts are the same in Class 25 as in Class 125. Bolt hole diameters of Class 25 shall not be modified when mated with Class 125 flanges or with steel flanges.

(4) For spot facing, see para 6.7.

(5) For flange bolt holes, see para. 6.6.

(6) For bolts and nuts, see para. 7.1.

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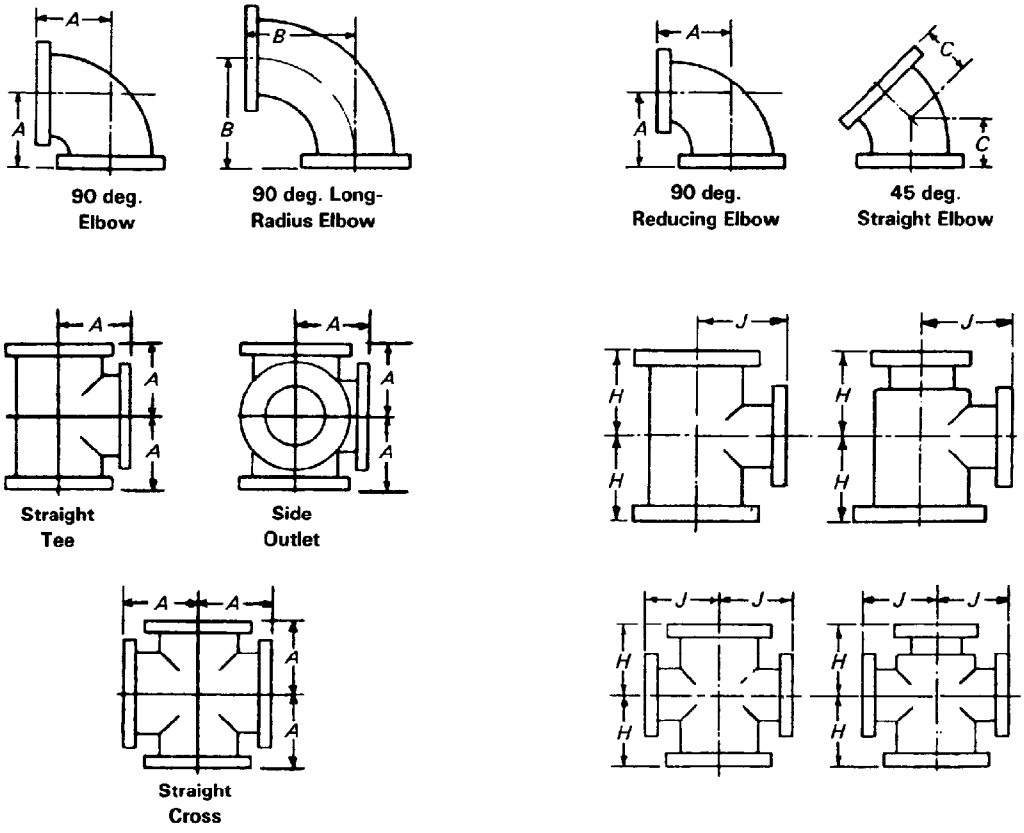

(For dimensions, see Table 3 on next page.)

FIG. 3 CLASS 25 FLANGED FITTINGS

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TABLE 3 DIMENSIONS OF CLASS 25 CAST IRON FLANGED FITTINGS[1–7]

	General				Straight Size [Note (4)]			Reducing Tees and Crosses (Short-Body Pattern) [Notes (13)–(15)]		
Nominal Pipe Size	Diameter of Flange	Thickness of Flange, Min.	Wall Thickness of Body [Note (8)]	Inside Diameter of Fitting	Center-to-Face Elbow, Tee, and Cross *A* [Notes (9)–(11)]	Center-to-Face Long-Radius Elbow *B*	Center-to-Face 45 deg. Elbow *C* [Note (12)]	NPS Size of Outlet and Smaller [Notes (16) and (17)]	Center-to-Face Run *H* [Note (4)]	Center-to-Face Outlet *J* [Note (4)]
4	9.00	0.75	0.42	4	6.5	9.00	4.0			
5	10.00	0.75	0.44	5	7.5	10.25	4.5			
6	11.00	0.75	0.44	6	8.0	11.50	5.0			
8	13.50	0.75	0.46	8	9.0	14.00	5.5	All reducing fittings NPS 16 and smaller have the same center-to-face dimensions as straight-size fittings.		
10	16.00	0.88	0.50	10	11.0	16.50	6.5			
12	19.00	1.00	0.54	12	12.0	19.00	7.5			
14	21.00	1.12	0.57	14	14.0	21.50	7.5			
16	23.50	1.12	0.60	16	15.0	24.00	8.0			
18	25.00	1.25	0.64	18	16.5	26.50	8.5	12.0	13.0	15.5
20	27.50	1.25	0.67	20	18.0	29.00	9.5	14.0	14.0	17.0
24	32.00	1.38	0.76	24	22.0	34.00	11.0	16.0	15.0	19.0
30	38.75	1.50	0.88	30	25.0	41.50	15.0	20.0	18.0	23.0
36	46.00	1.62	0.99	36	28.0	49.00	18.0	24.0	20.0	26.0
42	53.00	1.75	1.10	42	31.0	56.50	21.0	24.0	23.0	30.0
48	59.50	2.00	1.26	48	34.0	64.00	24.0	30.0	26.0	34.0
54	66.25	2.25	1.35	54	39.0	71.50	27.0	36.0	29.0	37.0
60	73.00	2.25	1.39	60	44.0	79.00	30.0	40.0	33.0	41.0
72	86.50	2.50	1.62	72	53.0	94.00	36.0	48.0	40.0	48.0

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) For facing, see para. 6.2.1.
(2) For flange bolt holes, refer to Table 2; see also para. 6.6.
(3) For spot facing, see para. 6.7.
(4) For center-to-face tolerances, see para. 6.4.
(5) For intersecting centerlines of side outlets, see para. 6.3.1.
(6) The flange diameter, bolt circle, and number of bolts are the same in Class 25 as in Class 125. Bolt hole diameters of Class 25 shall not be modified when mated with Class 125 flanges or with steel flanges.
(7) The center-to-face dimensions of fittings are the same as the Class 125.
(8) For wall thickness tolerance, see para. 6.1.
(9) For center-to-face dimensions of reducing elbows and side-outlet elbows, see paras. 6.3.2(b) and (c).
(10) Tees and crosses, reducing on run only, carry same dimensions center-to-face and face-to-face as a straight-size fitting of the larger opening.
(11) For reinforcement of crosses, see para. 6.8.
(12) For center-to-face dimensions of special degree elbows, see para. 6.3.2(d).
(13) Fittings reducing on the run only carry same dimensions center-to-face and face-to-face as straight-size fittings, corresponding to the size of the larger opening. Tees increasing on outlet, known as bull-head tees, will have same center-to-face and face-to-face dimensions as a straight fitting of the size of the outlet. For example, an NPS 12 × NPS 12 × NPS 18 tee will be governed by the dimensions of the NPS 18 long-body tee, given in Table 3, namely NPS 16½ center-to-face of all openings and NPS 33 face-to-face.
(14) Side-outlet tees, with outlet at 90 deg. or any other angle, straight or reducing, carry same dimensions center-to-face and face-to-face as regular tees having same reductions.
(15) In a side-outlet tee, the larger of the two side outlets governs the center-to-face dimension *J*.
(16) Tees, side-outlet tees, and crosses, NPS 16 and smaller, reducing on the outlet, have the same dimensions center-to-face and face-to-face as straight-size fittings, corresponding to the size of the larger opening. NPS 18 and larger, reducing on the outlet, are made in two lengths, depending on the size of the outlet as given in Table 3.
(17) Long-body patterns are used when outlets are larger than given above and, therefore, have the same dimensions as straight-size fittings.

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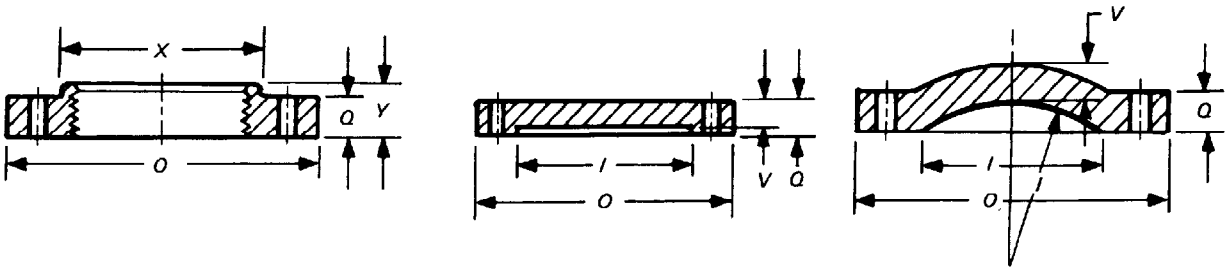

10 in. and Smaller Blind Flange

12 in. and Larger Blind Flange

(For dimensions, see Table 4 on next page.)

FIG. 4 CLASS 125 FLANGES

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TABLE 4 FLANGES, BOLT HOLES, AND BOLTING DIMENSIONS OF CLASS 125 CAST IRON FLANGES

	Flanges		Hub		Blind Flanges		Bolt Holes		Bolting			
Nominal Pipe Size	Diameter of Flange *O*	Thickness of Flange, Min. *Q* [Note (1)]	Diameter of Hub, Min. *X*	Length of Hub and Threads, Min. *Y* [Note (2)]	Diameter of Port *I* [Note (3)]	Wall Thickness *V* [Note (4)]	Diameter of Bolt Circle	Diameter of Bolt Holes [Notes (5) and (6)]	Number of Bolts	Diameter of Bolts	Length of Bolts [Notes (7) and (8)]	Length of Bolt-Stud With Two Nuts [Note (7)]
1	4.25	0.44	1.94	0.69	1.00	0.38	3.12	0.62	4	0.50	2.00	...
1¼	4.62	0.50	2.31	0.81	1.25	0.44	3.50	0.62	4	0.50	2.00	...
1½	5.00	0.56	2.56	0.88	1.50	0.50	3.88	0.62	4	0.50	2.00	...
2	6.00	0.62	3.06	1.00	2.00	0.56	4.75	0.75	4	0.62	2.50	...
2½	7.00	0.69	3.56	1.12	2.50	0.63	5.50	0.75	4	0.62	2.50	...
3	7.50	0.75	4.25	1.19	3.00	0.69	6.00	0.75	4	0.62	2.50	...
3½	8.50	0.81	4.81	1.25	3.50	0.75	7.00	0.75	8	0.62	3.00	...
4	9.00	0.94	5.31	1.31	4.00	0.88	7.50	0.75	8	0.62	3.00	...
5	10.00	0.94	6.44	1.44	5.00	0.88	8.50	0.88	8	0.75	3.00	...
6	11.00	1.00	7.56	1.56	6.00	0.94	9.50	0.88	8	0.75	3.50	...
8	13.50	1.12	9.69	1.75	8.00	1.06	11.75	0.88	8	0.75	3.50	...
10	16.00	1.19	11.94	1.94	10.00	1.12	14.25	1.00	12	0.88	4.00	...
12	19.00	1.25	14.06	2.19	12.00	0.81	17.00	1.00	12	0.88	4.00	...
14	21.00	1.38	15.38	2.25	14.00	0.88	18.75	1.12	12	1.00	4.50	...
16	23.50	1.44	17.50	2.50	16.00	1.00	21.25	1.12	16	1.00	4.50	...
18	25.00	1.56	19.62	2.69	18.00	1.06	22.75	1.25	16	1.12	5.00	...
20	27.50	1.69	21.75	2.88	20.00	1.12	25.00	1.25	20	1.12	5.00	...
24	32.00	1.88	26.00	3.25	24.00	1.25	29.50	1.38	20	1.25	5.50	...
30	38.75	2.12	...	...	30.00	1.44	36.00	1.38	28	1.25	6.50	...
36	46.00	2.38	...	...	36.00	1.62	42.75	1.62	32	1.50	7.00	9.00
42	53.00	2.62	...	...	42.00	1.81	49.50	1.62	36	1.50	7.50	9.50
48	59.50	2.75	...	...	48.00	2.00	56.00	1.62	44	1.50	8.00	9.50
54 [Note (9)]	66.25	3.00	...	...	...	...	62.75	2.00	44	1.75	8.50	10.50
60 [Note (9)]	73.00	3.12	...	...	...	...	69.25	2.00	52	1.75	9.00	11.00
72 [Note (9)]	86.50	3.50	...	...	...	...	82.50	2.00	60	1.75	9.50	11.50
84 [Note (9)]	99.75	3.88	...	...	...	...	95.50	2.25	64	2.00	10.50	13.00
96 [Note (9)]	113.25	4.25	...	...	...	...	108.50	2.50	68	2.25	11.50	14.00

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) For facing, see para. 6.2.1.
(2) For thread of threaded flanges, see paras. 6.5.1 and 6.5.2.
(3) All blind flanges NPS 12 and larger must be dished with inside radius equal to the port diameter.
(4) For wall thickness tolerance, see para. 6.1.
(5) For flange bolt holes, see para. 6.6.
(6) For spot facing, see para. 6.7.
(7) For bolts and nuts, see para. 7.1.
(8) Bolt lengths to be compensated for when bolting steel to cast iron flanges.
(9) These sizes are included for convenience. Pressure–temperature ratings are the user's responsibility.

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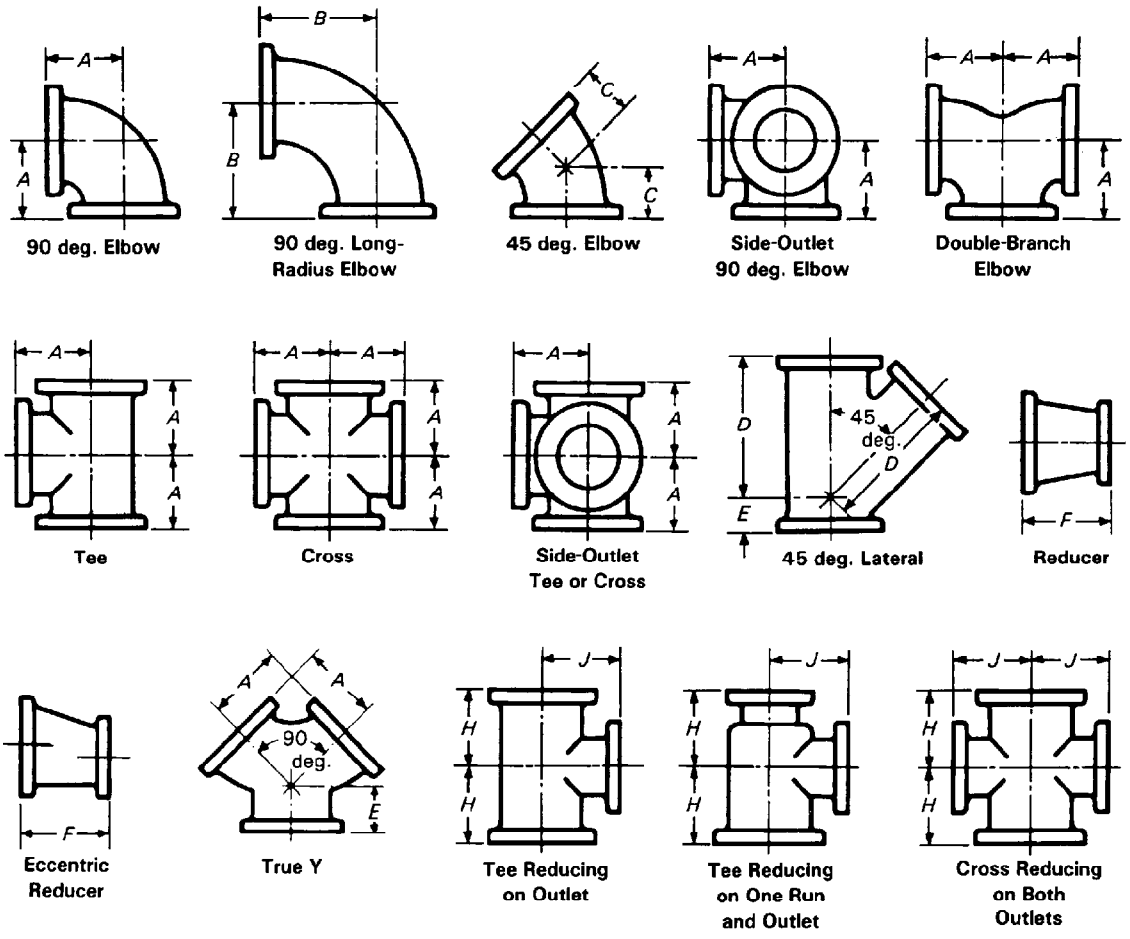

FIG. 5 CLASS 125 FLANGED FITTINGS

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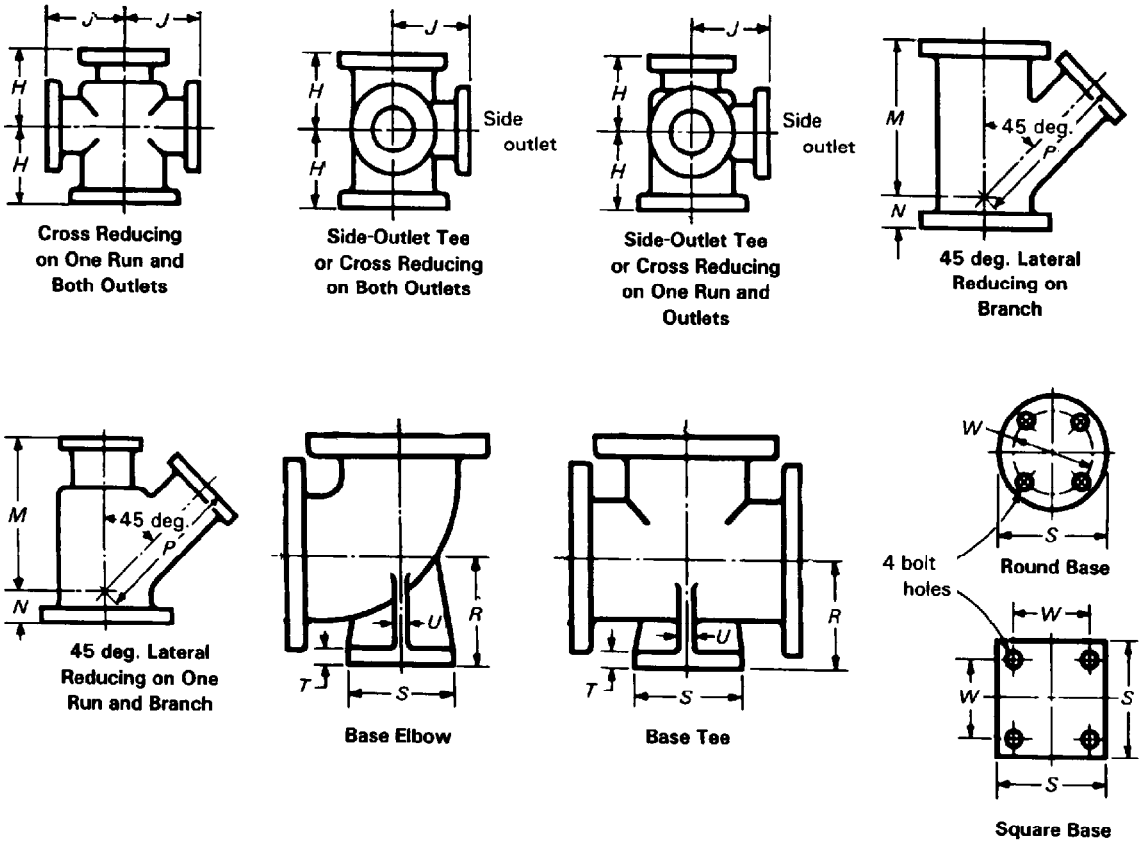

(For dimensions, see Table 5 on next page.)

FIG. 5 CLASS 125 FLANGED FITTINGS (CONT'D)

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TABLE 5 DIMENSIONS OF CLASS 125 CAST IRON FLANGED FITTINGS

	Flanges [Notes (1)–(3)]		General		Straight Fittings [Notes (5) and (6)]						Reducing Fittings (Short-Body Patterns) [Notes (11) and (12)]		
											Tees and Crosses [Notes (9), (13), and (14)]		
Nominal Pipe Size	Diameter of Flange	Thickness of Flange, Min.	Inside Diameter of Fittings	Wall Thickness [Note (4)]	Center-to-Face 90 deg. Elbow, Tees, Crosses, True Y, and Double-Branch Elbow *A* [Notes (6)–(9)]	Center-to-Face 90 deg. Long-Radius Elbow *B* [Notes (6)–(8)]	Center-to-Face 45 deg. Elbow *C* [Note (8)]	Center-to-Face Lateral *D* [Note (9)]	Short Center-to-Face True Y and Lateral *E* [Note (9)]	Face-to-Face Reducer *F* [Note (10)]	NPS Size of Outlet and Smaller [Notes (6) and (10)]	Center-to-Face Run *H*	Center-to-Face Outlet or Side Outlet *J*
1	4.25	0.44	1.00	0.31	3.50	5.00	1.75	5.75	1.75	...			
1¼	4.62	0.50	1.25	0.31	3.75	5.50	2.00	6.25	1.75	...			
1½	5.00	0.56	1.50	0.31	4.00	6.00	2.25	7.00	2.00	...			
2	6.00	0.62	2.00	0.31	4.50	6.50	2.50	8.00	2.50	5.0			
2½	7.00	0.69	2.50	0.31	5.00	7.00	3.00	9.50	2.50	5.5			
3	7.50	0.75	3.00	0.38	5.50	7.75	3.00	10.00	3.00	6.0	All reducing tees and crosses NPS 16 and smaller shall have the same center-to-face dimensions as straight-size fittings, corresponding to the size of the largest opening.		
3½	8.50	0.81	3.50	0.44	6.00	8.50	3.50	11.50	3.00	6.5			
4	9.00	0.94	4.00	0.50	6.50	9.00	4.00	12.00	3.00	7.0			
5	10.00	0.94	5.00	0.50	7.50	10.25	4.50	13.50	3.50	8.0			
6	11.00	1.00	6.00	0.56	8.00	11.50	5.00	14.50	3.50	9.0			
8	13.50	1.12	8.00	0.62	9.00	14.00	5.50	17.50	4.50	11.0			
10	16.00	1.19	10.00	0.75	11.00	16.50	6.50	20.50	5.00	12.0			
12	19.00	1.25	12.00	0.81	12.00	19.00	7.50	24.50	5.50	14.0			
14	21.00	1.38	14.00	0.88	14.00	21.50	7.50	27.00	6.00	16.0			
16	23.50	1.44	16.00	1.00	15.00	24.00	8.00	30.00	6.50	18.0			
18	25.00	1.56	18.00	1.06	16.50	26.50	8.50	32.00	7.00	19.0	12.0	13.0	15.5
20	27.50	1.69	20.00	1.12	18.00	29.00	9.50	35.00	8.00	20.0	14.0	14.0	17.0
24	32.00	1.88	24.00	1.25	22.00	34.00	11.00	40.50	9.00	24.0	16.0	15.0	19.0
30	38.75	2.12	30.00	1.44	25.00	41.50	15.00	49.00	10.00	30.0	20.0	18.0	23.0
36	46.00	2.38	36.00	1.62	28.00	49.00	18.00	...	...	36.0	24.0	20.0	26.0
42	53.00	2.62	42.00	1.81	31.00	56.50	21.00	...	...	42.0	24.0	23.0	30.0
48	59.50	2.75	48.00	2.00	34.00	64.00	24.00	...	...	48.0	30.0	26.0	34.0

(continued)

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TABLE 5 DIMENSIONS OF CLASS 125 CAST IRON FLANGED FITTINGS (CONT'D)

Nominal Pipe Size	Reducing Fittings (Short-Body Patterns) [Notes (11) and (12)]				Base Elbows and Tees [Notes (15)–(17)]						
	Laterals [Note (9)]									Base Drilling	
	NPS Size of Branch and Smaller	Center-to-Face Run *M*	Center-to-Face Run *N*	Center-to-Face Branch *P*	Center-to-Base *R*	Diameter of Round Base or Width of Square Base *S* [Notes (18) and (19)]	Thickness of Base *T*	Thickness of Ribs *U*	NPS Size of Supporting Pipe for Base	Bolt Circle or Bolt Spacing *W*	Diameter of Holes
1					3.50	3.50	0.44	0.38	3/4	2.75	0.62
1 1/4					3.62	3.50	0.44	0.38	3/4	2.75	0.62
1 1/2					3.75	4.25	0.44	0.50	1	3.12	0.62
2					4.12	4.62	0.50	0.50	1 1/4	3.50	0.62
2 1/2					4.50	4.62	0.50	0.50	1 1/4	3.50	0.62
3					4.88	5.00	0.56	0.50	1 1/2	3.88	0.62
3 1/2					5.25	5.00	0.56	0.50	1 1/2	3.88	0.62
4	All reducing laterals NPS 16 and smaller shall have the same center-to-face dimensions as straight-size fittings, corresponding to the size of the largest opening.				5.50	6.00	0.62	0.50	2	4.25	0.75
5					6.25	7.00	0.69	0.62	2 1/2	5.50	0.75
6					7.00	7.00	0.69	0.62	2 1/2	5.50	0.75
8					8.75	9.00	0.94	0.88	4	7.50	0.75
10					9.75	9.00	0.94	0.88	4	7.50	0.75
12					11.25	11.00	1.00	1.00	6	9.50	0.88
14					12.50	11.00	1.00	1.00	6	9.50	0.88
16					13.75	11.00	1.00	1.00	6	9.50	0.88
18	8	25.0	1.0	27.5	15.00	13.50	1.12	1.12	8	11.75	0.88
20	10	27.0	1.0	29.5	16.00	13.50	1.12	1.12	8	11.75	0.88
24	12	31.5	0.5	34.5	18.50	13.50	1.12	1.12	8	11.75	0.88
30	14	39.0	0.0	42.0	...	...	...	...	...	...	...

(continued)

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TABLE 5 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) For facing, see para. 6.2.1.
(2) For flange bolt holes, refer to Table 4 and para. 6.6.
(3) For spot facing, see para. 6.7.
(4) For wall thickness tolerances, see para. 6.1.
(5) For center-to-face tolerances, see para. 6.4.
(6) For intersecting centerlines of side-outlet fittings, see para. 6.3.1.
(7) For center-to-face dimensions of reducing elbows and side-outlet elbows, see paras. 6.3.2(b) and (c).
(8) For center-to-face dimensions of special degree elbows, see para. 6.3.2(d).
(9) For reinforcement of crosses and laterals, see para. 6.8.
(10) For face-to-face dimensions of reducers and eccentric reducers, see para. 6.3.5.
(11) For center-to-face dimensions of tees and crosses having outlets and laterals having branches larger than given above, see para. 6.3.3(b).
(12) For center-to-face dimensions of tees, crosses, and laterals reducing on run only, see para. 6.3.3(b).
(13) For center-to-face dimensions of tees reducing on both runs, known as bull-head tees, see para. 6.3.3(b).
(14) For center-to-face dimensions of reducing side-outlet tees and crosses having two different size reductions on the outlets, see para. 6.3.3(b).
(15) Bases are furnished only when specified by the purchaser.
(16) For tees, sizes larger than 24 in., anchorage fittings are recommended. See Table 8.
(17) The base dimension applies to all straight and reducing sizes.
(18) For reducing fittings, the size and center-to-face dimensions of base are determined by the size of the largest opening of the fitting. In the case of reducing base elbows, orders shall specify whether the base shall be opposite the larger or smaller opening.
(19) Bolt hole template shown for round base is the same as for the flange of the supporting pipe size, except using only four holes in all cases so placed as to straddle centerlines. The bases of these fittings are intended for support in compression and are not to be used for anchors or supports in tension or shear.

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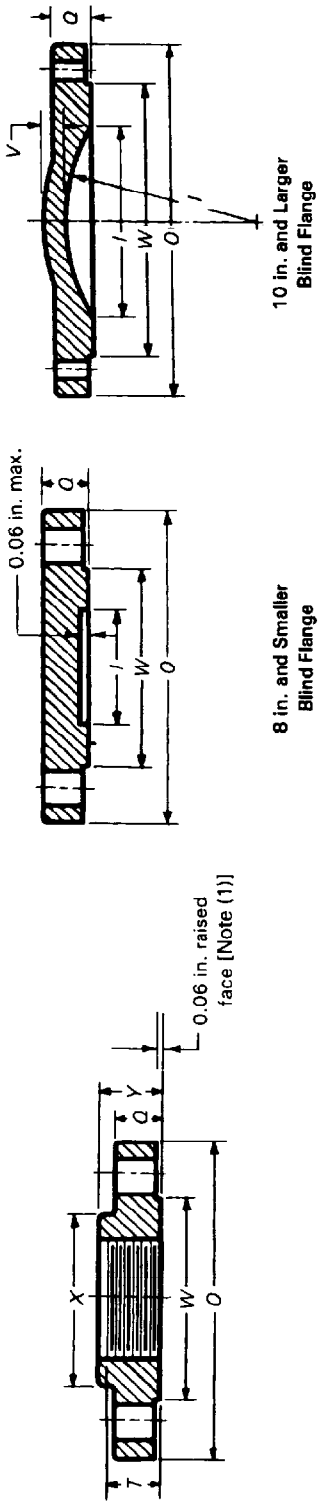

(For dimensions, see Table 6 on next page.)

FIG. 6 CLASS 250 FLANGES

NOTE:
(1) Diameter of raised face has tolerance of ±0.03 in.

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TABLE 6 FLANGES, BOLT HOLES, AND BOLTING DIMENSIONS OF CLASS 250 CAST IRON FLANGES

	Flanges			Blind Flanges [Note (2)]		Hubs			Bolt Holes		Bolting [Note (6)]			
Nominal Pipe Size	Diameter of Flange *O*	Thickness of Flange, Min. *Q*	Diameter of Raised Face *W* [Note (1)]	Diameter of Port *I*	Wall Thickness *V* [Note (3)]	Diameter of Hub, Min. *X*	Length Through Hub, Min. *Y*	Length of Threads, Min. *T* [Note (4)]	Diameter of Bolt Circle	Diameter of Bolt Holes [Note (5)]	Number of Bolts	Diameter of Bolts [Note (7)]	Length of Bolts [Note (8)]	Length of Stud Bolts [Note (8)]
1	4.88	0.69	2.69	1.00	...	2.06	0.88	0.68	3.50	0.75	4	0.62	2.50	...
1¼	5.25	0.75	3.06	1.25	...	2.50	1.00	0.81	3.88	0.75	4	0.62	2.50	...
1½	6.12	0.81	3.56	1.50	...	2.75	1.12	0.87	4.50	0.88	4	0.75	3.00	...
2	6.50	0.88	4.19	2.00	...	3.31	1.25	1.00	5.00	0.75	8	0.62	3.00	...
2½	7.50	1.00	4.94	2.50	...	3.94	1.43	1.13	5.88	0.88	8	0.75	3.50	...
3	8.25	1.12	5.69	3.00	...	4.62	1.56	1.19	6.62	0.88	8	0.75	3.50	...
3½	9.00	1.19	6.31	3.50	...	5.25	1.62	1.25	7.25	0.88	8	0.75	3.50	...
4	10.00	1.25	6.94	4.00	...	5.75	1.75	1.31	7.88	0.88	8	0.75	4.00	...
5	11.00	1.38	8.31	5.00	...	7.00	1.88	1.44	9.25	0.88	8	0.75	4.00	...
6	12.50	1.44	9.69	6.00	...	8.12	1.94	1.56	10.62	0.88	12	0.75	4.00	...
8	15.00	1.62	11.94	8.00	...	10.25	2.19	1.75	13.00	1.00	12	0.88	4.50	...
10	17.50	1.88	14.06	10.00	0.94	12.62	2.38	1.94	15.25	1.12	16	1.00	5.50	...
12	20.50	2.00	16.44	12.00	1.00	14.75	2.56	2.19	17.75	1.25	16	1.12	5.50	...
14	23.00	2.12	18.94	13.25	1.12	16.25	2.69	2.25	20.25	1.25	20	1.12	6.00	...
16	25.50	2.25	21.06	15.25	1.25	18.38	2.88	2.50	22.50	1.38	20	1.25	6.50	...
18	28.00	2.38	23.31	17.00	1.38	...	...	...	24.75	1.38	24	1.25	6.50	...
20	30.50	2.50	25.56	19.00	1.50	...	...	...	27.00	1.38	24	1.25	7.00	...
24	36.00	2.75	30.31	23.00	1.62	...	...	...	32.00	1.62	24	1.50	7.50	9.50
30	43.00	3.00	37.19	29.00	2.00	...	...	...	39.25	2.00	28	1.75	8.50	10.50
36 [Note (9)]	50.00	3.38	43.69	...	...	...	...	...	46.00	2.25	32	2.00	9.50	12.00
42 [Note (9)]	57.00	3.69	50.44	...	...	...	...	...	52.75	2.25	36	2.00	10.00	12.50
48 [Note (9)]	65.00	4.00	58.44	...	...	...	...	...	60.75	2.25	40	2.00	11.00	13.00

(continued)

TABLE 6 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) For facings, see para. 6.2.2.
(2) All blind flanges for NPS 10 and larger must be dished with inside radius equal to the port diameter.
(3) For wall thickness tolerance, see para. 6.1.
(4) For thread of threaded flanges, see paras. 6.5.1 and 6.5.3.
(5) For flange bolt holes, see para. 6.6.
(6) For bolts and nuts, see para. 7.1.
(7) For spot facing, see para. 6.7.
(8) When bolting to steel flanges, longer bolts or studs shall be used.
(9) Fittings in these sizes are not produced and used in sufficient quantities to warrant standardization; however, the flange dimensions are included for convenience where special fittings larger than NPS 30 are required. When these fittings are made, the body structure should be designed to be the equivalent of the flanges in service pressure ratings.

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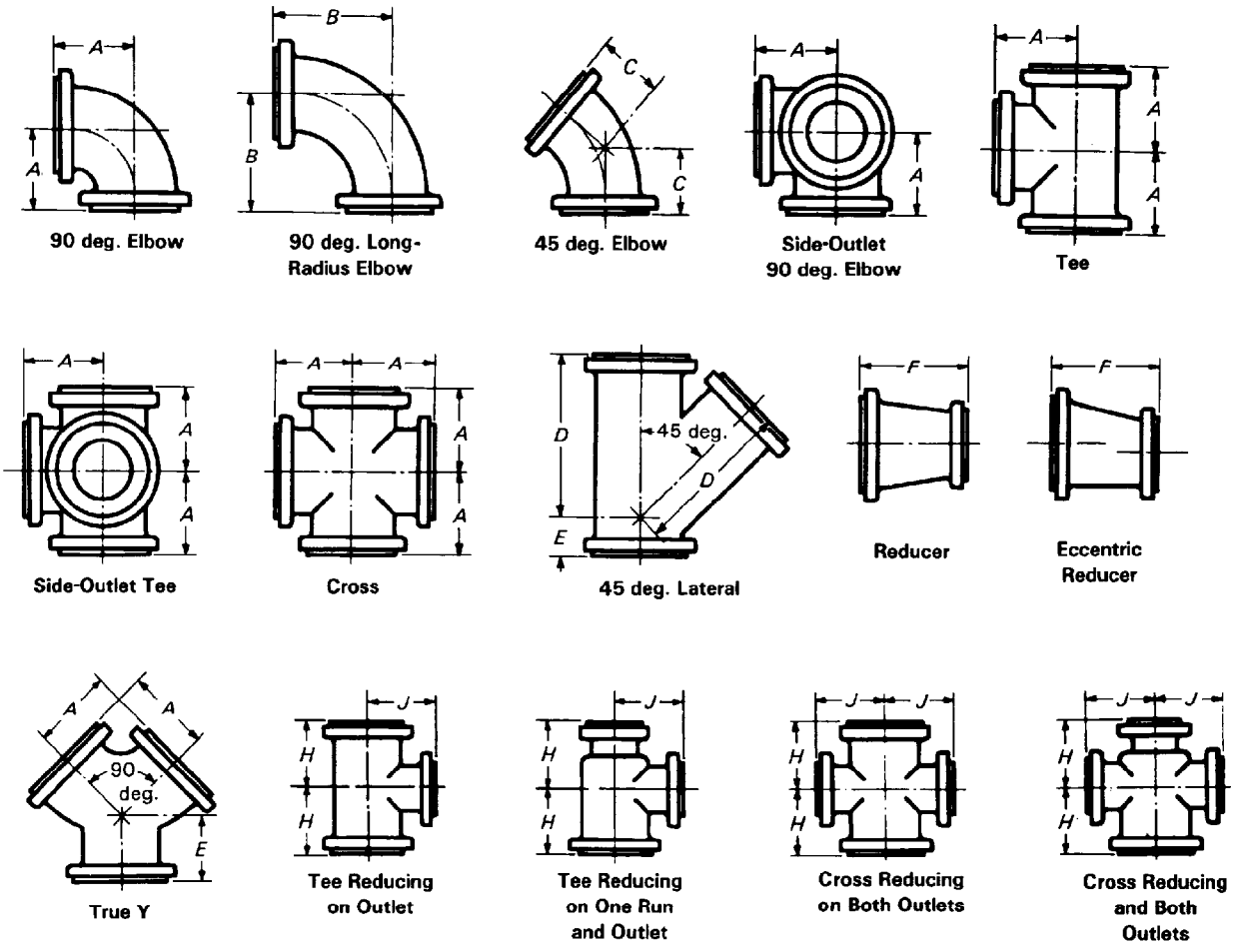

FIG. 7 CLASS 250 FLANGED FITTINGS

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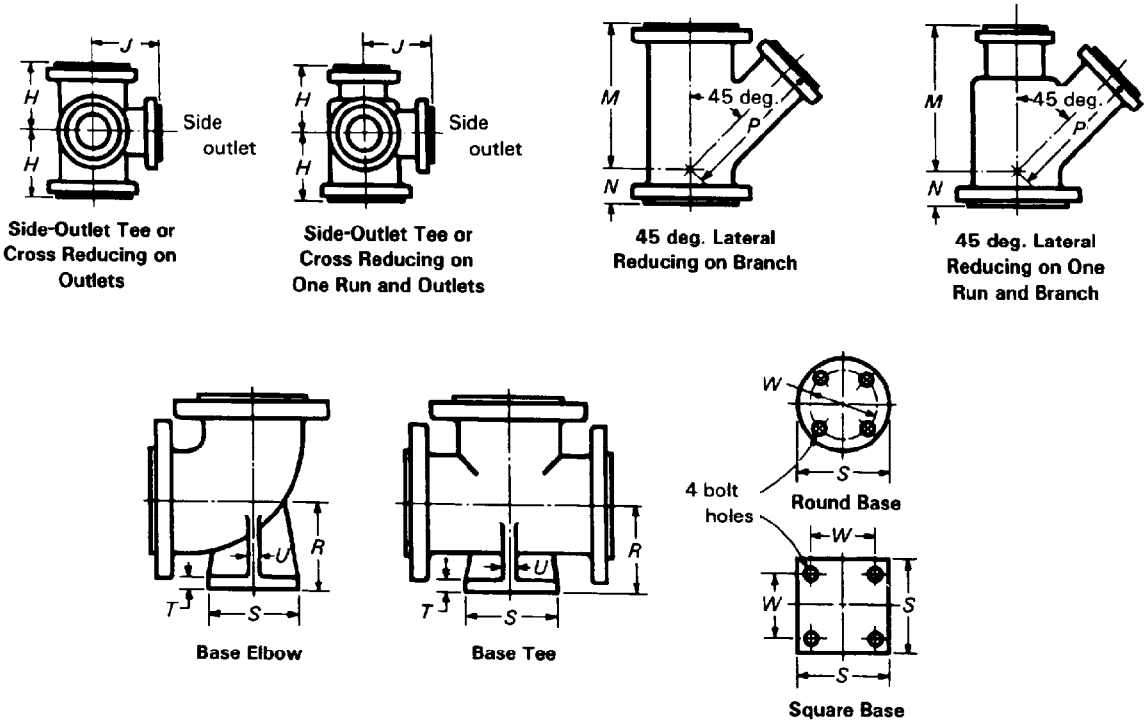

(For dimensions, see Table 7 on next page.)

FIG. 7 CLASS 250 FLANGED FITTINGS (CONT'D)

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TABLE 7 DIMENSIONS OF CLASS 250 CAST IRON FLANGED FITTINGS

	Flanges [Notes (1)–(3)]			General Fittings [Notes (5) and (6)]		Straight Fittings [Notes (5) and (6)]						Reducing (Short Body)		
												Tees and Crosses [Notes (10), (13), and (14)]		
Nominal Pipe Size	Diameter of Flange	Thickness of Flange, Min. *Q*	Diameter of Raised Face [Note (4)]	Inside Diameter of Fittings	Body Wall Thickness [Note (7)]	Center-to-Face 90 deg. Elbow, Tees, Crosses, and True Y *A* [Notes (8)–(10)]	Center-to-Face 90 deg. Long-Radius Elbow *B* [Notes (6), (8), and (9)]	Center-to-Face 45 deg. Elbow *C* [Note (9)]	Center-to-Face Lateral *D* [Notes (10) and (11)]	Short Center-to-Face True Y and Lateral *E* [Notes (10) and (11)]	Face-to-Face Reducer *F* [Note (12)]	NPS Size of Outlet and Smaller [Notes (6) and (12)]	Center-to-Face Run *H* [Notes (8) and (9)]	Center-to-Face Outlet or Side Outlet *J*
1	4.88	0.69	2.69	1.00	0.44	4.00	5.00	2.00	6.50	2.00	...			
1¼	5.25	0.75	3.06	1.25	0.44	4.25	5.50	2.50	7.25	2.25	...			
1½	6.12	0.81	3.56	1.50	0.44	4.50	6.00	2.75	8.50	2.50	...			
2	6.50	0.88	4.19	2.00	0.44	5.00	6.50	3.00	9.00	2.50	5.0			
2½	7.50	1.00	4.94	2.50	0.50	5.50	7.00	3.50	10.50	2.50	5.5	All reducing tees and crosses, NPS 16 and smaller, shall have the same center-to-face dimensions as straight-size fittings, corresponding to the size of the largest opening.		
3	8.25	1.12	5.69	3.00	0.56	6.00	7.75	3.50	11.00	3.00	6.0			
3½	9.00	1.19	6.31	3.50	0.56	6.50	8.50	4.00	12.50	3.00	6.5			
4	10.00	1.25	6.94	4.00	0.62	7.00	9.00	4.50	13.50	3.00	7.0			
5	11.00	1.38	8.31	5.00	0.69	8.00	10.25	5.00	15.00	3.50	8.0			
6	12.50	1.44	9.69	6.00	0.75	8.50	11.50	5.50	17.50	4.00	9.0			
8	15.00	1.62	11.94	8.00	0.81	10.00	14.00	6.00	20.50	5.00	11.0			
10	17.50	1.88	14.06	10.00	0.94	11.50	16.50	7.00	24.00	5.50	12.0			
12	20.50	2.00	16.44	12.00	1.00	13.00	19.00	8.00	27.50	6.00	14.0			
14	23.00	2.12	18.94	13.25	1.12	15.00	21.50	8.50	31.00	6.50	16.0			
16	25.50	2.25	21.06	15.25	1.25	16.50	24.00	9.50	34.50	7.50	18.0			
18	28.00	2.38	23.31	17.00	1.38	18.00	26.50	10.00	37.50	8.00	19.0	12	14.0	17.0
20	30.50	2.50	25.56	19.00	1.50	19.50	29.00	10.50	40.50	8.50	20.0	14	15.5	18.5
24	36.00	2.75	30.31	23.00	1.62	22.50	34.00	12.00	47.50	10.00	24.0	16	17.0	21.5
30	43.00	3.00	37.19	29.00	2.00	27.50	41.50	15.00	...	...	30.0	20	20.5	25.5

(continued)

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TABLE 7 DIMENSIONS OF CLASS 250 CAST IRON FLANGED FITTINGS (CONT'D)

	Reducing (Short Body) [Notes (11) and (15)]				Base, Elbows, and Tees [Notes (16)–(18)]						
	Laterals [Note (10)]									Base Drilling [Note (20)]	
Nominal Pipe Size	NPS Size of Branch and Smaller	Center-to-Face Run *M*	Center-to-Face Run *N*	Center-to-Face Branch *P*	Center-to-Base *R*	Diameter of Round Base or Width of Square Base *S* [Note (19)]	Thickness of Base *T*	Thickness of Ribs *U*	NPS Size of Supporting Pipe for Base	Bolt Circle or Bolt Spacing *W*	Diameter of Holes
2					4.50	5.25	0.75	0.50	1¼	3.88	0.75
2½					4.75	5.25	0.75	0.50	1¼	3.88	0.75
3					5.25	6.12	0.81	0.62	1½	4.50	0.88
3½					5.62	6.12	0.81	0.62	1½	4.50	0.88
4					6.00	6.50	0.88	0.62	2	5.00	0.75
5	All reducing laterals NPS 16 and smaller shall have the same center-to-face dimensions as straight-size fittings, corresponding to the size of the largest opening.				6.75	7.50	1.00	0.75	2½	5.88	0.88
6					7.50	7.50	1.00	0.75	2½	5.88	0.88
8					9.00	10.00	1.25	0.88	4	7.88	0.88
10					10.50	10.00	1.25	0.88	4	7.88	0.88
12					12.00	10.50	1.44	1.00	6	10.62	0.88
14					13.50	12.50	1.44	1.00	6	10.62	0.88
16					14.75	12.50	1.44	1.12	6	10.62	0.88
18	8	31	3	32.5	16.25	15.00	1.62	1.12	8	13.00	1.00
20	10	34	3	36	17.88	15.00	1.62	1.25	8	13.00	1.00
24	12	41	3	43	20.75	17.50	1.88	1.25	10	15.25	1.12

(continued)

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TABLE 7 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) For facing, see para. 6.2.2.
(2) For flange bolt holes, refer to Table 6 and para. 6.6.
(3) For spot facing, see para. 6.7.
(4) Tolerance of the diameter of the raised face is equal to ±0.03 in.
(5) For center-to-face tolerances, see para. 6.4.
(6) For intersecting centerlines of side-outlet fittings, see para. 6.3.1.
(7) For wall thickness tolerances, see para. 6.1.
(8) For center-to-face dimensions of reducing elbows and side-outlet elbows, see paras. 6.3.2(b) and (c).
(9) For center-to-face dimensions of special degree elbows, see para. 6.3.2(d).
(10) For reinforcement of crosses and laterals, see para. 6.8.
(11) For center-to-face dimensions of tees and crosses having outlets and laterals having branches larger than given above, see para. 6.3.3(b).
(12) For face-to-face dimensions of reducers and eccentric reducers, see para. 6.3.5.
(13) For center-to-face dimensions of tees reducing on both runs, known as bull-head tees, see para. 6.3.3(c).
(14) For center-to-face dimensions of reducing side-outlet tees and crosses having two different size reductions on the outlet, see para. 6.3.3(b).
(15) For center-to-face dimensions of tees, crosses, and laterals reducing on run only, see para. 6.3.3(b).
(16) Bases are furnished only when specified by purchaser.
(17) The base dimensions apply to all straight and reducing sizes.
(18) For tees, sizes larger than NPS 24, anchorage fittings are recommended. See Table 9.
(19) For reducing fittings, the size and center-to-face dimensions of base are determined by the size of the largest opening of the fitting. In the case of reducing base elbows, orders shall specify whether the base shall be opposite the larger or smaller opening.
(20) Bolt hole template shown for round base is the same as for the flange of the supporting pipe size, except using only four holes in all cases so placed as to straddle centerlines. The bases of these fittings are intended for support in compression and are not to be used for anchors or supports in tension or shear.

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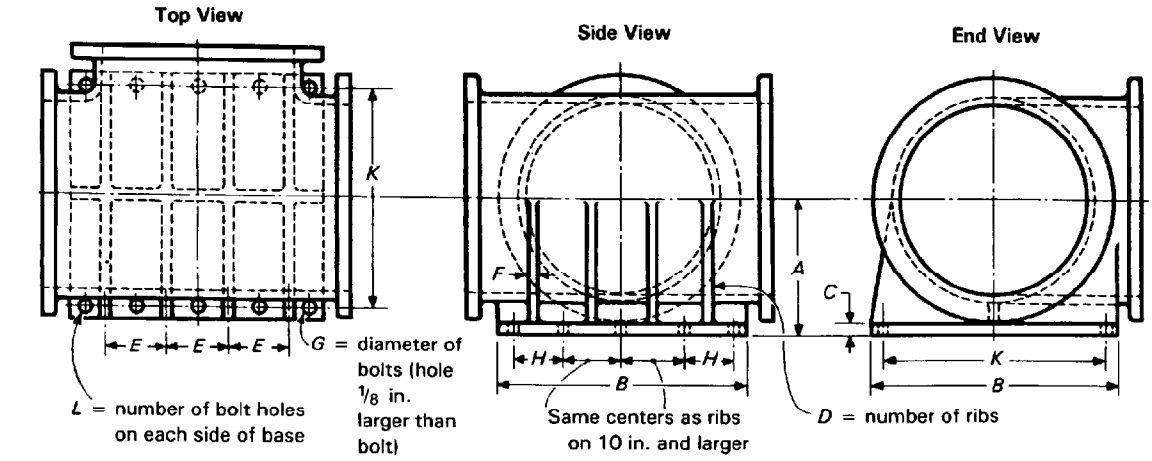
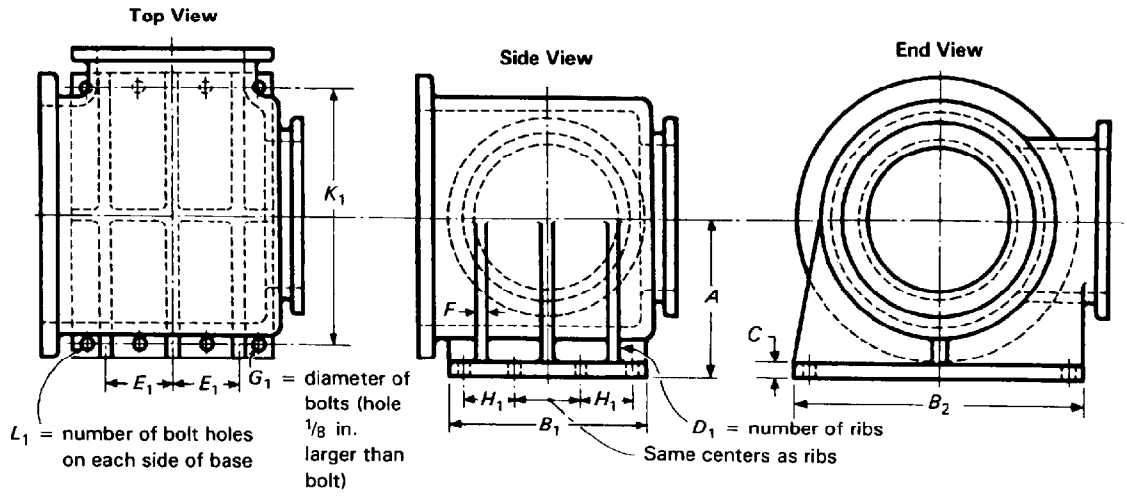


Straight Sizes



Reducing Sizes, Short Body Pattern

(For dimensions, see Table 8 on next page.)

FIG. 8 CLASS 125 TEES
Anchorage Bases

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TABLE 8 DIMENSIONS OF ANCHORAGE BASES FOR STRAIGHT AND REDUCING CLASS 125 TEES[1, 2]

	Common to Both Straight Sizes and Reducing Sizes				Straight Sizes					
Nominal Pipe Size	Center-to-Base-*A*	Thickness of Base *C* [Note (3)]	Diameter of Bolts *G*	Thickness of Ribs *F*	Width and Length of Square Base *B*	Transverse Bolt Centers *K*	Number of Bolt Holes on Each Side of Base *L*	Number of Ribs *D*	Centers of Ribs and Inside Bolt Holes *E*	Longitudinal Centers From End Bolt to Second End *H*
2½	4.50	0.69	0.62	0.44	7.00	4.50	2	1	...	4.50
3	4.88	0.75	0.62	0.44	7.50	5.00	2	1	...	5.00
3½	5.25	0.81	0.62	0.44	8.50	6.00	2	1	...	6.00
4	5.50	0.94	0.62	0.50	9.00	6.50	3	2	4.25	3.25
5	6.25	0.94	0.88	0.50	10.00	7.50	3	2	5.00	3.25
6	7.00	1.00	0.88	0.56	11.00	8.75	3	2	6.00	4.38
8	8.38	1.12	1.00	0.62	13.50	11.00	3	2	8.00	5.50
10	9.25	1.19	1.12	0.75	16.00	13.38	4	3	4.88	4.25
12	11.25	1.25	1.12	0.81	19.00	15.50	4	3	5.75	4.88
14	12.50	1.38	1.25	0.88	21.00	17.75	4	3	6.75	5.50
16	13.75	1.44	1.38	1.00	23.50	19.75	4	3	7.75	6.00
18	15.00	1.56	1.38	1.06	25.00	21.75	4	3	8.50	6.62
20	16.00	1.69	1.50	1.12	27.50	24.00	4	3	9.50	7.25
24	18.50	1.88	1.62	1.25	32.00	28.38	4	3	11.38	8.50
30	22.00	2.12	1.75	1.44	38.75	34.50	5	4	9.38	7.88
36	25.50	2.38	1.88	1.62	46.00	40.75	5	4	11.25	9.12
42	29.25	2.62	2.00	1.81	53.00	46.75	5	4	13.00	10.38
48	32.75	2.75	2.25	2.00	59.50	53.25	5	4	14.88	11.75

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) Bases are furnished only when specified by the purchaser.

(2) For tee dimensions, refer to Table 5.

(3) For NPS 18 and larger, if the outlet is the same size or smaller than given for reducing tees, the base dimensions shown in this Table shall be used. If the outlet is larger than shown for reducing tees, the base dimensions shall be the same as for the straight-size tee, corresponding to the size of the largest opening.

(4) Tees reducing on run only shall have the same base dimensions as straight-size tees, corresponding to the size of the largest opening.

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TABLE 8 DIMENSIONS OF ANCHORAGE BASES FOR STRAIGHT AND REDUCING CLASS 125 TEES[1, 2]

Reducing Tees [Notes (3) and (4)] (Short-Body Pattern)									
NPS Outlet Sizes and Smaller	Length of Base B_1 [Note (3)]	Number of Ribs D_1	Centers of Ribs E_1	Diameter of Bolts G_1	Longitudinal Center From End Bolt to Second Bolt H_1	Transverse Bolt Centers K_1	Number of Bolt Holes on Each Side of Base L_1	Width of Base B_2	Nominal Pipe Size
									$2\frac{1}{2}$
									3
									$3\frac{1}{2}$
									4
									5
Reducing tee NPS 16 and smaller shall have the same base B dimensions as a straight-size tee, corresponding to the size of the largest opening.									6
									8
									10
									12
									14
									16
12	19.00	3	5.25	1.25	5.12	21.50	4	24.75	18
14	21.00	3	6.00	1.25	5.38	23.75	4	26.75	20
16	23.50	3	7.00	1.38	6.25	28.00	4	31.62	24
20	27.50	3	9.00	1.50	7.25	34.25	4	39.00	30
24	32.00	3	10.75	1.50	8.38	41.50	4	46.25	36
24	36.50	4	8.50	1.62	7.50	48.50	5	54.75	42
30	41.75	4	9.75	1.62	8.25	53.75	5	60.00	48

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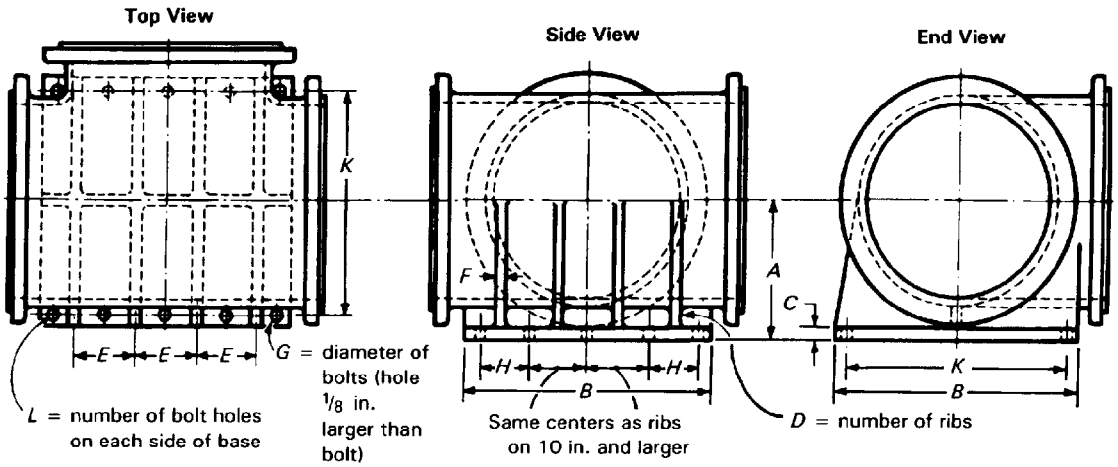
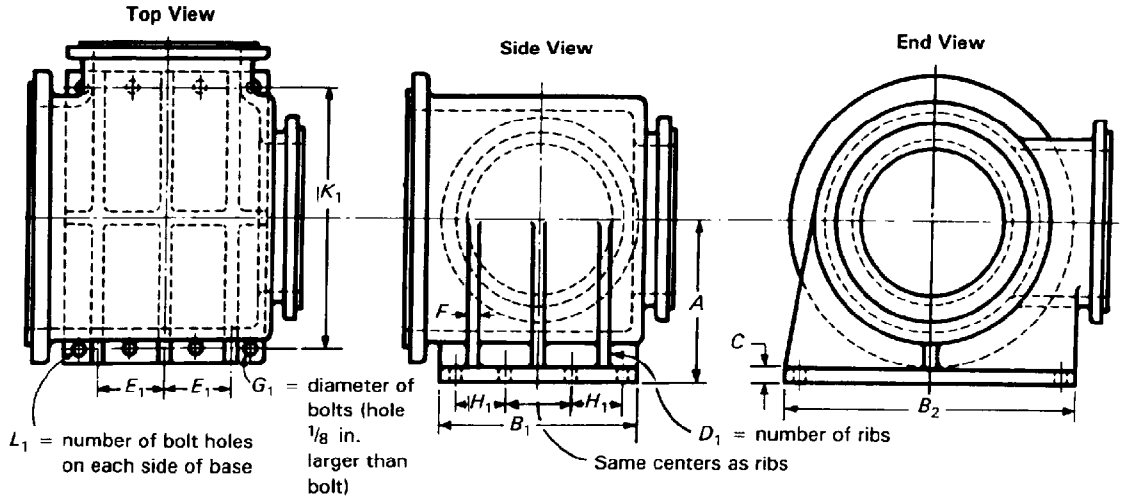


Straight Sizes



Reducing Sizes, Short Body Pattern

(For dimensions, see Table 9 on next page.)

FIG. 9 CLASS 250 TEES
Anchorage Bases

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TABLE 9 DIMENSIONS OF ANCHORAGE BASES FOR STRAIGHT AND REDUCING CLASS 250 TEES[1, 2]

	Common on Both Straight Sizes and Reducing Sizes				Straight Sizes						Reducing Sizes (Short-Body Pattern) [Notes (3) and (4)]					
Nominal Pipe Size	Center-to-Base *A*	Thickness of Base *C* [Notes (1) and (3)]	Diameter of Bolts *G*	Thickness of Ribs *F*	Width and Length of Square Base *B*	Transverse Bolt Centers *K*	Number of Bolt Holes on Each Side of Base *L*	Number of Ribs *D*	Centers of Ribs *E*	Longitudinal Center From End Bolt to Second Bolt *H*	NPS Outlet Sizes and Smaller [Note (2)]	Length of Base B_1 [Note (3)]	Centers of Ribs E_1	Longitudinal Center From End Bolt to Second Bolt H_1	Transverse Bolt Centers K_1	Width of Base B_2
2½	4.75	0.75	0.62	0.56	7.50	5.75	2	1	...	5.75						
3	5.25	0.81	0.62	0.56	8.25	6.50	2	1	...	6.50						
3½	5.62	0.94	0.62	0.56	9.00	7.25	2	1	...	7.25						
4	6.00	0.94	0.62	0.62	10.00	7.75	3	2	4	3.78						
5	6.75	1.00	0.88	0.69	11.00	8.75	3	2	5	4.38						
6	7.50	1.06	0.88	0.75	12.50	10.25	3	2	6	5.12	Reducing tee NPS 16 and smaller shall have the same base *B* dimensions as a straight-size tee, corresponding to the size of the largest opening.					
8	9.00	1.12	1.00	0.81	15.00	12.50	3	2	8	6.25						
10	10.50	1.25	1.12	0.94	17.50	14.75	4	3	5	4.88						
12	12.00	1.25	1.25	1.00	20.50	17.50	4	3	6	5.75						
14	13.50	1.38	1.25	1.12	23.00	20.00	4	3	7	6.50						
16	14.75	1.56	1.38	1.25	25.50	22.00	4	3	8	7.00						
18	16.25	1.69	1.38	1.38	28.00	24.25	4	3	9	7.38	12	20.5	6.50	5.25	24.5	28.25
20	17.88	1.88	1.50	1.50	30.50	26.75	4	3	10	8.38	14	23.0	7.00	6.00	26.5	30.25
24	20.75	2.06	1.62	1.62	36.00	31.75	4	3	12	9.88	16	25.5	8.12	6.69	32.0	36.25
30	24.75	2.31	1.75	2.00	43.00	38.00	5	4	10	9.00	20	30.5	6.62	6.12	38.0	43.00

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) Bases are furnished only when specified by the purchaser.

(2) For tee dimensions, refer to Table 7.

(3) For NPS 18 and larger, if the outlet is the same size or smaller than given for reducing tees, the base dimensions as shown in this Table for reducing tees shall be used. If the outlet is larger than shown for reducing tees, the base dimensions shall be the same as for the straight-size tees, corresponding to the size of the largest opening.

(4) Tees reducing on run only shall have the same base dimensions as straight-size tees, corresponding to the size of the largest opening.

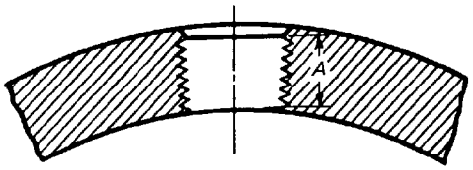

FIG. 10 DRAIN TAPPINGS

TABLE 10 MINIMUM THREAD LENGTH

Size of Tapping	Length of Thread *A*, in.
3/8	0.41
1/2	0.53
3/4	0.55
1	0.68
1 1/4	0.71
1 1/2	0.72
2	0.76

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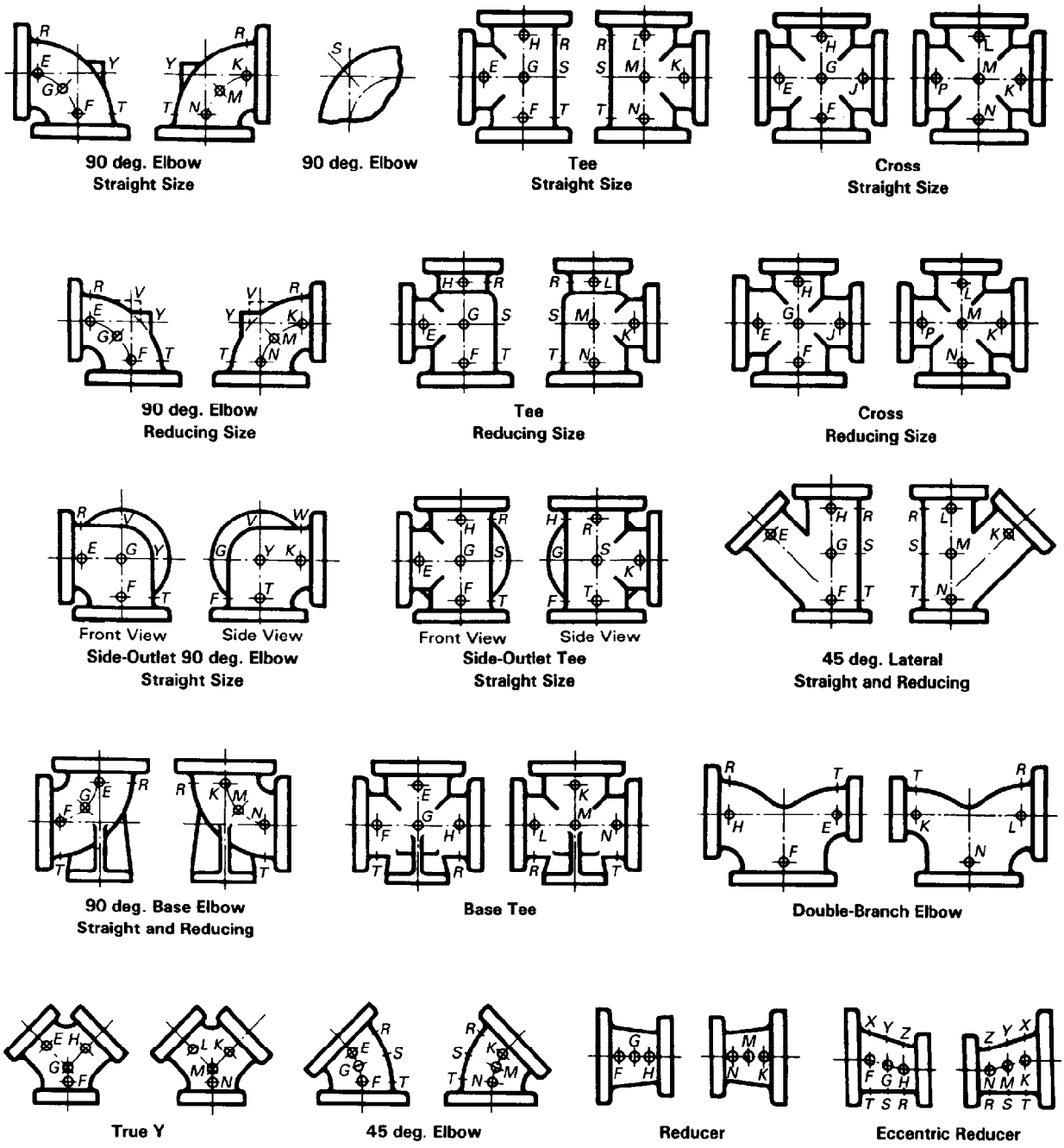

GENERAL NOTE:
The above sketches show two views of the same fitting and represent fittings with symmetrical shapes, with the exception of the side-outlet elbow and the side-outlet tee (straight sizes).

FIG. 11 METHOD OF DESIGNATING LOCATION OF TAPPED HOLES FOR DRAINS WHEN SPECIFIED

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STD.ASME B16.1-ENGL 1998 ■ 0759670 0608222 121 ■

ANNEX I
REFERENCES

(This Annex is part of ASME B16.1-1998.)

The following is a list of publications referenced in this Standard.

ASME B1.1-1989, Unified Inch Screw Threads (UN and UNR Thread Form)[1]

ASME B1.20.1-1983 (R1992), Pipe Threads, General Purpose (Inch)[1]

ASME B16.21-1992, Nonmetallic Flat Gaskets for Pipe Flanges[1]

ASME B18.2.1-1996, Square and Hex Bolts and Screws (Inch Series)[1]

ASME B18.2.2-1987 (R1993), Square and Hex Nuts (Inch Series)[1]

American Society of Mechanical Engineers (ASME), Three Park Avenue, New York, NY 10016-5990; Order Department: 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300

ASTM A 126-95, Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings

ASTM A 307-94, Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength

American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428

ISO 9000-1: 1994, Quality management and quality assurance standards, Part 1: Guidelines for selection and use

ISO 9000-2: 1997, Quality management and quality assurance standards, Part 2: Generic guidelines for the application of ISO 9001, ISO 9002, and ISO 9003

ISO 9000-3: 1991, Quality management and quality assurance standards, Part 3: Guidelines for the application of ISO 9001 to the development, supply, and maintenance of software

ISO 9001: 1994, Quality systems: Model for quality assurance in design, development, production, installation, and servicing

ISO 9002: 1994, Quality systems: Model for quality assurance in production and servicing

ISO 9003: 1994, Quality systems: Model for quality assurance in final inspection and test

International Organization for Standardization (ISO), 1 rue de Varembé, Case Postale 56, CH-1121, Genève 20, Switzerland/Suisse

MSS SP-6-1996, Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings

MSS SP-9-1997, Spot Facing for Bronze, Iron, and Steel Flanges

MSS SP-45-1992, Bypass and Drain Connections

Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park Street, NE, Vienna, VA 22180

[1] May also be obtained from American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036.

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ANNEX A
QUALITY SYSTEM PROGRAM

(This Annex is a nonmandatory part of ASME B16.1-1998 and is provided for informational purposes only.)

The products manufactured in accordance with this Standard shall be produced under a quality system program following the principles of an appropriate standard from the ISO 9000 series.[1] A determination of the need for registration and/or certification of the product manufacturer's quality system program by an independent organization shall be the responsibility of the manufacturer. The detailed documentation demonstrating program compliance shall be available to the purchaser at the manufacturer's facility. A written summary description of the program utilized by the product manufacturer shall be available to the purchaser upon request. The product manufacturer is defined as the entity whose name or trademark appears on the product in accordance with the marking or identification requirements of this Standard.

---

[1] The series is also available from the American National Standards Institute (ANSI) and the American Society for Quality (ASQ) as American National Standards that are identified by a prefix "Q" replacing the prefix "ISO." Each standard of the series is listed under Annex I.

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AN AMERICAN NATIONAL STANDARD

ASME B16.5a-1998

ADDENDA

to

ASME B16.5-1996
PIPE FLANGES AND FLANGED FITTINGS
NPS ½ Through NPS 24

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ASME B16.5a–1998

Following approval by the ASME B16 Committee and ASME, and after public review, ASME B16.5a-1998 was approved by the American National Standards Institute on February 20, 1998.

Addenda to the 1996 edition of ASME B16.5 are issued in the form of replacement pages. Revisions, additions, and deletions are incorporated directly into the affected pages. It is advisable, however, that this page, the Addenda title and copyright pages, and all replaced pages be retained for reference.

SUMMARY OF CHANGES

This is the first Addenda to be published to ASME B16.5-1996.

Replace or insert the pages listed. Changes given below are identified on the pages by a margin note, **(a)**, placed next to the affected area. The pages not listed are the reverse sides of the listed pages and contain no changes.

Page	*Location*	*Change*
v	Foreword	ASME address updated
vii	Committee Roster	Updated
x	Contents	Updated to reflect Addenda changes
1	1.2.1	In the third and seventh lines, *Annex G* corrected by Errata to read *Annex H*
	2.1	Revised
8	7.2.1	*PS* corrected by Errata to read *NPS*
9	7.6	Overall length for NPS 4 and smaller revised
	8.1	Title corrected by Errata
10–12	Table 1A	(1) A 350 Gr. LF6 Cl. 1 added to material group 1.1 (2) A 350 Gr. LF6 Cl. 2 added to material group 1.2 (3) A 351 Gr. CE8MN, A 351 Gr. CD4MCu, A 351 Gr. CD3MWCuN, A 182 Gr. F55, and A 240 Gr. S32760 added to material group 2.8 (4) New material groups 1.15 and 3.17 added (5) A 351 Gr. CN7M deleted from material group 3.1 (6) General Notes added
15	Table 2-1.1	(1) A 350 Gr. LF6 Cl. 1 added (2) Note (4) added

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Page	*Location*	*Change*
16	Table 2-1.2	(1) A 350 Gr. LF6 Cl. 2 added (2) Note (3) added
19	Table 2-1.5	First line of Note (1) corrected by Errata
20	Table 2-1.7	First line of Note (1) corrected by Errata
24.1	Table 2-1.15	Added
25	Table 2-2.1	Working pressure for Class 600 at 1400°F corrected by Errata to read *90*
28	Table 2-2.4	Working pressure for Class 600 at 1150°F corrected by Errata to read *475*
31	Table 2-2.7	(1) Working pressure for Class 2500 at 400°F corrected by Errata to read *4460* (2) Working pressure for Class 400 at 850°F corrected by Errata to read *570*
32	Table 2-2.8	A 351 Gr. CE8MN, A 351 Gr. CD4MCu, A 351 Gr. CD3MWCuN, A 182 Gr. F55, and A 240 Gr. S32760 added
33	Table 2-3.1	Revised in its entirety
35	Table 2-3.3	Working pressure for Class 600 at 900°F corrected by Errata to read *280*
36	Table 2-3.4	Working pressure for Class 400 at 900°F revised
37	Table 2-3.5	Working pressure for Class 900 at 800°F corrected by Errata to read *1520*
38	Table 2-3.6	Working pressure for Class 1500 at 750°F corrected by Errata to read *2650*
39	Table 2-3.7	Working pressure for Class 900 at 800°F corrected by Errata to read *1520*
40	Table 2-3.8	Working pressure for Class 900 at 800°F corrected by Errata to read *1520*
48	Table 2-3.16	Working pressure for Class 2500 at 1150°F corrected by Errata to read *1545*
48.1	Table 2-3.17	Added
53, 54	Fig. 7	(1) Top left sketch for Classes 150 and 300 revised (2) Top left sketch for Classes 400 and Higher revised
72	Table 9	In column 10, value for NPS 4 corrected by Errata to read *4.57*
84	Table 13	Note (19) renumbered to Note (18) by Errata

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Page	*Location*	*Change*
150	Annex H	ASME address updated
153	Interpretations	ASME address updated

SPECIAL NOTE:

The Interpretations to ASME B16.5 are included in this Addenda as a separate section for the user's convenience. This section, however, is not part of the Addenda or the edition.

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revisions. Following approval by the Standards Committee and ASME, approval as an American National Standard was given by ANSI on October 3, 1996 with the new designation ASME B16.5-1996.

(a) Requests for interpretations or suggestions for revision should be sent to the Secretary, B16 Committee, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

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Standardization of Valves, Flanges, Fittings, Gaskets, and Valve Actuators

(The following is the roster of the Committee at the time of approval of this Standard.)

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PIPE FLANGES AND FLANGED FITTINGS

1 SCOPE

1.1 General

This Standard covers pressure–temperature ratings, materials, dimensions, tolerances, marking, testing, and methods of designating openings for pipe flanges and flanged fittings in sizes NPS ½ through NPS 24 and in rating Classes 150, 300, 400, 600, 900, 1500, and 2500. Flanges and flanged fittings may be cast, forged, or (for blind flanges and certain reducing flanges only) plate materials as listed in Table 1A.

Requirements and recommendations regarding bolting and gaskets are also included.

1.2 References

(a) **1.2.1 Referenced Standards.** Standards and specifications adopted by reference in this Standard are shown in Annex H, which is part of this Standard. It is not considered practical to identify the specific edition of each standard and specification in the individual references. Instead, the specific edition reference is identified in Annex H. A flange or flanged fitting manufactured in accordance with earlier editions of the referenced standards and in all other respects conforming to this Standard will be considered to be in conformance with this Standard.

1.2.2 Codes and Regulations. A flange or flanged fitting used under the jurisdiction of the ASME Boiler and Pressure Vessel Code, the ASME Code for Pressure Piping, or a governmental regulation is subject to any limitation of that code or regulation. This includes any maximum temperature limitation, or rule governing the use of a material at low temperature, or provisions for operation at a pressure exceeding the pressure–temperature ratings in this Standard.

1.3 Applicable Ratings

The pressure–temperature ratings in this Standard are applicable upon its publication to all flanges and flanged fittings within its scope which otherwise meet its requirements. For unused flanges or flanged fittings maintained in inventory, the manufacturer of the flange or flanged fittings may certify conformance to this Edition provided he can demonstrate that all requirements of this Edition have been met. Where such components were installed in accordance with the pressure–temperature ratings of an earlier edition of this Standard, those ratings are applicable except as may be governed by the applicable code or regulation (see para. 1.2.2).

1.4 User Accountability

This Standard cites duties and responsibilities that are to be assumed by the user in the areas of application, installation, hydrostatic testing, operation, and material selection.

1.5 Quality Systems

Nonmandatory requirements relating to the product manufacturer's Quality System Program are described in Annex G.

2 PRESSURE–TEMPERATURE RATINGS

2.1 Ratings Basis (a)

Ratings are maximum allowable working gage pressures at the temperatures shown in Table 2 for the applicable material and rating. For intermediate temperatures, linear interpolation is permitted. See Annex D for methods of establishing pressure–temperature ratings.

2.2 Ratings of Flanged Joints

A flanged joint is composed of three separate and independent, although interrelated components: the flanges, the gasket, and the bolting, which are assembled by yet another influence, the assembler. Proper controls must be exercised in the selection and application for all these elements to attain a joint which has acceptable leak tightness. Special techniques, such as controlled bolt tightening, may be necessary to achieve a tight joint in service.

Ratings in this Standard apply to flanged joints which conform to the limitations on bolting in para. 5.3 and on gaskets in para. 5.4, and which are made up in accordance with good practice for alignment and assembly. See also para. 2.4. Use of the ratings for flanged joints not conforming to these limitations is the responsibility of the user. Requirements for alignment and assembly of joints are not given in this Standard.

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If the two flanges in a flanged joint do not have the same pressure–temperature ratings, the rating of the joint at any temperature is the lower of the two flange ratings at that temperature.

2.3 Rating Temperature

The temperature shown for a corresponding pressure rating is the temperature of the pressure-containing shell of the flange or flanged fitting. In general, this temperature is the same as that of the contained fluid. Use of a pressure rating corresponding to a temperature other than that of the contained fluid is the responsibility of the user, subject to the requirements of the applicable code or regulation. For any temperature below −20°F, the rating shall be no greater than the rating shown for −20°F.

2.4 Temperature Considerations

Application of the ratings in this Standard to flanged joints at both high and low temperatures shall take into consideration the risk of leakage due to forces and moments developed in the connected piping or equipment. The following provisions are intended to minimize these risks.

2.4.1 Flange Attachment. Socket welding and threaded flanges are not recommended for service above 500°F or below −50°F if severe thermal gradients or thermal cycling are involved.

2.4.2 High Temperature Service. At temperatures in the creep range, gradual relaxation of flanges, bolts, and gaskets may progressively reduce bolt loads. It may be necessary to arrange for periodic tightening of bolts to prevent leakage. Joints subject to substantial thermal gradients may require the same attention.

When used above 400°F, Class 150 flanged joints may develop leakage unless care is taken to avoid imposing severe external loads and/or severe thermal gradients. For other classes, similar consideration should be given above 750°F.

2.4.3 Low Temperature Service. The user should recognize that some of the material listed in the rating tables undergo sufficient decrease in toughness at low temperatures that they cannot safely sustain shock loadings, sudden changes of stress or temperature, or high stress concentrations.

2.5 System Hydrostatic Test

Flanged joints and flanged fittings may be subjected to system hydrostatic tests at a pressure not to exceed 1.5 times the 100°F rating rounded off to the next higher 25 psi. Testing at any higher pressure is the responsibility of the user, subject to the requirements of the applicable code or regulation.

2.6 Welding Neck Flanges

Ratings for welding neck flanges covered by this Standard are based upon their hubs at the welding end having thickness at least equal to that calculated for pipe having 40.0 ksi specified minimum yield strength. (For higher strength pipe with thinner wall, see MSS SP-44.) The ratings also apply to such flanges used with components of unequal strength and unequal wall thickness when the attachment weld is made in accordance with the applicable code or regulation. See Figs. 12, 13, and 14.

2.7 Multiple Material Grades

Materials for flanges and flanged fittings may meet the requirements for more than one specification or grade of a specification listed in Table 1A. In that event, the pressure–temperature ratings for any of these specifications or grades may be used provided that marking is in accordance with para. 4.1.2(d).

3 SIZE

3.1 Nominal Size

The size of a flange or flanged fitting covered by this Standard is its nominal pipe size, NPS. The diameter of a bolt is its nominal size. Use of "nominal" indicates that the stated size or dimension is only for designation, not measurement. The actual dimension may or may not be the nominal size and is subject to established tolerances.

3.2 Reducing Fittings

Reducing fittings shall be designated by the size of the openings in their proper sequence as indicated in the sketches of Fig. 2.

3.3 Reducing Flanges

Reducing flanges shall be designated by the two nominal pipe sizes. See examples in Note (4) of Table 7.

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6.8.2 Hub Dimensions

6.8.2.1 Threaded, Socket Weld, and Slip-On Flanges. The hub dimensions shall be at least as large as those of the standard flange of the size to which the reduction is being made. The hub may be larger or omitted as detailed in Table 7.

6.8.2.2 Welding Neck Flanges. The hub dimensions shall be the same as those of the standard flange of the size to which the reduction is being made.

6.9 Threads for Threaded Flanges

Except as provided in Note (5), Fig. 7, and Note (5), Table 4, threaded flanges shall have an American National Standard taper pipe thread conforming to ASME B1.20.1. The thread shall be concentric with the axis of the flange, and variations in alignment shall not exceed 0.06 in./ft (0.5%).

6.9.1 Class 150 flanges are made without a counterbore. The threads shall be chamfered approximately to the major diameter of the thread at the back of the flange at an angle of approximately 45 deg. with the axis of the thread. The chamfer shall be concentric with the thread and shall be included in the measurement of the thread length.

6.9.2 Class 300 and higher pressure flanges are made with a counterbore at the back of the flange. The threads shall be chamfered to the diameter of the counterbore at an angle of approximately 45 deg. with the axis of the threads. The counterbore and chamfer shall be concentric with the thread.

6.9.3 The minimum length of effective thread in reducing flanges shall be at least equal to dimension *T* of the corresponding class of threaded flange as shown in the tables. Threads do not necessarily extend to the face of the flange. See Table 7 for reducing threaded flanges.

6.9.4 The gaging notch of the working gage shall come flush with the bottom of the chamfer in all threaded flanges and shall be considered as being the intersection of the chamfer cone and the pitch cone of the thread. This depth of chamfer is approximately equal to one-half the pitch of the thread. The maximum allowable thread variation is one turn large or small from the gaging notch.

6.9.5 Annex A indicates the distance and number of turns that external pipe threads may be made longer than regular for use with the higher pressure flanges to bring the small end of the thread close to the face of the flange when the parts are assembled by power equipment. Annex A applies to ASME B1.20.1 and is considered part of this Standard.

6.10 Flange Bolting Dimensions

6.10.1 Dimensional Standards. Stud bolts threaded at both ends or full length, or bolts may be used. Dimensional recommendations for bolts, stud bolts, and nuts are shown in Table 1C. See para. 5.3 for bolting material recommendations.

6.10.2 Bolt Lengths. Stud bolts with a nut at each end are recommended for high temperature service. Stud bolt lengths are specified in Tables 8, 11, 14, 17, 20, 23, and 26, and include the thickness of two nuts. The stud bolt length does not include the height of any point. A point is that part of a stud bolt or a bolt beyond the thread and may be chamfered, rounded, or sheared. For the method of calculating bolt lengths, see Annex F.

These lengths are established for the convenience of industry to simplify the assembly of these parts on construction work, but users may select combinations of these bolt lengths to suit their needs. Hence, Annex F is not considered part of this Standard.

6.10.3 The end flange bolting is based on a stress on the effective tensile stress area of the bolts not to exceed 7.0 ksi, assuming a pressure in psi equal to the pressure rating class designation to act upon an area circumscribed by the outside diameter of the raised face, dimension *R*, Table 4.

6.11 Gaskets for Line Flanges

6.11.1 Ring joint gasket dimensions shall conform to ASME B16.20.

6.11.2 For flanges with raised face, or with large male-and-female face, gaskets shall conform to limiting dimensions of Annex E.

6.11.3 For flanges having large or small tongue-and-groove faces, all gaskets except solid flat metal gaskets shall cover the bottom of the groove, with minimum clearance. (See para. 7.2.1 for tolerance applicable to groove.) Solid flat metal gaskets shall have contact width not greater than for Group No. III gaskets.

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6.11.4 For flanges with small male-and-female face, care must be taken to insure that adequate bearing surface is provided for the gaskets. This applies particularly where the joint is made on the end of pipe. See Fig. 7.

6.12 Auxiliary Connections

No auxiliary connections, or openings therefore, will be provided except as specified by the purchaser. If assembly is required, the purchaser shall also specify the applicable code or regulation. Welded auxiliary connections shall be made by a qualified welder using a qualified weld procedure.

6.12.1 Pipe Thread Tapping. Holes may be tapped in the wall of a fitting if the metal is thick enough to allow the effective thread length specified in Fig. 3. Where thread length is insufficient or the tapped hole needs reinforcement, a boss shall be added.

6.12.2 Welded Connections

6.12.2.1 Sockets. Sockets (socket welding) may be provided in the wall of a fitting if the metal is thick enough to afford the depth of socket and retaining wall specified in Fig. 4. Where the wall thickness is insufficient, or the size of the connection requires opening reinforcement, a boss shall be added.

6.12.2.2 Butt Weld. Connections may be attached by butt welding directly to the wall of the fitting (see Fig. 5). Where the size of an opening requires reinforcement, a boss shall be added.

6.12.3 Bosses. Where bosses are required, the diameters shall be not less than those shown in Fig. 6, and the height shall provide lengths as specified in Fig. 3 or 4.

6.12.4 Size. Unless otherwise specified, auxiliary connections shall be of the pipe sizes given below.

Fitting Size, NPS	Connection, NPS
2–4	½
5–8	¾
10 and up	1

6.12.5 Designating Locations. This means of designating the locations for auxiliary connections in fittings are shown in Fig. 1.

Each possible location is designated by a letter so that the desired locations for the various types of fittings may be specified without using further sketches or description.

7 TOLERANCES[2]

7.1 General

For the purpose of determining conformance with this Standard, the convention for fixing significant digits where limits, maximum or minimum values are specified, shall be the rounding-off method defined in ASTM Practice E 29. This requires that an observed or calculated value shall be rounded to the nearest unit in the last right hand digit used for expressing the limit.

The listing of decimal tolerances does not imply a particular method of measurement.

7.2 Center-to-Contact Surfaces and Center-to-End

7.2.1 Center-to-Contact Surfaces Other Than Ring Joint (a)

NPS 10 and smaller	0.03 in.
NPS 12 and larger	0.06 in.

7.2.2 Center-to-End (Ring Joint)

NPS 10 and smaller	0.03 in.
NPS 12 and larger	0.06 in.

7.2.3 Contact Surface-to-Contact Surface Other Than Ring Joint

NPS 10 and smaller	0.06 in.
NPS 12 and larger	0.12 in.

7.2.4 End-to-End (Ring Joint)

NPS 10 and smaller	0.06 in.
NPS 12 and larger	0.12 in.

7.3 Facings

7.3.1 Inside and outside diameter of large and small tongue and groove and female, 0.02 in.

7.3.2 Outside diameter, 0.06 in. raised face, 0.03 in.

7.3.3 Outside diameter, 0.25 in. raised face, 0.02 in.

7.3.4 Ring joint groove tolerances are shown in Table 5.

7.4 Flange Thickness

NPS 18 and smaller	+0.12 in., –zero
NPS 20 and larger	+0.19 in., –zero

[2] Unless otherwise stated, tolerances are equal plus and minus.

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STD·ASME B16·5A-ENGL 1998 ■ 0759670 0608505 895 ■

7.5 Hub Dimensions and Welding Ends

7.5.1 Nominal outside diameter of welding end of welding neck flanges (dimension *A* of Figs. 8 and 9).

NPS 5 and smaller	+0.09 in., −0.03 in.
NPS 6 and larger	+0.16 in., −0.03 in.

7.5.2 Nominal inside diameter of welding ends of welding neck flanges and smaller bore of socket welding flanges (dimension *B* in the referenced figures).

Figs. 8 and 9:

NPS 10 and smaller	0.03 in.
NPS 12 to 18, inclusive	0.06 in.
NPS 20 and larger	+0.12 in., −0.06 in.

Fig. 10:

NPS 10 and smaller	+zero, −0.03 in.
NPS 12 and larger	+zero, −0.06 in.

7.5.3 Bore of backing ring of welding neck flanges (dimension *C* of Figs. 10 and 11).

All sizes	+0.010 in., − zero

7.5.4 Thickness of Hub. Regardless of tolerances specified for dimensions *A* and *B*, the thickness of hub at the welding end shall never be less than 87½% of the nominal thickness of the pipe to which the flange is to be attached.

(a) 7.6 Overall Length Through Hub on Welding Neck Flanges

NPS 4 and smaller	0.06 in.
NPS 5 to 10, inclusive	+0.06 in., −0.12 in.
NPS 12 and larger	+0.12 in., −0.18 in.

7.7 Bore of Flanges

7.7.1 Lapped, Slip-On, and Socket Welding Flanges

NPS 10 and smaller	+0.03 in., −zero
NPS 12 and larger	+0.06 in., −zero

7.7.2 Counterbore, Threaded Flanges

NPS 10 and smaller	+0.03 in., −zero
NPS 12 and larger	+0.06 in., −zero

7.8 Drilling and Facing

7.8.1 Bolt circle diameter, 0.06 in.

7.8.2 Center-to-center of adjacent bolt holes, 0.03 in.

7.8.3 Eccentricity between bolt circle diameter and machined facing diameters.

NPS 2½ and smaller	0.03 in.
NPS 3 and larger	0.06 in.

8 TEST

8.1 Flanged Fitting Testing (a)

Each flanged fitting shall be given a hydrostatic shell test as specified in para. 8.3.

8.2 Flange Testing

Flanges are not required to be hydrostatically tested.

8.3 Hydrostatic Shell Test

The hydrostatic shell test for flanged fittings shall be no less than 1.5 times the 100°F rating rounded off to the next higher 25 psi increment.

8.3.1 The test shall be made with water, which may contain a corrosion inhibitor, with kerosene, or with another suitable fluid provided its viscosity is no greater than that of water, at a test temperature not above 125°F.

8.3.2 The test duration shall be a minimum of 1 min for fittings NPS 2 and smaller, 2 min for fittings NPS 2½–NPS 8, and 3 min for fittings NPS 10 and larger.

8.3.3 No visible leakage is permitted through the pressure boundary wall.

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(a)

TABLE 1A LIST OF MATERIAL SPECIFICATIONS

Material Group	Nominal Designation	Pressure-Temperature Rating Table	Applicable ASTM Specifications[1]		
			Forgings	Castings	Plates
1.1	C-Si C-Mn-Si C-Mn-Si-V	2-1.1	A 105 A 350 Gr. LF2 A 350 Gr. LF6 Cl. 1	A 216 Gr. WCB	A 515 Gr. 70 A 516 Gr. 70 A 537 Cl. 1
1.2	C-Mn-Si C-Mn-Si-V 2½Ni 3½Ni	2-1.2	 A 350 Gr. LF6 Cl. 2 A 350 Gr. LF3	A 216 Gr. WCC A 352 Gr. LCC A 352 Gr. LC2 A 352 Gr. LC3	 A 203 Gr. B A 203 Gr. E
1.3	C-Si C-Mn-Si 2½Ni 3½Ni	2-1.3		A 352 Gr. LCB	A 515 Gr. 65 A 516 Gr. 65 A 203 Gr. A A 203 Gr. D
1.4	C-Si C-Mn-Si	2-1.4	 A 350 Gr. LF1 Cl. 1		A 515 Gr. 60 A 516 Gr. 60
1.5	C-½Mo	2-1.5	A 182 Gr. F1	A 217 Gr. WC1 A 352 Gr. LC1	A 204 Gr. A A 204 Gr. B
1.7	C-½Mo ½Cr-½Mo Ni-½Cr-½Mo ¾Ni-¾Cr-1Mo	2-1.7	 A 182 Gr. F2	 A 217 Gr. WC4 A 217 Gr. WC5	A 204 Gr. C
1.9	1Cr-½Mo 1¼Cr-½Mo 1¼Cr-½Mo-Si	2-1.9	A 182 Gr. F12 Cl. 2 A 182 Gr. F11 Cl. 2	 A 217 Gr. WC6	 A 387 Gr. 11 Cl. 2
1.10	2¼Cr-1Mo	2-1.10	A 182 Gr. F22 Cl. 3	A 217 Gr. WC9	A 387 Gr. 22 Cl. 2
1.13	5Cr-½Mo	2-1.13	A 182 Gr. F5 A 182 Gr. F5a	 A 217 Gr. C5	
1.14	9Cr-1Mo	2-1.14	A 182 Gr. F9	A 217 Gr. C12	
1.15	9Cr-1Mo-V	2-1.15	A 182 Gr. F91	A 217 Gr. C12A	A 387 Gr. 91 Cl. 2
2.1	18Cr-8Ni	2-2.1	A 182 Gr. F304 A 182 Gr. F304H	A 351 Gr. CF3 A 351 Gr. CF8	A 240 Gr. 304 A 240 Gr. 304H
2.2	16Cr-12Ni-2Mo 18Cr-13Ni-3Mo 19Cr-10Ni-3Mo	2-2.2	A 182 Gr. F316 A 182 Gr. F316H	A 351 Gr. CF3M A 351 Gr. CF8M A 351 Gr. CG8M	A 240 Gr. 316 A 240 Gr. 316H A 240 Gr. 317
2.3	18Cr-8Ni 16Cr-12Ni-2Mo	2-2.3	A 182 Gr. F304L A 182 Gr. F316L		A 240 Gr. 304L A 240 Gr. 316L
2.4	18Cr-10Ni-Ti	2-2.4	A 182 Gr. F321 A 182 Gr. F321H		A 240 Gr. 321 A 240 Gr. 321H

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a)

TABLE 1A LIST OF MATERIAL SPECIFICATIONS (CONT'D)

Material Group	Nominal Designation	Pressure-Temperature Rating Table	Applicable ASTM Specifications[1]		
			Forgings	Castings	Plates
2.5	18Cr–10Ni–Cb	2-2.5	A 182 Gr. F347 A 182 Gr. F347H A 182 Gr. F348 A 182 Gr. F348H	A 351 Gr. CF8C	A 240 Gr. 347 A 240 Gr. 347H A 240 Gr. 348 A 240 Gr. 348H
2.6	25Cr–12Ni 23Cr–12Ni	2-2.6		A 351 Gr. CH8 A 351 Gr. CH20	 A 240 Gr. 309S A 240 Gr. 309H
2.7	25Cr–20Ni	2-2.7	A 182 Gr. F310	A 351 Gr. CK20	A 240 Gr. 310S A 240 Gr. 310H
2.8	20Cr–18Ni–6Mo 22Cr–5Ni–3Mo–N 25Cr–7Ni–4Mo–N 24Cr–10Ni–4Mo–V 25Cr–5Ni–2Mo–3Cu 25Cr–7Ni–3.5Mo–W–Cb 25Cr–7Ni–3.5Mo–N–Cu–W	2-2.8	A 182 Gr. F44 A 182 Gr. F51 A 182 Gr. F53 A 182 Gr. F55	A 351 Gr. CK3MCuN A 351 Gr. CE8MN A 351 Gr. CD4MCu A 351 Gr. CD3MWCuN	A 240 Gr. S31254 A 240 Gr. S31803 A 240 Gr. S32750 A 240 Gr. S32760
3.1	35Ni–35Fe–20Cr–Cb	2-3.1	B 462 Gr. N08020		B 463 Gr. N08020
3.2	99.0Ni	2-3.2	B 160 Gr. N02200		B 162 Gr. N02200
3.3	99.0Ni–Low C	2-3.3	B 160 Gr. N02201		B 162 Gr. N02201
3.4	67Ni–30Cu 67Ni–30Cu–S	2-3.4	B 564 Gr. N04400 B 164 Gr. N04405		B 127 Gr. N04400
3.5	72Ni–15Cr–8Fe	2-3.5	B 564 Gr. N06600		B 168 Gr. N06600
3.6	33Ni–42Fe–21Cr	2-3.6	B 564 Gr. N08800		B 409 Gr. N08800
3.7	65Ni–28Mo–2Fe	2-3.7	B 335 Gr. N10665		B 333 Gr. N10665
3.8	54Ni–16Mo–15Cr 60Ni–22Cr–9Mo–3.5Cb 62Ni–28Mo–5Fe 70Ni–16Mo–7Cr–5Fe 61Ni–16Mo–16Cr 42Ni–21.5Cr–3Mo–2.3Cu	2-3.8	B 564 Gr. N10276 B 564 Gr. N06625 B 335 Gr. N10001 B 573 Gr. N10003 B 574 Gr. N06455 B 564 Gr. N08825		B 575 Gr. N10276 B 443 Gr. N06625 B 333 Gr. N10001 B 434 Gr. N10003 B 575 Gr. N06455 B 424 Gr. N08825
3.9	47Ni–22Cr–9Mo–18Fe	2-3.9	B 572 Gr. N06002		B 435 Gr. N06002
3.10	25Ni–46Fe–21Cr–5Mo	2-3.10	B 672 Gr. N08700		B 599 Gr. N08700
3.11	44Fe–25Ni–21Cr–Mo	2-3.11	B 649 Gr. N08904		B 625 Gr. N08904
3.12	26Ni–43Fe–22Cr–5Mo 47Ni–22Cr–20Fe–7Mo	2-3.12	B 621 Gr. N08320 B 581 Gr. N06985		B 620 Gr. N08320 B 582 Gr. N06985

(Table 1A continues on next page; Notes follow at end of Table)

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(a)

TABLE 1A LIST OF MATERIAL SPECIFICATIONS (CONT'D)

Material Group	Nominal Designation	Pressure–Temperature Rating Table	Applicable ASTM Specifications[1]		
			Forgings	Castings	Plates
3.13	49Ni–25Cr–18Fe–6Mo Ni–Fe–Cr–Mo–Low Cu	2-3.13	B 581 Gr. N06975 B 564 Gr. N08031		B 582 Gr. N06975 B 625 Gr. N08031
3.14	47Ni–22Cr–19Fe–6Mo	2-3.14	B 581 Gr. N06007		B 582 Gr. N06007
3.15	33Ni–42Fe–21Cr	2-3.15	B 564 Gr. N08810		B 409 Gr. N08810
3.16	35Ni–19Cr–1¼Si	2-3.16	B 511 Gr. N08330		B 536 Gr. N08330
3.17	29Ni–20.5Cr–3.5Cu–2.5Mo	2-3.17		A 351 Gr. CN7M	

GENERAL NOTES:

(a) For temperature limitations, see Notes in Table 2.

(b) Plate materials are listed only for use as blind flanges (see para. 5.1). Additional plate materials listed in ASME B16.34 may also be used with corresponding B16.34 Standard Class ratings.

(c) Material Groups not listed in Table 1A are intended for use in valves. See ASME B16.34.

NOTE:

(1) ASME Boiler and Pressure Vessel Code, Section II materials, which also meet the requirements of the listed ASTM specifications, may also be used.

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TABLES 2
PRESSURE-TEMPERATURE RATINGS FOR GROUPS 1.1 THROUGH 3.17 MATERIALS

TABLE 2-1.1 RATINGS FOR GROUP 1.1 MATERIALS (a)

Nominal Designation	Forgings	Castings	Plates
C-Si	A 105 (1)	A 216 Gr. WCB (1)	A 515 Gr. 70 (1)
C-Mn-Si	A 350 Gr. LF2 (1)		A 516 Gr. 70 (1)(2) A 537 Cl. 1 (3)
C-Mn-Si-V	A 350 Gr. LF6 Cl. 1 (4)		

NOTES:
(1) Upon prolonged exposure to temperatures above 800°F, the carbide phase of steel may be converted to graphite. Permissible, but not recommended for prolonged use above 800°F.
(2) Not to be used over 850°F.
(3) Not to be used over 700°F.
(4) Not to be used over 500°F.

	WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	150	300	400	600	900	1500	2500
-20 to 100	285	740	990	1480	2220	3705	6170
200	260	675	900	1350	2025	3375	5625
300	230	655	875	1315	1970	3280	5470
400	200	635	845	1270	1900	3170	5280
500	170	600	800	1200	1795	2995	4990
600	140	550	730	1095	1640	2735	4560
650	125	535	715	1075	1610	2685	4475
700	110	535	710	1065	1600	2665	4440
750	95	505	670	1010	1510	2520	4200
800	80	410	550	825	1235	2060	3430
850	65	270	355	535	805	1340	2230
900	50	170	230	345	515	860	1430
950	35	105	140	205	310	515	860
1000	20	50	70	105	155	260	430

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(a)

TABLE 2-1.2 RATINGS FOR GROUP 1.2 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C–Mn–Si		A 216 Gr. WCC (1) A 352 Gr. LCC (2)	
C–Mn–Si–V	A 350 Gr. LF6 Cl. 2 (3)		
2½Ni		A 352 Gr. LC2	A 203 Gr. B (1)
3½Ni	A 350 Gr. LF3	A 352 Gr. LC3	A 203 Gr. E (1)

NOTES:
(1) Upon prolonged exposure to temperatures above 800°F, the carbide phase of steel may be converted to graphite. Permissible, but not recommended for prolonged use above 800°F.
(2) Not to be used over 650°F.
(3) Not to be used over 500°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	730	970	1455	2185	3640	6070
400	200	705	940	1410	2115	3530	5880
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	505	670	1010	1510	2520	4200
800	80	410	550	825	1235	2060	3430
850	65	270	355	535	805	1340	2230
900	50	170	230	345	515	860	1430
950	35	105	140	205	310	515	860
1000	20	50	70	105	155	260	430

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TABLE 2-1.5 RATINGS FOR GROUP 1.5 MATERIALS (a)

Nominal Designation	Forgings	Castings	Plates
C-½Mo	A 182 Gr. F1 (1)	A 217 Gr. WC1 (1)(2) A 352 Gr. LC1 (3)	A 204 Gr. A (1) A 204 Gr. B (1)

NOTES:
(1) Upon prolonged exposure to temperatures above 875°F, the carbide phase of carbon-molybdenum steel may be converted to graphite. Permissible, but not recommended for prolonged use above 875°F.
(2) Use normalized and tempered material only.
(3) Not to be used over 650°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
-20 to 100	265	695	925	1390	2085	3470	5785
200	260	680	905	1360	2035	3395	5660
300	230	655	870	1305	1955	3260	5435
400	200	640	855	1280	1920	3200	5330
500	170	620	830	1245	1865	3105	5180
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	280	375	560	845	1405	2345
1000	20	165	220	330	495	825	1370

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(a)

TABLE 2-1.7 RATINGS FOR GROUP 1.7 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C–½Mo			A 204 Gr. C (1)
½Cr–½Mo	A 182 Gr. F2 (3)		
Ni–½Cr–½Mo		A 217 Gr. WC4 (2)(3)	
¾Ni–¾Cr–1Mo		A 217 Gr. WC5 (2)	

NOTES:
(1) Upon prolonged exposure to temperatures above 875°F, the carbide phase of carbon-molybdenum steel may be converted to graphite. Permissible, but not recommended for prolonged use above 875°F.
(2) Use normalized and tempered material only.
(3) Not to be used over 1000°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	720	965	1445	2165	3610	6015
400	200	695	925	1385	2080	3465	5775
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	315	420	630	945	1575	2630
1000	20	200	270	405	605	1010	1685
1050	...	160	210	315	475	790	1315

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TABLE 2-1.15 RATINGS FOR GROUP 1.15 MATERIALS (a)

Nominal Designation	Forgings	Castings	Plates
9Cr–1Mo–V	A 182 Gr. F91	A 217 Gr. C12A	A 387 Gr. 91 Cl. 2

WORKING PRESSURES BY CLASSES, psig							
Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	730	970	1455	2185	3640	6070
400	200	705	940	1410	2115	3530	5880
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	385	515	775	1160	1930	3220
1000	20	365	485	725	1090	1820	3030
1050	. . .	360	480	720	1080	1800	3000
1100	. . .	300	400	605	905	1510	2515
1150	. . .	225	295	445	670	1115	1855
1200	. . .	145	190	290	430	720	1200

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TABLE 2-2.1 RATINGS FOR GROUP 2.1 MATERIALS (a)

Nominal Designation	Forgings	Castings	Plates
18Cr–8Ni	A 182 Gr. F304 (1)	A 351 Gr. CF3 (2)	A 240 Gr. 304 (1)
	A 182 Gr. F304H	A 351 Gr. CF8 (1)	A 240 Gr. 304H

NOTES:
(1) At temperatures over 1000°F, use only when the carbon content is 0.04% or higher.
(2) Not to be used over 800°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
-20 to 100	275	720	960	1440	2160	3600	6000
200	230	600	800	1200	1800	3000	5000
300	205	540	720	1080	1620	2700	4500
400	190	495	660	995	1490	2485	4140
500	170	465	620	930	1395	2330	3880
600	140	435	580	875	1310	2185	3640
650	125	430	575	860	1290	2150	3580
700	110	425	565	850	1275	2125	3540
750	95	415	555	830	1245	2075	3460
800	80	405	540	805	1210	2015	3360
850	65	395	530	790	1190	1980	3300
900	50	390	520	780	1165	1945	3240
950	35	380	510	765	1145	1910	3180
1000	20	320	430	640	965	1605	2675
1050	...	310	410	615	925	1545	2570
1100	...	255	345	515	770	1285	2145
1150	...	200	265	400	595	995	1655
1200	...	155	205	310	465	770	1285
1250	...	115	150	225	340	565	945
1300	...	85	115	170	255	430	715
1350	...	60	80	125	185	310	515
1400	...	50	65	90	145	240	400
1450	...	35	45	70	105	170	285
1500	...	25	35	55	80	135	230

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TABLE 2-2.2 RATINGS FOR GROUP 2.2 MATERIALS

Nominal Designation	Forgings	Castings	Plates
16Cr–12Ni–2Mo	A 182 Gr. F316 (1) A 182 Gr. F316H	A 351 Gr. CF3M (2) A 351 Gr. CF8M (1)	A 240 Gr. 316 (1) A 240 Gr. 316H
18Cr–13Ni–3Mo			A 240 Gr. 317 (1)
19Cr–10Ni–3Mo		A 351 Gr. CG8M (3)	

NOTES:
(1) At temperatures over 1000°F, use only when the carbon content is 0.04% or higher.
(2) Not to be used over 850°F.
(3) Not to be used over 1000°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	275	720	960	1440	2160	3600	6000
200	235	620	825	1240	1860	3095	5160
300	215	560	745	1120	1680	2795	4660
400	195	515	685	1025	1540	2570	4280
500	170	480	635	955	1435	2390	3980
600	140	450	600	900	1355	2255	3760
650	125	445	590	890	1330	2220	3700
700	110	430	580	870	1305	2170	3620
750	95	425	570	855	1280	2135	3560
800	80	420	565	845	1265	2110	3520
850	65	420	555	835	1255	2090	3480
900	50	415	555	830	1245	2075	3460
950	35	385	515	775	1160	1930	3220
1000	20	350	465	700	1050	1750	2915
1050	...	345	460	685	1030	1720	2865
1100	...	305	405	610	915	1525	2545
1150	...	235	315	475	710	1185	1970
1200	...	185	245	370	555	925	1545
1250	...	145	195	295	440	735	1230
1300	...	115	155	235	350	585	970
1350	...	95	130	190	290	480	800
1400	...	75	100	150	225	380	630
1450	...	60	80	115	175	290	485
1500	...	40	55	85	125	205	345

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TABLE 2-2.3 RATINGS FOR GROUP 2.3 MATERIALS

Nominal Designation	Forgings	Castings	Plates
16Cr–12Ni–2Mo	A 182 Gr. F316L		A 240 Gr. 316L
18Cr–8Ni	A 182 Gr. F304L (1)		A 240 Gr. 304L (1)

NOTE:
(1) Not to be used over 800°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	230	600	800	1200	1800	3000	5000
200	195	505	675	1015	1520	2530	4220
300	175	455	605	910	1360	2270	3780
400	160	415	550	825	1240	2065	3440
500	145	380	510	765	1145	1910	3180
600	140	360	480	720	1080	1800	3000
650	125	350	470	700	1050	1750	2920
700	110	345	460	685	1030	1715	2860
750	95	335	450	670	1010	1680	2800
800	80	330	440	660	985	1645	2740
850	65	320	430	645	965	1610	2680

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(a)

TABLE 2-2.4 RATINGS FOR GROUP 2.4 MATERIALS

Nominal Designation	Forgings	Castings	Plates
18Cr–10Ni–Ti	A 182 Gr. F321 (2) A 182 Gr. F321H (1)		A 240 Gr. 321 (2) A 240 Gr. 321H (1)

NOTES:
(1) At temperatures over 1000°F, use only if the material is heat treated by heating to a minimum temperature of 2000°F.
(2) Not to be used over 1000°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	275	720	960	1440	2160	3600	6000
200	245	645	860	1290	1935	3230	5380
300	230	595	795	1190	1785	2975	4960
400	200	550	735	1105	1655	2760	4600
500	170	515	685	1030	1545	2570	4285
600	140	485	650	975	1460	2435	4060
650	125	480	635	955	1435	2390	3980
700	110	465	620	930	1395	2330	3880
750	95	460	610	915	1375	2290	3820
800	80	450	600	900	1355	2255	3760
850	65	445	595	895	1340	2230	3720
900	50	440	590	885	1325	2210	3680
950	35	385	515	775	1160	1930	3220
1000	20	355	475	715	1070	1785	2970
1050	...	315	415	625	940	1565	2605
1100	...	270	360	545	815	1360	2265
1150	...	235	315	475	710	1185	1970
1200	...	185	245	370	555	925	1545
1250	...	140	185	280	420	705	1170
1300	...	110	145	220	330	550	915
1350	...	85	115	170	255	430	715
1400	...	65	85	130	195	325	545
1450	...	50	70	105	155	255	430
1500	...	40	50	75	115	190	315

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TABLE 2-2.7 RATINGS FOR GROUP 2.7 MATERIALS (a)

Nominal Designation	Forgings	Castings	Plates
25Cr–20Ni	A 182 Gr. F310 (1)(3)	A 351 Gr. CK20 (1)	A 240 Gr. 310S (1)(2)(3) A 240 Gr. 310H

NOTES:
(1) At temperatures over 1000°F, use only when the carbon content is 0.04% or higher.
(2) For temperatures above 1000°F, use only if the material is heat treated by heating it to a temperature of at least 1900°F and quenching in water or rapidly cooling by other means.
(3) Service temperatures of 1050°F and above should be used only when assurance is provided that grain size is not finer than ASTM 6.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	260	670	895	1345	2015	3360	5600
200	235	605	810	1215	1820	3035	5060
300	220	570	760	1140	1705	2845	4740
400	200	535	715	1070	1605	2675	4460
500	170	505	675	1015	1520	2530	4220
600	140	480	640	960	1440	2400	4000
650	125	470	625	935	1405	2340	3900
700	110	455	610	910	1370	2280	3800
750	95	450	600	900	1345	2245	3740
800	80	435	580	875	1310	2185	3640
850	65	425	570	855	1280	2135	3560
900	50	420	555	835	1255	2090	3480
950	35	385	515	775	1160	1930	3220
1000	20	345	460	685	1030	1720	2865
1050	. . .	335	450	670	1010	1680	2800
1100	. . .	260	345	520	780	1305	2170
1150	. . .	190	250	375	565	945	1570
1200	. . .	135	185	275	410	685	1145
1250	. . .	105	135	205	310	515	855
1300	. . .	75	100	150	225	375	630
1350	. . .	60	80	115	175	290	485
1400	. . .	45	60	90	135	225	370
1450	. . .	35	45	65	100	165	275
1500	. . .	25	35	50	75	130	215

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(a)

TABLE 2-2.8 RATINGS FOR GROUP 2.8 MATERIALS

Nominal Designation	Forgings	Castings	Plates
20Cr–18Ni–6Mo	A 182 Gr. F44	A 351 Gr. CK3MCuN	A 240 Gr. S31254
22Cr–5Ni–3Mo–N	A 182 Gr. F51 (1)		A 240 Gr. S31803 (1)
25Cr–7Ni–4Mo–N	A 182 Gr. F53 (1)		A 240 Gr. S32750 (1)
24Cr–10Ni–4Mo–V		A 351 Gr. CE8MN (1)	
25Cr–5Ni–2Mo–3Cu		A 351 Gr. CD4MCu (1)	
25Cr–7Ni–3.5Mo–W–Cb		A 351 Gr. CD3MWCuN (1)	
25Cr–7Ni–3.5Mo–N–Cu–W	A 182 Gr. F55 (1)		A 240 Gr. S32760 (1)

NOTE:
(1) This steel may become brittle after service at moderately elevated temperatures. Not to be used over 600°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	290	750	1000	1500	2250	3750	6250
200	260	720	960	1440	2160	3600	6000
300	230	665	885	1330	1995	3325	5540
400	200	615	820	1230	1845	3070	5120
500	170	575	770	1150	1730	2880	4800
600	140	555	740	1115	1670	2785	4640
650	125	550	735	1100	1650	2750	4580
700	110	540	725	1085	1625	2710	4520
750	95	530	710	1065	1595	2660	4430

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TABLE 2-3.1 RATINGS FOR GROUP 3.1 MATERIALS (a)

Nominal Designation	Forgings	Castings	Plates
35Ni–35Fe–20Cr–Cb	B 462 Gr. N08020 (1)		B 463 Gr. N08020 (1)

NOTE:
(1) Use annealed material only.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	290	750	1000	1500	2250	3750	6250
200	260	720	960	1440	2160	3600	6000
300	230	715	950	1425	2140	3565	5940
400	200	675	900	1345	2020	3365	5610
500	170	655	875	1310	1965	3275	5460
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230

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TABLE 2-3.2 RATINGS FOR GROUP 3.2 MATERIALS

Nominal Designation	Forgings	Castings	Plates
99.0Ni	B 160 Gr. N02200 (1)(2)		B 162 Gr. N02200 (1)

NOTES:
(1) Use annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
-20 to 100	140	360	480	720	1080	1800	3000
200	140	360	480	720	1080	1800	3000
300	140	360	480	720	1080	1800	3000
400	140	360	480	720	1080	1800	3000
500	140	360	480	720	1080	1800	3000
600	140	360	480	720	1080	1800	3000

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TABLE 2-3.3 RATINGS FOR GROUP 3.3 MATERIALS (a)

Nominal Designation	Forgings	Castings	Plates
99.0Ni–Low C	B 160 Gr. N02201 (1)(2)		B 162 Gr. N02201 (1)

NOTES:
(1) Use annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	90	240	320	480	720	1200	2000
200	85	230	305	455	685	1140	1900
300	85	225	300	445	670	1115	1860
400	85	215	290	430	650	1080	1800
500	85	215	290	430	650	1080	1800
600	85	215	290	430	650	1080	1800
650	85	215	290	430	650	1080	1800
700	85	215	290	430	650	1080	1800
750	80	210	280	420	635	1055	1760
800	80	205	270	410	610	1020	1700
850	65	205	270	410	610	1020	1700
900	50	140	185	280	415	695	1155
950	35	115	150	230	345	570	950
1000	20	95	125	185	280	465	770
1050	...	75	100	150	220	370	615
1100	...	60	80	125	185	310	515
1150	...	45	60	95	140	230	385
1200	...	35	50	75	110	185	310

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(a)

TABLE 2-3.4 RATINGS FOR GROUP 3.4 MATERIALS

Nominal Designation	Forgings	Castings	Plates
67Ni–30Cu	B 564 Gr. N04400 (1)		B 127 Gr. N04400 (1)
67Ni–30Cu–S	B 164 Gr. N04405 (1)(2)		

NOTES:
(1) Use annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	230	600	800	1200	1800	3000	5000
200	200	530	705	1055	1585	2640	4400
300	190	495	660	990	1485	2470	4120
400	185	480	635	955	1435	2390	3980
500	170	475	635	950	1435	2375	3960
600	140	475	635	950	1435	2375	3960
650	125	475	635	950	1435	2375	3960
700	110	475	635	950	1435	2375	3960
750	95	470	625	935	1405	2340	3900
800	80	460	610	915	1375	2290	3820
850	65	340	455	680	1020	1695	2830
900	50	245	330	495	740	1235	2055

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TABLE 2-3.5 RATINGS FOR GROUP 3.5 MATERIALS (a)

Nominal Designation	Forgings	Castings	Plates
72Ni–15Cr–8Fe	B 564 Gr. N06600 (1)		B 168 Gr. N06600 (1)

NOTE:
(1) Use annealed material only.

Class / Temp., °F	WORKING PRESSURES BY CLASSES, psig						
	150	300	400	600	900	1500	2500
–20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	730	970	1455	2185	3640	6070
400	200	705	940	1410	2115	3530	5880
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1520	2540	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	325	435	655	980	1635	2725
1000	20	215	290	430	650	1080	1800
1050	. . .	140	185	280	415	695	1155
1100	. . .	95	125	185	280	465	770
1150	. . .	70	90	135	205	340	565
1200	. . .	60	80	125	185	310	515

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(a)

TABLE 2-3.6 RATINGS FOR GROUP 3.6 MATERIALS

Nominal Designation	Forgings	Castings	Plates
33Ni-42Fe-21Cr	B 564 Gr. N08800 (1)		B 409 Gr. N08800 (1)

NOTE:
(1) Use annealed material only.

	WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	150	300	400	600	900	1500	2500
-20 to 100	275	720	960	1440	2160	3600	6000
200	255	660	885	1325	1990	3310	5520
300	230	625	830	1250	1870	3120	5200
400	200	600	800	1200	1800	3000	5000
500	170	580	770	1155	1735	2890	4820
600	140	575	765	1145	1720	2870	4780
650	125	570	760	1140	1705	2845	4740
700	110	565	750	1130	1690	2820	4700
750	95	530	710	1065	1595	2650	4430
800	80	505	675	1015	1520	2535	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	385	515	775	1160	1930	3220
1000	20	365	485	725	1090	1820	3030
1050	...	360	480	720	1080	1800	3000
1100	...	325	430	645	965	1610	2685
1150	...	275	365	550	825	1370	2285
1200	...	205	270	405	610	1020	1695
1250	...	130	175	260	390	650	1080
1300	...	60	80	125	185	310	515
1350	...	50	65	100	150	245	410
1400	...	35	45	70	100	170	285
1450	...	30	40	60	95	155	255
1500	...	25	35	50	75	125	205

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TABLE 2-3.7 RATINGS FOR GROUP 3.7 MATERIALS (a)

Nominal Designation	Forgings	Castings	Plates
65Ni–28Mo–2Fe	B 335 Gr. N10665 (1)(2)		B 333 Gr. N10665 (1)

NOTES:
(1) Use solution annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	730	970	1455	2185	3640	6070
400	200	705	940	1410	2115	3530	5880
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1520	2540	4230

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(a)

TABLE 2-3.8 RATINGS FOR GROUP 3.8 MATERIALS

Nominal Designation	Forgings	Castings	Plates
54Ni-16Mo-15Cr	B 564 Gr. N10276 (1)(4)		B 575 Gr. N10276 (1)(4)
60Ni-22Cr-9Mo-3.5Cb	B 564 Gr. N06625 (3)(5)		B 443 Gr. N06625 (3)(5)
62Ni-28Mo-5Fe	B 335 Gr. N10001 (1)(2)(6)		B 333 Gr. N10001 (1)(6)
70Ni-16Mo-7Cr-5Fe	B 573 Gr. N10003 (2)(3)		B 434 Gr. N10003 (3)
61Ni-16Mo-16Cr	B 574 Gr. N06455 (1)(2)(6)		B 575 Gr. N06455 (1)(6)
42Ni-21.5Fe-3Cr-2.3Cu	B 564 Gr. N08825 (3)(7)		B 424 Gr. N08825 (3)(7)

NOTES:
(1) Use solution annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.
(3) Use annealed material only.
(4) Not to be used over 1250°F.
(5) Not to be used over 1200°F. Alloy N06625 in the annealed condition is subject to severe loss of impact strength at room temperatures after exposure in the range of 1000°F to 1400°F.
(6) Not to be used over 800°F.
(7) Not to be used over 1000°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
-20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	730	970	1455	2185	3640	6070
400	200	705	940	1410	2115	3530	5880
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1520	2540	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	385	515	775	1160	1930	3220
1000	20	365	485	725	1090	1820	3030
1050	...	360	480	720	1080	1800	3000
1100	...	325	430	645	965	1610	2685
1150	...	275	365	550	825	1370	2285
1200	...	185	245	370	555	925	1545
1250	...	145	195	295	440	735	1220
1300	...	110	145	215	325	540	900

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TABLE 2-3.15 RATINGS FOR GROUP 3.15 MATERIALS

Nominal Designation	Forgings	Castings	Plates
33Ni–42Fe–21Cr	B 564 Gr. N08810 (1)		B 409 Gr. N08810 (1)

NOTE:
(1) Use solution annealed material only.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	230	600	800	1200	1800	3000	5000
200	205	540	720	1080	1620	2700	4500
300	195	505	675	1015	1520	2530	4220
400	185	480	640	960	1440	2400	4000
500	170	455	610	910	1370	2280	3800
600	140	440	585	880	1320	2195	3660
650	125	425	565	850	1275	2125	3540
700	110	420	560	840	1260	2100	3500
750	95	415	550	825	1240	2065	3440
800	80	410	545	815	1225	2040	3400
850	65	400	530	795	1195	1990	3320
900	50	395	530	790	1190	1980	3300
950	35	385	515	775	1160	1930	3220
1000	20	365	485	725	1090	1820	3030
1050	. . .	325	435	650	975	1625	2710
1100	. . .	320	430	640	965	1605	2675
1150	. . .	275	365	550	825	1370	2285
1200	. . .	205	275	410	620	1030	1715
1250	. . .	180	245	365	545	910	1515
1300	. . .	140	185	275	410	685	1145
1350	. . .	105	140	205	310	515	860
1400	. . .	75	100	150	225	380	630
1450	. . .	60	80	115	175	290	485
1500	. . .	40	55	85	125	205	345

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(a)

TABLE 2-3.16 RATINGS FOR GROUP 3.16 MATERIALS

Nominal Designation	Forgings	Castings	Plates
35Ni–19Cr–1¼Si	B 511 Gr. N08330 (1)(2)		B 536 Gr. N08330 (1)

NOTES:
(1) Use solution annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	275	720	960	1440	2160	3600	6000
200	245	635	850	1270	1910	3180	5300
300	225	590	785	1175	1765	2940	4900
400	200	550	735	1105	1655	2760	4600
500	170	525	700	1050	1575	2630	4380
600	140	500	670	1005	1505	2510	4180
650	125	490	655	980	1470	2450	4080
700	110	480	645	965	1445	2410	4020
750	95	470	625	940	1410	2350	3920
800	80	465	620	925	1390	2315	3860
850	65	455	605	905	1360	2270	3780
900	50	445	590	885	1330	2215	3690
950	35	385	515	775	1160	1930	3220
1000	20	365	485	725	1090	1820	3030
1050	...	310	410	615	925	1545	2570
1100	...	240	320	480	720	1205	2005
1150	...	185	245	370	555	925	1545
1200	...	145	195	290	435	725	1210
1250	...	115	155	235	350	585	975
1300	...	95	130	190	285	480	795
1350	...	75	100	150	220	370	615
1400	...	55	75	110	165	280	465
1450	...	45	60	95	140	230	385
1500	...	35	45	70	100	170	285

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TABLE 2-3.17 RATINGS FOR GROUP 3.17 MATERIAL (a)

Nominal Designation	Forgings	Castings	Plates
29Ni-20.5Cr-3.5Cu-2.5Mo		A 351 Gr. CN7M (1)	

NOTE:
(1) Use solution annealed material only.

WORKING PRESSURES BY CLASSES, psig							
Class Temp., °F	150	300	400	600	900	1500	2500
-20 to 100	230	600	800	1200	1800	3000	5000
200	200	520	690	1035	1555	2590	4320
300	180	465	620	930	1395	2330	3880
400	160	420	565	845	1265	2110	3520
500	150	390	520	780	1165	1945	3240
600	140	360	480	720	1080	1800	3000

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END FLANGE FACINGS
Flange Thickness and Center-to-End Dimensions
Classes 150 and 300

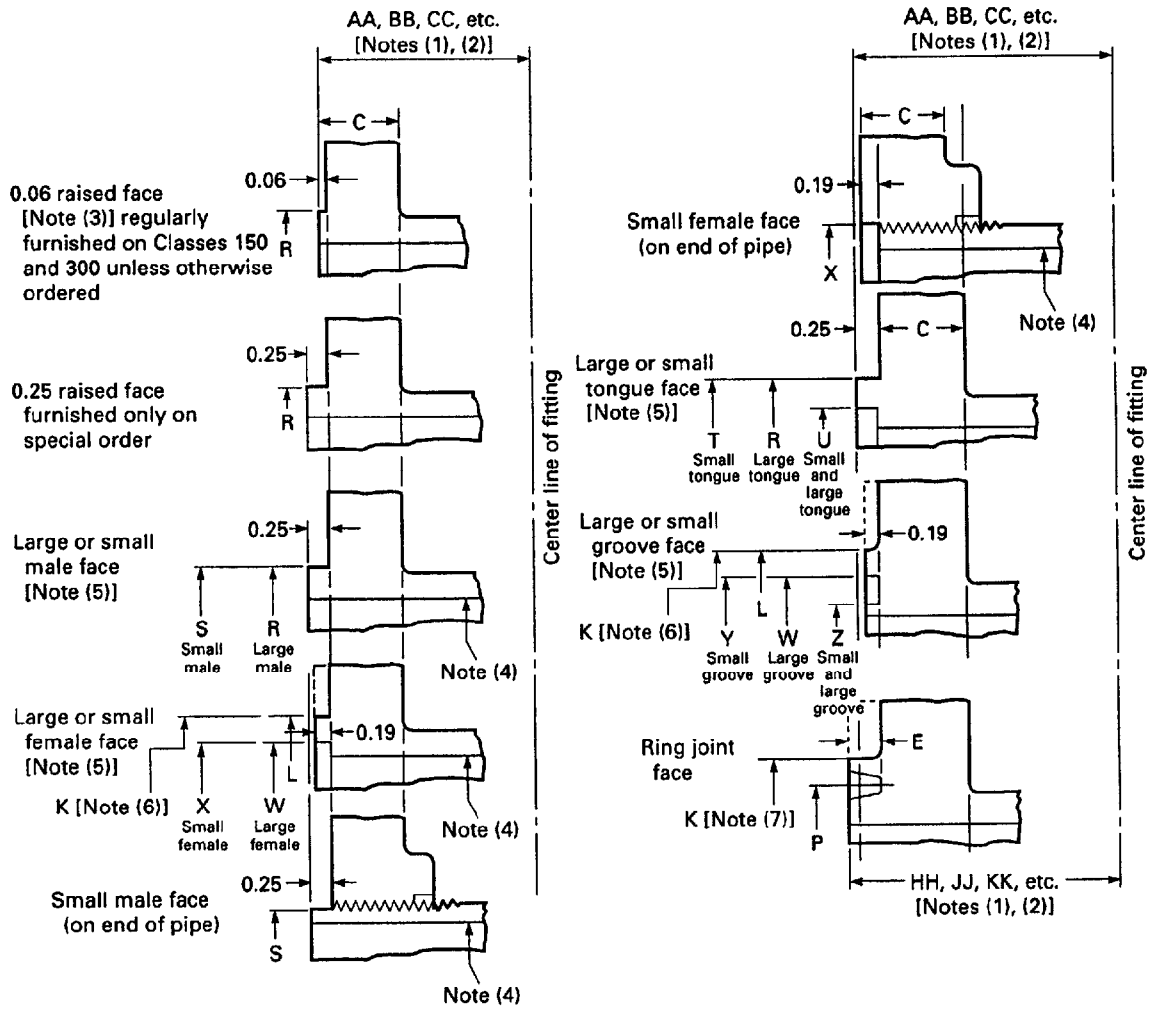

FIG. 7 END FLANGE FACINGS AND THEIR RELATIONSHIP TO FLANGE THICKNESS AND CENTER-TO-END AND END-TO-END DIMENSIONS[1,3] (a)

(Figure continues on next page; Notes follow at end of Figure)

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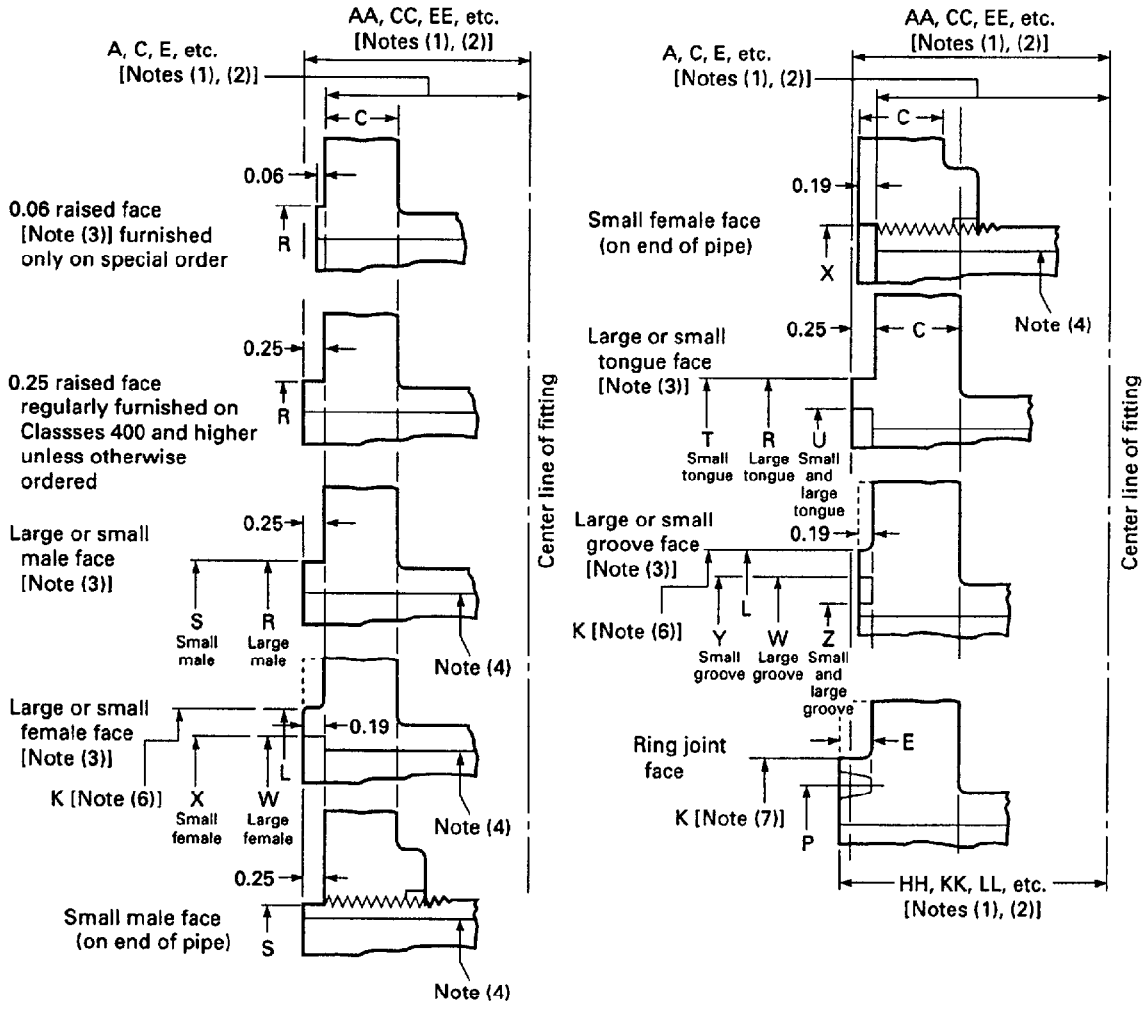
END FLANGE FACINGS
Flange Thickness and Center-to-End Dimensions
Classes 400 and Higher



(a) FIG. 7 END FLANGE FACINGS AND THEIR RELATIONSHIP TO FLANGE THICKNESS AND CENTER-TO-END AND END-TO-END DIMENSIONS[1,3] (CONT'D)

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STD.ASME B16.5A-ENGL 1998 ■ 0759670 0608533 75T ■

TABLE 8 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) Length of stud bolt does not include the height of the points. See para. 6.10.2.
(2) For other dimensions, see Tables 9 and 10.
(3) For flange bolt holes, see para. 6.5.
(4) For spot facing, see para. 6.6.
(5) Bolt lengths not shown in Table are determined in accordance with Annex F. See para. 6.10.2.

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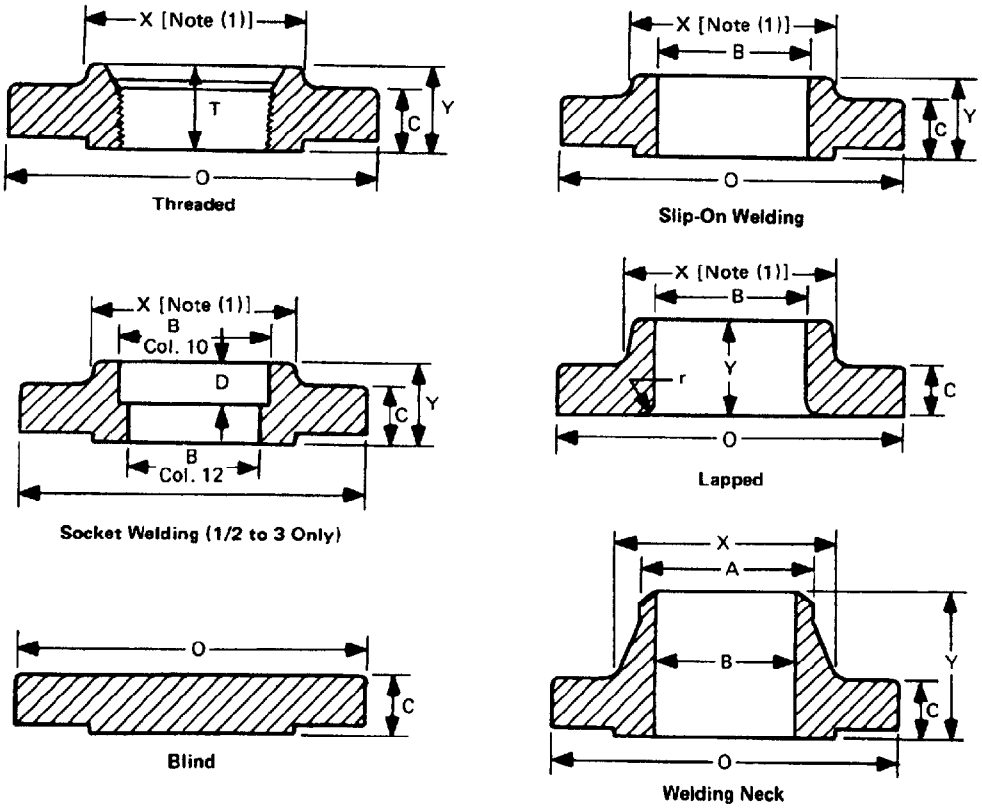

(a)

TABLE 9 DIMENSIONS OF CLASS 150 FLANGES[2-8]

1	2	3	4	5	6	7	8	9	10	11	12	13	14
					Length Through Hub				Bore				
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange [(9)–(11)], Min. C	Diameter of Hub X	Hub Diameter Beginning of Chamfer Welding Neck (12) A	Threaded Slip-On Socket Welding Y	Lapped Y	Welding Neck Y	Thread Length Threaded Flange (13), Min. T	Slip-On Socket Welding, Min. B	Lapped, Min. B	Welding Neck Socket Welding (14) B	Corner Radius of Bore of Lapped Flange and Pipe r	Depth of Socket D
½	3.50	0.44	1.19	0.84	0.62	0.62	1.88	0.62	0.88	0.90	0.62	0.12	0.38
¾	3.88	0.50	1.50	1.05	0.62	0.62	2.06	0.62	1.09	1.11	0.82	0.12	0.44
1	4.25	0.56	1.94	1.32	0.69	0.69	2.19	0.69	1.36	1.38	1.05	0.12	0.50
1¼	4.62	0.62	2.31	1.66	0.81	0.81	2.25	0.81	1.70	1.72	1.38	0.19	0.56
1½	5.00	0.69	2.56	1.90	0.88	0.88	2.44	0.88	1.95	1.97	1.61	0.25	0.62
2	6.00	0.75	3.06	2.38	1.00	1.00	2.50	1.00	2.44	2.46	2.07	0.31	0.69
2½	7.00	0.88	3.56	2.88	1.12	1.12	2.75	1.12	2.94	2.97	2.47	0.31	0.75
3	7.50	0.94	4.25	3.50	1.19	1.19	2.75	1.19	3.57	3.60	3.07	0.38	0.81
3½	8.50	0.94	4.81	4.00	1.25	1.25	2.81	1.25	4.07	4.10	3.55	0.38	...
4	9.00	0.94	5.31	4.50	1.31	1.31	3.00	1.31	4.57	4.60	4.03	0.44	...
5	10.00	0.94	6.44	5.56	1.44	1.44	3.50	1.44	5.66	5.69	5.05	0.44	...
6	11.00	1.00	7.56	6.63	1.56	1.56	3.50	1.56	6.72	6.75	6.07	0.50	...
8	13.50	1.12	9.69	8.63	1.75	1.75	4.00	1.75	8.72	8.75	7.98	0.50	...
10	16.00	1.19	12.00	10.75	1.94	1.94	4.00	1.94	10.88	10.92	10.02	0.50	...
12	19.00	1.25	14.38	12.75	2.19	2.19	4.50	2.19	12.88	12.92	12.00	0.50	...
14	21.00	1.38	15.75	14.00	2.25	3.12	5.00	2.25	14.14	14.18	To be specified by purchaser	0.50	...
16	23.50	1.44	18.00	16.00	2.50	3.44	5.00	2.50	16.16	16.19		0.50	...
18	25.00	1.56	19.88	18.00	2.69	3.81	5.50	2.69	18.18	18.20		0.50	...
20	27.50	1.69	22.00	20.00	2.88	4.06	5.69	2.88	20.20	20.25		0.50	...
24	32.00	1.88	26.12	24.00	3.25	4.38	6.00	3.25	24.25	24.25		0.50	...

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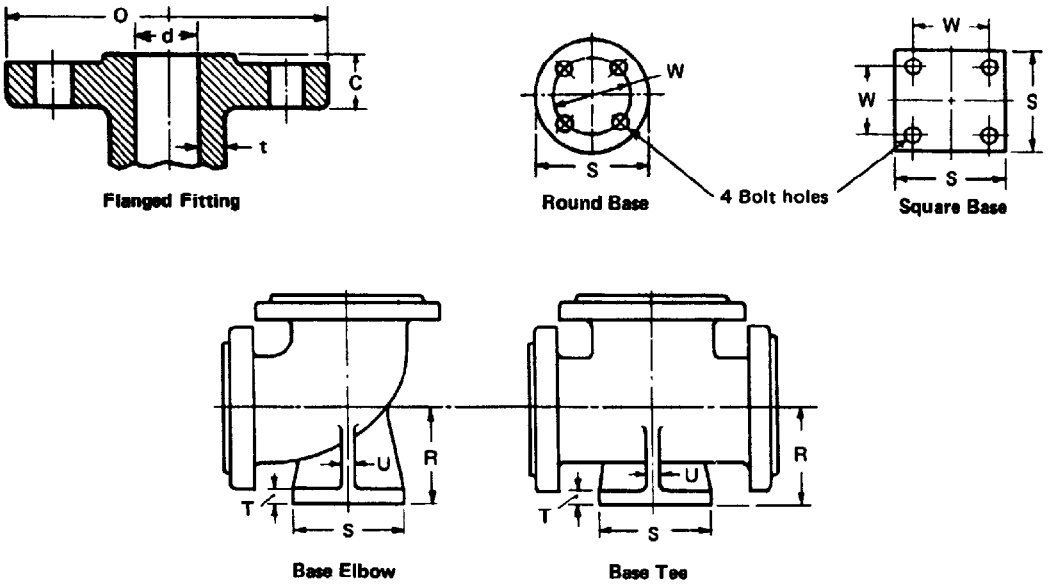

TABLE 13 DIMENSIONS OF CLASS 300 FLANGED FITTINGS[1-9] (CONT'D)

13	14	15	16	17	18	19	20	21	22	23	1
Ring Joint (12)									Base Drilling (18)		
Center-to-End Long Radius Elbow (13) JJ	Center-to-End 45 deg. Elbow (13) KK	Long Center-to-End Lateral (13) LL	Short Center-to-End Lateral and True "Y" (13) MM	End-to-End Reducer NN	Center-to-Base [(14)–(16)] R	Diameter of Round Base or Width of Square Base (14) S	Thickness of Base [(14)–(17)] T	Thickness of Ribs (14) U	Bolt Circle or Bolt Spacing W	Diameter of Drilled Holes	Nominal Pipe Size
5.25	2.50	6.75	2.25	See Notes (12) and (13)	...	...	...	...	...	...	1
5.75	2.75	7.50	2.50		...	...	...	...	...	...	1¼
6.25	3.00	8.75	2.75		...	...	...	...	...	...	1½
6.81	3.31	9.31	2.81		4.50	5.25	0.75	0.50	3.88	0.75	2
7.31	3.81	10.81	2.81		4.75	5.25	0.75	0.50	3.88	0.75	2½
8.06	3.81	11.31	3.31		5.25	6.12	0.81	0.62	4.50	0.88	3
8.81	4.31	12.81	3.31		5.62	6.12	0.81	0.62	4.50	0.88	3½
9.31	4.88	13.81	3.31		6.00	6.50	0.88	0.62	5.00	0.75	4
10.56	5.31	15.31	3.81		6.75	7.50	1.00	0.75	5.88	0.88	5
11.81	5.81	17.81	4.31		7.50	7.50	1.00	0.75	5.88	0.88	6
14.31	6.31	20.81	5.31		9.00	10.00	1.25	0.88	7.88	0.88	8
16.81	7.31	24.31	5.81		10.50	10.00	1.25	0.88	7.88	0.88	10
19.31	8.31	27.81	6.31		12.00	12.50	1.44	1.00	10.62	0.88	12
21.81	8.81	31.31	6.81		13.50	12.50	1.44	1.00	10.62	0.88	14
24.31	9.81	34.81	7.81		14.75	12.50	1.44	1.12	10.62	0.88	16
26.81	10.31	37.81	8.31		16.25	15.00	1.62	1.12	13.00	1.00	18
29.38	10.88	40.88	8.88		17.88	15.00	1.62	1.25	13.00	1.00	20
34.44	12.44	47.94	10.44		20.75	17.50	1.88	1.25	15.25	1.12	24

(Notes follow on next page)

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TABLE 13 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) For tolerances, see Section 7.
(2) For facings, see para. 6.4.
(3) For flange bolt holes, see para. 6.5 and Table 11.
(4) For spot facing, see para. 6.6.
(5) For intersecting center lines, center-to-contact surface, and center-to-end dimensions of side outlet fittings, see para. 6.2.4.
(6) For center-to-contact surface and center-to-end dimensions of special degree elbows, see para. 6.2.5.
(7) For reinforcement of certain fittings, see para. 6.1.
(8) For drains, see para. 6.12.
(9) When these fittings are required with flat face flange, either the full thickness or thickness with raised face removed may be furnished. Users are reminded that removing the raised face will make the center-to-face dimension nonstandard. See para. 6.4.1.1 for additional restrictions.
(10) The thickness of flange dimension illustrated is for regularly furnished 0.06 in. raised face (except lapped); for thickness requirement of other facings, see Fig. 7.
(11) For center-to-contact surface and center-to-end dimensions of reducing fittings, see para. 6.2.3.
(12) For contact surface-to-contact surface and end-to-end dimensions of reducers and eccentric reducers, see para. 6.2.3.
(13) These dimensions apply to straight sizes only. See paras. 6.2.3 and 6.4.1.3. For center-to-end dimensions of reducing fittings or end-to-end dimensions of reducers, use center-to-contact surface or contact surface-to-contact surface dimensions of 0.06 in. raised face (flange edge) for largest opening and add the proper height to provide for ring joint groove applying to each flange. See Table 5 for ring joint facing dimensions.
(14) The base dimensions apply to all straight and reducing sizes.
(15) For reducing fittings, the size and center-to-face dimension of base are determined by the size of the largest opening of fittings. In the case of reducing base elbows, orders shall specify whether the base shall be opposite the larger or smaller opening.
(16) Bases shall be plain faced unless otherwise specified, and the center-to-base dimension R shall be the finished dimension.
(17) Bases may be cast integral or attached as weldments at the option of the manufacturer.
(a) (18) The bolt hole template for round base is the same as for Class 300 flanges, Table 11, of corresponding outside diameter, except using only four holes in all cases so placed as to straddle center lines. The bases of these fittings are intended for support in compression and are not to be used for anchors or supports in tension or shear.

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B 333-95	Nickel-Molybdenum Alloy Plate, Sheet and Strip
B 335-95	Nickel-Molybdenum Alloy Rod
B 408-95	Nickel-Iron-Chromium Alloy Plate, Sheet and Strip
B 409-95	Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip
B 424-93	Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and N08821) Plate, Sheet and Strip
B 425-93	Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and UNS N08221) Rod and Bar
B 434-95	Nickel-Molybdenum-Chromium-Iron Alloy (UNS N10003) Plate, Sheet and Strip
B 435-94	UNS N06002, UNS N06230, and UNS R30556 Plate, Sheet, and Strip
B 443-93	Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Plate, Sheet, and Strip
B 446-93	Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Rod and Bar
B 462-95	Forged or Rolled UNS N08020, UNS N00824, UNS N08026, and UNS N08367 Alloy Pipe Flanges, Forged Fittings, and Valves and Parts for Corrosive High-Temperature Service
B 463-93	UNS N08020, UNS N08024 and UNS N08026 Alloy Plate Sheet and Strip
B 473-95	UNS N08020, UNS N08026, and UNS N08024 Nickel Alloy Bar and Wire
B 511-93	Nickel-Iron-Chromium-Silicon Alloy Bars and Shapes
B 536-95	Nickel-Iron Chromium-Silicon Alloys (UNS N08830 and N08332) Plate, Sheet, and Strip
B 564-95a$^{\epsilon 1}$	Nickel Alloy Forgings
B 572-94	UNS N06002, UNS N06230, and UNS R30556 Rod
B 573-95	Nickel-Molybdenum-Chromium-Iron Alloy (UNS N10003) Rod
B 574-94$^{\epsilon 1}$	Low-Carbon Nickel-Molybdenum-Chromium and Low-Carbon Nickel-Chromium-Molybdenum Alloy Rod
B 575-94	Low-Carbon Nickel-Molybdenum-Chromium and Low-Carbon Nickel-Chromium-Molybdenum Alloy Plate, Sheet, and Strip
B 581-94$^{\epsilon 1}$	Nickel-Chromium-Iron-Molybdenum-Copper Alloy Rod
B 582-93	Nickel-Chromium-Iron-Molybdenum-Copper Alloy Plate, Sheet and Strip
B 599-93b	Nickel-Iron-Chromium-Molybdenum-Columbium Stabilized Alloy (UNS N08700) Plate, Sheet and Strip
B 620-93	Nickel-Iron-Chromium-Molybdenum Alloy (UNS N08320) Plate, Sheet, and Strip
B 621-95	Nickel-Iron-Chromium-Molybdenum Alloy (UNS N08320) Rod
B 625-93a	UNS N08904, UNS N08925, UNS N08031, UNS N08932, and UNS N08925 Plate, Sheet and Strip

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B 649-93	Ni-Fe-Cr-Mo-Cu Low Carbon Alloy (UNS N08904) and Ni-Fe-Cr-Mo-Cu-N Low Carbon Alloys (UNS N08925, UNS N08031, and UNS N08926) Bar and Wire
B 672-95	Nickel-Iron-Chromium-Molybdenum-Columbium Stabilized Alloy (UNS N08700) Bar and Wire
E 29-93	Using Significant Digits in Test Data to Determine Conformance with Specifications

International Standards Organization (ISO)

ISO 9000-1: 1994	Quality management and quality assurance standards — Part 1: Guidelines for selection and use
ISO 9000-2: 1993	Quality management and quality assurance standard — Part 2: Generic guidelines for the application of ISO 9001, ISO 9002, and ISO 9003
ISO 9000-3: 1991	Quality management and quality assurance standards — Part 3: Guidelines for the application of ISO 9001 to the development, supply and maintenance of software
ISO 9001: 1994	Quality systems — Model for quality assurance in design, development, production, installation, and servicing
ISO 9002: 1994	Quality systems — Model for quality assurance in production and servicing
ISO 9003: 1994	Quality systems — Model for quality assurance in final inspection and test

MSS Publications

MSS SP-9-1992	Spot Facing for Bronze, Iron, and Steel Flanges
MSS SP-25-1978(R1985)	Standard Marking System for Valves, Fittings, Flanges, and Unions
MSS SP-44-1991	Steel Pipe Line Flanges
MSS SP-45-1992	Bypass and Drain Connections
MSS SP-61-1992	Pressure Testing of Steel Valves

Publications of the following organizations appear in the above list:

(a)

ASME	The American Society of Mechanical Engineers Three Park Avenue, New York, New York 10016-5990 ASME Order Department 22 Law Drive, Box 2300, Fairfield, New Jersey 07007-2300

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STD.ASME B16.5-ENGL 1996 ■ 0759670 0579386 568 ■

ASME B16.5-1996
(Revision of ASME/ANSI B16.5-1988)

PIPE FLANGES AND FLANGED FITTINGS

NPS 1/2 Through NPS 24

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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FOREWORD

(This Foreword is not part of ASME B16.5-1996)

In 1920, the American Engineering Standards Committee [later the American Standards Association (ASA)] organized Sectional Committee B16 to unify and further develop standards for pipe flanges and fittings (and later for valves and gaskets). Cosponsors of the B16 Committee were the American Society of Mechanical Engineers (ASME), the Heating and Piping Contractors National Association [now Mechanical Contractors Association of America (MCAA)], and the Manufacturers Standardization Society of the Valve and Fittings Industry (MSS). Cosponsors were later designated as cosecretariat organizations.

The Committee soon recognized the need for standardization of steel pipe flanges. In May 1923, Subcommittee 3 was organized to develop such standards for pressures in the 250 psi to 3200 psi range and for elevated temperatures. Active work began in October, including steel flanged fittings. The first proposed standard was submitted to the Committee in April 1926 and approved by letter ballot in December. After favorable review by the three sponsor organizations, the Standard was approved as American Tentative Standard B16e in June 1927.

Experience in using the Standard showed the need for hub dimensions of companion flanges and for other changes, including rerating of 250 lb and 1350 lb flanges and development of flanged fittings with integral bases. An investigation was made into the factors determining stiffness of flanges and flange hubs. The revised edition was approved as ASA B16e-1932.

A revision was initiated in 1936, stimulated by suggestions from Committee members and industrial users. The resulting 1939 edition contained standards for welding neck flanges (completed in March 1937), 1500 lb flanges in the 14 in. through 24 in. range, 2500 lb flanges and flanged fittings in the ½ in. through 12 in. range, and dimensions for a full line of ring joint flanges developed by the American Petroleum Institute. Pressure-temperature ratings for alloy steel flanges and fittings, developed by Subcommittee 4, were included for the first time.

In August 1942, the War Production Board requested a review of measures to conserve vital materials in piping components. A special War Committee of B16 was appointed and, operating under War Standards Procedure, developed revised pressure-temperature ratings for all materials and all pressure classes. The ratings were published as American War Standard B16e5-1943. In 1945, under normal procedures, Subcommittees 3 and 4 reviewed the 1939 Standard and the 1943 ratings, and recommended adoption of the wartime ratings. Their report was approved as Supplement No. 1 to B16e-1939 and published as ASA B16e6-1949. In addition to ratings, the supplement updated material specification references and added a table of metal wall thicknesses for welding-end valves.

Subcommittee 3 then began a revision of the entire standard. Technically, the 1949 Supplement was absorbed, new materials were recognized, a general rating method was developed and added as an appendix, and welding end preparations were expanded. Editorially, a new style of presentation was worked out, including tables rearranged for easier use. Approval by Sectional Committee, cosponsors, and ASA resulted in publication of ASA B16.5-1953 (designation changed from B16e).

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Work soon began on further revisions. Class B ratings were deleted and Class A ratings were clarified as the standard. An appendix defined qualifications for gaskets, other than ring joint, which would merit the ratings. Another appendix defined the method for calculating bolt lengths (including measurement of the length of stud bolts between thread ends instead of between points). Pressure-temperature ratings for several new materials were added, the table of welding end dimensions was expanded, and the temperature used in determining ratings were redefined. The resulting new edition, after approval, was published as ASA B16.5-1957.

The more modest revision approved as ASA B16.5-1961 changed the text to clarify the intent or to make requirements easier to administer. The next revision began in 1963 with nearly 100 comments and suggestions. No fundamental changes were made, but the text was further clarified and wall thicknesses less than $\frac{1}{4}$ in. for flanged fittings were recognized in the 1968 edition.

A new joint study of ratings between Subcommittees 3 and 4 was initiated before the next revision. Based on Subcommittee 4's report, the rating procedure was revised and a rating basis for Class 150 (150 lb) flanges was developed. New product forms, bar and plate, were added for special applications, including fabricated flanged valves and fittings. Reference to welding-end valves was deleted because a separate standard for them was in preparation. Bolt length calculations based on worst case tolerances led to a revision of tabulated lengths. Testing of valve closure members was added to the test requirements. Following final approval on October 23, the Standard was published as ANSI B16.5-1973.

Subcommittee N was assigned responsibility for all valve standards in late 1973. Subcommittee C (formerly 3) continues to have responsibility for flange standards. A revision was accordingly initiated to remove all references to valves. At the same time, comments from users and changes in the ASME Boiler and Pressure Vessel Code led to significant revisions in the Class 150 rating basis, and in the ratings of stainless steel and certain alloy steel flanges and flanged fittings in all rating classes. Extensive public review comments led to addition of considerations for flanged joints, for bolting and gaskets, and of marking requirements. To avoid frequent and confusing changes in ratings as further changes in Code allowable stresses are made, it was agreed with Subcommittee N to leave ratings alone unless the relevant Code stress values are changed by more than 10%. After final approval by Standards Committee, cosponsors, and ANSI, ANSI B16.5-1977 Steel Pipe Flanges and Flanged Fittings, was published on June 16, 1977.

In 1979, work began on another new edition. Materials coverage was expanded by the addition of nickel and nickel alloys. Bolting rules were revised to cover nickel alloy bolts. Bolt hole and bolting were changed to provide interchangeability between inch and metric dimensions. Metric dimensional tables were made informational rather than alternative requirements of the Standard. Final approval was granted for ANSI B16.5-1981, Pipe Flanges and Flanged Fittings on August 14.

In 1982, American National Standards Committee B16 was reorganized as an ASME Committee operating under procedures accredited by ANSI. The 1988 edition of the Standard extended nickel alloy ratings to higher temperatures, clarified flat face flange requirements, and included other minor revisions. The Committee determined that any metric standard for flanges will stand alone, with metric bolting and gaskets; hence metric equivalents have been deleted. Following approval by the Standards Committee and ASME, approval as American National Standard was given by ANSI on April 7, 1988, with the new designation ASME/ANSI B16.5-1988.

This 1996 Edition allows flanges marked with more than one material grade or specification, revises flange facing finish requirements, has revised pressure–temperature ratings for several material groups, adds a nonmandatory quality system annex, and includes several other

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revisions. Following approval by the Standards Committee and ASME, approval as an American National Standard was given by ANSI on October 3, 1996 with the new designation ASME B16.5-1996.

Requests for interpretations or suggestions for revision should be sent to the Secretary, B16 Committee, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017.

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(The following is a roster of the Committee at the time of approval of this Standard.)

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PIPE FLANGES AND FLANGED FITTINGS

1 SCOPE

1.1 General

This Standard covers pressure–temperature ratings, materials, dimensions, tolerances, marking, testing, and methods of designating openings for pipe flanges and flanged fittings in sizes NPS ½ through NPS 24 and in rating Classes 150, 300, 400, 600, 900, 1500, and 2500. Flanges and flanged fittings may be cast, forged, or (for blind flanges and certain reducing flanges only) plate materials as listed in Table 1A.

Requirements and recommendations regarding bolting and gaskets are also included.

1.2 References

1.2.1 Referenced Standards. Standards and specifications adopted by reference in this Standard are shown in Annex G, which is part of this Standard. It is not considered practical to identify the specific edition of each standard and specification in the individual references. Instead, the specific edition reference is identified in Annex G. A flange or flanged fitting manufactured in accordance with earlier editions of the referenced standards and in all other respects conforming to this Standard will be considered to be in conformance with this Standard.

1.2.2 Codes and Regulations. A flange or flanged fitting used under the jurisdiction of the ASME Boiler and Pressure Vessel Code, the ASME Code for Pressure Piping, or a governmental regulation is subject to any limitation of that code or regulation. This includes any maximum temperature limitation, or rule governing the use of a material at low temperature, or provisions for operation at a pressure exceeding the pressure–temperature ratings in this Standard.

1.3 Applicable Ratings

The pressure–temperature ratings in this Standard are applicable upon its publication to all flanges and flanged fittings within its scope which otherwise meet its requirements. For unused flanges or flanged fittings maintained in inventory, the manufacturer of the flange or flanged fittings may certify conformance to this Edition provided he can demonstrate that all requirements of this Edition have been met. Where such components were installed in accordance with the pressure–temperature ratings of an earlier edition of this Standard, those ratings are applicable except as may be governed by the applicable code or regulation (see para. 1.2.2).

1.4 User Accountability

This Standard cites duties and responsibilities that are to be assumed by the user in the areas of application, installation, hydrostatic testing, operation, and material selection.

1.5 Quality Systems

Nonmandatory requirements relating to the product manufacturer's Quality System Program are described in Annex G.

2 PRESSURE–TEMPERATURE RATINGS

2.1 Ratings Basis

Ratings are maximum allowable working gage pressures at the temperatures shown in Table 2 for the applicable material and rating. For intermediate temperatures, linear interpolation is permitted. See Annex D, which is part of this Standard, for methods of establishing pressure–temperature ratings.

2.2 Ratings of Flanged Joints

A flanged joint is composed of three separate and independent, although interrelated components: the flanges, the gasket, and the bolting, which are assembled by yet another influence, the assembler. Proper controls must be exercised in the selection and application for all these elements to attain a joint which has acceptable leak tightness. Special techniques, such as controlled bolt tightening, may be necessary to achieve a tight joint in service.

Ratings in this Standard apply to flanged joints which conform to the limitations on bolting in para. 5.3 and on gaskets in para. 5.4, and which are made up in accordance with good practice for alignment and assembly. See also para. 2.4. Use of the ratings for flanged joints not conforming to these limitations is the responsi-

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bility of the user. Requirements for alignment and assembly of joints are not given in this Standard.

If the two flanges in a flanged joint do not have the same pressure–temperature ratings, the rating of the joint at any temperature is the lower of the two flange ratings at that temperature.

2.3 Rating Temperature

The temperature shown for a corresponding pressure rating is the temperature of the pressure-containing shell of the flange or flanged fitting. In general, this temperature is the same as that of the contained fluid. Use of a pressure rating corresponding to a temperature other than that of the contained fluid is the responsibility of the user, subject to the requirements of the applicable code or regulation. For any temperature below −20°F, the rating shall be no greater than the rating shown for −20°F.

2.4 Temperature Considerations

Application of the ratings in this Standard to flanged joints at both high and low temperatures shall take into consideration the risk of leakage due to forces and moments developed in the connected piping or equipment. The following provisions are intended to minimize these risks.

2.4.1 Flange Attachment. Socket welding and threaded flanges are not recommended for service above 500°F or below −50°F if severe thermal gradients or thermal cycling are involved.

2.4.2 High Temperature Service. At temperatures in the creep range, gradual relaxation of flanges, bolts, and gaskets may progressively reduce bolt loads. It may be necessary to arrange for periodic tightening of bolts to prevent leakage. Joints subject to substantial thermal gradients may require the same attention.

When used above 400°F, Class 150 flanged joints may develop leakage unless care is taken to avoid imposing severe external loads and/or severe thermal gradients. For other classes, similar consideration should be given above 750°F.

2.4.3 Low Temperature Service. The user should recognize that some of the material listed in the rating tables undergo sufficient decrease in toughness at low temperatures that they cannot safely sustain shock loadings, sudden changes of stress or temperature, or high stress concentrations.

2.5 System Hydrostatic Test

Flanged joints and flanged fittings may be subjected to system hydrostatic tests at a pressure not to exceed 1.5 times the 100°F rating rounded off to the next higher 25 psi. Testing at any higher pressure is the responsibility of the user, subject to the requirements of the applicable code or regulation.

2.6 Welding Neck Flanges

Ratings for welding neck flanges covered by this Standard are based upon their hubs at the welding end having thickness at least equal to that calculated for pipe having 40.0 ksi specified minimum yield strength. (For higher strength pipe with thinner wall, see MSS SP-44.) The ratings also apply to such flanges used with components of unequal strength and unequal wall thickness when the attachment weld is made in accordance with the applicable code or regulation. See Figs. 12, 13, and 14.

2.7 Multiple Material Grades

Materials for flanges and flanged fittings may meet the requirements for more than one specification or grade of a specification listed in Table 1A. In that event, the pressure–temperature ratings for any of these specifications or grades may be used provided that marking is in accordance with para. 4.1.2(d).

3 SIZE

3.1 Nominal Size

The size of a flange or flanged fitting covered by this Standard is its nominal pipe size, NPS. The diameter of a bolt is its nominal size. Use of "nominal" indicates that the stated size or dimension is only for designation, not measurement. The actual dimension may or may not be the nominal size and is subject to established tolerances.

3.2 Reducing Fittings

Reducing fittings shall be designated by the size of the openings in their proper sequence as indicated in the sketches of Fig. 2.

3.3 Reducing Flanges

Reducing flanges shall be designated by the two nominal pipe sizes. See examples in Note (4) of Table 7.

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4 MARKING

4.1 General

Except as modified herein, flanges and flanged fittings shall be marked as required in MSS SP-25.

4.1.1 Name. The manufacturer's name or trademark shall be applied.

4.1.2 Material

(a) Cast flanges and flanged fittings shall be marked with the ASTM specification,[1] grade identification symbol, and the melt number or melt identification.

(b) Plate flanges, forged flanges, and flanged fittings shall be marked with the ASTM specification number[1] and grade identification symbol.

(c) A manufacturer may supplement these mandatory material indications with his trade designation for the material grade, but confusion of symbols shall be avoided.

(d) Flanges and flanged fittings manufactured from material which meets the requirements for more than one specification or grade of a specification listed in Table 1A may be marked with more than one of the applicable specification or grade symbols. The symbols shall be placed to avoid confusion in identification.

4.1.3 Rating Class. The marking shall be the applicable pressure rating class: 150, 300, 400, 600, 900, 1500, or 2500.

4.1.4 Designation. The designation B16 shall be applied, preferably located adjacent to the class designation, to indicate conformance to this Standard.

4.1.5 Temperature. No temperature markings are required on flanges and flanged fittings, but if marked, the temperature shall be shown with its corresponding tabulated pressure rating for the material.

4.1.6 Size. The nominal pipe size shall be given, but may be omitted from reducing flanges and reducing flanged fittings.

4.1.7 Ring Joint Flange. The edge (periphery) of each ring joint flange shall be marked with the letter R and the corresponding ring groove number.

[1] The ASME Boiler and Pressure Vessel Code, Section II specification number may be substituted provided the material is covered by Section II.

5 MATERIALS

5.1 General

Flanges and flanged fittings covered by this Standard shall be castings, forgings, and (for blind flanges only) plate as listed in Table 1A. Recommended bolting materials are listed in Table 1B. (See also para. 5.3.) ASME Boiler and Pressure Vessel Code, Section II materials, which also meet the requirements of the specifications listed in Tables 1A, 1B, and 1C, may also be used.

5.1.1 Application. Criteria for the selection of materials are not within the scope of this Standard. The possibility of material deterioration in service should be considered by the user. Carbide phase conversion to graphite and excessive oxidation of ferritic materials, susceptibility to intergranular corrosion of austenitic materials, or grain boundary attack of nickel base alloys are among those items requiring attention. A detailed discussion of precautionary considerations can be found in Appendix F of ASME/ANSI B31.3.

5.1.2 Toughness. Some of the materials listed in Table 1A undergo a decrease in toughness when used at low temperatures, to the extent that Codes referencing this Standard may require impact tests for application even at temperatures higher than +20°F. It is the responsibility of the user to assure that such testing is performed.

5.1.3 Responsibility. When service conditions dictate the implementation of special material requirements, e.g., using a Group 2 material above 1000°F, it is the users responsibility to so specify to the manufacturer in order to ensure compliance with metallurgical requirements listed in the notes in Table 2.

5.2 Mechanical Properties

Mechanical properties shall be obtained from test specimens that represent the final heat treated condition of the material required by the material specification.

5.3 Bolting

Bolting listed in Table 1B is recommended for use in flanged joints covered by this Standard. Bolting of other material may be used if permitted by the applicable code or government regulation. All bolting materials are subject to the following limitations.

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5.3.1 High Strength Bolting. Bolting materials having allowable stresses not less than those for ASTM A 193 Grade B7 are listed as high strength in Table 1B. These and other materials of comparable strength may be used in any flanged joint.

5.3.2 Intermediate Strength Bolting. Bolting materials listed as intermediate strength in Table 1B, and other bolting of comparable strength, may be used in any flanged joint, provided the user verifies their ability to seat the selected gasket and maintain a sealed joint under expected operating conditions.

5.3.3 Low Strength Bolting. Bolting materials having not more than 30 ksi specified minimum yield strength are listed as low strength in Table 1B. These materials and others of comparable strength shall be used only in Classes 150 and 300 joints, and only with gaskets described in para. 5.4.1. Flanged joints using low strength carbon steel bolts shall not be used above 400°F or below −20°F.

5.3.4 Bolting to Gray Cast Iron Flanges. The following recommendations are made in recognition of the low ductility of gray cast iron.

(a) Alignment of flange faces is essential along with control of assembly bolt torque so as not to over-stress the cast iron flanges. Care must also be exercised to ensure that piping loads transmitted to cast iron flanges are controlled, taking into account its lack of ductility and recognizing that cast iron flanges should not be used where suddenly applied loads such as rapid pressure fluctuation may occur.

(b) Where Class 150 steel flanges are bolted to Class 125 cast iron flanges, the gaskets should be made of Group No. Ia materials, the steel flanges should have flat faces, and:

(1) low strength bolting within the limitations of para. 5.3.3 should be used with ring gaskets extending to the bolt holes; or

(2) bolting of low (para. 5.3.3), intermediate (para. 5.3.2), or high (para. 5.3.1) strength may be used with full face gaskets extending to the outside diameters of the flanges.

(c) Where Class 300 steel flanges are bolted to Class 250 cast iron flanges, the gaskets should be made of Group No. Ia materials, and:

(1) low strength bolting within the limitations of para. 5.3.3 should be used with gaskets extending to the bolt holes and with the flanges having either raised or flat faces; or

(2) bolting of low (para. 5.3.3), intermediate (para. 5.3.2), or high (para. 5.3.1) strength may be used with full face gaskets extending to the outside diameters of the flanges and with both the Class 300 steel and Class 250 cast iron flanges having flat faces.

5.4 Gaskets

Ring joint gasket materials shall conform to ASME B16.20. Materials for other gaskets are described in Annex E, which is part of this Standard. The user is responsible for selection of gasket materials which will withstand the expected bolt loading without injurious crushing, and which are suitable for the service conditions. Particular attention should be given to gasket selection if a system hydrostatic test approaches or exceeds the test pressure specified in para. 2.5.

5.4.1 Gaskets for Low Strength Bolting. If bolting listed as low strength in Table 1B is used, gaskets shown in Fig. E1, Group No. Ia, shall be used.

5.4.2 Gaskets for Class 150 Flanged Joints. It is recommended that only Fig. E1, Group No. I, gaskets be used for Class 150 flanged joints. When the ring joint or spiral wound gasket is selected, it is recommended that line flanges be of the welding neck or lapped joint type.

6 DIMENSIONS

6.1 Wall Thickness

For inspection purposes the minimum wall thickness t_m of flanged fittings at the time of manufacture shall be as shown in Tables 10, 13, 16, 19, 22, 25, and 28, except as provided in para. 6.1.1. See Annex D for the basis used to establish values of t_m.

Additional metal thickness needed to withstand assembly stresses, shapes other than circular, and stress concentrations must be determined by the manufacturer, since these factors vary widely. In particular, 45 deg. laterals, true Y's, and crosses may require additional reinforcement to compensate for inherent weaknesses in these shapes.

6.1.1 Local Areas. Local areas having less than minimum wall thickness will be acceptable provided that:

(a) the area of subminimum thickness can be enclosed by a circle whose diameter is no greater than $0.35\sqrt{dt_m}$ where d is the inside diameter as defined above and t_m is the minimum wall thickness as shown in the tables listed in para. 6.1; and

(b) measured thickness is not less than $0.75\ t_m$; and,

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(c) enclosure circles are separated from each other by an edge-to-edge distance of more than $1.75\sqrt{dt_m}$.

6.2 Center-to-Center Surface and Center-to-End

6.2.1 Design. A principle of design in this Standard is to maintain a fixed position for the flange edge with reference to the body of the fitting. The addition of any facing is beyond the outside edge of the flange except for the 0.06 in. raised face in the Classes 150 and 300 Standards. (See para. 6.4.)

6.2.2 Standard Fittings. Center-to-contact surface, center-to-flange edge, and center-to-end (ring joint) dimensions are shown in Tables 10, 13, 16, 19, 22, 25, and 28.

6.2.3 Reducing Fittings. Center-to-contact surface or center-to-flange edge dimensions for all openings shall be the same as those of straight size fittings of the largest opening. The contact surface-to-contact surface or flange edge-to-flange edge dimensions for all combinations of reducers and eccentric reducers shall be as listed for the larger opening.

6.2.4 Side Outlet Fittings. Side outlet elbows, side outlet tees, and side outlet crosses shall have all openings on intersecting center lines, and the center-to-contact surface dimensions of the side outlet shall be the same as for the largest opening. Long radius elbows with side outlet shall have the side outlet on the radial center line of the elbow, and the center-to-contact surface dimension of the side outlet shall be the same as for the regular 90 deg. elbow of the largest opening.

6.2.5 Special Degree Elbows. Special degree elbows ranging from 1 deg. to 45 deg., inclusive, shall have the same center-to-contact surface dimensions as 45 deg. elbows and those over 45 deg. and up to 90 deg., inclusive, shall have the same center-to-contact surface dimensions as 90 deg. elbows. The angle designation of an elbow is its deflection from straight line flow and is also the angle between the flange faces.

6.3 Flat Face Flanges

This Standard permits flat face flanges in all classes, by providing flanges having either the full thickness or the thickness with the raised face removed, without reduction of the pressure–temperature ratings subject to the following provisions.

6.3.1 The thickness of a Class 150 or 300 flange from which the raised face has been removed shall be no less than the applicable dimension *C* of Tables 9, 10, 12, and 13 minus 0.06 in.

6.3.2 The thickness of a flange of Class 400 or higher from which the raised face has been removed shall be no less than the applicable dimension *C* of Tables 15, 16, 18, 19, 21, 22, 24, 25, 27, and 28.

6.3.3 A gasket of Group No. Ia material (see Fig. E1) is recommended for all joints having two flat faced flanges using a gasket which has a larger diameter than the raised face shown in Table 4.

6.3.4 The flange facing shall conform with para. 6.4.4 for the full width of seating of the gasket.

6.4 Facings

6.4.1 For Other Than Lapped Joints. Table 4 gives dimensions for facings other than ring joint. Table 5 gives dimensions for ring joint facings. Figure 7 shows application of facings. Classes 150 and 300 fittings and companion flanges are regularly furnished with a 0.06 in. raised face which is included in the minimum flange thickness *C*. Classes 400, 600, 900, 1500, and 2500 fittings and companion flanges are regularly furnished with 0.25 in. raised face which is additional to the minimum flange thickness *C*. Any other facing than the above, when required for any class, shall be furnished as follows.

6.4.1.1 No metal shall be cut from the minimum flange thickness specified herein except as permitted in para. 6.3.

6.4.1.2 In the case of the 0.25 in. raised face, tongue or male face (other than 0.06 in. raised face for Classes 150 and 300), the minimum flange thickness *C* shall be first provided and then the raised face, tongue or male face shall be added thereto.

6.4.1.3 With ring joint, groove, or female face, the minimum flange thickness shall be first provided and then sufficient metal added thereto so that the bottom of the ring joint groove, or the contact face of the groove or female face is in the same plane as the flange edge of a full thickness flange.

6.4.2 For Lapped Joints. Facings shall be furnished as follows.

6.4.2.1 Raised Face. Finished height of face shall be no less than nominal pipe wall thickness.

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6.4.2.2 Large Male and Female. Finished height of a male face shall be no less than wall thickness of pipe used or 0.25 in., whichever is greater. Thickness of lap remaining after matching the female face shall be no less than the nominal wall thickness of pipe used.

6.4.2.3 Tongue and Groove. Thickness of lap remaining after matching tongue or groove face shall be no less than the nominal wall thickness of the pipe used.

6.4.2.4 Ring Joint. Thickness of lap remaining after machining the ring groove shall be no less than the nominal wall thickness of pipe used.

6.4.2.5 The outside diameters of laps for ring joints are shown in Table 5, dimension *K*. The outside diameters of laps for large female, large tongue and groove, and small tongue and groove are shown in Table 4. Small male and female facings are not used with lapped joints.

6.4.3 Blind flanges need not be faced in the center if, when this center part is raised, its diameter is at least 1 in. smaller than the inside diameter of fittings of the corresponding pressure class, as given in the tables. When the center part is depressed, its diameter shall not be greater than the inside diameter of the corresponding pressure class fittings, as given in the tables. Machining of the depressed center is not required.

6.4.4 Flange Facing Finish. The finish of contact faces of pipe flanges and connecting end flanges of fittings shall be judged by visual comparison with Ra standards (see ASME B46.1) and not by instruments having stylus tracers and electronic amplification. The finishes required are given below. Other finishes may be furnished by agreement between user and manufacturer.

6.4.4.1 Tongue and Groove and Small Male and Female. The gasket contact surface shall not exceed 125 μin. roughness.

6.4.4.2 Ring Joint. The side wall surface of gasket groove shall not exceed 63 μin. roughness.

6.4.4.3 Other Flange Facings. Either a serrated concentric or serrated spiral finish having a resultant surface finish from 125 μin. to 250 μin. average roughness shall be furnished. The cutting tool employed should have an approximate 0.06 in. or larger radius, and there should be from 45 grooves/in. through 55 grooves/in.

6.4.5 Flange Facing Finish Imperfections. Imperfections in the flange facing finish shall not exceed the dimensions shown in Table 3. Adjacent imperfections shall be separated by a distance of at least four times the maximum radial projection. A radial projection shall be measured by the difference between an outer radius and an inner radius encompassing the imperfection where the radii are struck from the centerline of the bore. Imperfections less than half the depth of the serrations shall not be considered cause for rejection. Protrusions above the serrations are not permitted.

6.5 Flange Bolt Holes

Bolt holes are in multiples of four. Bolt holes shall be equally spaced and pairs of bolt holes shall straddle fitting center lines.

6.6 Spot Facing

All cast and forged flanges and flanged fittings shall have bearing surfaces for bolting which shall be parallel to the flange face from within 1 deg. Any back facing or spot facing required to accomplish parallelism shall not reduce the flange thickness *C* below the dimensions given in Tables 9, 10, 12, 13, 15, 16, 18, 19, 21, 22, 24, 25, 27, and 28. Any spot facing or back facing shall be in accordance with MSS SP-9.

6.7 Welding End Preparation for Welding Neck Flanges

6.7.1 Welding ends are shown in Figs. 8 through 14.

6.7.2 The contours of the outside of the welding neck beyond the welding groove are shown in Figs. 8, 9, 12, and 14.

6.7.3 Straight through bores shown in Figs. 8 and 9 are standard unless otherwise specifically order to suit the special conditions illustrated in Figs. 10, 11, 13, and 14.

6.7.4 Other welding end preparations furnished by agreement of purchaser and manufacturer do not invalidate compliance with this Standard.

6.8 Reducing Flanges

6.8.1 Drilling, Outside Diameter, Thickness, and Facing Dimensions. Flange drilling, outside diameter, thickness, and facing are the same as those of the standard flange of the size from which the reduction is being made.

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6.8.2 Hub Dimensions

6.8.2.1 Threaded, Socketweld, and Slip-On Flanges. The hub dimensions shall be at least as large as those of the standard flange of the size to which the reduction is being made. The hub may be larger or omitted as detailed in Table 7.

6.8.2.2 Welding Neck Flanges. The hub dimensions shall be the same as those of the standard flange of the size to which the reduction is being made.

6.9 Threads for Threaded Flanges

Except as provided in Note (5), Fig. 7, and Note (5), Table 4, threaded flanges shall have an American National Standard taper pipe thread conforming to ASME B1.20.1. The thread shall be concentric with the axis of the flange, and variations in alignment shall not exceed 0.06 in./ft (0.5%).

6.9.1 Class 150 flanges are made without a counterbore. The threads shall be chamfered approximately to the major diameter of the thread at the back of the flange at an angle of approximately 45 deg. with the axis of the thread. The chamfer shall be concentric with the thread and shall be included in the measurement of the thread length.

6.9.2 Class 300 and higher pressure flanges are made with a counterbore at the back of the flange. The threads shall be chamfered to the diameter of the counterbore at an angle of approximately 45 deg. with the axis of the threads. The counterbore and chamfer shall be concentric with the thread.

6.9.3 The minimum length of effective thread in reducing flanges shall be at least equal to dimension *T* of the corresponding class of threaded flange as shown in the tables. Threads do not necessarily extend to the face of the flange. See Table 7 for reducing threaded flanges.

6.9.4 The gaging notch of the working gage shall come flush with the bottom of the chamfer in all threaded flanges and shall be considered as being the intersection of the chamfer cone and the pitch cone of the thread. This depth of chamfer is approximately equal to one-half the pitch of the thread. The maximum allowable thread variation is one turn large or small from the gaging notch.

6.9.5 Annex A indicates the distance and number of turns that external pipe threads may be made longer than regular for use with the higher pressure flanges to bring the small end of the thread close to the face of the flange when the parts are assembled by power equipment. Annex A applies to ASME B1.20.1 and is considered part of this Standard.

6.10 Flange Bolting Dimensions

6.10.1 Dimensional Standards. Stud bolts threaded at both ends or full length, or bolts may be used. Dimensional recommendations for bolts, stud bolts, and nuts are shown in Table 1C. See para. 5.3 for bolting material recommendations.

6.10.2 Bolt Lengths. Stud bolts with a nut at each end are recommended for high temperature service. Stud bolt lengths are specified in Tables 8, 11, 14, 17, 20, 23, and 26, and include the thickness of two nuts. The stud bolt length does not include the height of any point. A point is that part of a stud bolt or a bolt beyond the thread and may be chamfered, rounded, or sheared. For the method of calculating bolt lengths, see Annex F.

These lengths are established for the convenience of industry to simplify the assembly of these parts on construction work, but users may select combinations of these bolt lengths to suit their needs. Hence, Annex F is not considered part of this Standard.

6.10.3 The end flange bolting is based on a stress on the effective tensile stress area of the bolts not to exceed 7.0 ksi, assuming a pressure in psi equal to the pressure rating class designation to act upon an area circumscribed by the outside diameter of the raised face, dimension *R*, Table 4.

6.11 Gaskets for Line Flanges

6.11.1 Ring joint gasket dimensions shall conform to ASME B16.20.

6.11.2 For flanges with raised face, or with large male-and-female face, gaskets shall conform to limiting dimensions of Annex E.

6.11.3 For flanges having large or small tongue-and-groove faces, all gaskets except solid flat metal gaskets shall cover the bottom of the groove, with minimum clearance. (See para. 7.2.1 for tolerance applicable to groove.) Solid flat metal gaskets shall have contact width not greater than for Group No. III gaskets.

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6.11.4 For flanges with small male-and-female face, care must be taken to insure that adequate bearing surface is provided for the gaskets. This applies particularly where the joint is made on the end of pipe. See Fig. 7.

6.12 Auxiliary Connections

No auxiliary connections, or openings therefore, will be provided except as specified by the purchaser. If assembly is required, the purchaser shall also specify the applicable code or regulation. Welded auxiliary connections shall be made by a qualified welder using a qualified weld procedure.

6.12.1 Pipe Thread Tapping. Holes may be tapped in the wall of a fitting if the metal is thick enough to allow the effective thread length specified in Fig. 3. Where thread length is insufficient or the tapped hole needs reinforcement, a boss shall be added.

6.12.2 Welded Connections

6.12.2.1 Sockets. Sockets (socket welding) may be provided in the wall of a fitting if the metal is thick enough to afford the depth of socket and retaining wall specified in Fig. 4. Where the wall thickness is insufficient, or the size of the connection requires opening reinforcement, a boss shall be added.

6.12.2.2 Butt Weld. Connections may be attached by butt welding directly to the wall of the fitting (see Fig. 5). Where the size of an opening requires reinforcement, a boss shall be added.

6.12.3 Bosses. Where bosses are required, the diameters shall be not less than those shown in Fig. 6, and the height shall provide lengths as specified in Fig. 3 or 4.

6.12.4 Size. Unless otherwise specified, auxiliary connections shall be of the pipe sizes given below.

Fitting Size, NPS	Connection, NPS
2–4	½
5–8	¾
10 and up	1

6.12.5 Designating Locations. This means of designating the locations for auxiliary connections in fittings are shown in Fig. 1.

Each possible location is designated by a letter so that the desired locations for the various types of fittings may be specified without using further sketches or description.

7 TOLERANCES[2]

7.1 General

For the purpose of determining conformance with this Standard, the convention for fixing significant digits where limits, maximum or minimum values are specified, shall be the rounding-off method defined in ASTM Practice E 29. This requires that an observed or calculated value shall be rounded to the nearest unit in the last right hand digit used for expressing the limit.

The listing of decimal tolerances does not imply a particular method of measurement.

7.2 Center-to-Contact Surfaces and Center-to-End

7.2.1 Center-to-Contact Surfaces Other Than Ring Joint

PS 10 and smaller	0.03 in.
NPS 12 and larger	0.06 in.

7.2.2 Center-to-End (Ring Joint)

NPS 10 and smaller	0.03 in.
NPS 12 and larger	0.06 in.

7.2.3 Contact Surface-to-Contact Surface Other Than Ring Joint

NPS 10 and smaller	0.06 in.
NPS 12 and larger	0.12 in.

7.2.4 End-to-End (Ring Joint)

NPS 10 and smaller	0.06 in.
NPS 12 and larger	0.12 in.

7.3 Facings

7.3.1 Inside and outside diameter of large and small tongue and groove and female, 0.02 in.

7.3.2 Outside diameter, 0.06 in. raised face, 0.03 in.

7.3.3 Outside diameter, 0.25 in. raised face, 0.02 in.

7.3.4 Ring joint groove tolerances are shown in Table 5.

7.4 Flange Thickness

NPS 18 and smaller	+0.12 in., –zero
NPS 20 and larger	+0.19 in., –zero

[2] Unless otherwise stated, tolerances are equal plus and minus.

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7.5 Hub Dimensions and Welding Ends

7.5.1 Nominal outside diameter of welding end of welding neck flanges (dimension *A* of Figs. 8 and 9).

NPS 5 and smaller	+0.09 in., −0.03 in.
NPS 6 and larger	+0.16 in., −0.03 in.

7.5.2 Nominal inside diameter of welding ends of welding neck flanges and smaller bore of socket welding flanges (dimension *B* in the referenced figures).

Figs. 8 and 9:

NPS 10 and smaller	0.03 in.
NPS 12 to 18, inclusive	0.06 in.
NPS 20 and larger	+0.12 in., −0.06 in.

Fig. 10:

NPS 10 and smaller	+zero, −0.03 in.
NPS 12 and larger	+zero, −0.06 in.

7.5.3 Bore of backing ring of welding neck flanges (dimension *C* of Figs. 10 and 11).

All sizes	+0.010 in., − zero

7.5.4 Thickness of Hub. Regardless of tolerances specified for dimensions *A* and *B*, the thickness of hub at the welding end shall never be less than 87½% of the nominal thickness of the pipe to which the flange is to be attached.

7.6 Overall Length Through Hub on Welding Neck Flanges

NPS 4 and smaller	+0.06
NPS 5 to 10, inclusive	+0.06, −0.12
NPS 12 and larger	+0.12, −0.18

7.7 Bore of Flanges

7.7.1 Lapped, Slip-On, and Socket Welding Flanges

NPS 10 and smaller	+0.03 in., −zero
NPS 12 and larger	+0.06 in., −zero

7.7.2 Counterbore, Threaded Flanges

NPS 10 and smaller	+0.03 in., −zero
NPS 12 and larger	+0.06 in., −zero

7.8 Drilling and Facing

7.8.1 Bolt circle diameter, 0.06 in.

7.8.2 Center-to-center of adjacent bolt holes, 0.03 in.

7.8.3 Eccentricity between bolt circle diameter and machined facing diameters.

NPS 2½ and smaller	0.03 in.
NPS 3 and larger	0.06 in.

8 TEST

8.1 Flanged Fitting Training

Each flanged fitting shall be given a hydrostatic shell test as specified in para. 8.3.

8.2 Flange Testing

Flanges are not required to be hydrostatically tested.

8.3 Hydrostatic Shell Test

The hydrostatic shell test for flanged fittings shall be no less than 1.5 times the 100°F rating rounded off to the next higher 25 psi increment.

8.3.1 The test shall be made with water, which may contain a corrosion inhibitor, with kerosene, or with another suitable fluid provided its viscosity is no greater than that of water, at a test temperature not above 125°F.

8.3.2 The test duration shall be a minimum of 1 min for fittings NPS 2 and smaller, 2 min for fittings NPS 2½–NPS 8, and 3 min for fittings NPS 10 and larger.

8.3.3 No visible leakage is permitted through the pressure boundary wall.

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TABLE 1A LIST OF MATERIAL SPECIFICATIONS

Material Group	Nominal Designation	Pressure-Temperature Rating Table	Applicable ASTM Specifications[1]		
			Forgings	Castings	Plates
1.1	C-Si C-Mn-Si	2-1.1	A 105 A 350 Gr. LF2	A 216 Gr. WCB	A 515 Gr. 70 A 516 Gr. 70 A 537 Cl. 1
1.2	C-Mn-Si 2½Ni 3½Ni	2-1.2	 A 350 Gr. LF3	A 216 Gr. WCC A 352 Gr. LCC A 352 Gr. LC2 A 352 Gr. LC3	 A 203 Gr. B A 203 Gr. E
1.3	C-Si C-Mn-Si 2½Ni 3½Ni	2-1.3		A 352 Gr. LCB	A 515 Gr. 65 A 516 Gr. 65 A 203 Gr. A A 203 Gr. D
1.4	C-Si C-Mn-Si	2-1.4	 A 350 Gr. LF1 Cl. 1		A 515 Gr. 60 A 516 Gr. 60
1.5	C-½Mo	2-1.5	A 182 Gr. F1	A 217 Gr. WC1 A 352 Gr. LC1	A 204 Gr. A A 204 Gr. B
1.7	C-½Mo ½Cr-½Mo Ni-½Cr-½Mo ¾Ni-¾Cr-1Mo	2-1.7	 A 182 Gr. F2	 A 217 Gr. WC4 A 217 Gr. WC5	A 204 Gr. C
1.9	1Cr-½Mo 1¼Cr-½Mo 1¼Cr-½Mo-Si	2-1.9	A 182 Gr. F12 Cl. 2 A 182 Gr. F11 Cl. 2	 A 217 Gr. WC6	 A 387 Gr. 11 Cl. 2
1.10	2¼Cr-1Mo	2-1.10	A 182 Gr. F22 Cl. 3	A 217 Gr. WC9	A 387 Gr. 22 Cl. 2
1.13	5Cr-½Mo	2-1.13	A 182 Gr. F5 A 182 Gr. F5a	 A 217 Gr. C5	
1.14	9Cr-1Mo	2-1.14	A 182 Gr. F9	A 217 Gr. C12	
2.1	18Cr-8Ni	2-2.1	A 182 Gr. F304 A 182 Gr. F304H	A 351 Gr. CF3 A 351 Gr. CF8	A 240 Gr. 304 A 240 Gr. 304H
2.2	16Cr-12Ni-2Mo 18Cr-13Ni-3Mo 19Cr-10Ni-3Mo	2-2.2	A 182 Gr. F316 A 182 Gr. F316H	A 351 Gr. CF3M A 351 Gr. CF8M A 351 Gr. CG8M	A 240 Gr. 316 A 240 Gr. 316H A 240 Gr. 317
2.3	18Cr-8Ni 16Cr-12Ni-2Mo	2-2.3	A 182 Gr. F304L A 182 Gr. F316L		A 240 Gr. 304L A 240 Gr. 316L
2.4	18Cr-10Ni-Ti	2-2.4	A 182 Gr. F321 A 182 Gr. F321H		A 240 Gr. 321 A 240 Gr. 321H

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TABLE 1A LIST OF MATERIAL SPECIFICATIONS (CONT'D)

Material Group	Nominal Designation	Pressure-Temperature Rating Table	Applicable ASTM Specifications[1]		
			Forgings	Castings	Plates
2.5	18Cr–10Ni–Cb	2-2.5	A 182 Gr. F347 A 182 Gr. F347H A 182 Gr. F348 A 182 Gr. F348H	A 351 Gr. CF8C	A 240 Gr. 347 A 240 Gr. 347H A 240 Gr. 348 A 240 Gr. 348H
2.6	25Cr–12Ni 23Cr–12Ni	2-2.6		A 351 Gr. CH8 A 351 Gr. CH20	 A 240 Gr. 309S A 240 Gr. 309H
2.7	25Cr–20Ni	2-2.7	A 182 Gr. F310	A 351 Gr. CK20	A 240 Gr. 310S A 240 Gr. 310H
2.8	20Cr–18Ni–6Mo 22Cr–5Ni–3Mo–N 25Cr–7Ni–4Mo–N	2-2.8	A 182 Gr. F44 A 182 Gr. F51 A 182 Gr. F53	A 351 Gr. CK3MCuN	A 240 Gr. S31254 A 240 Gr. S31803 A 240 Gr. S32750
3.1	35Ni–35Fe–20Cr–Cb 28Ni–19Cr–Cu–Mo	2-3.1	B 462 Gr. N08020	A 351 Gr. CN7M	B 463 Gr. N08020
3.2	99.0Ni	2-3.2	B 160 Gr. N02200		B 162 Gr. N02200
3.3	99.0Ni–Low C	2-3.3	B 160 Gr. N02201		B 162 Gr. N02201
3.4	67Ni–30Cu 67Ni–30Cu–S	2-3.4	B 564 Gr. N04400 B 164 Gr. N04405		B 127 Gr. N04400
3.5	72Ni–15Cr–8Fe	2-3.5	B 564 Gr. N06600		B 168 Gr. N06600
3.6	33Ni–42Fe–21Cr	2-3.6	B 564 Gr. N08800		B 409 Gr. N08800
3.7	65Ni–28Mo–2Fe	2-3.7	B 335 Gr. N10665		B 333 Gr. N10665
3.8	54Ni–16Mo–15Cr 60Ni–22Cr–9Mo–3.5Cb 62Ni–28Mo–5Fe 70Ni–16Mo–7Cr–5Fe 61Ni–16Mo–16Cr 42Ni–21.5Cr–3Mo–2.3Cu	2-3.8	B 564 Gr. N10276 B 564 Gr. N06625 B 335 Gr. N10001 B 573 Gr. N10003 B 574 Gr. N06455 B 564 Gr. N08825		B 575 Gr. N10276 B 443 Gr. N06625 B 333 Gr. N10001 B 434 Gr. N10003 B 575 Gr. N06455 B 424 Gr. N08825
3.9	47Ni–22Cr–9Mo–18Fe	2-3.9	B 572 Gr. N06002		B 435 Gr. N06002
3.10	25Ni–46Fe–21Cr–5Mo	2-3.10	B 672 Gr. N08700		B 599 Gr. N08700
3.11	44Fe–25Ni–21Cr–Mo	2-3.11	B 649 Gr. N08904		B 625 Gr. N08904
3.12	26Ni–43Fe–22Cr–5Mo 47Ni–22Cr–20Fe–7Mo	2-3.12	B 621 Gr. N08320 B 581 Gr. N06985		B 620 Gr. N08320 B 582 Gr. N06985

(Table 1A continues on next page; Notes follow at end of Table)

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TABLE 1A LIST OF MATERIAL SPECIFICATIONS (CONT'D)

Material Group	Nominal Designation	Pressure–Temperature Rating Table	Applicable ASTM Specifications[1]		
			Forgings	Castings	Plates
3.13	49Ni–25Cr–18Fe–6Mo Ni–Fe–Cr–Mo–Low Cu	2-3.13	B 581 Gr. N06975 B 564 Gr. N08031		B 582 Gr. N06975 B 625 Gr. N08031
3.14	47Ni–22Cr–19Fe–6Mo	2-3.14	B 581 Gr. N06007		B 582 Gr. N06007
3.15	33Ni–42Fe–21Cr	2-3.15	B 564 Gr. N08810		B 409 Gr. N08810
3.16	35Ni–19Cr–1¼Si	2-3.16	B 511 Gr. N08330		B 536 Gr. N08330

NOTE:
(1) ASME Boiler and Pressure Vessel Code, Section II materials, which also meet the requirements of the listed ASTM specifications, may also be used.

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TABLE 1B LIST OF BOLTING SPECIFICATIONS
Applicable ASTM Specifications[15]

Bolting Materials [Note (1)]											
High Strength [Note (2)]			Intermediate Strength [Note (3)]			Low Strength [Note (4)]			Nickel and Special Alloy [Note (5)]		
Spec. No.	Grade	Notes	Spec. No.	Grade	Notes	Spec. No.	Grade	Notes	Spec. No.	Grade	Notes
A193	B7	...	A 193	B5	...	A 193	B8 Cl.1	(6)	B 164	...	(7)(8)(9)
A193	B16	...	A 193	B6	...	A 193	B8C Cl.1	(6)			
			A 193	B6X	...	A 193	B8M Cl.1	(6)	B 166	...	(7)(8)(9)
A 320	L7	(10)	A 193	B7M	...	A 193	B8T Cl.1	(6)			
A 320	L7A	(10)	A 193	B8 Cl.2	(11)	A 193	B8A	(6)	B 335	N10665	(7)
A 320	L7B	(10)	A 193	B8C Cl.2	(11)	A 193	B8CA	(6)			
A 320	L7C	(10)	A 193	B8M Cl.2	(11)	A 193	B8MA	(6)	B 408	...	(7)(8)(9)
A 320	L43	(10)	A 193	B8T Cl.2	(11)	A 193	B8TA	(6)			
									B 473	...	(7)
A 354	BC	...	A 320	B8 Cl.2	(11)	A 307	B	(12)			
A 354	BD	...	A 320	B8C Cl.2	(11)				B 574	N10276	(7)
			A 320	B8F Cl.2	(11)	A 320	B8 Cl.1	(6)			
A 540	B21	...	A 320	B8M Cl.2	(11)	A 320	B8C Cl.1	(6)			
A 540	B22	...	A 320	B8T Cl.2	(11)	A 320	B8M Cl.1	(6)			
A 540	B23	...				A 320	B8T Cl.1	(6)			
A 540	B24	...	A 449	...	(13)						
			A 453	651	(14)						
			A 453	660	(14)						

GENERAL NOTE: Bolting material shall not be used beyond temperature limits specified in the governing code.

NOTES:
(1) Repair welding of bolting material is prohibited.
(2) These bolting materials may be used with all listed materials and gaskets.
(3) These bolting materials may be used with all listed materials and gaskets, provided it has been varified that a sealed joint can be maintained under rated working pressure and temperature.
(4) These bolting materials may be used with all listed materials but are limited to Classes 150 and 300 joints. See para. 5.4.1 for required gasket practices.
(5) These materials may be used as bolting with comparable nickel and special alloy parts.
(6) This austenitic stainless material has been carbide solution treated but not strain hardened. Use A 194 nuts of corresponding material.
(7) Nuts may be machined from the same material or may be of a compatible grade of ASTM A 194.
(8) Maximum operating temperature is arbitrarily set at 500°F, unless material has been annealed, solution annealed, or hot finished because hard temper adversely affects design stress in the creep rupture range.
(9) Forging quality not permitted unless the producer last heating or working these parts tests them as required for other permitted conditions in the same specification and certifies their final tensile, yield, and elongation properties to equal or exceed the requirements for one of the other permitted conditions.
(10) This ferritic material is intended for low temperature service. Use A 194 Grade 4 or Grade 7 nuts.
(11) This austenitic stainless material has been carbide solution treated and strain hardened. Use A 194 nuts of corresponding material.
(12) This carbon steel fastener shall not be used above 400°F or below −20°F. See also Note (4). Bolts with drilled or undersized heads shall not be used.
(13) Acceptable nuts for use with quenched and tempered bolts are A 194 Grades 2 and 2H. Mechanical property requirements for studs shall be the same as those for bolts.
(14) This special alloy is intended for high temperature service with austenitic stainless steel.
(15) ASME Boiler and Pressure Vessel Code, Section II materials, which also meet the requirements of the listed ASTM specifications, may also be used.

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TABLE 1C FLANGE BOLTING DIMENSIONAL RECOMMENDATIONS

Product	Carbon Steel	Alloy Steel
Stud bolts	ASME B18.2.1	ASME B18.2.1
Bolts smaller than 3/4 in.	ASME B18.2.1, square or heavy hex head	ASME B18.2.1, heavy hex head
Bolts equal to or larger than 3/4 in.	ASME B18.2.1, square or hex head	ASME B18.2.1, heavy hex head
Nuts smaller than 3/4 in.	ASME B18.2.2, heavy hex	ASME B18.2.2, heavy hex
Nuts equal to or larger than 3/4 in.	ASME B18.2.2, hex or heavy hex	ASME B18.2.2, heavy hex
Male threads	ASME B1.1, Cl. 2A course series	ASME B1.1, Cl. 2A course series up through 1 in.; eight thread series for larger bolts
Female threads	ASME B1.1, Cl. 2B course series	ASME B1.1, Cl. 2B course series up through 1 in.; eight thread series for larger bolts

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TABLES 2
PRESSURE-TEMPERATURE RATINGS FOR GROUPS 1.1 THROUGH 3.16 MATERIALS

TABLE 2-1.1 RATINGS FOR GROUP 1.1 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C-Si	A 105 (1)	A 216 Gr. WCB (1)	A 515 Gr. 70 (1)
C-Mn-Si	A 350 Gr. LF2 (1)		A 516 Gr. 70 (1)(2) A 537 Cl. 1 (3)

NOTES:
(1) Upon prolonged exposure to temperatures above 800°F, the carbide phase of steel may be converted to graphite. Permissible, but not recommended for prolonged use above 800°F.
(2) Not to be used over 850°F.
(3) Not to be used over 700°F.

	WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	285	740	990	1480	2220	3705	6170
200	260	675	900	1350	2025	3375	5625
300	230	655	875	1315	1970	3280	5470
400	200	635	845	1270	1900	3170	5280
500	170	600	800	1200	1795	2995	4990
600	140	550	730	1095	1640	2735	4560
650	125	535	715	1075	1610	2685	4475
700	110	535	710	1065	1600	2665	4440
750	95	505	670	1010	1510	2520	4200
800	80	410	550	825	1235	2060	3430
850	65	270	355	535	805	1340	2230
900	50	170	230	345	515	860	1430
950	35	105	140	205	310	515	860
1000	20	50	70	105	155	260	430

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TABLE 2-1.2 RATINGS FOR GROUP 1.2 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C–Mn–Si		A 216 Gr. WCC (1) A 352 Gr. LCC (2)	
2½Ni		A 352 Gr. LC2	A 203 Gr. B (1)
3½Ni	A 350 Gr. LF3	A 352 Gr. LC3	A 203 Gr. E (1)

NOTES:
(1) Upon prolonged exposure to temperatures above 800°F, the carbide phase of steel may be converted to graphite. Permissible, but not recommended for prolonged use above 800°F.
(2) Not to be used over 650°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	730	970	1455	2185	3640	6070
400	200	705	940	1410	2115	3530	5880
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	505	670	1010	1510	2520	4200
800	80	410	550	825	1235	2060	3430
850	65	270	355	535	805	1340	2230
900	50	170	230	345	515	860	1430
950	35	105	140	205	310	515	860
1000	20	50	70	105	155	260	430

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TABLE 2-1.3 RATINGS FOR GROUP 1.3 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C–Si		A 352 Gr. LCB (3)	A 515 Gr. 65 (1)
C–Mn–Si			A 516 Gr. 65 (1)(2)
2½Ni			A 203 Gr. A (1)
3½Ni			A 203 Gr. D (1)

NOTES:
(1) Upon prolonged exposure to temperatures above 800°F, the carbide phase of steel may be converted to graphite. Permissible, but not recommended for prolonged use above 800°F.
(2) Not to be used over 850°F.
(3) Not to be used over 650°F.

	WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	265	695	925	1390	2085	3470	5785
200	250	655	875	1315	1970	3280	5470
300	230	640	850	1275	1915	3190	5315
400	200	620	825	1235	1850	3085	5145
500	170	585	775	1165	1745	2910	4850
600	140	535	710	1065	1600	2665	4440
650	125	525	695	1045	1570	2615	4355
700	110	520	690	1035	1555	2590	4320
750	95	475	630	945	1420	2365	3945
800	80	390	520	780	1175	1955	3260
850	65	270	355	535	805	1340	2230
900	50	170	230	345	515	860	1430
950	35	105	140	205	310	515	860
1000	20	50	70	105	155	260	430

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TABLE 2-1.4 RATINGS FOR GROUP 1.4 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C–Si			A 515 Gr. 60 (1)
C–Mn–Si	A 350 Gr. LF1, Cl. 1 (1)		A 516 Gr. 60 (1)(2)

NOTES:
(1) Upon prolonged exposure to temperatures above 800°F, the carbide phase of steel may be converted to graphite. Permissible, but not recommended for prolonged use above 800°F.
(2) Not to be used over 850°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	235	620	825	1235	1850	3085	5145
200	215	560	750	1125	1685	2810	4680
300	210	550	730	1095	1640	2735	4560
400	200	530	705	1060	1585	2645	4405
500	170	500	665	995	1495	2490	4150
600	140	455	610	915	1370	2285	3805
650	125	450	600	895	1345	2245	3740
700	110	450	600	895	1345	2245	3740
750	95	445	590	885	1325	2210	3685
800	80	370	495	740	1110	1850	3085
850	65	270	355	535	805	1340	2230
900	50	170	230	345	515	860	1430
950	35	105	140	205	310	515	860
1000	20	50	70	105	155	260	430

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TABLE 2-1.5 RATINGS FOR GROUP 1.5 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C-½Mo	A 182 Gr. F1 (1)	A 217 Gr. WC1 (1)(2) A 352 Gr. LC1 (3)	A 204 Gr. A (1) A 204 Gr. B (1)

NOTES:
(1) Upon prolonged exposure to temperatures above 875°F, the carbide phase of Carbon-molybdenum steel may be converted to graphite. Permissible, but not recommended for prolonged use above 875°F.
(2) Use normalized and tempered material only.
(3) Not to be used over 650°F.

	WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	265	695	925	1390	2085	3470	5785
200	260	680	905	1360	2035	3395	5660
300	230	655	870	1305	1955	3260	5435
400	200	640	855	1280	1920	3200	5330
500	170	620	830	1245	1865	3105	5180
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	280	375	560	845	1405	2345
1000	20	165	220	330	495	825	1370

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TABLE 2-1.7 RATINGS FOR GROUP 1.7 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C-½Mo			A 204 Gr. C (1)
½Cr-½Mo	A 182 Gr. F2 (3)		
Ni-½Cr-½Mo		A 217 Gr. WC4 (2)(3)	
¾Ni-¾Cr-1Mo		A 217 Gr. WC5 (2)	

NOTES:
(1) Upon prolonged exposure to temperatures above 875°F, the carbide phose of carbon-molybdenum steel may be converted to graphite. Permissible, but not recommended for prolonged use above 875°F.
(2) Use normalized and tempered material only.
(3) Not to be used over 1000°F.

WORKING PRESSURES BY CLASSES, psig							
Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	720	965	1445	2165	3610	6015
400	200	695	925	1385	2080	3465	5775
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	315	420	630	945	1575	2630
1000	20	200	270	405	605	1010	1685
1050	. . .	160	210	315	475	790	1315

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TABLE 2-1.9 RATINGS FOR GROUP 1.9 MATERIALS

Nominal Designation	Forgings	Castings	Plates
1Cr–½Mo	A 182 Gr. F12 Cl. 2 (1)(2)		
1¼Cr–½Mo		A 217 Gr. WC6 (1)(3)	
1¼Cr–½Mo	A 182 Gr. F11 Cl. 2 (1)(2)		A 387 Gr. 11 Cl. 2 (2)

NOTES:
(1) Use normalized and tempered material only.
(2) Permissible, but not recommended for prolonged use above 1100°F.
(3) Not to be used over 1100°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	720	965	1445	2165	3610	6015
400	200	695	925	1385	2080	3465	5775
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	320	425	640	955	1595	2655
1000	20	215	290	430	650	1080	1800
1050	. . .	145	190	290	430	720	1200
1100	. . .	95	130	190	290	480	800
1150	. . .	60	80	125	185	310	515
1200	. . .	40	50	75	115	190	315

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TABLE 2-1.10 RATINGS FOR GROUP 1.10 MATERIALS

Nominal Designation	Forgings	Castings	Plates
2¼Cr–1Mo	A 182 Gr. F22 Cl. 3 (2)	A 217 Gr. WC9 (1)(3)	A 387 Gr. 22 Cl. 2 (2)

NOTES:
(1) Use normalized and tempered material only.
(2) Permissible, but not recommended for prolonged use above 1100°F.
(3) Not to be used over 1100°F.

WORKING PRESSURES BY CLASSES, psig							
Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	730	970	1455	2185	3640	6070
400	200	705	940	1410	2115	3530	5880
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	375	505	755	1130	1885	3145
1000	20	260	345	520	780	1305	2170
1050	. . .	175	235	350	525	875	1455
1100	. . .	110	145	220	330	550	915
1150	. . .	70	90	135	205	345	570
1200	. . .	40	55	80	125	205	345

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TABLE 2-1.13 RATINGS FOR GROUP 1.13 MATERIALS

Nominal Designation	Forgings	Castings	Plates
5Cr–½Mo	A 182 Gr. F5 A 182 Gr. F5a	A 217 Gr. C5 (1)	

NOTE:
(1) Use normalized and tempered material only.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	290	750	1000	1500	2250	3750	6250
200	260	745	995	1490	2235	3725	6205
300	230	715	955	1430	2150	3580	5965
400	200	705	940	1410	2115	3530	5880
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	705	1055	1585	2640	4400
800	80	510	675	1015	1525	2540	4230
850	65	485	645	965	1450	2415	4030
900	50	370	495	740	1110	1850	3085
950	35	275	365	550	825	1370	2285
1000	20	200	265	400	595	995	1655
1050	. . .	145	190	290	430	720	1200
1100	. . .	100	135	200	300	495	830
1150	. . .	60	80	125	185	310	515
1200	. . .	35	45	70	105	170	285

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TABLE 2-1.14 RATINGS FOR GROUP 1.14 MATERIALS

Nominal Designation	Forgings	Castings	Plates
9Cr–1Mo	A 182 Gr. F9	A 217 Gr. C12 (1)	

NOTE:
(1) Use normalized and tempered material only.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	730	970	1455	2185	3640	6070
400	200	705	940	1410	2115	3530	5880
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1360	2245	3745
950	35	375	505	755	1130	1885	3145
1000	20	255	340	505	760	1270	2115
1050	. . .	170	230	345	515	855	1430
1100	. . .	115	150	225	340	565	945
1150	. . .	75	100	150	225	375	630
1200	. . .	50	70	105	155	255	430

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TABLE 2-2.1 RATINGS FOR GROUP 2.1 MATERIALS

Nominal Designation	Forgings	Castings	Plates
18Cr–8Ni	A 182 Gr. F304 (1)	A 351 Gr. CF3 (2)	A 240 Gr. 304 (1)
	A 182 Gr. F304H	A 351 Gr. CF8 (1)	A 240 Gr. 304H

NOTES:
(1) At temperatures over 1000°F, use only when the carbon content is 0.04% or higher.
(2) Not to be used over 800°F.

	WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	275	720	960	1440	2160	3600	6000
200	230	600	800	1200	1800	3000	5000
300	205	540	720	1080	1620	2700	4500
400	190	495	660	995	1490	2485	4140
500	170	465	620	930	1395	2330	3880
600	140	435	580	875	1310	2185	3640
650	125	430	575	860	1290	2150	3580
700	110	425	565	850	1275	2125	3540
750	95	415	555	830	1245	2075	3460
800	80	405	540	805	1210	2015	3360
850	65	395	530	790	1190	1980	3300
900	50	390	520	780	1165	1945	3240
950	35	380	510	765	1145	1910	3180
1000	20	320	430	640	965	1605	2675
1050	...	310	410	615	925	1545	2570
1100	...	255	345	515	770	1285	2145
1150	...	200	265	400	595	995	1655
1200	...	155	205	310	465	770	1285
1250	...	115	150	225	340	565	945
1300	...	85	115	170	255	430	715
1350	...	60	80	125	185	310	515
1400	...	50	65	95	145	240	400
1450	...	35	45	70	105	170	285
1500	...	25	35	55	80	135	230

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TABLE 2-2.2 RATINGS FOR GROUP 2.2 MATERIALS

Nominal Designation	Forgings	Castings	Plates
16Cr–12Ni–2Mo	A 182 Gr. F316 (1) A 182 Gr. F316H	A 351 Gr. CF3M (2) A 351 Gr. CF8M (1)	A 240 Gr. 316 (1) A 240 Gr. 316H
18Cr–13Ni–3Mo			A 240 Gr. 317 (1)
19Cr–10Ni–3Mo		A 351 Gr. CG8M (3)	

NOTES:
(1) At temperatures over 1000°F, use only when the carbon content is 0.04% or higher.
(2) Not to be used over 850°F.
(3) Not to be used over 1000°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	275	720	960	1440	2160	3600	6000
200	235	620	825	1240	1860	3095	5160
300	215	560	745	1120	1680	2795	4660
400	195	515	685	1025	1540	2570	4280
500	170	480	635	955	1435	2390	3980
600	140	450	600	900	1355	2255	3760
650	125	445	590	890	1330	2220	3700
700	110	430	580	870	1305	2170	3620
750	95	425	570	855	1280	2135	3560
800	80	420	565	845	1265	2110	3520
850	65	420	555	835	1255	2090	3480
900	50	415	555	830	1245	2075	3460
950	35	385	515	775	1160	1930	3220
1000	20	350	465	700	1050	1750	2915
1050	...	345	460	685	1030	1720	2865
1100	...	305	405	610	915	1525	2545
1150	...	235	315	475	710	1185	1970
1200	...	185	245	370	555	925	1545
1250	...	145	195	295	440	735	1230
1300	...	115	155	235	350	585	970
1350	...	95	130	190	290	480	800
1400	...	75	100	150	225	380	630
1450	...	60	80	115	175	290	485
1500	...	40	55	85	125	205	345

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TABLE 2-2.3 RATINGS FOR GROUP 2.3 MATERIALS

Nominal Designation	Forgings	Castings	Plates
16Cr–12Ni–2Mo	A 182 Gr. F316L		A 240 Gr. 316L
18Cr–8Ni	A 182 Gr. F304L (1)		A 240 Gr. 304L (1)

NOTE:
(1) Not to be used over 800°F.

	WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	230	600	800	1200	1800	3000	5000
200	195	505	675	1015	1520	2530	4220
300	175	455	605	910	1360	2270	3780
400	160	415	550	825	1240	2065	3440
500	145	380	510	765	1145	1910	3180
600	140	360	480	720	1080	1800	3000
650	125	350	470	700	1050	1750	2920
700	110	345	460	685	1030	1715	2860
750	95	335	450	670	1010	1680	2800
800	80	330	440	660	985	1645	2740
850	65	320	430	645	965	1610	2680

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TABLE 2-2.4 RATINGS FOR GROUP 2.4 MATERIALS

Nominal Designation	Forgings	Castings	Plates
18Cr–10Ni–Ti	A 182 Gr. F321 (2) A 182 Gr. F321H (1)		A 240 Gr. 321 (2) A 240 Gr. 321H (1)

NOTES:
(1) At temperatures over 1000°F, use only if the material is heat treated by heating to a minimum temperature of 2000°F.
(2) Not to be used over 1000°F.

	WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	275	720	960	1440	2160	3600	6000
200	245	645	860	1290	1935	3230	5380
300	230	595	795	1190	1785	2975	4960
400	200	550	735	1105	1655	2760	4600
500	170	515	685	1030	1545	2570	4285
600	140	485	650	975	1460	2435	4060
650	125	480	635	955	1435	2390	3980
700	110	465	620	930	1395	2330	3880
750	95	460	610	915	1375	2290	3820
800	80	450	600	900	1355	2255	3760
850	65	445	595	895	1340	2230	3720
900	50	440	590	885	1325	2210	3680
950	35	385	515	775	1160	1930	3220
1000	20	355	475	715	1070	1785	2970
1050	...	315	415	625	940	1565	2605
1100	...	270	360	545	815	1360	2265
1150	...	235	315	465	710	1185	1970
1200	...	185	245	370	555	925	1545
1250	...	140	185	280	420	705	1170
1300	...	110	145	220	330	550	915
1350	...	85	115	170	255	430	715
1400	...	65	85	130	195	325	545
1450	...	50	70	105	155	255	430
1500	...	40	50	75	115	190	315

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TABLE 2-2.5 RATINGS FOR GROUP 2.5 MATERIALS

Nominal Designation	Forgings	Castings	Plates
18Cr–10Ni–Cb	A 182 Gr. F347 (2) A 182 Gr. F347H (1) A 182 Gr. F348 (2) A 182 Gr. F348H (1)	A 351 Gr. CF8C (3)	A 240 Gr. 347 (2) A 240 Gr. 347H (1) A 240 Gr. 348 (2) A 240 Gr. 348H (1)

NOTES:
(1) For temperatures over 1000°F, use only if the material is heat treated by heating to a minimum temperature of 2000°F.
(2) Not to be used over 1000°F.
(3) At temperatures over 1000°F, use the material only when the carbon content is 0.04% or higher.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	275	720	960	1440	2160	3600	6000
200	255	660	880	1320	1980	3300	5500
300	230	615	820	1230	1845	3070	5120
400	200	575	765	1145	1720	2870	4780
500	170	540	720	1080	1620	2700	4500
600	140	515	685	1025	1540	2570	4280
650	125	505	670	1010	1510	2520	4200
700	110	495	660	990	1485	2470	4120
750	95	490	655	985	1475	2460	4100
800	80	485	650	975	1460	2435	4060
850	65	485	645	970	1455	2425	4040
900	50	450	600	900	1350	2245	3745
950	35	385	515	775	1160	1930	3220
1000	20	365	485	725	1090	1820	3030
1050	. . .	360	480	720	1080	1800	3000
1100	. . .	325	430	645	965	1610	2685
1150	. . .	275	365	550	825	1370	2285
1200	. . .	170	230	345	515	855	1430
1250	. . .	125	165	245	370	615	1030
1300	. . .	95	125	185	280	465	770
1350	. . .	70	90	135	205	345	570
1400	. . .	55	75	110	165	275	455
1450	. . .	40	55	80	125	205	345
1500	. . .	35	45	70	105	170	285

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TABLE 2-2.6 RATINGS FOR GROUP 2.6 MATERIALS

Nominal Designation	Forgings	Castings	Plates
23Cr–12Ni			A 240 Gr. 309S (1)(2)(3) A 240 Gr. 309H
25Cr–12Ni		A 351 Gr. CH8 (1) A 351 Gr. CH20 (1)	

NOTES:
(1) At temperatures over 1000°F, use only when the carbon content is 0.04% or higher.
(2) For temperatures above 1000°F, use only if the material solution is heat treated to the minimum temperature specified in the specification but not lower than 1900°F, and quenching in water or rapidly cooling by other means.
(3) This material should be used for service temperatures 1050°F and above only when assurance is provided that grain size is not finer than ASTM 6.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	260	670	895	1345	2015	3360	5600
200	230	605	805	1210	1815	3025	5040
300	220	570	760	1140	1705	2845	4740
400	200	535	710	1065	1600	2665	4440
500	170	505	670	1010	1510	2520	4200
600	140	480	635	955	1435	2390	3980
650	125	465	620	930	1395	2330	3880
700	110	455	610	910	1370	2280	3800
750	95	445	595	895	1340	2230	3720
800	80	435	580	870	1305	2170	3620
850	65	425	565	850	1275	2125	3540
900	50	415	555	830	1245	2075	3460
950	35	385	515	775	1160	1930	3220
1000	20	335	450	670	1010	1680	2800
1050	...	290	390	585	875	1460	2430
1100	...	225	300	445	670	1115	1860
1150	...	170	230	345	515	860	1430
1200	...	130	175	260	390	650	1085
1250	...	100	135	200	300	495	830
1300	...	80	105	160	235	395	660
1350	...	60	80	115	175	290	485
1400	...	45	60	90	135	225	370
1450	...	30	40	60	95	155	260
1500	...	25	30	50	70	120	200

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TABLE 2-2.7 RATINGS FOR GROUP 2.7 MATERIALS

Nominal Designation	Forgings	Castings	Plates
25Cr–20Ni	A 182 Gr. F310 (1)(3)	A 351 Gr. CK20 (1)	A 240 Gr. 310S (1)(2)(3) A 240 Gr. 310H

NOTES:
(1) At temperatures over 1000°F, use only when the carbon content is 0.04% or higher.
(2) For temperatures above 1000°F, use only if the material is heat treated by heating it to a temperature of at least 1900°F and quenching in water or rapidly cooling by other means.
(3) Service temperatures of 1050°F and above should be used only when assurance is provided that grain size is not finer than ASTM 6.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	260	670	895	1345	2015	3360	5600
200	235	605	810	1215	1820	3035	5060
300	220	570	760	1140	1705	2845	4740
400	200	535	715	1070	1605	2675	4260
500	170	505	675	1015	1520	2530	4220
600	140	480	640	960	1440	2400	4000
650	125	470	625	935	1405	2340	3900
700	110	455	610	910	1370	2280	3800
750	95	450	600	900	1345	2245	3740
800	80	435	580	875	1310	2185	3640
850	65	425	575	855	1280	2135	3560
900	50	420	555	835	1255	2090	3480
950	35	385	515	775	1160	1930	3220
1000	20	345	460	685	1030	1720	2865
1050	...	335	450	670	1010	1680	2800
1100	...	260	345	520	780	1305	2170
1150	...	190	250	375	565	945	1570
1200	...	135	185	275	410	685	1145
1250	...	105	135	205	310	515	855
1300	...	75	100	150	225	375	630
1350	...	60	80	115	175	290	485
1400	...	45	60	90	135	225	370
1450	...	35	45	65	100	165	275
1500	...	25	35	50	75	130	215

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TABLE 2-2.8 RATINGS FOR GROUP 2.8 MATERIALS

Nominal Designation	Forgings	Castings	Plates
20Cr–18Ni–6Mo	A 182 Gr. F44	A 351 Gr. CK3MCuN	A 240 Gr. S31254
22Cr–5Ni–3Mo–N	A 182 Gr. F51 (1)		A 240 Gr. S31803 (1)
25Cr–7Ni–4Mo–N	A 182 Gr. F53 (1)		A 240 Gr. S32750 (1)

NOTE:
(1) This steel may become brittle after service at moderately elevated temperatures. Not to be used over 600°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	290	750	1000	1500	2250	3750	6250
200	260	720	960	1440	2160	3600	6000
300	230	665	885	1330	1995	3325	5540
400	200	615	820	1230	1845	3070	5120
500	170	575	770	1150	1730	2880	4800
600	140	555	740	1115	1670	2785	4640
650	125	550	735	1100	1650	2750	4580
700	110	540	725	1085	1625	2710	4520
750	95	530	710	1065	1595	2660	4430

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TABLE 2-3.1 RATINGS FOR GROUP 3.1 MATERIALS

Nominal Designation	Forgings	Castings	Plates
28Ni–19Cr–Cu–Mo		A 351 Gr. CN7M (2)(3)	
35Ni–35Fe–20Cr–Cb	B 462 Gr. N08020 (1)		B 463 Gr. N08020 (1)

NOTES:
(1) Use annealed material only.
(2) Use solution annealed material only.
(3) Ratings apply for 300°F and lower.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	230	600	800	1200	1800	3000	5000
200	200	520	695	1045	1565	2610	4350
300	190	490	655	980	1470	2450	4080
400	190	490	655	980	1470	2450	4080
500	170	490	655	980	1470	2450	4080
600	140	490	655	980	1470	2450	4080
650	125	490	655	980	1470	2450	4080
700	110	490	655	980	1470	2450	4080
750	95	490	655	980	1470	2450	4080
800	80	490	655	980	1470	2450	4080

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TABLE 2-3.2 RATINGS FOR GROUP 3.2 MATERIALS

Nominal Designation	Forgings	Castings	Plates
99.0Ni	B 160 Gr. N02200 (1)(2)		B 162 Gr. N02200 (1)

NOTES:
(1) Use annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	140	360	480	720	1080	1800	3000
200	140	360	480	720	1080	1800	3000
300	140	360	480	720	1080	1800	3000
400	140	360	480	720	1080	1800	3000
500	140	360	480	720	1080	1800	3000
600	140	360	480	720	1080	1800	3000

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TABLE 2-3.3 RATINGS FOR GROUP 3.3 MATERIALS

Nominal Designation	Forgings	Castings	Plates
99.0Ni–Low C	B 160 Gr. N02201 (1)(2)		B 162 Gr. N02201 (1)

NOTES:
(1) Use annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	90	240	320	480	720	1200	2000
200	85	230	305	455	685	1140	1900
300	85	225	300	445	670	1115	1860
400	85	215	290	430	650	1080	1800
500	85	215	290	430	650	1080	1800
600	85	215	290	430	650	1080	1800
650	85	215	290	430	650	1080	1800
700	85	215	290	430	650	1080	1800
750	80	210	280	420	635	1055	1760
800	80	205	270	410	610	1020	1700
850	65	205	270	410	610	1020	1700
900	50	140	185	380	415	695	1155
950	35	115	150	230	345	570	950
1000	20	95	125	185	280	465	770
1050	. . .	75	100	150	220	370	615
1100	. . .	60	80	125	185	310	515
1150	. . .	45	60	95	140	230	385
1200	. . .	35	50	75	110	185	310

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TABLE 2-3.4 RATINGS FOR GROUP 3.4 MATERIALS

Nominal Designation	Forgings	Castings	Plates
67Ni–30Cu	B 564 Gr. N04400 (1)		B 127 Gr. N04400 (1)
67Ni–30Cu–S	B 164 Gr. N04405 (1)(2)		

NOTES:
(1) Use annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
–20 to 100	230	600	800	1200	1800	3000	5000
200	200	530	705	1055	1585	2640	4400
300	190	495	660	990	1485	2470	4120
400	185	480	635	955	1435	2390	3980
500	170	475	635	950	1435	2375	3960
600	140	475	635	950	1435	2375	3960
650	125	475	635	950	1435	2375	3960
700	110	475	635	950	1435	2375	3960
750	95	470	625	935	1405	2340	3900
800	80	460	610	915	1375	2290	3820
850	65	340	455	680	1020	1695	2830
900	50	245	340	495	740	1235	2055

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TABLE 2-3.5 RATINGS FOR GROUP 3.5 MATERIALS

Nominal Designation	Forgings	Castings	Plates
72Ni–15Cr–8Fe	B 564 Gr. N06600 (1)		B 168 Gr. N06600 (1)

NOTE:
(1) Use annealed material only.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	730	970	1455	2185	3640	6070
400	200	705	940	1410	2115	3530	5880
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	325	435	655	980	1635	2725
1000	20	215	290	430	650	1080	1800
1050	...	140	185	280	415	695	1155
1100	...	95	125	185	280	465	770
1150	...	70	90	135	205	340	565
1200	...	60	80	125	185	310	515

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TABLE 2-3.6 RATINGS FOR GROUP 3.6 MATERIALS

Nominal Designation	Forgings	Castings	Plates
33Ni–42Fe–21Cr	B 564 Gr. N08800 (1)		B 409 Gr. N08800 (1)

NOTE:
(1) Use annealed material only.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	275	720	960	1440	2160	3600	6000
200	255	660	885	1325	1990	3310	5520
300	230	625	830	1250	1870	3120	5200
400	200	600	800	1200	1800	3000	5000
500	170	580	770	1155	1735	2890	4820
600	140	575	765	1145	1720	2870	4780
650	125	570	760	1140	1705	2845	4740
700	110	565	750	1130	1690	2820	4700
750	95	530	710	1065	1595	2660	4430
800	80	505	675	1015	1520	2535	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	385	515	775	1160	1930	3220
1000	20	365	485	725	1090	1820	3030
1050	. . .	360	480	720	1080	1800	3000
1100	. . .	325	430	645	965	1610	2685
1150	. . .	275	365	550	825	1370	2285
1200	. . .	205	270	405	610	1020	1695
1250	. . .	130	175	260	390	650	1080
1300	. . .	60	80	125	185	310	515
1350	. . .	50	65	100	150	245	410
1400	. . .	35	45	70	100	170	285
1450	. . .	30	40	60	95	155	255
1500	. . .	25	35	50	75	125	205

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TABLE 2-3.7 RATINGS FOR GROUP 3.7 MATERIALS

Nominal Designation	Forgings	Castings	Plates
65Ni–28Mo–2Fe	B 335 Gr. N10665 (1)(2)		B 333 Gr. N10665 (1)

NOTES:
(1) Use solution annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	730	970	1455	2185	3640	6070
400	200	705	940	1410	2115	3530	5880
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230

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TABLE 2-3.8 RATINGS FOR GROUP 3.8 MATERIALS

Nominal Designation	Forgings	Castings	Plates
54Ni-16Mo-15Cr	B 564 Gr. N10276 (1)(4)		B 575 Gr. N10276 (1)(4)
60Ni-22Cr-9Mo-3.5Cb	B 564 Gr. N06625 (3)(5)		B 443 Gr. N06625 (3)(5)
62Ni-28Mo-5Fe	B 335 Gr. N10001 (1)(2)(6)		B 333 Gr. N10001 (1)(6)
70Ni-16Mo-7Cr-5Fe	B 573 Gr. N10003 (2)(3)		B 434 Gr. N10003 (3)
61Ni-16Mo-16Cr	B 574 Gr. N06455 (1)(2)(6)		B 575 Gr. N06455 (1)(6)
42Ni-21.5Fe-3Cr-2.3Cu	B 564 Gr. N08825 (3)(7)		B 424 Gr. N08825 (3)(7)

NOTES:
(1) Use solution annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.
(3) Use annealed material only.
(4) Not to be used over 1250°F.
(5) Not to be used over 1200°F. Alloy N06625 in the annealed condition is subject to severe loss of impact strength at room temperatures after exposure in the range of 1000°F to 1400°F.
(6) Not to be used over 800°F.
(7) Not to be used over 1000°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	730	970	1455	2185	3640	6070
400	200	705	940	1410	2115	3530	5880
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	385	515	775	1160	1930	3220
1000	20	365	485	725	1090	1820	3030
1050	...	360	480	720	1080	1800	3000
1100	...	325	430	645	965	1610	2685
1150	...	275	365	550	825	1370	2285
1200	...	185	245	370	555	925	1545
1250	...	145	195	295	440	735	1220
1300	...	110	145	215	325	540	900

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TABLE 2-3.9 RATINGS FOR GROUP 3.9 MATERIALS

Nominal Designation	Forgings	Castings	Plates
47Ni-22Cr-9Mo-18Fe	B 572 Gr. N06002 (1)(2)		B 435 Gr. N06002 (1)

NOTES:
(1) Use solution annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

	WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	680	905	1360	2040	3395	5660
400	200	600	795	1195	1795	2990	4980
500	170	575	770	1150	1730	2880	4800
600	140	560	745	1120	1680	2795	4660
650	125	560	745	1120	1680	2795	4660
700	110	560	745	1120	1680	2795	4660
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	385	515	775	1160	1930	3220
1000	20	365	485	725	1090	1820	3030
1050	...	360	480	720	1080	1800	3000
1100	...	325	430	645	965	1610	2685
1150	...	275	365	550	825	1370	2285
1200	...	205	275	410	620	1030	1715
1250	...	180	245	365	545	910	1515
1300	...	140	185	275	410	685	1145
1350	...	105	140	205	310	515	860
1400	...	75	100	150	225	380	630
1450	...	60	80	115	175	290	485
1500	...	40	55	85	125	205	345

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TABLE 2-3.10 RATINGS FOR GROUP 3.10 MATERIALS

Nominal Designation	Forgings	Castings	Plates
25Ni–46Fe–21Cr–5Mo	B 672 Gr. N08700 (1)(2)		B 599 Gr. N08700 (1)

NOTES:
(1) Use solution annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	275	720	960	1440	2160	3600	6000
200	260	720	960	1440	2160	3600	6000
300	230	680	905	1360	2040	3400	5670
400	200	640	855	1280	1920	3205	5340
500	170	610	815	1225	1835	3060	5100
600	140	595	790	1190	1780	2970	4950
650	125	570	760	1140	1705	2845	4740

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TABLE 2-3.11 RATINGS FOR GROUP 3.11 MATERIALS

Nominal Designation	Forgings	Castings	Plates
44Fe-25Ni-21Cr-Mo	B 649 Gr. N08904 (1)(2)		B 625 Gr. N08904 (1)

NOTES:
(1) Use annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	245	640	855	1280	1920	3205	5340
200	230	600	800	1200	1805	3005	5010
300	210	545	725	1085	1630	2720	4530
400	190	495	660	995	1490	2485	4140
500	170	455	610	915	1370	2285	3810
600	140	430	575	865	1295	2160	3600
650	125	420	560	840	1265	2105	3510
700	110	410	545	820	1230	2050	3420

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TABLE 2-3.12 RATINGS FOR GROUP 3.12 MATERIALS

Nominal Designation	Forgings	Castings	Plates
26Ni–43Fe–22Cr–5Mo	B 621 Gr. N08320 (1)(2)		B 620 Gr. N08320 (1)
47Ni–22Cr–20Fe–7Mo	B 581 Gr. N06985 (1)(2)		B 582 Gr. N06985 (1)

NOTES:
(1) Use solution annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	260	670	895	1345	2015	3360	5600
200	240	625	830	1245	1870	3115	5190
300	225	585	780	1175	1760	2935	4890
400	200	535	715	1075	1610	2680	4470
500	170	500	665	1000	1500	2500	4170
600	140	475	635	950	1425	2375	3960
650	125	465	620	930	1395	2320	3870
700	110	450	600	900	1350	2250	3750
750	95	445	590	885	1330	2215	3690
800	80	430	575	865	1295	2160	3600

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TABLE 2-3.13 RATINGS FOR GROUP 3.13 MATERIALS

Nominal Designation	Forgings	Castings	Plates
49Ni-25Cr-18Fe-6Mo	B 581 Gr. N06975 (1)(2)		B 582 Gr. N06975 (1)
Ni-Fe-Cr-Mo-Low Cu	B 564 Gr. N08031 (3)		B 625 Gr. N08031 (3)

NOTES:
(1) Use solution annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.
(3) Use annealed material only.

WORKING PRESSURES BY CLASSES, psig							
Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	290	750	1000	1500	2250	3750	6250
200	260	705	940	1410	2115	3530	5880
300	230	660	885	1325	1985	3310	5520
400	200	635	845	1265	1900	3170	5280
500	170	595	790	1190	1780	2970	4950
600	140	560	750	1125	1685	2810	4680
650	125	555	735	1105	1660	2765	4605
700	110	545	725	1085	1630	2720	4530
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230

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TABLE 2-3.14 RATINGS FOR GROUP 3.14 MATERIALS

Nominal Designation	Forgings	Castings	Plates
47Ni-22Cr-19Fe-6	MoB 581 Gr. N06007 (1)(2)		B 582 Gr. N06007 (1)

NOTES:
(1) Use solution annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	275	720	960	1440	2160	3600	6000
200	245	645	860	1290	1935	3230	5380
300	230	600	795	1195	1795	2990	4980
400	200	560	750	1125	1685	2810	4680
500	170	535	715	1070	1605	2675	4460
600	140	520	690	1035	1555	2590	4320
650	125	510	680	1020	1535	2555	4260
700	110	505	675	1015	1520	2530	4220
750	95	500	670	1005	1505	2510	4180
800	80	495	660	995	1490	2485	4140
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	385	515	775	1160	1930	3220
1000	20	365	485	725	1090	1820	3030

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TABLE 2-3.15 RATINGS FOR GROUP 3.15 MATERIALS

Nominal Designation	Forgings	Castings	Plates
33Ni–42Fe–21Cr	B 564 Gr. N08810 (1)		B 409 Gr. N08810 (1)

NOTE:
(1) Use solution annealed material only.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	230	600	800	1200	1800	3000	5000
200	205	540	720	1080	1620	2700	4500
300	195	505	675	1015	1520	2530	4220
400	185	480	640	960	1440	2400	4000
500	170	455	610	910	1370	2280	3800
600	140	440	585	880	1320	2195	3660
650	125	425	565	850	1275	2125	3540
700	110	420	560	840	1260	2100	3500
750	95	415	550	825	1240	2065	3440
800	80	410	545	815	1225	2040	3400
850	65	400	530	795	1195	1990	3320
900	50	395	530	790	1190	1980	3300
950	35	385	515	775	1160	1930	3220
1000	20	365	485	725	1090	1820	3030
1050	...	325	435	650	975	1625	2710
1100	...	320	430	640	965	1605	2675
1150	...	275	365	550	825	1370	2285
1200	...	205	275	410	620	1030	1715
1250	...	180	245	365	545	910	1515
1300	...	140	185	275	410	685	1145
1350	...	105	140	205	310	515	860
1400	...	75	100	150	225	380	630
1450	...	60	80	115	175	290	485
1500	...	40	55	85	125	205	345

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TABLE 2-3.16 RATINGS FOR GROUP 3.16 MATERIALS

Nominal Designation	Forgings	Castings	Plates
35Ni–19Cr–1¼Si	B 511 Gr. N08330 (1)(2)		B 536 Gr. N08330 (1)

NOTES:
(1) Use solution annealed material only.
(2) The chemical composition, mechanical properties, heat treating requirements, and grain size requirements shall conform to the applicable ASTM specification. The manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	150	300	400	600	900	1500	2500
−20 to 100	275	720	960	1440	2160	3600	6000
200	245	635	850	1270	1910	3180	5300
300	225	590	785	1175	1765	2940	4900
400	200	550	735	1105	1655	2760	4600
500	170	525	700	1050	1575	2630	4380
600	140	500	670	1005	1505	2510	4180
650	125	490	655	980	1470	2450	4080
700	110	480	645	965	1445	2410	4020
750	95	470	625	940	1410	2350	3920
800	80	465	620	925	1390	2315	3860
850	65	455	605	905	1360	2270	3780
900	50	445	590	885	1330	2215	3690
950	35	385	515	775	1160	1930	3220
1000	20	365	485	725	1090	1820	3030
1050	...	310	410	615	925	1545	2570
1100	...	240	320	480	720	1205	2005
1150	...	185	245	370	555	925	2545
1200	...	145	195	290	435	725	1210
1250	...	115	155	235	350	585	975
1300	...	95	130	190	285	480	795
1350	...	75	100	150	220	370	615
1400	...	55	75	110	165	280	465
1450	...	45	60	95	140	230	385
1500	...	35	45	70	100	170	285

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TABLE 3 PERMISSIBLE IMPERFECTIONS IN FLANGE FACING FINISH FOR RAISED FACE AND LARGE MALE AND FEMALE FLANGES

NPS	Maximum Radial Projection of Imperfections Which Are No Deeper Than the Bottom of the Serrations, in.	Maximum Depth and Radial Projection of Imperfections Which Are Deeper Than the Bottom of the Serrations, in.
½	0.12	0.06
¾	0.12	0.06
1	0.12	0.06
1¼	0.12	0.06
1½	0.12	0.06
2	0.12	0.06
2½	0.12	0.06
3	0.18	0.06
3½	0.25	0.12
4	0.25	0.12
5	0.25	0.12
6	0.25	0.12
8	0.31	0.18
10	0.31	0.18
12	0.31	0.18
14	0.31	0.18
16	0.38	0.18
18	0.50	0.25
20	0.50	0.25
24	0.50	0.25

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FLANGED FITTINGS

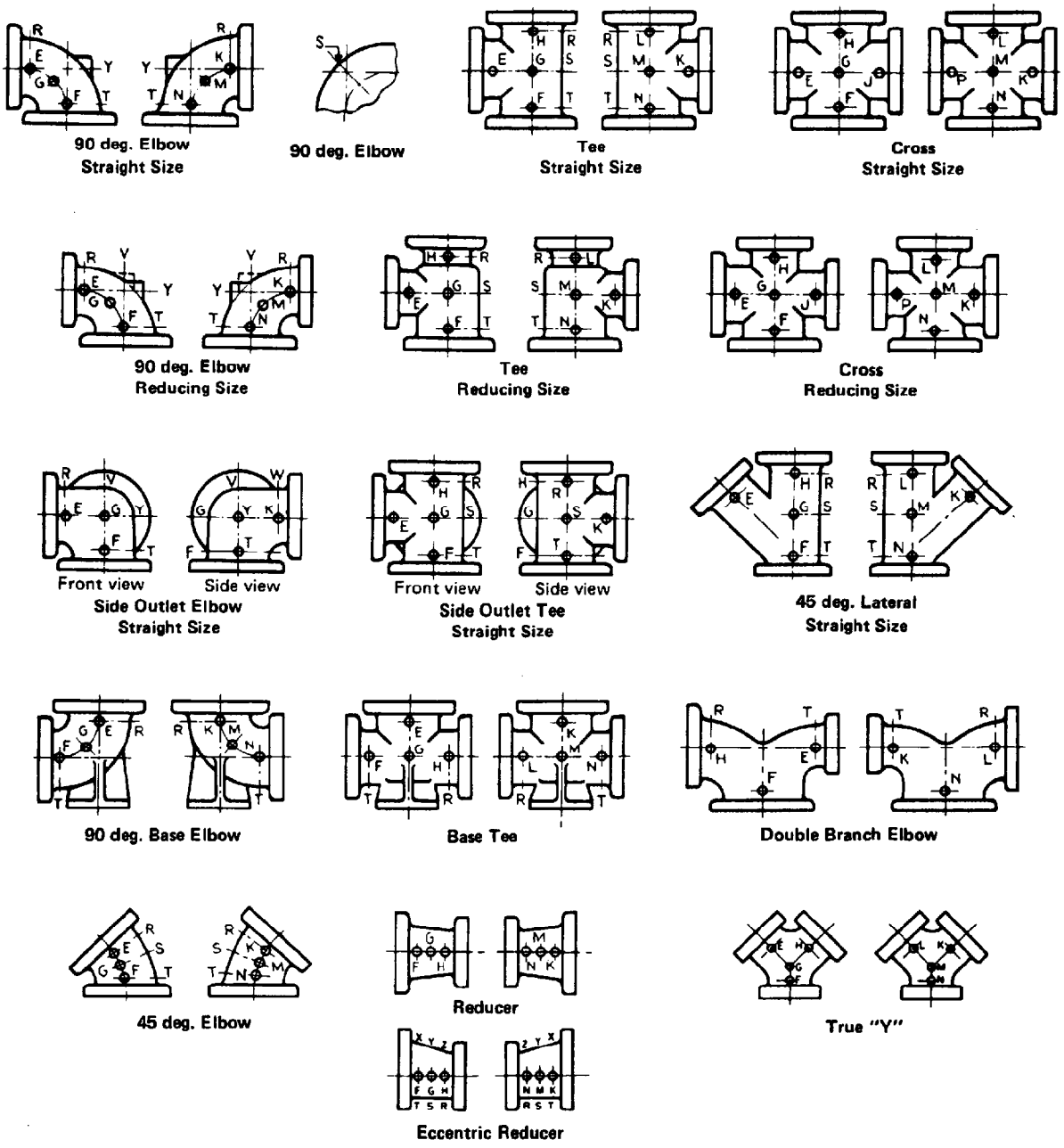

FIG. 1 METHOD OF DESIGNATING LOCATION OF AUXILIARY CONNECTIONS WHEN SPECIFIED[1]

NOTE:
(1) The above sketches show views of the same fitting and represent fittings with symmetrcial shapes, with the exception of the side outlet elbow and the side outlet tee (straight sizes). Sketches are illustrative only and do not imply required design (see para. 6.12).

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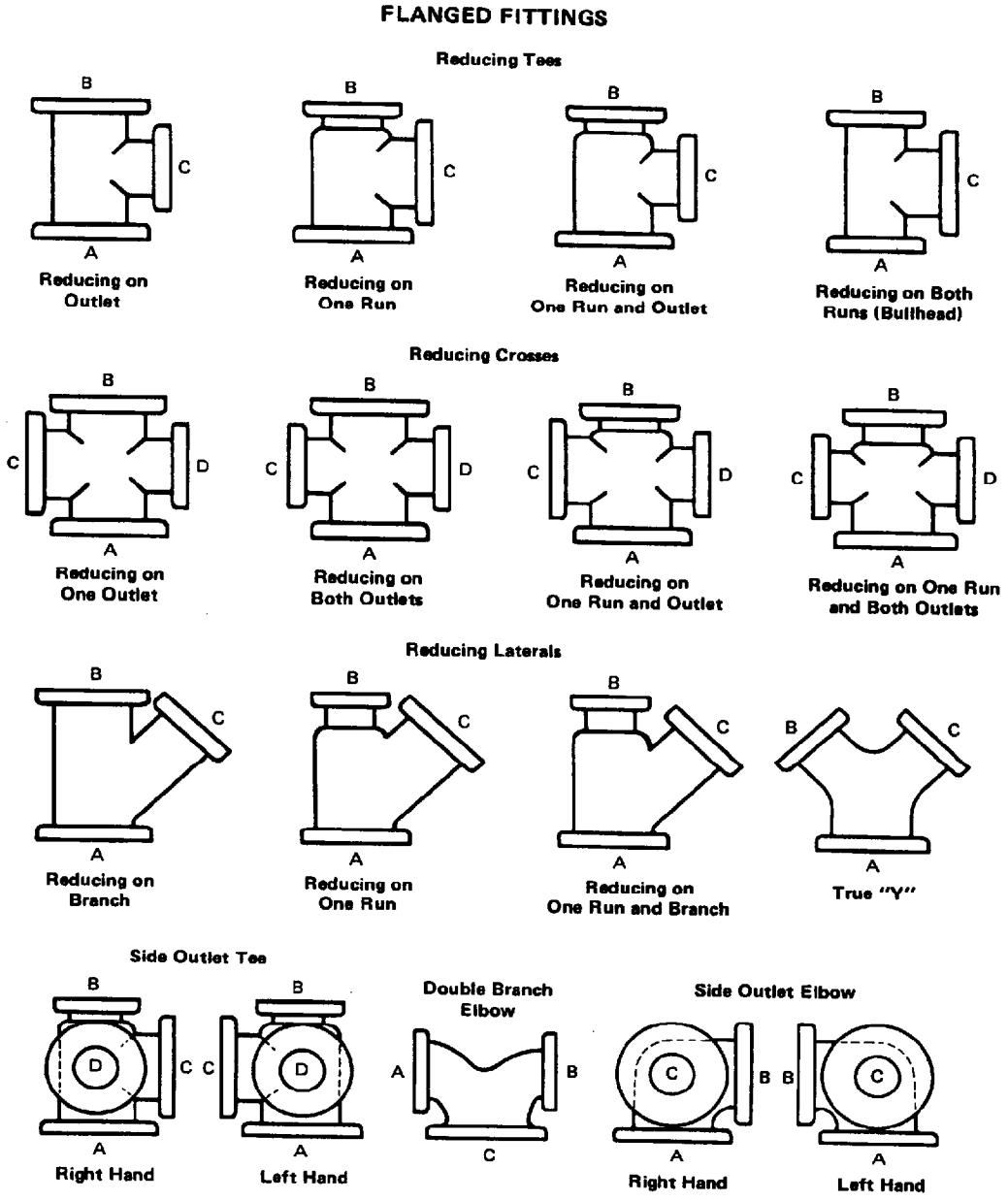

FIG. 2 METHOD OF DESIGNATING OUTLETS OF REDUCING FITTINGS IN SPECIFICATIONS[1-3]

NOTES:

(1) The largest opening establishes the basic size of a reducing fitting. The largest opening is named first, except that for bull head tees which are reducing on both runs and for double branch elbows where both branches are reducing, the outlet is the largest opening and named last in both cases.

(2) In designating the openings of reducing fittings, they should be read in the order indicated by the sequence of the letters A, B, C, and D. In designating the outlets of side outlet reducing fittings, the side outlet is named last, and in the case of the cross which is not shown, the side outlet is designated by the letter E.

(3) Sketches are illustrative only and do not imply required design (see para. 3.2).

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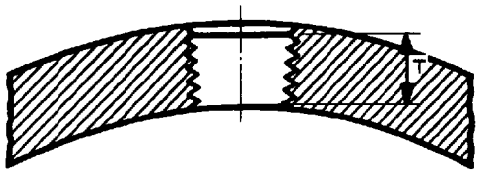

FIG. 3 THREAD LENGTH FOR CONNECTION TAPPING[1]

Connection size, NPS	3/8	1/2	3/4	1	1 1/4	1 1/2	2
Thread length T, in. [Note (2)]	0.41	0.53	0.55	0.68	0.71	0.72	0.76

NOTES:
(1) See paras. 6.12.1, 6.12.3, and 6.12.4.
(2) In no case shall the effective length of thread T be less than that shown in Table above. These lengths are equal to the effective thread length of external pipe threads (ASME B1.20.1).

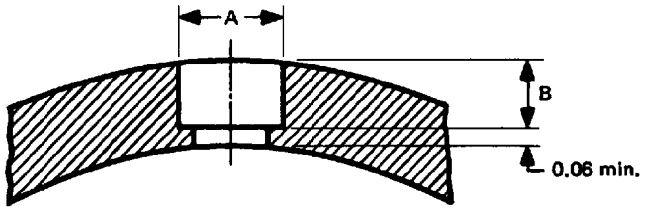

FIG. 4 SOCKET WELDING FOR CONNECTIONS[1]

Connection size, NPS	3/8	1/2	3/4	1	1 1/4	1 1/2	2
Minimum diameter of socket A, in.	0.69	0.86	1.06	1.33	1.68	1.92	2.41
Minimum depth B, in.	0.19	0.19	0.25	0.25	0.25	0.25	0.31

NOTE:
(1) See paras. 6.12.2.1, 6.12.3, and 6.12.4.

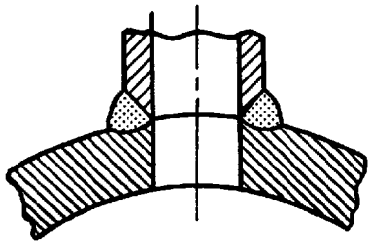

FIG. 5 BUTT WELDING FOR CONNECTIONS[1]

NOTE:
(1) See paras. 6.12.2.2, and 6.12.4.

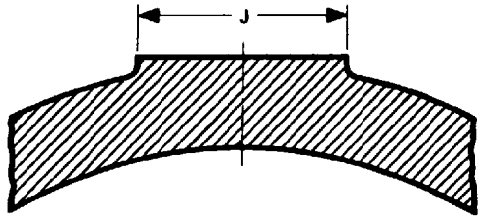

FIG. 6 BOSSES FOR CONNECTIONS[1]

Connection size, NPS	3/8	1/2	3/4	1	1 1/4	1 1/2	2
Minimum boss diameter J, in.	1.25	1.50	1.75	2.12	2.50	2.75	3.38

NOTE:
(1) See para. 6.12.3.

END FLANGE FACINGS
Flange Thickness and Center-to-End Dimensions
Classes 150 and 300

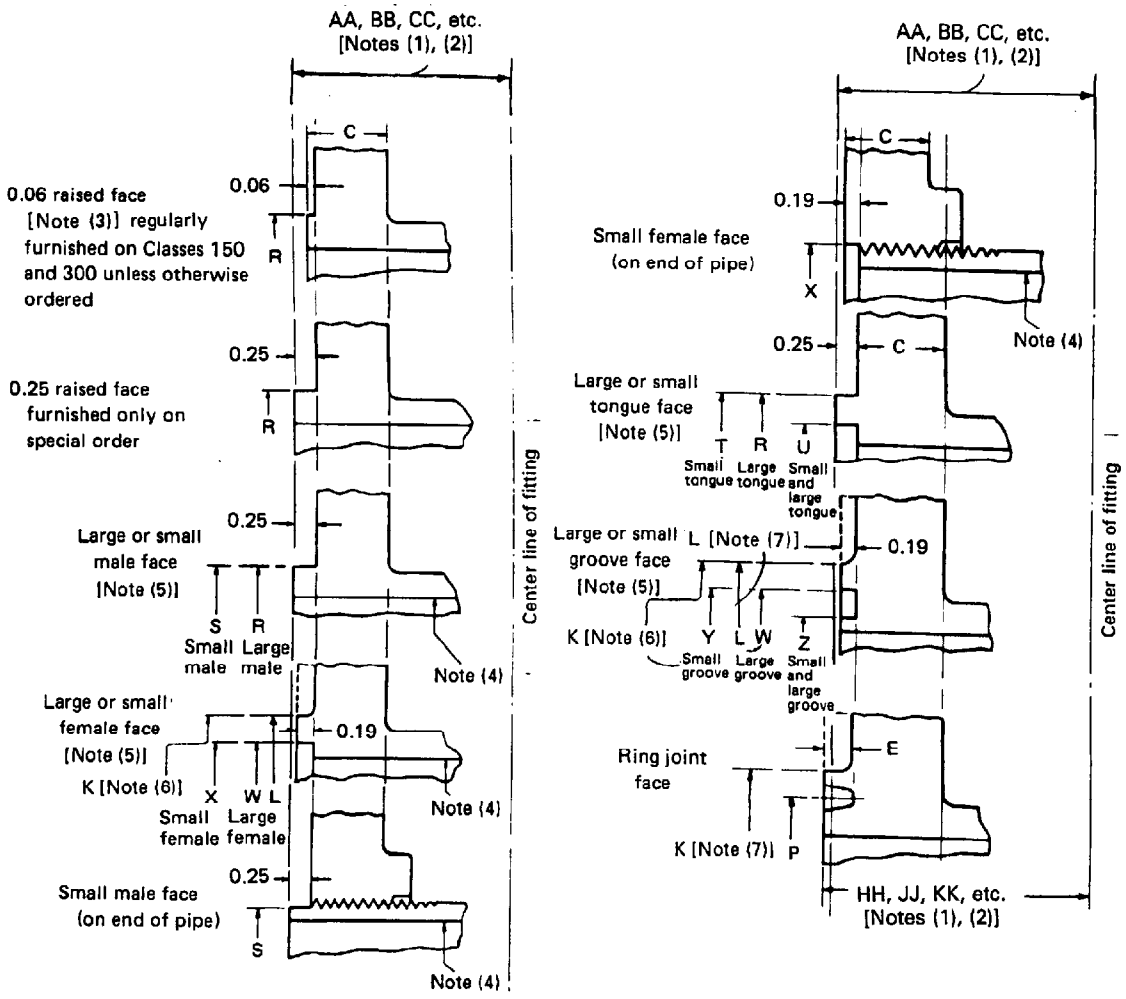

FIG. 7 END FLANGE FACINGS AND THEIR RELATIONSHIP TO FLANGE THICKNESS AND CENTER-TO-END AND END-TO-END DIMENSIONS[1,3]

(Figure continues on next page; Notes follow at end of Figure)

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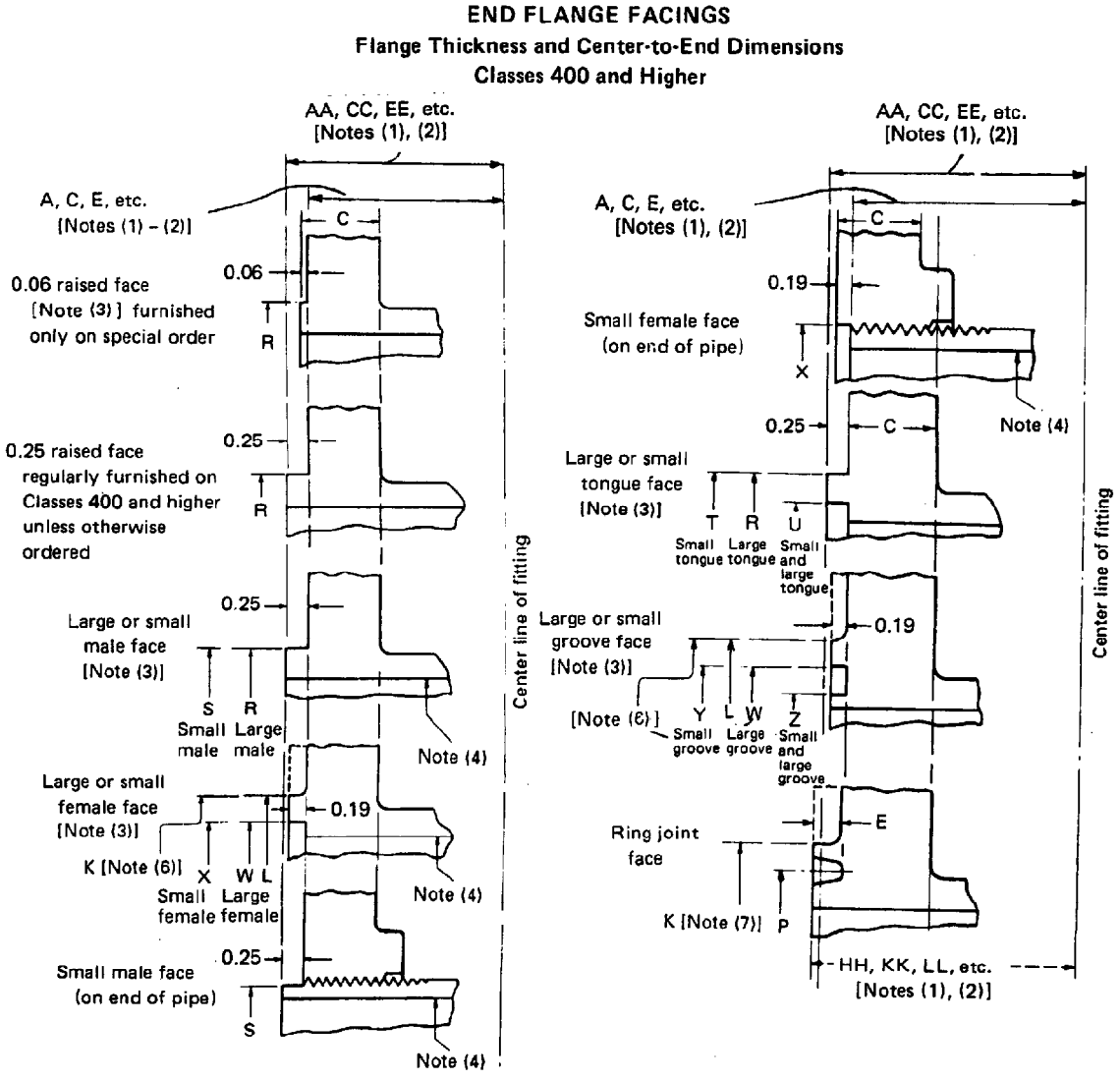

FIG. 7 END FLANGE FACINGS AND THEIR RELATIONSHIP TO FLANGE THICKNESS AND CENTER-TO-END AND END-TO-END DIMENSIONS[1,3] (CONT'D)

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END FLANGE FACINGS
Flange Thickness and End-to-End Dimensions
Lapped Joints

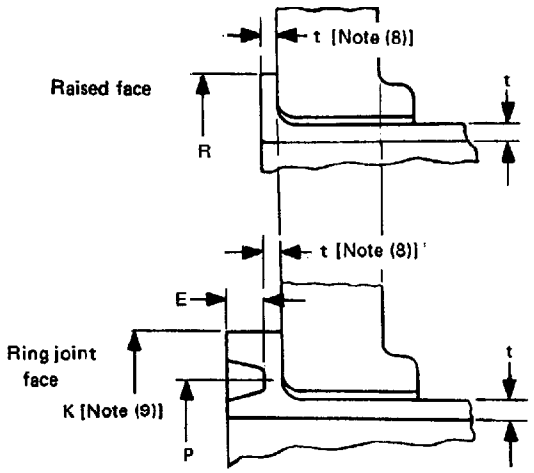

FIG. 7 END FLANGE FACINGS AND THEIR RELATIONSHIP TO FLANGE THICKNESS AND CENTER-TO-END AND END-TO-END DIMENSIONS[1,3] (CONT'D)

NOTES:
(1) See paras. 6.2 and 6.4.1.
(2) See Tables 10, 13, 16, 19, 22, 25, and 28.
(3) See Table 4 for dimensions of facings (other than ring joint) and Table 5 for ring joint facing.
(4) For small male and female joints, care should be taken in the use of these dimensions to insure that the inside diameter of fitting or pipe is small enough to permit sufficient bearing surface to prevent the crushing of the gasket. (See Table 4.) This applies particularly on lines where the joint is made on the end of the pipe. Threaded companion flanges for small male and female joints are furnished with plain face and are threaded with American National Standard Locknut Thread (NPSL).
(5) Large male and female faces and large tongue and groove are not applicable to Class 150 because of potential dimensional conflicts.
(6) See Table 4.
(7) See Table 5.
(8) See para. 6.4.2.
(9) See para. 6.4.2.5 and Table 5.

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STD·ASME B16·5-ENGL 1996 ■ 0759670 0579452 066 ■

TABLE 4 DIMENSIONS OF FACINGS[1-4] (OTHER THAN RING JOINTS, ALL PRESSURE RATING CLASSES)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1
	Outside Diameter					Outside Diameter				Height			Minimum [(6), (7)] Outside Diameter of Raised Portion		
Nominal Pipe Size	Raised Face Large Male and Large Tongue R	Small Male (5) S	Small Tongue T	Inside Diameter of Large and Small Tongue U	Inside Diameter of Small Male	Large Female and Large Groove W	Small Female (5) X	Small Groove Y	Inside Diameter of Large and Small Groove Z	Raised Face	Large and Small Male and Tongue	Depth of Groove or Female	Small Female and Groove K	Large Female and Groove L	Nominal Pipe Size
½	1.38	0.72	1.38	1.00		1.44	0.78	1.44	0.94				1.75	1.81	½
¾	1.69	0.94	1.69	1.31		1.75	1.00	1.75	1.25				2.06	2.12	¾
1	2.00	1.19	1.88	1.50		2.06	1.25	1.94	1.44				2.25	2.44	1
1¼	2.50	1.50	2.25	1.88		2.56	1.56	2.31	1.81				2.62	2.94	1¼
1½	2.88	1.75	2.50	2.12		2.94	1.81	2.56	2.06				2.88	3.31	1½
2	3.62	2.25	3.25	2.88		3.69	2.31	3.31	2.81				3.62	4.06	2
2½	4.12	2.69	3.75	3.38		4.19	2.75	3.81	3.31				4.12	4.56	2½
3	5.00	3.31	4.62	4.25		5.06	3.38	4.69	4.19				5.00	5.44	3
3½	5.50	3.81	5.12	4.75		5.56	3.88	5.19	4.69				5.50	5.94	3½
4	6.19	4.31	5.69	5.19		6.25	4.38	5.75	5.12				6.19	6.62	4
5	7.31	5.38	6.81	6.31		7.38	5.44	6.88	6.25				7.31	7.75	5
6	8.50	6.38	8.00	7.50		8.56	6.44	8.06	7.44				8.50	8.94	6
8	10.62	8.38	10.00	9.38		10.69	8.44	10.06	9.31				10.62	11.06	8
10	12.75	10.50	12.00	11.25		12.81	10.56	12.06	11.19				12.75	13.19	10
12	15.00	12.50	14.25	13.50		15.06	12.56	14.31	13.44				15.00	15.44	12
14	16.25	13.75	15.50	14.75		16.31	13.81	15.56	14.69				16.25	16.69	14
16	18.50	15.75	17.62	16.75		18.56	15.81	17.69	16.69				18.50	18.94	16
18	21.00	17.75	20.12	19.25		21.06	17.81	20.19	19.19				21.00	21.44	18
20	23.00	19.75	22.00	21.00		23.06	19.81	22.06	20.94				23.00	23.44	20
24	27.25	23.75	26.25	25.25		27.31	23.81	26.31	25.19				27.25	27.69	24

See Note (5) — Inside Diameter of Small Male

See Notes (4) and (8) — Raised Face

See Notes (4) and (9) — Large and Small Male and Tongue

See Notes (4) and (10) — Depth of Groove or Female

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TABLE 4 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) For facing requirements for flanges and flanged fittings, see paras. 6.3 and 6.4 and Fig. 7.
(2) For facing requirements for lapped joints, see para. 6.4.2 and Fig.7.
(3) For facing tolerances, see para. 7.2.
(4) See para. 6.4.2 and Fig. 7 for thickness and outside diameters of laps.
(5) For small male and female joints, care should be taken in the use of these dimensions to insure that the inside diameter of fitting or pipe is small enough to permit sufficient bearing surface to prevent the crushing of the gasket. This applies particularly on lines where the joint is made on the end of the pipe. Inside diameter of fitting should match inside diamter of pipe as specified by purchaser. Threaded companion flanges for small male and female joints are furnished with plain face and are threaded with American National Standard Locknut Thread (NPSL).
(6) Raised portion of full face may be furnished unless otherwise specified on order.
(7) Large male and female faces and large tongue and groove are not applicable to Class 150 because of potential dimensional conflicts.
(8) Height of raised face is either 0.06 in. or 0.25 in. See para. 6.4.1.
(9) Height of large and small male and tongue is 0.25 in.
(10) Depth of groove or female is 0.19 in.

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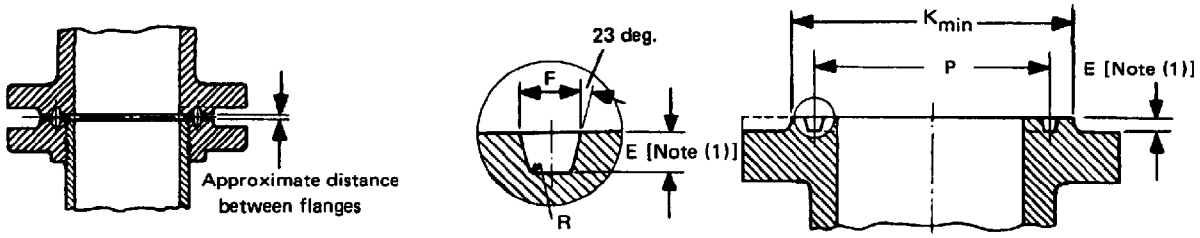

TABLE 5 DIMENSIONS OF RING JOINT FACINGS[2–4] ALL PRESSURE RATING CLASSES)

1	2	3	4	5	6	7	8	9	10	11	12
Nominal Pipe Size								Groove Dimensions			
150	300	400 (5)	600	900 (6)	1500	2500	Groove Number	Pitch Diameter P	Depth E(1)	Width F	Radius at Bottom R
...	½	...	½	...	...	...	R11	1.344	0.219	0.281	0.03
...	...	...	...	...	½	...	12	1.562	0.250	0.344	0.03
...	¾	...	¾	...	...	½	13	1.688	0.250	0.344	0.03
...	...	...	...	...	¾	...	14	1.750	0.250	0.344	0.03
1	...	...	...	...	...	...	15	1.875	0.250	0.344	0.03
...	1	...	1	...	1	¾	16	2.000	0.250	0.344	0.03
1¼	...	...	...	...	...	...	17	2.250	0.250	0.344	0.03
...	1¼	...	1¼	...	1¼	1	18	2.375	0.250	0.344	0.03
1½	...	...	...	...	...	...	19	2.562	0.250	0.344	0.03
...	1½	...	1½	...	1½	...	20	2.688	0.250	0.344	0.03
...	...	...	...	...	...	1¼	21	2.844	0.312	0.469	0.03
2	...	...	...	...	...	...	22	3.250	0.250	0.344	0.03
...	2	...	2	...	...	1½	23	3.250	0.312	0.469	0.03
...	...	...	...	...	2	...	24	3.750	0.312	0.469	0.03
2½	...	...	...	...	...	...	25	4.000	0.250	0.344	0.03
...	2½	...	2½	...	...	2	26	4.000	0.312	0.469	0.03
...	...	...	...	...	2½	...	27	4.250	0.312	0.469	0.03
...	...	...	...	...	...	2½	28	4.375	0.375	0.531	0.06
3	...	...	...	...	...	...	29	4.500	0.250	0.344	0.03
...	(7)	...	(7)	...	...	...	30	4.625	0.312	0.469	0.03
...	3 (7)	...	3 (7)	3	...	...	31	4.875	0.312	0.469	0.03
...	...	...	...	...	...	3	32	5.000	0.375	0.531	0.06
3½	...	...	...	...	...	...	33	5.188	0.250	0.344	0.03
...	3½	...	3½	...	...	...	34	5.188	0.312	0.469	0.03
...	...	...	...	...	3	...	35	5.375	0.312	0.469	0.03
4	...	...	...	...	...	...	36	5.875	0.250	0.344	0.03
...	4	4	4	4	...	...	37	5.875	0.312	0.469	0.03
...	...	...	...	...	...	4	38	6.188	0.438	0.656	0.06
...	...	...	...	...	4	...	39	6.375	0.312	0.469	0.03
5	...	...	...	...	...	...	40	6.750	0.250	0.344	0.03
...	5	5	5	5	...	...	41	7.125	0.312	0.469	0.03
...	...	...	...	...	...	5	42	7.500	0.500	0.781	0.06
6	...	...	...	...	...	...	43	7.625	0.250	0.344	0.03
...	...	...	...	...	5	...	44	7.625	0.312	0.469	0.03
...	6	6	6	6	...	...	45	8.312	0.312	0.469	0.03

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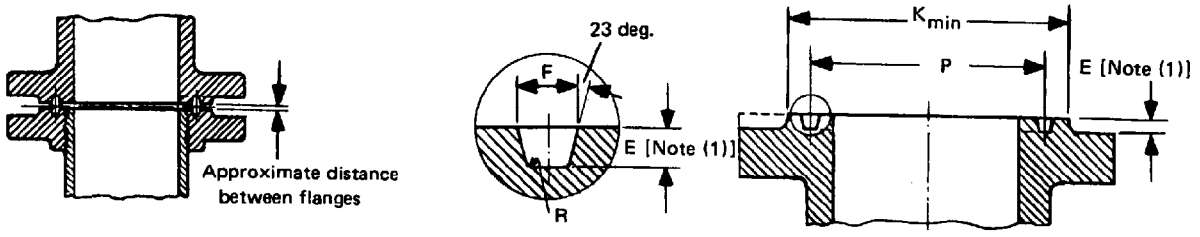

TABLE 5 DIMENSIONS OF RING JOINT FACINGS[2-4] (ALL PRESSURE RATING CLASSES) (CONT'D)

13	14	15	16	17	18	19	20	21	22	23	24
Diameter of Raised Portion K					Approximate Distance Between Flanges						
150	300, 400, 600	900	1500	2500	150	300	400	600	900	1500	2500
...	2.00	...	...	...	...	0.12	...	0.12	...	...	...
...	...	...	2.38	...	...	...	...	...	...	0.16	...
...	2.50	...	...	2.56	...	0.16	...	0.16	...	...	0.16
...	...	...	2.62	...	...	...	...	...	...	0.16	...
2.50	...	...	...	...	0.16	...	...	...	...	...	...
...	2.75	...	2.81	2.88	...	0.16	...	0.16	...	0.16	0.16
2.88	...	...	...	...	0.16	...	...	...	...	...	...
...	3.12	...	3.19	3.25	...	0.16	...	0.16	...	0.16	0.16
3.25	...	...	...	...	0.16	...	...	...	...	...	...
...	3.56	...	3.62	...	...	0.16	...	0.16	...	0.16	...
...	...	...	...	4.00	...	...	...	...	...	...	0.12
4.00	...	...	...	...	0.16	...	...	...	...	...	...
...	4.25	...	...	4.50	...	0.22	...	0.19	...	...	0.12
...	...	...	4.88	...	...	...	...	...	...	0.12	...
4.75	...	...	...	...	0.16	...	...	...	...	...	...
...	5.00	...	...	5.25	...	0.22	...	0.19	...	...	0.12
...	...	...	5.38	...	...	...	...	...	...	0.12	...
...	...	...	...	5.88	...	...	...	...	...	...	0.12
5.25	...	...	...	...	0.16	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...
...	5.75	6.12	...	...	...	0.22	...	0.19	0.16	...	...
...	...	...	...	6.62	...	...	...	...	...	...	0.12
6.06	...	...	...	...	0.16	...	...	...	...	...	...
...	6.25	...	...	...	...	0.22	...	0.19	...	...	...
...	...	...	6.62	...	...	...	...	...	...	0.12	...
6.75	...	...	...	...	0.16	...	...	...	...	...	...
...	6.88	7.12	...	...	...	0.22	0.22	0.19	0.16	...	...
...	...	...	...	8.00	...	...	...	...	...	...	0.16
...	...	...	7.62	...	...	...	...	...	...	0.12	...
7.62	...	...	...	...	0.16	...	...	...	...	...	...
...	8.25	8.50	...	...	...	0.22	0.22	0.19	0.16	...	...
...	...	...	...	9.50	...	...	...	...	...	...	0.16
8.62	...	...	...	...	0.16	...	...	...	...	...	...
...	...	...	9.00	...	...	...	...	...	...	0.12	...
...	9.50	9.50	...	...	...	0.22	0.22	0.19	0.16	...	...

(Table 5 continues on next page; Notes and tolerances follow at end of Table)

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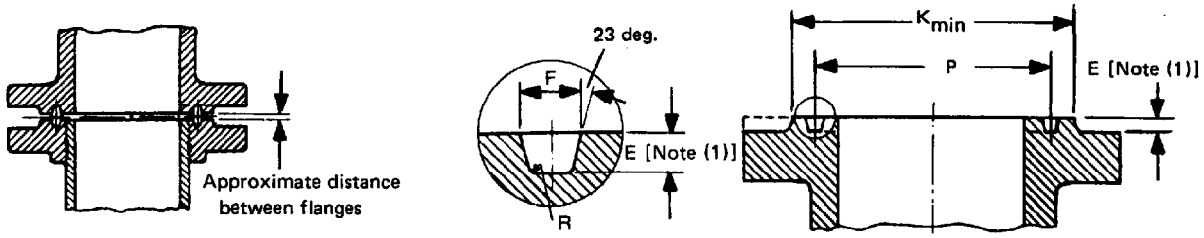

TABLE 5 DIMENSIONS OF RING JOINT FACINGS[2–4] (ALL PRESSURE RATING CLASSES)

1	2	3	4	5	6	7	8	9	10	11	12
Nominal Pipe Size								Groove Dimensions			
150	300	400 (5)	600	900 (6)	1500	2500	Groove Number	Pitch Diameter P	Depth E(1)	Width F	Radius at Bottom R
...	...	...	...	...	6	...	46	8.312	0.375	0.531	0.06
...	...	...	...	...	...	6	47	9.000	0.500	0.781	0.06
8	...	...	...	...	...	...	48	9.750	0.250	0.344	0.03
...	8	8	8	8	...	...	49	10.625	0.312	0.469	0.03
...	...	...	...	...	8	...	50	10.625	0.438	0.656	0.06
...	...	...	...	...	...	8	51	11.000	0.562	0.906	0.06
10	...	...	...	...	...	...	52	12.000	0.250	0.344	0.03
...	10	10	10	10	...	...	53	12.750	0.312	0.469	0.03
...	...	...	...	...	10	...	54	12.750	0.438	0.656	0.06
...	...	...	...	...	...	10	55	13.500	0.688	1.188	0.09
12	...	...	...	...	...	...	56	15.000	0.250	0.344	0.03
...	12	12	12	12	...	...	57	15.000	0.312	0.469	0.03
...	...	...	...	...	12	...	58	15.000	0.562	0.906	0.06
14	...	...	...	...	...	...	59	15.625	0.250	0.344	0.03
...	...	...	...	...	...	12	60	16.000	0.688	1.312	0.09
...	14	14	14	...	...	...	61	16.500	0.312	0.469	0.03
...	...	...	...	14	...	...	62	16.500	0.438	0.656	0.06
...	...	...	...	...	14	...	63	16.500	0.625	1.062	0.09
16	...	...	...	...	...	...	64	17.875	0.250	0.344	0.03
...	16	16	16	...	...	...	65	18.500	0.312	0.469	0.03
...	...	...	...	16	...	...	66	18.500	0.438	0.656	0.06
...	...	...	...	...	16	...	67	18.500	0.688	1.188	0.09
18	...	...	...	...	...	...	68	20.375	0.250	0.344	0.03
...	18	18	18	...	...	...	69	21.000	0.312	0.469	0.03
...	...	...	...	18	...	...	70	21.000	0.500	0.781	0.06
...	...	...	...	...	18	...	71	21.000	0.688	1.188	0.09
20	...	...	...	...	...	...	72	22.000	0.250	0.344	0.03
...	20	20	20	...	...	...	73	23.000	0.375	0.531	0.06
...	...	...	...	20	...	...	74	23.000	0.500	0.781	0.06
...	...	...	...	...	20	...	75	23.000	0.688	1.312	0.09
24	...	...	...	...	...	...	76	26.500	0.250	0.344	0.03
...	24	24	24	...	...	...	77	27.250	0.438	0.656	0.06
...	...	...	...	24	...	...	78	27.250	0.625	1.062	0.09
...	...	...	...	...	24	...	79	27.250	0.812	1.438	0.09

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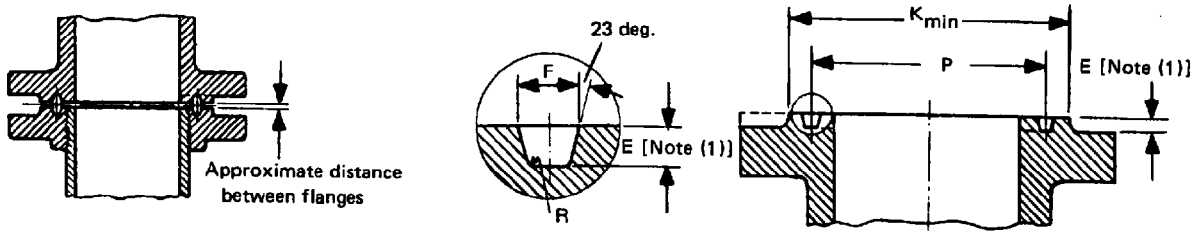

TABLE 5 DIMENSIONS OF RING JOINT FACINGS[2-4] (ALL PRESSURE RATING CLASSES) (CONT'D)

13	14	15	16	17	18	19	20	21	22	23	24
Diameter of Raised Portion K					Approximate Distance Between Flanges						
150	300, 400, 600	900	1500	2500	150	300	400	600	900	1500	2500
...	...	...	9.75	...	...	...	...	...	...	0.12	
...	...	...	...	11.00	...	...	...	...	...	...	0.16
10.75	...	...	...	...	0.16	...	...	...	...	...	...
...	11.88	12.12	...	...	...	0.22	0.22	0.19	0.16	...	...
...	...	...	12.50	...	...	...	...	...	...	0.16	...
...	...	...	...	13.38	...	...	...	...	...	...	0.19
13.00	...	...	...	...	0.16	...	...	...	...	...	...
...	14.00	14.25	...	...	...	0.22	0.22	0.19	0.16	...	...
...	...	...	14.62	...	...	...	...	...	...	0.16	...
...	...	...	...	16.75	...	...	...	...	...	...	0.25
16.00	...	...	...	...	0.16	...	...	...	...	...	...
...	16.25	16.50	...	...	...	0.22	0.22	0.19	0.16	...	...
...	...	...	17.25	...	...	...	...	...	...	0.19	...
16.75	...	...	...	...	0.12	...	...	...	...	...	...
...	...	...	...	19.50	...	...	...	...	...	...	0.31
...	18.00	...	...	...	...	0.22	0.22	0.19	...	...	...
...	...	18.38	...	...	...	...	...	...	0.16	...	...
...	...	...	19.25	...	...	...	...	...	...	0.22	...
19.00	...	...	...	...	0.12	...	...	...	...	...	...
...	20.00	...	...	...	...	0.22	0.22	0.19	...	...	...
...	...	20.62	...	...	...	...	...	...	0.16	...	...
...	...	...	21.50	...	...	...	...	...	...	0.31	...
21.50	...	...	...	...	0.12	...	...	...	...	...	...
...	22.62	...	...	...	...	0.22	0.22	0.19	...	...	...
...	...	23.38	...	...	...	...	...	...	0.19	...	...
...	...	...	24.12	...	...	...	...	...	...	0.31	...
23.50	...	...	...	...	0.12	...	...	...	...	...	...
...	25.00	...	...	...	...	0.22	0.22	0.19	...	...	...
...	...	25.50	...	...	...	...	...	...	0.19	...	...
...	...	...	26.50	...	...	...	...	...	...	0.38	...
28.00	...	...	...	...	0.12	...	...	...	...	...	...
...	29.50	...	...	...	...	0.25	0.25	0.22	...	...	...
...	...	30.38	...	...	...	...	...	...	0.22	...	...
...	...	...	31.25	...	...	...	...	...	...	0.44	...

(Notes and tolerances follow on next page)

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TABLE 5 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) Height of raised portion is equal to the depth of groove dimension E, but is not subjected to the tolerances for E. Former full-face contour may be used.
(2) For facing requirements for flanges and flanged fittings, see para. 6.4.1 and Fig. 7.
(3) For facing requirements for lapped joints, see para. 6.4.2 and Fig. 7.
(4) See para. 4.1.7 for marking requirements.
(5) Use Class 600 in sizes NPS ½ to NPS 3½ for Class 400.
(6) Use Class 1500 in sizes NPS ½ to NPS 2½ for Class 900.
(7) For ring joints with lapped flanges in Classes 300 and 600, ring and groove number R30 are used instead of R31.

TOLERANCES:

E	(depth) +0.016, −0
F	(width) ±0.008
P	(pitch diameter) ±0.005
R	(radius at bottom)
	R ≤ 0.06 +0.03, −0
	R > 0.06 ±0.03
23 deg.	(angle) ± ½ deg.

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WELDING ENDS
(Welding Neck Flanges, No Backing Rings)

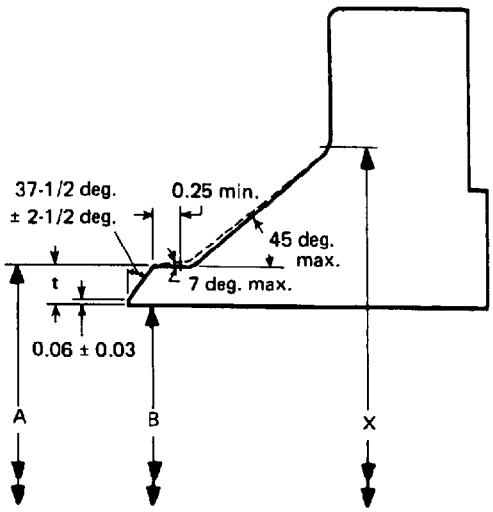

FIG. 8 BEVEL FOR WALL THICKNESSES t FROM 0.19 in. TO 0.88 in., INCLUSIVE[1-3]

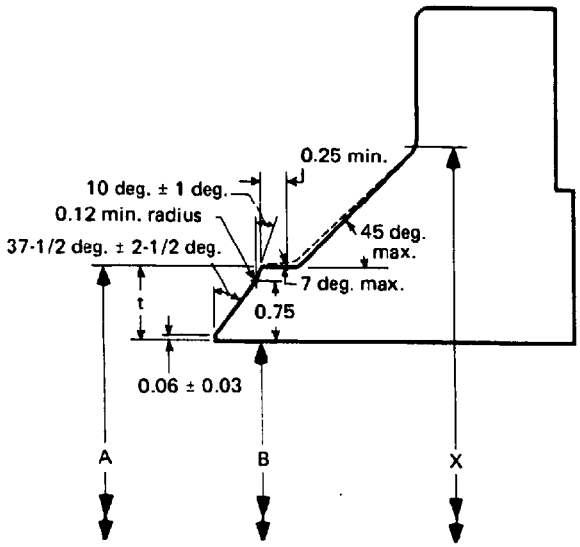

FIG. 9 BEVEL FOR WALL THICKNESSES t GREATER THAN 0.88 in.[1-3]

A = nominal outside diameter of pipe, in.
B = nominal inside diameter of pipe, in.
t = nominal wall thickness of pipe, in.

NOTES:
(1) See paras. 6.7, 6.8, and 7.4 for details and tolerances.
(2) See Figs. 10 and 11 for additional details of welding ends.
(3) When the thickness of the hub at the bevel is greater than that of the pipe to which the flange is joined and the additional thickness is provided on the outside diameter, a taper weld having a slope not exceeding 1 to 3 may be employed or, alternatively, the greater outside diameter may be tapered, at the same maximum slope or less, from a point on the welding bevel equal to the outside diameter of the mating pipe. Similarly, when the greater thickness is provided on the inside of the flange, it shall be taper-bored from the welding end at a slope not exceeding 1 to 3.

When flanges covered by this Standard are intended for services with light wall, higher strength pipe, the thickness of the hub at the bevel may be greater than that of the pipe to which the flange is joined. Under these conditions a single taper hub may be provided, and the outside diameter of the hub at the base (dimension X) may also be modified.

The additional thickness may be provided on either inside or outside or partially on each side, but the total additional thickness shall not exceed one-half times the nominal wall thickness of intended mating pipe. See Figs. 12, 13, and 14.

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WELDING ENDS
(Welding Neck Flanges With Backing Rings)

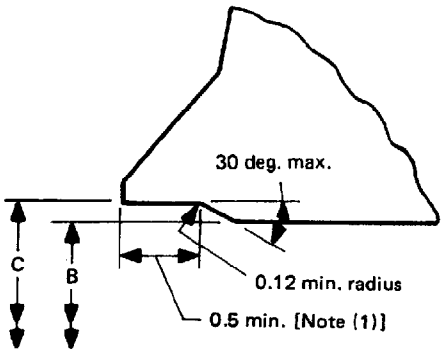

FIG. 10 INSIDE CONTOUR FOR USE WITH RECTANGULAR BACKING RING[1-4]

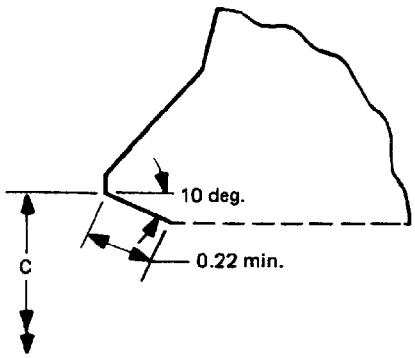

FIG. 11 INSIDE CONTOUR FOR USE WITH TAPER BACKING RING[1-4]

A = nominal outside diameter of welding end, in.
B = nominal inside diameter of pipe, in.
= A − 2t
C = A − 0.031 − 1.75t − 0.010 in.
t = nominal wall thickness of pipe, in.
0.031 = minus tolerance on outside diameter of pipe, in., to ASTM A 106, etc.
1.75t = 87½% of nominal wall (permitted by ASTM A 106, etc.) multiplied by two to convert into terms of diameter
0.010 = plus tolerance on diameter C, in. See para. 7.5.3.

NOTES:
(1) 0.5 in. depth based on use of 0.75 in. wide backing ring.
(2) See paras. 6.7, 6.8, and 7.5 for details and tolerances.
(3) See Figs. 8 and 9 for welding end details of welding neck flanges.
(4) For dimensions, see Table 6.

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WELDING ENDS
(Welding Neck Flanges)
ADDITIONAL THICKNESS FOR
WELDING TO HIGHER STRENGTH PIPE

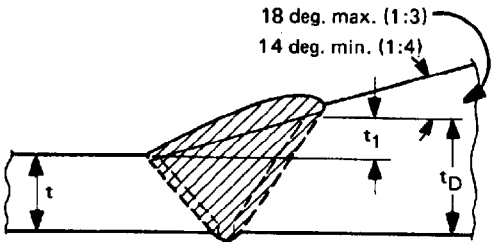

FIG. 12 BEVEL FOR OUTSIDE THICKNESS[1-4]

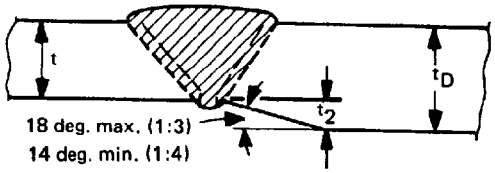

FIG. 13 BEVEL FOR INSIDE THICKNESS[1-3]

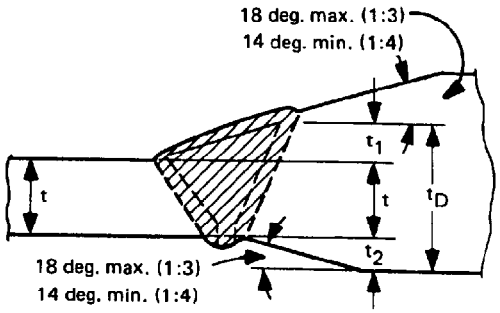

FIG. 14 BEVEL FOR COMBINED THICKNESS[1-4]

NOTES:
(1) When the materials joined have equal minimum specified yield strength, there shall be no restriction on the minimum slope.
(2) Neither t_1, t_2, nor their sum $t_1 + t_2$ shall exceed 0.5t.
(3) When the minimum specified yield strengths of the sections to be joined are unequal, the value of t_D shall at least equal times the ratio of minimum specified yield strength of the pipe to minimum specified yield strength of the flange.
(4) Welding shall be in accordance with the applicable code.

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TABLE 6 DIMENSIONS OF WELDING ENDS
(See Figs. 8 Through 14, Inclusive)

1	2	3	4	5	6
Nominal Pipe Size	Wall Thickness (1) or Schedule	A (2)	B (2)	C [(2)–(4)]	t [(2),(4)]
2½	40	2.88	2.469	2.479	0.203
	80		2.323	2.351	0.276
	160		2.125	2.178	0.375
	XXS		1.771	1.868	0.552
3	40	3.50	3.068	3.081	0.216
	80		2.900	2.934	0.300
	160		2.624	2.692	0.438
	XXS		2.300	2.409	0.600
3½	40	4.00	3.548	3.564	0.226
	80		3.364	3.402	0.316
4	40	4.50	4.026	4.044	0.237
	80		3.826	3.869	0.337
	120		3.624	3.692	0.438
	160		3.438	3.530	0.531
	XXS		3.152	3.279	0.674
5	40	5.56	5.047	5.070	0.258
	80		4.813	4.866	0.375
	120		4.563	4.647	0.500
	160		4.313	4.428	0.625
	XXS		4.063	4.209	0.750
6	40	6.62	6.065	6.094	0.280
	80		5.761	5.828	0.432
	120		5.501	5.600	0.562
	160		5.189	5.327	0.718
	XXS		4.897	5.072	0.864
8	40	8.62	7.981	8.020	0.322
	60		7.813	7.873	0.406
	80		7.625	7.709	0.500
	100		7.439	7.546	0.593
	120		7.189	7.327	0.718
	140		7.001	7.163	0.812
	XXS		6.875	7.053	0.875
	160		6.813	6.998	0.906
10	40	10.75	10.020	10.070	0.365
	60		9.750	9.834	0.500
	80		9.564	9.671	0.593
	100		9.314	9.452	0.718
	120		9.064	9.234	0.843
	140		8.750	8.959	1.000
	160		8.500	8.740	1.125
12	STD	12.75	12.000	12.053	0.375
	40		11.938	11.999	0.406
	XS		11.750	11.834	0.500
	60		11.626	11.725	0.562
	80		11.376	11.507	0.687
	100		11.064	11.234	0.843
	120		10.750	10.959	1.000
	140		10.500	10.740	1.125
	160		10.126	10.413	1.312

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TABLE 6 DIMENSIONS OF WELDING ENDS (CONT'D)
(See Figs. 8 Through 14, Inclusive)

1	2	3	4	5	6
Nominal Pipe Size	Wall Thickness (1) or Schedule	A (2)	B (2)	C [(2)–(4)]	t [(2),(4)]
	STD		13.250	13.303	0.375
	40		13.124	13.192	0.438
	XS		13.000	13.064	0.500
	60		12.814	12.921	0.593
14	80	14.00	12.500	12.646	0.750
	100		12.126	12.319	0.937
	120		11.814	12.046	1.093
	140		11.500	11.771	1.250
	160		11.188	11.498	1.406
	STD		15.250	15.303	0.375
	40		15.000	15.084	0.500
	60		14.688	14.811	0.656
	80		14.314	14.484	0.843
16	100	16.00	13.938	14.155	1.031
	120		13.564	13.827	1.218
	140		13.124	13.442	1.438
	160		12.814	13.171	1.593
	STD		17.250	17.303	0.375
	XS		17.000	17.084	0.500
	40		16.876	16.975	0.562
	60		16.500	16.646	0.750
18	80	18.00	16.126	16.319	0.937
	100		15.688	15.936	1.156
	120		16.250	15.553	1.375
	140		14.876	15.225	1.562
	160		14.438	14.842	1.781
	STD		19.250	19.303	0.375
	XS		19.000	19.084	0.500
	40		18.814	18.921	0.593
	60		18.376	18.538	0.812
20	80	20.00	17.938	18.155	1.031
	100		17.438	17.717	1.281
	120		17.000	17.334	1.500
	140		16.500	16.896	1.750
	160		16.064	16.515	1.968
	STD		23.250	23.303	0.375
	XS		23.000	23.084	0.500
	30		22.876	22.975	0.562
	40		22.626	22.757	0.687
	60		22.064	22.265	0.968
24	80	24.00	21.564	21.827	1.218
	100		20.938	21.280	1.531
	120		20.376	20.788	1.812
	140		19.876	20.350	2.062
	160		19.314	19.859	2.343

(Notes follow on next page)

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TABLE 6 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) Designations per Annexes B and C and ASME B36.10:
STD = standard wall thickness
XS = extra-strong wall thickness
XXS = double extra-strong wall thickness
(2) For tolerances, see para. 7.4.
(3) There is no fixed relation between ASME B16.5 pressure classes and pipe schedules.
(4) When the wall thickness is less than 0.562 in., it may be necessary to provide additional material by weld deposition in order to be able to machine to the dimension C.

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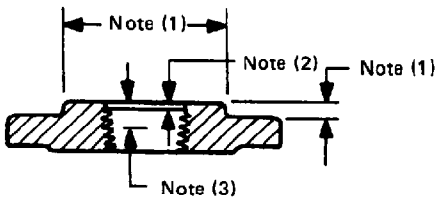
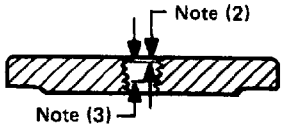
REDUCING THREADED AND SLIP-ON PIPE FLANGES





Blind Flange

TABLE 7 REDUCING THREADED AND SLIP-ON FLANGES FOR CLASSES 150 TO 2500

1	2	3	4	5	6
Nominal Pipe Size (4)	Smallest Size (1) of Reducing Outlet Requiring Hub Flanges	Nominal Pip Size (4)	Smallest Size (1) of Reducing Outlet Requiring Hub Flanges	Nominal Pipe Size (4)	Smallest Size (1) of Reducing Outlet Requiring Hub Flanges
1	½	3½	1½	12	3½
1¼	½	4	1½	14	3½
1½	½	5	1½	16	4
2	1	6	2½	18	4
2½	1¼	8	3	20	4
3	1¼	10	3½	24	4

NOTES:

(1) The hub dimensions shall be at least as large as those of the standard flanges of the size to which the reduction is being made, except flanges reducing to a size smaller than those of Columns 2, 4, and 6 may be made from blind flanges. See Example 2.

(2) Class 150 flanges do not have a counterbore. Class 300 and higher pressure flanges will have depth of counterbore q of 0.25 in. for NPS 2 and smaller tapping and 0.38 in. for NPS 2½ and larger. The diameter Q of counterbore is the same as that given in the tables of threaded flanges for the corresponding tapping.

(3) Minimum length of effective threads shall be at least equal to dimension T of the corresponding pressure class threaded flange as shown in tables but does not necessarily extend for the face of the flange. For thread of threaded flanges, see para. 6.9.

(4) For method of designating reducing threaded flanges, see para. 3.3 and Examples below.

EXAMPLES:

(1) The size designation is NPS 6 × 2½ — Class 300 reducing threaded flange. This flange has the following dimensions:

NPS 2½ = taper pipe thread tapping (ASME B1.20.1)
12.5 in. = diameter of regular NPS 6 Class 300 threaded flange
1.44 in. = thickness of regular NPS 6 Class 300 threaded flange
7.0 in. = diameter of hub for regular NPS 5 Class 300 threaded flange
0.62 in. = height of hub for regular NPS 5 Class 300 thread flange

Other dimensions the same as for regular NPS 6 Class 300 threaded flange, Table 12.

(2) The size designation is NPS 6 × 2 — Class 300 reducing threaded flange. Use regular NPS 6 Class 300 blind flange tapped with NPS 2 taper pipe thread (ASME B1.20.1).

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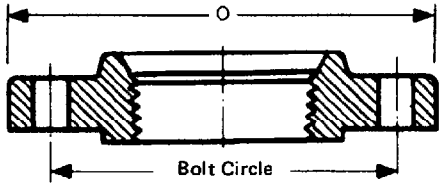
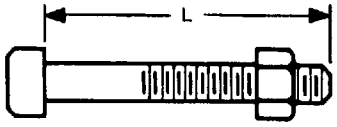
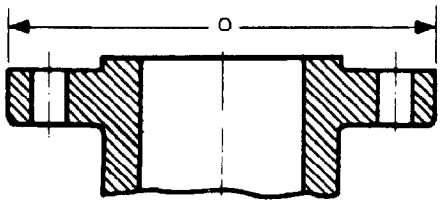
CLASS 150 PIPE FLANGES, AND FLANGED FITTINGS



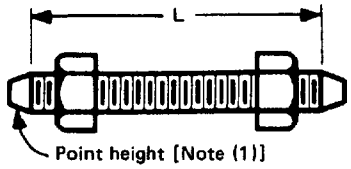
Flange



Machine Bolt With Nut



Flanged Fitting



Stud Bolt With Nuts

TABLE 8 TEMPLATES FOR DRILLING CLASS 150 FLANGES[2]

1	2	3	4	5	6	7	8	9
		Drilling [(3),(4)]				Length of Bolts (5) L		
						Stud Bolts (1)		Machine Bolts
Nominal Pipe Size	Outside Diameter of Flange O	Diameter of Bolt Circle	Diameter of Bolt Holes	Number of Bolts	Diameter of Bolts	0.06 in. Raised Face	Ring Joint	0.06 in. Raised Face
½	3.50	2.38	0.62	4	½	2.25	...	2.00
¾	3.88	2.75	0.62	4	½	2.50	...	2.00
1	4.25	3.12	0.62	4	½	2.50	3.00	2.25
1¼	4.62	3.50	0.62	4	½	2.75	3.25	2.25
1½	5.00	3.88	0.62	4	½	2.75	3.25	2.50
2	6.00	4.75	0.75	4	⅝	3.25	3.75	2.75
2½	7.00	5.50	0.75	4	⅝	3.50	4.00	3.00
3	7.50	6.00	0.75	4	⅝	3.50	4.00	3.00
3½	8.50	7.00	0.75	8	⅝	3.50	4.00	3.00
4	9.00	7.50	0.75	8	⅝	3.50	4.00	3.00
5	10.00	8.50	0.88	8	¾	3.75	4.25	3.25
6	11.00	9.50	0.88	8	¾	4.00	4.50	3.25
8	13.50	11.75	0.88	8	¾	4.25	4.75	3.50
10	16.00	14.25	1.00	12	⅞	4.50	5.00	4.00
12	19.00	17.00	1.00	12	⅞	4.75	5.25	4.00
14	21.00	18.75	1.12	12	1	5.25	5.75	4.50
16	23.50	21.25	1.12	16	1	5.25	5.75	4.50
18	25.00	22.75	1.25	16	1⅛	5.75	6.25	5.00
20	27.50	25.00	1.25	20	1⅛	6.25	6.75	5.50
24	32.00	29.50	1.38	20	1¼	6.75	7.25	6.00

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TABLE 8 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) Length of stud bolt does not include the height of the points. See para. 6.10.2.
(2) For other dimensions, see Tables 9 and 10.
(3) For flange bolt holes, see para. 6.5.
(4) For spot facing, see para. 6.6.
(5) Bolt lengths not shown in Table are determined in accordance with Annex F. See para. 6.10.2.

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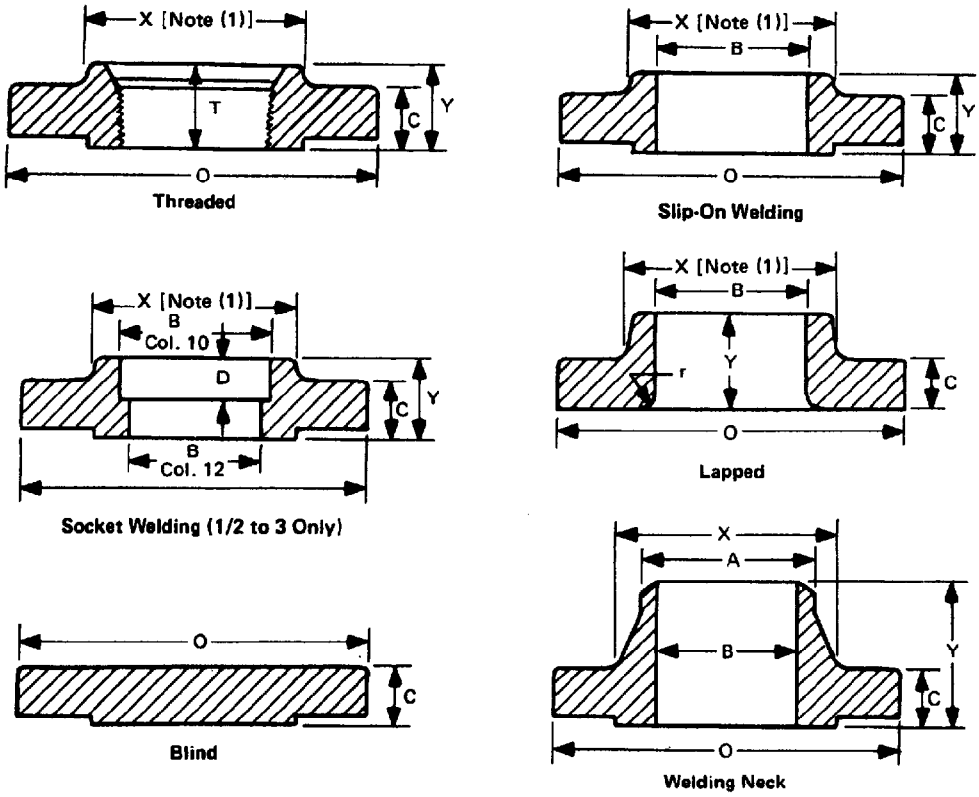

TABLE 9 DIMENSIONS OF CLASS 150 FLANGES[2-8]

1	2	3	4	5	6	7	8	9	10	11	12	13	14
					Length Through Hub				Bore				
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange [(9)–(11)], Min. C	Diameter of Hub X	Hub Diameter Beginning of Chamfer Welding Neck (12) A	Threaded Slip-On Socket Welding Y	Lapped Y	Welding Neck Y	Thread Length Threaded Flange (13), Min. T	Slip-On Socket Welding, Min. B	Lapped, Min. B	Welding Neck Socket Welding (14) B	Corner Radius of Bore of Lapped Flange and Pipe r	Depth of Socket D
½	3.50	0.44	1.19	0.84	0.62	0.62	1.88	0.62	0.88	0.90	0.62	0.12	0.38
¾	3.88	0.50	1.50	1.05	0.62	0.62	2.06	0.62	1.09	1.11	0.82	0.12	0.44
1	4.25	0.56	1.94	1.32	0.69	0.69	2.19	0.69	1.36	1.38	1.05	0.12	0.50
1¼	4.62	0.62	2.31	1.66	0.81	0.81	2.25	0.81	1.70	1.72	1.38	0.19	0.56
1½	5.00	0.69	2.56	1.90	0.88	0.88	2.44	0.88	1.95	1.97	1.61	0.25	0.62
2	6.00	0.75	3.06	2.38	1.00	1.00	2.50	1.00	2.44	2.46	2.07	0.31	0.69
2½	7.00	0.88	3.56	2.88	1.12	1.12	2.75	1.12	2.94	2.97	2.47	0.31	0.75
3	7.50	0.94	4.25	3.50	1.19	1.19	2.75	1.19	3.57	3.60	3.07	0.38	0.81
3½	8.50	0.94	4.81	4.00	1.25	1.25	2.81	1.25	4.07	4.10	3.55	0.38	...
4	9.00	0.94	5.31	4.50	1.31	1.31	3.00	1.31	4.60	4.60	4.03	0.44	...
5	10.00	0.94	6.44	5.56	1.44	1.44	3.50	1.44	5.66	5.69	5.05	0.44	...
6	11.00	1.00	7.56	6.63	1.56	1.56	3.50	1.56	6.72	6.75	6.07	0.50	...
8	13.50	1.12	9.69	8.63	1.75	1.75	4.00	1.75	8.72	8.75	7.98	0.50	...
10	16.00	1.19	12.00	10.75	1.94	1.94	4.00	1.94	10.88	10.92	10.02	0.50	...
12	19.00	1.25	14.38	12.75	2.19	2.19	4.50	2.19	12.88	12.92	12.00	0.50	...
14	21.00	1.38	15.75	14.00	2.25	3.12	5.00	2.25	14.14	14.18	To be specified by purchaser	0.50	...
16	23.50	1.44	18.00	16.00	2.50	3.44	5.00	2.50	16.16	16.19		0.50	...
18	25.00	1.56	19.88	18.00	2.69	3.81	5.50	2.69	18.18	18.20		0.50	...
20	27.50	1.69	22.00	20.00	2.88	4.06	5.69	2.88	20.20	20.25		0.50	...
24	32.00	1.88	26.12	24.00	3.25	4.38	6.00	3.25	24.25	24.25		0.50	...

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TABLE 9 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) This dimension is for large end of hub, which may be straight or tapered. Taper shall not exceed 7 deg. on threaded, slip-on, socket-welding, and lapped flanges.
(2) For tolerances, see Section 7.
(3) For facings, see para. 6.4.
(4) For flange bolt holes, see para. 6.5 and Table 8.
(5) For spot facing, see para. 6.6.
(6) For reducing threaded and slip-on flanges, see Table 7.
(7) Blind flanges may be made with or without hubs at the manufacturer's option.
(8) For reducing welding neck flanges, see para. 6.8.
(9) The minimum thickness of these loose flanges, in sizes NPS $3\frac{1}{2}$ and smaller, is slightly greater than the thickness of flanges on fittings, Table 10, which are reinforced by being cast integral with the body of the fitting.
(10) When these flanges are required with flat face, either the full thickness or thickness with raised face removed may be furnished. Users are reminded that removing the raised face will make the length through the hub nonstandard. See para. 6.4.1.1 for additional restrictions.
(11) The flange dimensions illustrated are for regularly furnished 0.06 in. raised face (except lapped); for requirements of other facings, see Fig. 7.
(12) For welding end bevel, see para. 6.7.
(13) For thread of threaded flanges, see para. 6.9.
(14) Dimensions in Column 12 correspond to the inside diameters of pipe as given in ASME B36.10M for Standard Wall pipe. Thickness of Standard Wall is the same as Schedule 40 in sizes NPS 10 and smaller. Tolerances in para. 7.4.2 apply. These bore sizes are furnished unless otherwise specified by the purchaser.

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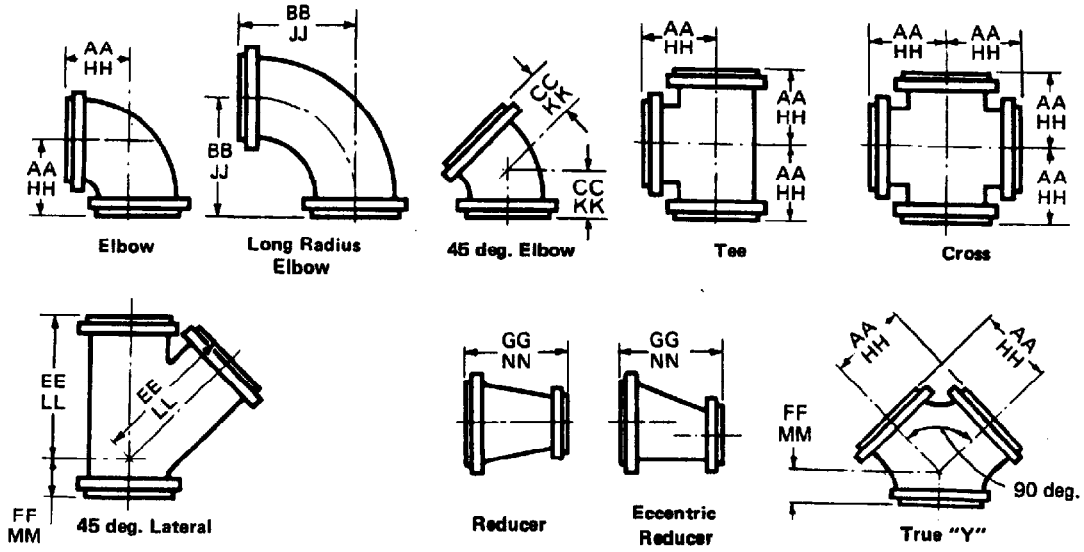

TABLE 10 DIMENSIONS OF CLASS 150 FLANGED FITTINGS[1-8]

1	2	3	4	5	6	7	8	9	10	11	12
					0.06 in. Raised Face (Flange Edge) (12)						Ring Joint (12)
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange [(9)–(11)], Min. C	Wall Thickness of Fitting, Min. t_m	Inside Diameter of Fitting, d	Center-to-Contact Surface of Raised Face Elbow, Tee, Cross, and True "Y" AA	Center-to-Contact Surface of Raised Face Long Radius Elbow BB	Center-to-Contact Surface of Raised Face 45 deg. Elbow CC	Long Center-to-Contact Surface of Raised Face Lateral EE	Short Center-to-Contact Surface of Raised Face Lateral and True "Y" FF	Contact Surface-to-Contact Surface of Raised Face Reducer (13) GG	Center-to-End Elbow Tee, Cross, and True "Y" (14) HH
½	3.5	0.38	0.11	0.50	...	...	...	...	...	...	...
¾	3.88	0.41	0.12	0.75	...	...	...	...	...	...	...
1	4.25	0.44	0.16	1.00	3.50	5.00	1.75	5.75	1.75	4.50	3.75
1¼	4.62	0.50	0.19	1.25	3.75	5.50	2.00	6.25	1.75	4.50	4.00
1½	5.00	0.56	0.19	1.50	4.00	6.00	2.25	7.00	2.00	4.50	4.25
2	6.00	0.62	0.22	2.00	4.50	6.50	2.50	8.00	2.50	5.00	4.75
2½	7.00	0.69	0.22	2.50	5.00	7.00	3.00	9.50	2.50	5.50	5.25
3	7.50	0.75	0.22	3.00	5.50	7.75	3.00	10.00	3.00	6.00	5.75
3½	8.50	0.81	0.25	3.50	6.00	8.50	3.50	11.50	3.00	6.50	6.25
4	9.00	0.94	0.25	4.00	6.50	9.00	4.00	12.00	3.00	7.00	6.75
5	10.00	0.94	0.28	5.00	7.50	10.25	4.50	13.50	3.50	8.00	7.75
6	11.00	1.00	0.28	6.00	8.00	11.50	5.00	14.50	3.50	9.00	8.25
8	13.50	1.12	0.31	8.00	9.00	14.00	5.50	17.50	4.50	11.00	9.25
10	16.00	1.19	0.34	10.00	11.00	16.50	6.50	20.50	5.00	12.00	11.25
12	19.00	1.25	0.38	12.00	12.00	19.00	7.50	24.50	6.50	14.00	12.25
14	21.00	1.38	0.41	13.25	14.00	21.50	7.50	27.00	6.00	16.00	14.25
16	23.50	1.44	0.44	15.25	15.00	24.00	8.00	30.00	6.50	18.00	15.25
18	25.00	1.56	0.47	17.25	16.50	26.50	8.50	32.00	7.00	19.00	16.75
20	27.50	1.69	0.50	19.25	18.00	29.00	9.50	35.00	8.00	20.00	18.25
24	32.00	1.88	0.57	23.25	22.00	34.00	11.00	40.50	9.00	24.00	22.25

(Figure continues on next page; Notes follow Table)

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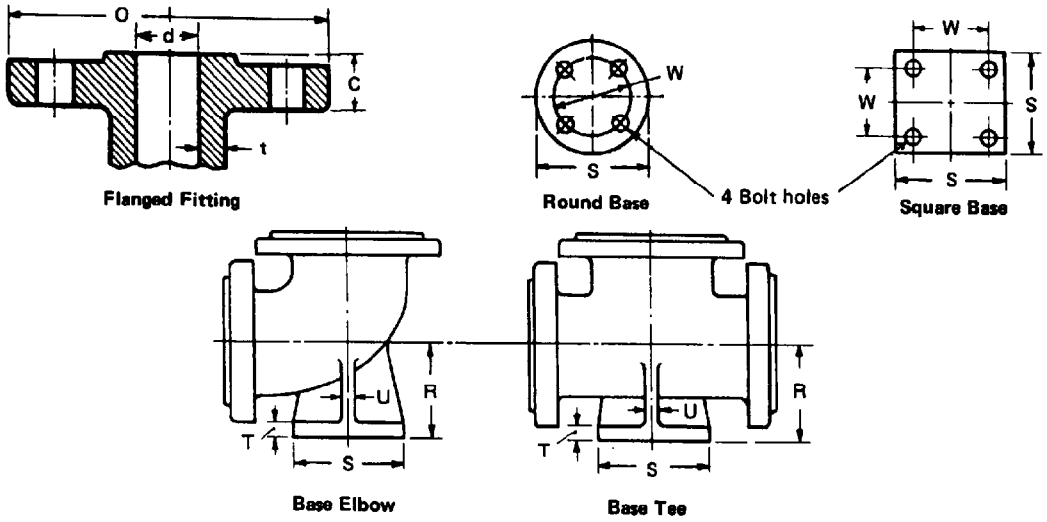

TABLE 10 DIMENSIONS OF CLASS 150 FLANGED FITTINGS[1-8] (CONT'D)

13	14	15	16	17	18	19	20	21	22	23	1
Ring Joint (12)									Base Drilling (19)		
Center-to-End Long Radius Elbow (14) JJ	Center-to-End 45 deg. Elbow (14) KK	Long Center-to-End Lateral (14) LL	Short Center-to-End Lateral and True "Y" (14) MM	End-to-End Reducer NN	Center-to-Base [(15)–(17)] R	Diameter of Round Base or Width of Square Base (15) S	Thickness of Base [(15)–(18)] T	Thickness of Ribs (15) U	Bolt Circle or Bolt Spacing W	Diameter of Drilled Holes	Nominal Pipe Size
...	...	...	...		...	...	...	...	...	...	½
...	...	...	...		...	...	...	...	...	...	¾
5.25	2.00	6.00	2.00		...	...	...	...	...	...	1
5.75	2.25	6.50	2.00		...	...	...	...	...	...	1¼
6.25	2.50	7.25	2.25		...	...	...	...	...	...	1½
6.75	2.75	8.25	2.75		4.12	4.62	0.50	0.50	3.50	0.62	2
7.25	3.25	9.75	2.75		4.50	4.62	0.50	0.50	3.50	0.62	2½
8.00	3.25	10.25	3.25		4.88	5.00	0.56	0.56	3.88	0.62	3
8.75	3.75	11.75	3.25		5.25	5.00	0.56	0.56	3.88	0.62	3½
9.25	4.25	12.25	3.25		5.50	6.00	0.62	0.62	4.75	0.75	4
10.50	4.75	13.75	3.75		6.25	7.00	0.69	0.65	5.50	0.75	5
11.75	5.25	14.75	3.75		7.00	7.00	0.69	0.65	5.50	0.75	6
14.25	5.75	17.75	4.75		8.38	9.00	0.94	0.94	7.50	0.75	8
16.75	6.75	20.75	5.25		9.75	9.00	0.94	0.94	7.50	0.75	10
19.25	7.75	24.75	5.75		11.25	11.00	1.00	1.00	9.50	0.88	12
21.75	7.75	27.25	6.25		12.50	11.00	1.00	1.00	9.50	0.88	14
24.25	8.25	30.25	6.75		13.75	11.00	1.00	1.00	9.50	0.88	16
26.75	8.75	32.25	7.25		15.00	13.50	1.12	1.12	11.75	0.86	18
29.25	9.75	35.25	8.25		16.00	13.50	1.12	1.12	11.75	0.88	20
34.25	11.25	40.75	9.25		18.50	13.50	1.12	1.12	11.75	0.88	24

See Notes (13) and (14)

(Notes follow on next page)

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TABLE 10 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) For tolerances, see Section 7.
(2) For facings, see para. 6.4.
(3) For flange bolt holes, see para. 6.5 and Table 8.
(4) For spot facing, see para. 6.6.
(5) For intersecting center lines, center-to-contact surface, and center-to-end dimensions of side outlet fittings, see para. 6.2.4.
(6) For center-to-contact surface and center-to-end dimensions of special degree elbows, see para. 6.2.5.
(7) For reinforcement of certain fittings, see para. 6.1.
(8) For drains, see para. 6.12.
(9) The thickness of flange minimum dimensions for loose flanges, Table 9, sizes $3\frac{1}{2}$ in. and smaller, are slightly heavier than for flanges on these fittings which are reinforced by being cast integral with the body of the fitting.
(10) When these fittings are required with flat face flange, either the full thickness or thickness with raised face removed may be furnished. Users are reminded that removing the raised face will make the center-to-face dimension nonstandard. See para. 6.4.1.1 for additional restrictions.
(11) The thickness of flange dimension illustrated is for regularly furnished 0.06 in. raised face (except lapped); for thickness requirements of other facings, see Fig. 7.
(12) For center-to-contact surface and center-to-end dimensions of reducing fittings, see para. 6.2.3.
(13) For contact surface-to-contact surface and end-to-end dimensions of reducers and eccentric reducers, see para. 6.2.3.
(14) These dimensions apply to straight sizes only. See paras. 6.2.3 and 6.4.1.3. For center-to-end dimensions of reducing fittings or end-to-end dimensions of reducers, use center-to-contact surface or contact surface-to-contact surface dimensions of 0.06 in. raised face (flange edge) for largest opening and add the proper height to provide for ring joint groove applying to each flange. See Table 5 for ring joint facing dimensions.
(15) The base dimensions apply to all straight and reducing sizes.
(16) The reducing fittings, the size and center-to-face dimension of base are determined by the size of the largest opening of fittings. In the case of reducing base elbows, orders shall specify whether the base shall be opposite the larger or smaller opening.
(17) Bases shall be plain faced unless otherwise specified, and the center-to-base dimension R shall be the finished dimension.
(18) Bases may be cast integral or attached as weldments at the option of the manufacturer.
(19) The bolt hole template is the same as for Class 150 flanges, Table 8, of corresponding outside diameter, except using only four holes in all cases so placed as to straddle centerlines. The bases of these fittings are intended for support in compression and are not to be used for anchors or supports in tension or shear.

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CLASS 300 PIPE FLANGES, AND FLANGED FITTINGS

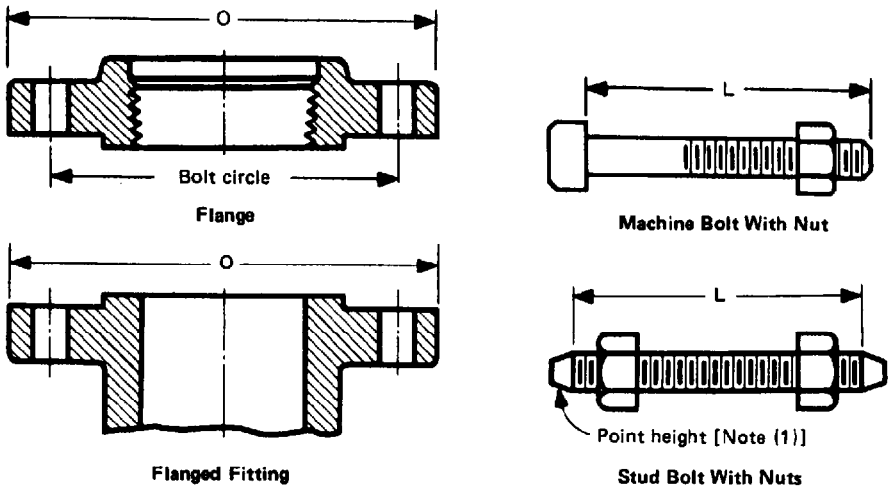

TABLE 11 TEMPLATES FOR DRILLING CLASS 300 FLANGES[2]

1	2	3	4	5	6	7	8	9
		Drilling [(3),(4)]				Length of Bolts (5) L		
						Stud Bolts (1)		Machine Bolts
Nominal Pipe Size	Outside Diameter of Flange O	Diameter of Bolt Circle	Diameter of Bolt Holes	Number of Bolts	Diameter of Bolts	0.06 in. Raised Face	Ring Joint	0.06 in. Raised Face
1/2	3.75	2.62	0.62	4	1/2	2.50	3.00	2.25
3/4	4.62	3.25	0.75	4	5/8	3.00	3.50	2.50
1	4.88	3.50	0.75	4	5/8	3.00	3.50	2.50
1 1/4	5.25	3.88	0.75	4	5/8	3.25	3.75	2.75
1 1/2	6.12	4.50	0.88	4	3/4	3.50	4.00	3.00
2	6.50	5.00	0.75	8	5/8	3.50	4.00	3.00
2 1/2	7.50	5.88	0.88	8	3/4	4.00	4.50	3.25
3	8.25	6.62	0.88	8	3/4	4.25	4.75	3.50
3 1/2	9.00	7.25	0.88	8	3/4	4.25	5.00	3.75
4	10.00	7.88	0.88	8	3/4	4.50	5.00	3.75
5	11.00	9.25	0.88	8	3/4	4.75	5.25	4.25
6	12.50	10.62	0.88	12	3/4	4.75	5.50	4.25
8	15.00	13.00	1.00	12	7/8	5.50	6.00	4.75
10	17.50	15.25	1.12	16	1	6.25	6.75	5.50
12	20.50	17.75	1.25	16	1 1/8	6.75	7.25	5.75
14	23.00	20.25	1.25	20	1 1/8	7.00	7.50	6.25
16	25.50	22.50	1.38	20	1 1/4	7.50	8.00	6.50
18	28.00	24.75	1.38	24	1 1/4	7.75	8.25	6.75
20	30.50	27.00	1.38	24	1 1/4	8.00	8.75	7.25
24	36.00	32.00	1.62	24	1 1/2	9.00	10.00	8.00

(Notes follow on next page)

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TABLE 11 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) Length of stud bolt does not include the height of the points. See para. 6.10.2.
(2) For other dimensions, see Tables 12 and 13.
(3) For flange bolt holes, see para. 6.5.
(4) For spot facing, see para. 6.6.
(5) Bolt lengths not shown in Table are determined in accordance with Annex F. See para. 6.10.2.

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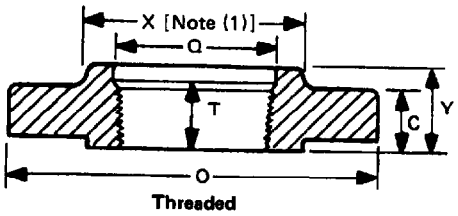
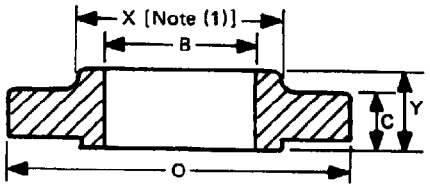
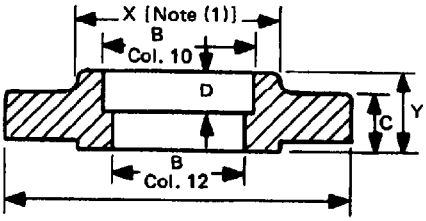


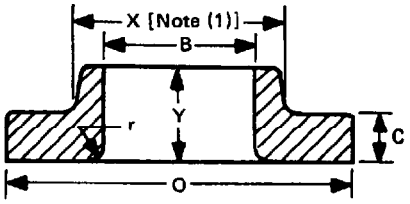
Threaded



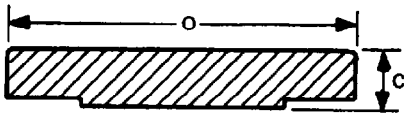
Slip-On Welding



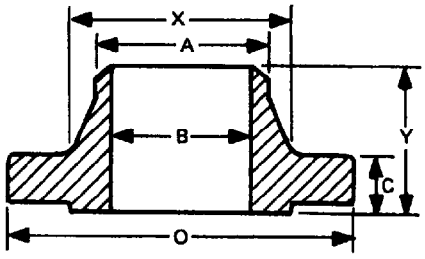
Socket Welding (1/2 to 3 Only)



Lapped



Blind



Welding Neck

TABLE 12 DIMENSIONS OF CLASS 300 FLANGES[2–8]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				Hub Diameter Beginning of Chamfer Welding Neck (11)	Length Through Hub				Bore			Corner Radius of Bore of Lapped Flange and Pipe		
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange [(9)–(11)], Min. C	Diameter of Hub X	A	Threaded Slip-On Socket Welding Y	Lapped Y	Welding Neck Y	Thread Length Threaded (12), Min. T	Slip-On Socket Welding, Min. B	Lapped, Min. B	Welding Neck Socket Welding (13) B	r	Counterbore Threaded Flange, Min. Q	Depth of Socket D
½	3.75	0.56	1.50	0.84	0.88	0.88	2.06	0.62	0.88	0.90	0.62	0.12	0.93	0.38
¾	4.62	0.62	1.88	1.05	1.00	1.00	2.25	0.62	1.09	1.11	0.82	0.12	1.14	0.44
1	4.88	0.69	2.12	1.32	1.06	1.06	2.44	0.69	1.36	1.38	1.05	0.12	1.41	0.50
1¼	5.25	0.75	2.50	1.66	1.06	1.06	2.56	0.81	1.70	1.72	1.38	0.19	1.75	0.56
1½	6.12	0.81	2.75	1.90	1.19	1.19	2.69	0.88	1.95	1.97	1.61	0.25	1.98	0.62
2	6.50	0.88	3.31	2.38	1.31	1.31	2.75	1.12	2.44	2.46	2.07	0.31	2.50	0.69
2½	7.50	1.00	3.94	2.88	1.50	1.50	3.00	1.25	2.94	2.97	2.47	0.31	3.00	0.75
3	8.25	1.12	4.62	3.50	1.69	1.69	3.12	1.25	3.57	3.60	3.07	0.38	3.63	0.81
3½	9.00	1.19	5.25	4.00	1.75	1.75	3.19	1.44	4.07	4.10	3.55	0.38	4.13	...
4	10.00	1.25	5.75	4.50	1.88	1.88	3.38	1.44	4.57	4.60	4.03	0.44	4.63	...
5	11.00	1.38	7.00	5.56	2.00	2.00	3.88	1.69	5.66	5.69	5.05	0.44	5.69	...
6	12.50	1.44	8.12	6.63	2.06	2.06	3.88	1.81	6.72	6.75	6.07	0.50	6.75	...
8	15.00	1.62	10.25	8.63	2.44	2.44	4.38	2.00	8.72	8.75	7.98	0.50	8.75	...
10	17.50	1.88	12.62	10.75	2.62	3.75	4.62	2.19	10.88	10.92	10.02	0.50	10.88	...
12	20.50	2.00	14.75	12.75	2.88	4.00	5.12	2.38	12.88	12.92	12.00	0.50	12.94	...
14	23.00	2.12	16.75	14.00	3.00	4.38	5.62	2.50	14.14	14.18	To be specified by purchaser	0.50	14.19	...
16	25.50	2.25	19.00	16.00	3.25	4.75	5.75	2.69	16.16	16.19		0.50	16.19	...
18	28.00	2.38	21.00	18.00	3.50	5.12	6.25	2.75	18.18	18.20		0.50	18.19	...
20	30.50	2.50	23.12	20.00	3.75	5.50	6.38	2.88	20.20	20.25		0.50	20.19	...
24	36.00	2.75	27.62	24.00	4.19	6.00	6.62	3.25	24.25	24.25		0.50	24.19	...

(Notes follow on next page)

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TABLE 12 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) This dimension is for large end of hub, which may be straight or tapered. Taper shall not exceed 7 deg. on threaded, slip-on, socket-welding, and lapped flanges.
(2) For tolerances, see Section 7.
(3) For facings, see para. 6.4.
(4) For flange bolt holes, see para. 6.5 and Table 11.
(5) For spot facing, see para. 6.6.
(6) For reducing threaded and slip-on flanges, see Table 7.
(7) Blind flanges may be made with or without hubs at the option of the manufacturer.
(8) For reducing welding neck flanges, see para. 6.8.
(9) When these flanges are required with flat face, either the full thickness or thickness with raised face removed may be furnished. Users are reminded that removing the raised face will make the length through the hub nonstandard. See para. 6.4.1.1 for additional restrictions.
(10) The flange dimensions illustrated are for regularly furnished 0.06 in. raised face (except lapped); for requirements of other facings, see Fig. 7.
(11) For welding end and bevel, see para. 6.7.
(12) For thread of threaded flanges, see para. 6.9.
(13) Dimensions in Column 12 correspond to the inside diameters of pipe as given in ASME B36.10M for Standard Wall Pipe. Standard Wall dimensions are the same as Schedule 40 in sizes NPS 10 and smaller. Tolerances in para. 7.5.2 apply. These bore sizes are furnished unless otherwise specified by the purchaser.

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Table 13 begins on next page

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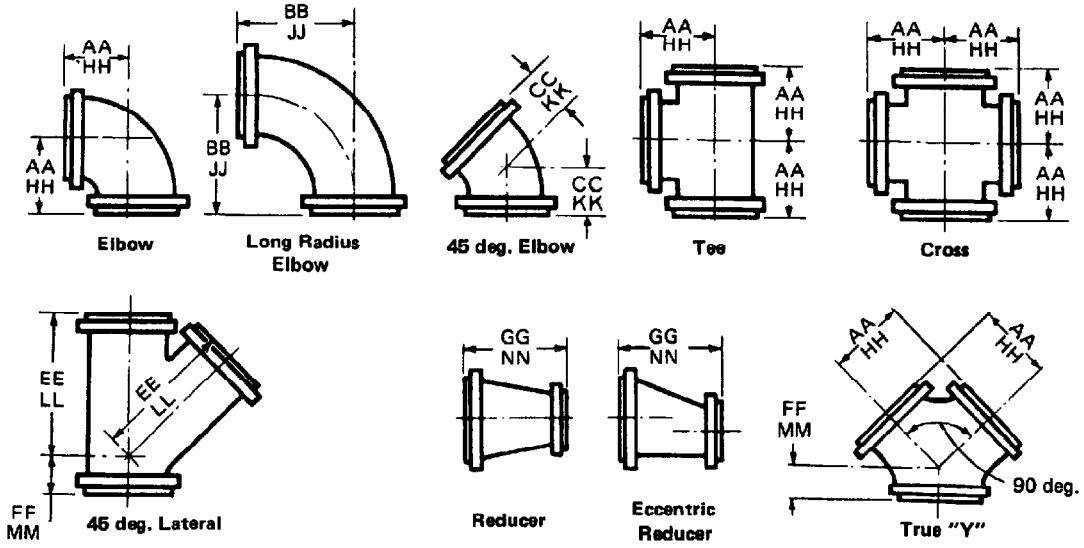

TABLE 13 DIMENSIONS OF CLASS 300 FLANGED FITTINGS[1-9]

1	2	3	4	5	6	7	8	9	10	11	12
					0.06 in. Raised Face (Flange Edge) (11)						Ring Joint (11)
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange [(9)–(11)], Min. C	Wall Thickness of Fitting, Min. t_m	Inside Diameter of Fitting, d	Center-to-Contact Surface of Raised Face Elbow, Tee, Cross, and True "Y" AA	Center-to-Contact Surface of Raised Face Long Radius Elbow BB	Center-to-Contact Surface of Raised Face 45 deg. Elbow CC	Long Center-to-Contact Surface of Raised Face Lateral EE	Short Center-to-Contact Surface of Raised Face Lateral and True "Y" FF	Contact Surface-to-Contact Surface of Raised Face Reducer (12) GG	Center-to-End Elbow Tee, Cross, and True "Y" (13) HH
1	4.88	0.69	0.19	1.00	4.00	5.00	2.25	6.50	2.00	4.50	4.25
1¼	5.25	0.75	0.19	1.25	4.25	5.50	2.50	7.25	2.25	4.50	4.50
1½	6.12	0.81	0.19	1.50	4.50	6.00	2.75	8.50	2.50	4.50	4.75
2	6.50	0.88	0.25	2.00	5.00	6.50	3.00	9.00	2.50	5.00	5.31
2½	7.50	1.00	0.25	2.50	5.50	7.00	3.50	10.50	2.50	5.50	5.81
3	8.25	1.12	0.28	3.00	6.00	7.75	3.50	11.00	3.00	6.00	6.31
3½	9.00	1.19	0.29	3.50	6.50	8.50	4.00	12.50	3.00	6.50	6.81
4	10.00	1.25	0.31	4.00	7.00	9.00	4.50	13.50	3.00	7.00	7.31
5	11.00	1.38	0.38	5.00	8.00	10.25	5.00	15.00	3.50	8.00	8.31
6	12.50	1.44	0.38	6.00	8.50	11.50	5.50	17.50	4.00	9.00	8.81
8	15.00	1.62	0.44	8.00	10.00	14.00	6.00	20.50	5.00	11.00	10.31
10	17.50	1.88	0.50	10.00	11.50	16.50	7.00	24.00	5.50	12.00	11.81
12	20.50	2.00	0.56	12.00	13.00	19.00	8.00	27.50	6.00	14.00	13.31
14	23.00	2.12	0.62	13.25	15.00	21.50	8.50	31.00	8.50	16.00	15.31
16	25.50	2.25	0.69	15.25	16.50	24.00	9.50	34.50	7.50	18.00	16.81
18	28.00	2.38	0.75	17.00	18.00	26.50	10.00	37.50	8.00	19.00	18.31
20	30.50	2.50	0.81	19.00	19.50	29.00	10.50	40.50	8.50	20.00	19.88
24	36.00	2.75	0.94	23.00	22.50	34.00	12.00	47.50	10.00	24.00	22.94

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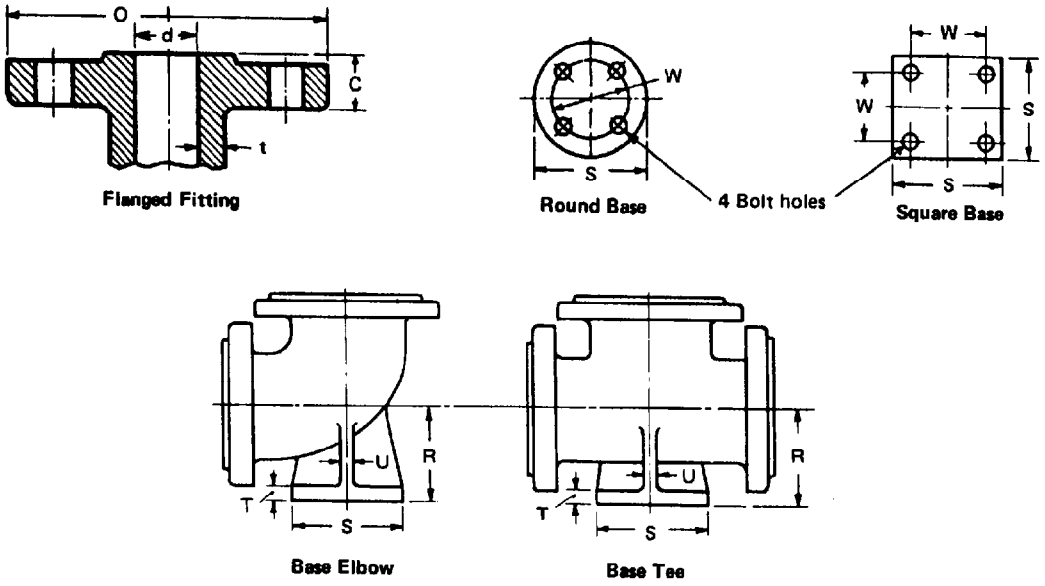

TABLE 13 DIMENSIONS CLASS OF 300 FLANGED FITTINGS[1-9] (CONT'D)

13	14	15	16	17	18	19	20	21	22	23	1
Ring Joint (12)									Base Drilling (18)		
Center-to-End Long Radius Elbow (13) JJ	Center-to-End 45 deg. Elbow (13) KK	Long Center-to-End Lateral (13) LL	Short Center-to-End Lateral and True "Y" (13) MM	End-to-End Reducer NN	Center-to-Base [(14)–(16)] R	Diameter of Round Base or Width of Square Base (14) S	Thickness of Base [(14)–(17)] T	Thickness of Ribs (14) U	Bolt Circle or Bolt Spacing W	Diameter of Drilled Holes	Nominal Pipe Size
5.25	2.50	6.75	2.25	See Notes (12) and (13)	...	...	...	...	...	...	1
5.75	2.75	7.50	2.50		...	...	...	...	...	...	1¼
6.25	3.00	8.75	2.75		...	...	...	...	...	...	1½
6.81	3.31	9.31	2.81		4.50	5.25	0.75	0.50	3.88	0.75	2
7.31	3.81	10.81	2.81		4.75	5.25	0.75	0.50	3.88	0.75	2½
8.06	3.81	11.31	3.31		5.25	6.12	0.81	0.62	4.50	0.88	3
8.81	4.31	12.81	3.31		5.62	6.12	0.81	0.62	4.50	0.88	3½
9.31	4.88	13.81	3.31		6.00	6.50	0.88	0.62	5.00	0.75	4
10.56	5.31	15.31	3.81		6.75	7.50	1.00	0.75	5.88	0.88	5
11.81	5.81	17.81	4.31		7.50	7.50	1.00	0.75	5.88	0.88	6
14.31	6.31	20.81	5.31		9.00	10.00	1.25	0.88	7.88	0.88	8
16.81	7.31	24.31	5.81		10.50	10.00	1.25	0.88	7.88	0.88	10
19.31	8.31	27.81	6.31		12.00	12.50	1.44	1.00	10.62	0.88	12
21.81	8.81	31.31	6.81		13.50	12.50	1.44	1.00	10.62	0.88	14
24.31	9.81	34.81	7.81		14.75	12.50	1.44	1.12	10.62	0.88	16
26.81	10.31	37.81	8.31		16.25	15.00	1.62	1.12	13.00	1.00	18
29.38	10.88	40.88	8.88		17.88	15.00	1.62	1.25	13.00	1.00	20
34.44	12.44	47.94	10.44		20.75	17.50	1.88	1.25	15.25	1.12	24

(Notes follow on next page)

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TABLE 13 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) For tolerances, see Section 7.
(2) For facings, see para. 6.4.
(3) For flange bolt holes, see para. 6.5 and Table 11.
(4) For spot facing, see para. 6.6.
(5) For intersecting center lines, center-to-contact surface, and center-to-end dimensions of side outlet fittings, see para. 6.2.4.
(6) For center-to-contact surface and center-to-end dimensions of special degree elbows, see para. 6.2.5.
(7) For reinforcement of certain fittings, see para. 6.1.
(8) For drains, see para. 6.12.
(9) When these fittings are required with flat face flange, either the full thickness or thickness with raised face removed may be furnished. Users are reminded that removing the raised face will make the center-to-face dimension nonstandard. See para. 6.4.1.1 for additional restrictions.
(10) The thickness of flange dimension illustrated is for regularly furnished 0.06 in. raised face (except lapped); for thickness requirement of other facings, see Fig. 7.
(11) For center-to-contact surface and center-to-end dimensions of reducing fittings, see para. 6.2.3.
(12) For contact surface-to-contact surface and end-to-end dimensions of reducers and eccentric reducers, see para. 6.2.3.
(13) These dimensions apply to straight sizes only. See paras. 6.2.3 and 6.4.1.3. For center-to-end dimensions of reducing fittings or end-to-end dimensions of reducers, use center-to-contact surface or contact surface-to-contact surface dimensions of 0.06 in. raised face (flange edge) for largest opening and add the proper height to provide for ring joint groove applying to each flange. See Table 5 for ring joint facing dimensions.
(14) The base dimensions apply to all straight and reducing sizes.
(15) For reducing fittings, the size and center-to-face dimension of base are determined by the size of the largest opening of fittings. In the case of reducing base elbows, orders shall specify whether the base shall be opposite the larger or smaller opening.
(16) Bases shall be plain faced unless otherwise specified, and the center-to-base dimension R shall be the finished dimension.
(17) Bases may be cast integral or attached as weldments at the option of the manufacturer.
(19) The bolt hole template for round base is the same as for Class 300 flanges, Table 11, of corresponding outside diameter, except using only four holes in all cases so placed as to straddle center lines. The bases of these fittings are intended for support in compression and are not to be used for anchors or supports in tension or shear.

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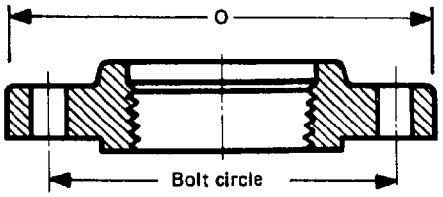
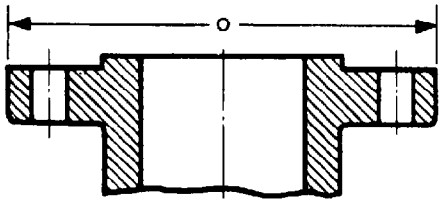
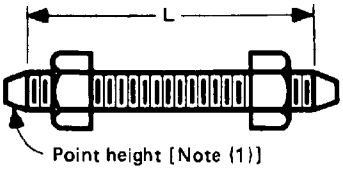
CLASS 400 PIPE FLANGES, AND FLANGED FITTINGS



Flange



Flanged Fitting



Stud Bolt With Nuts

TABLE 14 TEMPLATES FOR DRILLING CLASS 400 FLANGES[2]

1	2	3	4	5	6	7	8	9
		Drilling [(3), (4)]				Length of Bolts [(1), (5)] L		
Nominal Pipe Size	Outside Diameter of Flange O	Diameter of Bolt Circle	Diameter of Bolt Holes	Number of Bolts	Diameter of Bolts	0.25 in. Raised Face	Male and Female; also Tongue and Groove	Ring Joint
½ ¾ 1 1¼ 1½ 2 2½ 3 3½	Use Class 600 dimensions in these sizes.							
4	10.00	7.88	1.00	8	⅞	5.50	5.25	5.50
5	11.00	9.25	1.00	8	⅞	5.75	5.25	5.75
6	12.50	10.62	1.00	12	⅞	6.00	5.75	6.00
8	15.00	13.00	1.12	12	1	6.75	6.50	6.75
10	17.50	15.25	1.25	16	1⅛	7.50	7.25	7.50
12	20.50	17.75	1.38	16	1¼	8.00	7.75	8.00
14	23.00	20.25	1.38	20	1¼	8.25	8.00	8.25
16	25.50	22.50	1.50	20	1⅜	8.75	8.50	8.75
18	28.00	24.75	1.50	24	1⅜	9.00	8.75	9.00
20	30.50	27.00	1.62	24	1½	9.50	9.25	9.75
24	36.00	32.00	1.88	24	1¾	10.50	10.25	11.00

(Notes follow on next page)

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TABLE 14 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) Length of stud bolt does not include the height of the points. See para. 6.10.2.
(2) For other dimensions, see Tables 15 and 16.
(3) For flange bolt holes, see para. 6.5.
(4) For spot facing, see para. 6.6.
(5) Bolt lengths not shown in Table are determined in accordance with Annex F. See para. 6.10.2.

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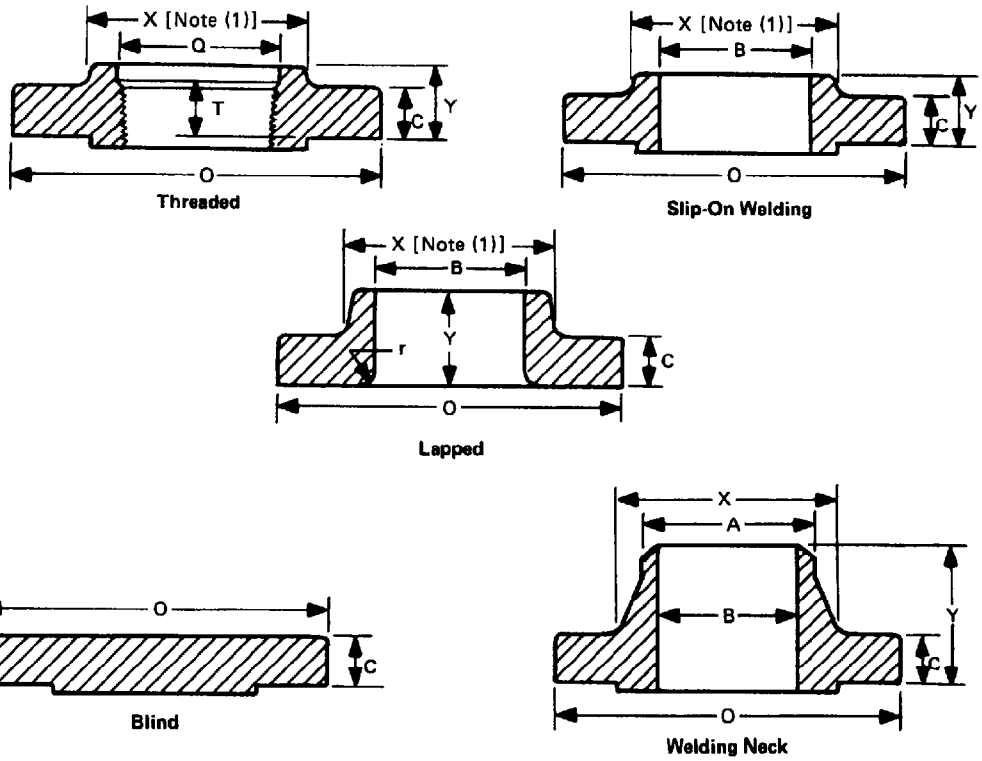

TABLE 15 DIMENSIONS OF CLASS 400 FLANGES[2-8]

1	2	3	4	5	6	7	8	9	10	11	12	13	14
					Length Through Hub				Bore				
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange Min. C	Diameter of Hub X	Hub Diameter Beginning of Chamfer Welding Neck (9) A	Threaded Slip-On Y	Lapped Y	Welding Neck Y	Thread Length Threaded Flange (10), Min. T	Slip-On Min. B	Lapped, Min. B	Welding Neck B	Corner Radius of Bore of Lapped Flange and Pipe r	Counter-bore Threaded Flange, Min. Q
½ ¾ 1 1¼ 1½ 2 2½ 3 3½	Use Class 600 dimensions in these sizes (11).												
4	10.00	1.38	5.75	4.50	2.00	2.00	3.50	1.44	4.57	4.60	To be specified by purchaser	0.44	4.63
5	11.00	1.50	7.00	5.56	2.12	2.12	4.00	1.69	5.66	5.69		0.44	5.69
6	12.50	1.62	8.12	6.63	2.25	2.25	4.06	1.81	6.72	6.75		0.50	6.75
8	15.00	1.88	10.25	8.63	2.69	2.69	4.62	2.00	8.72	8.75		0.50	8.75
10	17.50	2.12	12.62	10.75	2.88	4.00	4.88	2.19	10.88	10.92		0.50	10.88
12	20.50	2.25	14.75	12.75	3.12	4.25	5.38	2.38	12.88	12.92		0.50	12.94
14	23.00	2.38	16.75	14.00	3.31	4.62	5.88	2.50	14.14	14.18		0.50	14.19
16	25.50	2.50	19.00	16.00	3.69	5.00	6.00	2.69	16.16	16.19		0.50	16.19
18	28.00	2.62	21.00	18.00	3.88	5.38	6.50	2.75	18.18	18.20		0.50	18.19
20	30.50	2.75	23.12	20.00	4.00	5.75	6.62	2.88	20.20	20.25		0.50	20.19
24	36.00	3.00	27.62	24.00	4.50	6.25	6.88	3.25	24.25	24.25		0.50	24.19

(Notes follow on next page)

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TABLE 15 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) This dimension is for large end of hub, which may be straight or tapered. Taper shall not exceed 7 deg. on threaded, slip-on, and lapped flanges.
(2) For tolerances, see Section 7.
(3) For facings, see para. 6.4.
(4) For flange bolt holes, see para. 6.5 and Table 14.
(5) For spot facing, see para. 6.6.
(6) For reducing threaded and slip-on flanges, see Table 7.
(7) Blind flanges may be made with or without hubs at the manufacturer's option.
(8) For reducing welding neck flanges, see para. 6.8.
(9) For welding end bevel, see para. 6.7.
(10) For threads in threaded flanges, see para. 6.9.
(11) Socket welding flanges may be provided in NPS ½ through 2½ using Class 600 dimensions.

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Table 16 begins on next page

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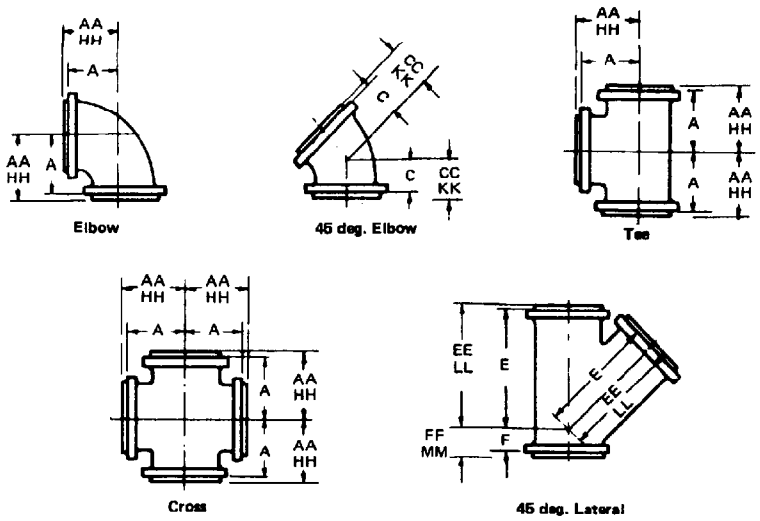

TABLE 16 DIMENSIONS OF CLASS 400 FLANGED FITTINGS[1-8]

1	2	3	4	5	6	7	8	9	10	11	12	13	14
					Flange Edge					0.25 in. Raised Face (9)			
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange Min. C	Wall Thickness of Fitting, Min. t_m	Inside Diameter of Fitting d	Center-to-Flange Edge Elbow, Tee, Cross, and True "Y" A	Center-to-Flange Edge 45 deg. Elbow C	Long Center-to-Flange Edge Lateral E	Short Center-to-Flange Edge Lateral and True "Y" F	Flange Edge-to-Flange Edge Reducer G	Center-to-Contact Surface of Raised Face Elbow, Tee, Cross, and True "Y" AA	Center-to-Contact Surface of Raised Face 45 deg. Elbow CC	Long Center-to-Contact Surface of Raised Face Lateral EE	Short Center-to-Contact Surface of Raised Face Lateral and True "Y" FF
½ ¾ 1 1¼ 1½ 2 2½ 3 3½	Use Class 600 dimensions in these sizes.												
4	10.00	1.38	0.38	4.00	7.75	5.25	15.75	4.25	7.75	8.00	5.50	16.00	4.50
5	11.00	1.50	0.44	5.00	8.75	5.75	16.50	4.75	8.75	9.00	6.00	16.75	5.00
6	12.50	1.62	0.44	6.00	9.50	6.00	18.50	5.00	9.50	9.75	6.25	18.75	5.25
8	15.00	1.88	0.56	8.00	11.50	6.50	22.00	5.50	11.50	11.75	6.75	22.25	5.75
10	17.50	2.12	0.69	10.00	13.00	7.50	25.50	6.00	13.00	13.25	7.75	25.75	6.25
12	20.50	2.25	0.75	12.00	14.75	8.50	29.50	6.25	14.75	15.00	8.75	29.75	6.50
14	23.00	2.38	0.81	13.12	16.00	9.00	32.50	6.75	16.00	16.25	9.25	32.75	7.00
16	25.50	2.50	0.88	15.00	17.50	10.00	36.00	7.75	18.00	17.75	10.25	36.25	8.00
18	28.00	2.62	0.94	17.00	19.00	10.50	39.00	8.25	19.00	19.25	10.75	39.25	8.50
20	30.50	2.75	1.06	18.88	20.50	11.00	42.50	8.75	20.50	20.75	11.25	42.75	9.00
24	36.00	3.00	1.19	22.62	24.00	12.50	50.00	10.25	24.00	24.25	12.75	50.25	10.50

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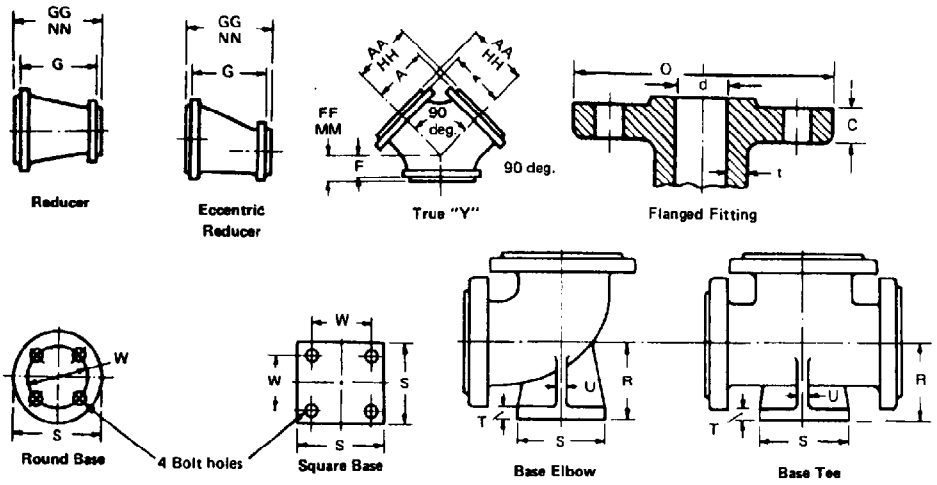

TABLE 16 DIMENSIONS CLASS OF 400 FLANGED FITTINGS[1-8] (CONT'D)

15	16	17	18	19	20	21	22	23	24	25	26	1
0.25 in. Raised Face (9)	Ring Joint (9)									Base Drilling (16)		
Contact Surface-to-Contact Surface of Raised Face Reducer (10) GG	Center-to-End Elbow, Tee, Cross, and True "Y" (11) HH	Center-to-End 45 deg. Elbow (11) KK	Long Center-to-End Lateral (11) LL	Short Center-to-End Lateral and True "Y" (11) MM	End-to-End Reducer NN	Center-to-Base [(12)–(14)] R	Diameter of Round Base or Width of Square Base (12) S	Thickness of Base [(12), (15)] T	Thickness of Ribs (12) U	Bolt Circle or Bolt Spacing W	Diameter of Drilled Holes	Nominal Pipe Size
Use Class 600 dimensions in these sizes.												½ ¾ 1 1¼ 1½ 2 2½ 3 3½
8.25	8.06	5.56	16.06	4.56	See Notes (10) and (11).	6.00	6.50	0.88	0.62	5.00	0.75	4
9.25	9.06	6.06	16.81	5.06		6.75	7.50	1.00	0.75	5.88	0.88	5
10.00	9.81	6.31	18.81	5.31		7.50	7.50	1.00	0.75	5.88	0.88	6
12.00	11.81	6.81	22.31	5.81		9.00	10.00	1.25	0.88	7.88	0.88	8
13.50	13.31	7.81	25.81	6.31		10.50	10.00	1.25	0.88	7.88	0.88	10
15.25	15.06	8.81	29.81	6.56		12.00	12.50	1.44	1.00	10.62	0.88	12
16.50	16.31	9.31	32.81	7.06		13.50	12.50	1.44	1.00	10.62	0.88	14
18.50	17.81	10.31	36.31	8.06		14.75	12.50	1.44	1.12	10.62	0.88	16
19.50	19.31	10.81	39.31	8.56		16.25	15.00	1.62	1.12	13.00	1.00	18
21.00	20.88	11.38	42.88	9.12		17.88	15.00	1.62	1.25	13.00	1.00	20
24.50	24.44	12.94	50.44	10.69		20.75	17.50	1.88	1.25	15.25	1.12	24

(Notes follow on next page)

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TABLE 16 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) For tolerances, see Section 7.
(2) For facings, see para. 6.4.
(3) For flange bolt holes, see para. 6.5 and Table 14.
(4) For spot facing, see para. 6.6.
(5) For intersecting center lines, center-to-contact surface, and center-to-end dimensions of side outlet fittings, see para. 6.2.4.
(6) For center-to-contact surface and center-to-end dimensions of special degree elbows, see para. 6.2.5.
(7) For reinforcement of certain fittings, see para. 6.1.
(8) For drains, see para. 6.12.
(9) For center-to-contact surface and center-to-end dimensions of reducing fittings, see para. 6.2.3.
(10) For contact surface-to-contact surface and end-to-end dimensions of reducers and eccentric reducers, see para. 6.2.3.
(11) These dimensions apply to straight sizes only. (See paras. 6.2.3 and 6.4.1.3.) For the center-to-end dimensions of reducing fittings or end-to-end dimensions of reducers, use center-to-flange edge or flange edge-to-flange edge dimensions for largest opening, and add the proper height to provide for ring joint groove applying to each flange. See Table 5 for ring joint facing dimensions.
(12) The base dimensions apply to all straight and reducing sizes.
(13) For reducing fittings, the size and center-to-face dimensions of base are determined by the size of the largest opening of fitting. In the case of reducing base elbows, orders shall specify whether the base shall be opposite the larger or smaller opening.
(14) Bases shall be plain faced unless otherwise specified, and the center-to-base face dimension R shall be the finished dimension.
(15) Bases may be cast integral or attached as weldments at the option of the manufacturer.
(16) The bolt hole template for round base is the same as for Class 300 flanges, Table 11, of corresponding outside diameter, except using only four holes in all cases so placed as to straddle center lines. The bases of these fittings are intended for support in compression and are not to be used for anchors or supports in tension or shear.

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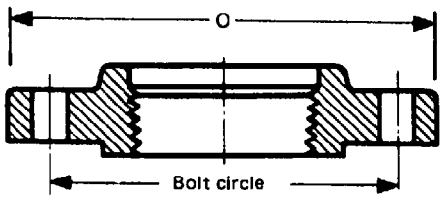
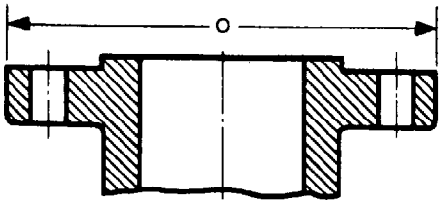
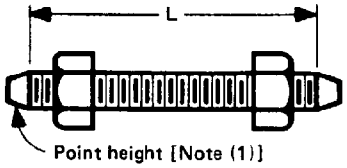
CLASS 600 PIPE FLANGES, AND FLANGED FITTINGS



Flange



Flanged Fitting



Stud Bolt With Nuts

TABLE 17 TEMPLATES FOR DRILLING CLASS 600 FLANGES[2]

1	2	3	4	5	6	7	8	9
		Drilling [(3), (4)]				Length of Bolts [(1), (5)] L		
Nominal Pipe Size	Outside Diameter of Flange O	Diameter of Bolt Circle	Diameter of Bolt Holes	Number of Bolts	Diameter of Bolts	0.25 in. Raised Face	Male and Female; also Tongue and Groove	Ring Joint
½	3.75	2.62	0.62	4	½	3.00	2.75	3.00
¾	4.62	3.25	0.75	4	⅝	3.50	3.25	3.50
1	4.88	3.50	0.75	4	⅝	3.50	3.25	3.50
1¼	5.25	3.88	0.75	4	⅝	3.75	3.50	3.75
1½	6.12	4.50	0.88	4	¾	4.25	4.00	4.25
2	6.50	5.00	0.75	8	⅝	4.25	4.00	4.25
2½	7.50	5.88	0.88	8	¾	4.75	4.50	4.75
3	8.25	6.62	0.88	8	¾	5.00	4.75	5.00
3½	9.00	7.25	1.00	8	⅞	5.50	5.25	5.50
4	10.75	8.50	1.00	8	⅞	5.75	5.50	5.75
5	13.00	10.50	1.12	8	1	6.50	6.25	6.50
6	14.00	11.50	1.12	12	1	6.75	6.50	6.75
8	16.50	13.75	1.25	12	1⅛	7.50	7.25	7.75
10	20.00	17.00	1.38	16	1¼	8.50	8.25	8.50
12	22.00	19.25	1.38	20	1¼	8.75	8.50	8.75
14	23.75	20.75	1.50	20	1⅜	9.25	9.00	9.25
16	27.00	23.75	1.62	20	1½	10.00	9.75	10.00
18	29.25	25.75	1.75	20	1⅝	10.75	10.50	10.75
20	32.00	28.50	1.75	24	1⅝	11.25	11.00	11.50
24	37.00	33.00	2.00	24	1⅞	13.00	12.75	13.25

(Notes follow on next page)

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TABLE 17 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) Length of stud bolt does not include the height of the points. See para. 6.10.2.
(2) For other dimensions, see Tables 18 and 19.
(3) For flange bolt holes, see para. 6.5.
(4) For spot facing, see para. 6.6.
(5) Bolt lengths not shown in Table are determined in accordance with Annex F. See para. 6.10.2.

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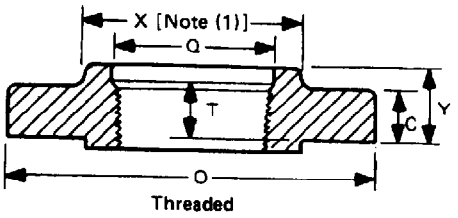
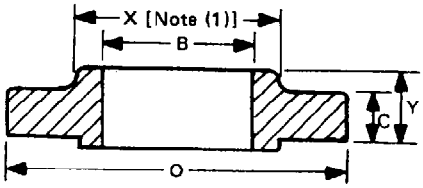
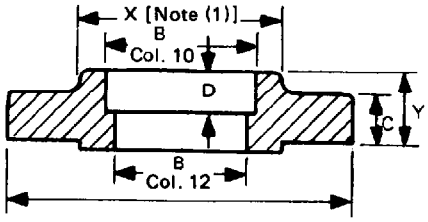


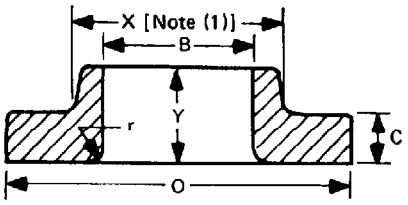
Threaded



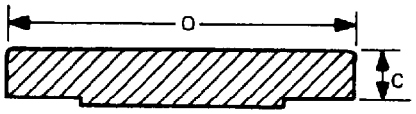
Slip-On Welding



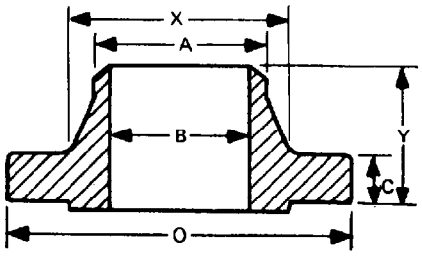
Socket Welding (1/2 to 3 Only)



Lapped



Blind



Welding Neck

TABLE 18 DIMENSIONS OF CLASS 600 FLANGES[2-8]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
					Length Through Hub				Bore					
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange, Min. C	Diameter of Hub X	Hub Diameter Beginning of Chamfer Welding Neck (9) A	Threaded Slip-On Socket Welding Y	Lapped Y	Welding Neck Y	Thread Length Threaded Flange (10), Min. T	Slip-On Socket Welding, Min. B	Lapped, Min. B	Welding Neck Socket Welding B	Corner Radius of Bore of Lapped Flange and Pipe r	Counterbore Threaded Flange, Min. Q	Depth of Socket D
½	3.75	0.56	1.50	0.84	0.88	0.88	2.06	0.62	0.88	0.90		0.12	0.93	0.38
¾	4.62	0.62	1.88	1.05	1.00	1.00	2.25	0.62	1.09	1.11		0.12	1.14	0.44
1	4.88	0.69	2.12	1.32	1.06	1.06	2.44	0.69	1.36	1.38		0.12	1.41	0.50
1¼	5.25	0.81	2.50	1.66	1.12	1.12	2.62	0.81	1.70	1.72		0.19	1.75	0.56
1½	6.12	0.88	2.75	1.90	1.25	1.25	2.75	0.88	1.95	1.97		0.25	1.99	0.62
2	6.50	1.00	3.31	2.38	1.44	1.44	2.88	1.12	2.44	2.46		0.31	2.50	0.69
2½	7.50	1.12	3.94	2.88	1.62	1.62	3.12	1.25	2.94	2.97		0.31	3.00	0.75
3	8.25	1.25	4.62	3.50	1.81	1.81	3.25	1.38	3.57	3.60		0.38	3.63	0.81
3½	9.00	1.38	5.25	4.00	1.94	1.94	3.38	1.56	4.07	4.10		0.38	4.13	...
4	10.75	1.50	6.00	4.50	2.12	2.12	4.00	1.62	4.57	4.60		0.44	4.63	...
5	13.00	1.75	7.44	5.56	2.38	2.38	4.50	1.88	5.66	5.69		0.44	5.69	...
6	14.00	1.88	8.75	6.63	2.62	2.62	4.62	2.00	6.72	6.75		0.50	6.75	...
8	16.50	2.19	10.75	8.63	3.00	3.00	5.25	2.25	8.72	8.75		0.50	8.75	...
10	20.00	2.50	13.50	10.75	3.38	4.38	6.00	2.56	10.88	10.92		0.50	10.88	...
12	22.00	2.62	15.75	12.75	3.62	4.62	6.12	2.75	12.88	12.92		0.50	12.94	...
14	23.75	2.75	17.00	14.00	3.69	5.00	6.50	2.88	14.14	14.18		0.50	14.19	...
16	27.00	3.00	19.50	16.00	4.19	5.50	7.00	3.06	16.16	16.19		0.50	16.19	...
18	29.25	3.25	21.50	18.00	4.62	6.00	7.25	3.12	18.18	18.20		0.50	18.19	...
20	32.00	3.50	24.00	20.00	5.00	6.50	7.50	3.25	20.20	20.25		0.50	20.19	...
24	37.00	4.00	28.25	24.00	5.50	7.25	8.00	3.62	24.25	24.25		0.50	24.19	...

To be specified by purchaser.

(Notes follow on next page)

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TABLE 18 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) This dimension is for large end of hub, which may be straight or tapered. Taper shall not exceed 7 deg. on threaded, slip-on, socket welding, and lapped flanges.
(2) For tolerances, see Section 7.
(3) For facings, see para. 6.4.
(4) For flange bolt holes, see para. 6.5 and Table 17.
(5) For spot facing, see para. 6.6.
(6) For reducing threaded and slip-on flanges, see Table 7.
(7) Blind flanges may be made with or without hubs at the manufacturer's option.
(8) For reducing welding neck flanges, see para. 6.8.
(9) For welding end bevel, see para. 6.7.
(10) For threads in threaded flanges, see para. 6.9.

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Table 19 begins on next page

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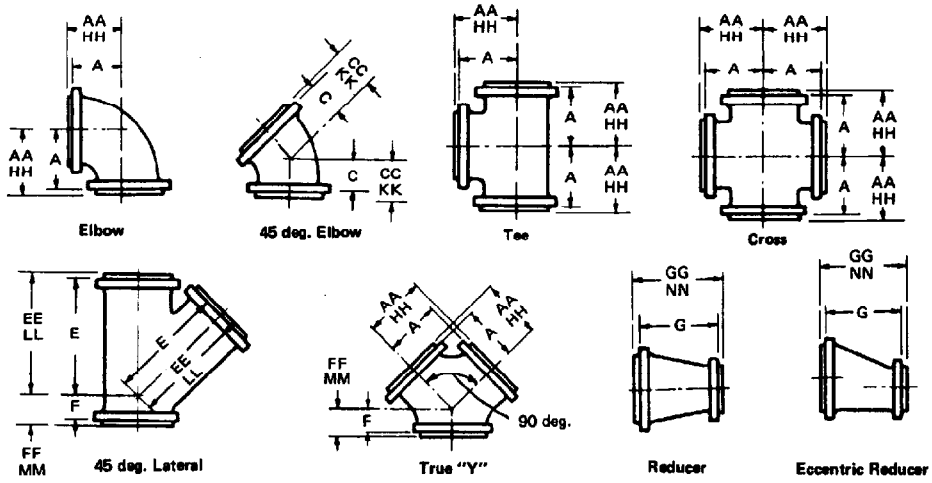

TABLE 19 DIMENSIONS OF CLASS 600 FLANGED FITTINGS[1-8]

1	2	3	4	5	6	7	8	9	10	11	12	13	14
					Flange Edge					0.25 in. Raised Face (9)			
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange, Min. C	Wall Thickness of Fitting, Min. t_m	Inside Diameter of Fitting, d	Center-to-Flange Edge Elbow, Tee, Cross, and True "Y" A	Center-to-Flange Edge 45 deg. Elbow C	Long Center-to-Flange Edge Lateral E	Short Center-to-Flange Edge Lateral and True "Y" F	Flange Edge-to-Flange Edge Reducer G	Center-to-Contact Surface of Raised Face Elbow, Tee, Cross, and True "Y" AA	Center-to-Contact Surface of Raised Face 45 deg. Elbow CC	Long Center-to-Contact Surface of Raised Face Lateral EE	Short Center-to-Contact Surface of Raised Face Lateral and True "Y" FF
½	3.75	0.56	0.16	0.50	3.00	1.75	5.50	1.50	4.50	3.25	2.00	5.75	1.75
¾	4.62	0.62	0.16	0.75	3.50	2.25	6.50	1.75	4.50	3.75	2.50	6.75	2.00
1	4.88	0.69	0.19	1.00	4.00	2.25	7.00	2.00	4.50	4.25	2.50	7.25	2.25
1¼	5.25	0.81	0.19	1.25	4.25	2.50	7.75	2.25	4.50	4.50	2.75	8.00	2.50
1½	6.12	0.88	0.22	1.50	4.50	2.75	8.75	2.50	4.50	4.75	3.00	9.00	2.75
2	6.50	1.00	0.25	2.00	5.50	4.00	10.00	3.25	5.50	5.75	4.25	10.25	3.50
2½	7.50	1.12	0.28	2.50	6.25	4.25	11.25	3.25	6.25	6.50	4.50	11.50	3.50
3	8.25	1.25	0.31	3.00	6.75	4.75	12.50	3.75	6.75	7.00	5.00	12.75	4.00
3½	9.00	1.38	0.34	3.50	7.25	5.25	13.75	4.25	7.25	7.50	5.50	14.00	4.50
4	10.75	1.50	0.38	4.00	8.25	5.75	16.25	4.25	8.25	8.50	6.00	16.50	4.50
5	13.00	1.75	0.44	5.00	9.75	6.75	19.25	5.75	9.75	10.00	7.00	19.50	6.00
6	14.00	1.88	0.50	6.00	10.75	7.25	20.75	6.25	10.75	11.00	7.50	21.00	6.50
8	16.50	2.19	0.62	7.88	12.75	8.25	24.25	6.75	12.75	13.00	8.50	24.50	7.00
10	20.00	2.50	0.75	9.75	15.25	9.25	29.25	7.75	15.25	15.50	9.50	29.50	8.00
12	22.00	2.62	0.91	11.75	16.25	9.75	31.25	8.25	16.25	16.50	10.00	31.50	8.50
14	23.75	2.75	0.97	12.88	17.25	10.50	34.00	8.75	17.25	17.50	10.75	34.25	9.00
16	27.00	3.00	1.09	14.75	19.25	11.50	38.25	9.75	19.25	19.50	11.75	38.50	10.00
18	29.25	3.25	1.22	16.50	21.25	12.00	41.75	10.25	21.25	21.50	12.25	42.00	10.50
20	32.00	3.50	1.34	18.25	23.25	12.75	45.25	10.75	23.25	23.50	13.00	45.50	11.00
24	37.00	4.00	1.59	22.00	27.25	14.50	52.75	12.75	27.25	27.50	14.75	53.00	13.00

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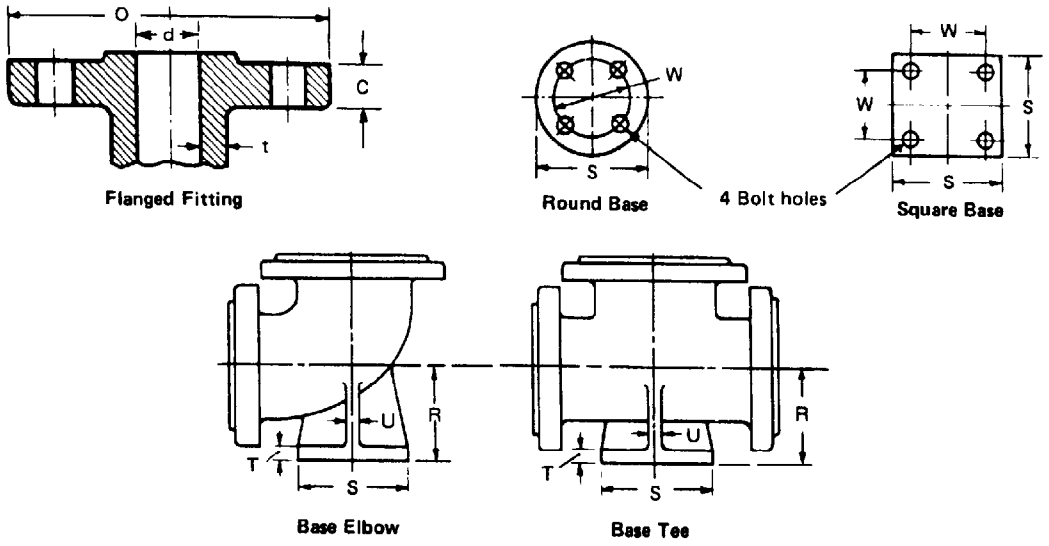

TABLE 19 DIMENSIONS OF CLASS 600 FLANGED FITTINGS[1–8] (CONT'D)

15	16	17	18	19	20	21	22	23	24	25	26	1
0.25 in. Raised Face (9)	Ring Joint (9)									Base Drilling (16)		
Contact Surface-to-Contact Surface of Raised Face Reducer (10) GG	Center-to-End Elbow Tee Cross and True "Y" (11) HH	Center-to-End 45 deg. Elbow (11) KK	Long Center-to-End Lateral (11) LL	Short Center-to-End Lateral and True "Y" (11) MM	End-to-End Reducer NN	Center-to-Base [(12)–(14)] R	Diameter of Round Base or Width of Square Base (12) S	Thickness of Base [(12), (15)] T	Thickness of Ribs (12) U	Bolt Circle or Bolt Spacing W	Diameter of Drilled Holes	Nominal Pipe Size
5.00	3.22	1.97	5.72	1.72		...	...	...	...	...	...	½
5.00	3.75	2.50	6.75	2.00		...	...	...	...	...	...	¾
5.00	4.25	2.50	7.25	2.25		...	...	...	...	...	...	1
5.00	4.50	2.75	8.00	2.50		...	...	...	...	...	...	1¼
5.00	4.75	3.00	9.00	2.75		...	...	...	...	...	...	1½
6.00	5.81	4.31	10.31	3.56		4.75	6.12	0.81	0.62	4.50	0.88	2
6.75	6.56	4.56	11.56	3.56		5.25	6.12	0.81	0.62	4.50	0.88	2½
7.25	7.06	5.06	12.81	4.06		5.75	6.50	0.88	0.75	5.00	0.75	3
7.75	7.56	5.56	14.06	4.56		6.50	6.50	0.88	0.75	5.00	0.75	3½
8.75	8.56	6.06	16.56	4.56		7.00	7.50	1.00	0.75	5.88	0.88	4
10.25	10.06	7.06	19.56	6.06		8.25	10.00	1.25	0.75	7.88	0.88	5
11.25	11.06	7.56	21.06	6.56		9.00	10.00	1.25	0.75	7.88	0.88	6
13.25	13.06	8.56	24.56	7.06		11.00	12.50	1.44	1.00	10.62	0.88	8
15.75	15.56	9.56	29.56	8.06		12.50	12.50	1.44	1.00	10.62	0.88	10
16.75	16.56	10.06	31.56	8.56		13.25	15.00	1.62	1.12	13.00	1.00	12
17.75	17.56	10.81	34.31	9.06		14.75	15.00	1.62	1.12	13.00	1.00	14
19.75	19.56	11.81	38.56	10.06		16.00	15.00	1.62	1.25	13.00	1.00	16
21.75	21.56	12.31	42.06	10.56		...	...	...	...	...	...	18
23.75	23.62	13.12	45.62	11.12		...	...	...	...	...	...	20
27.75	27.69	14.94	53.19	13.19		...	...	...	...	...	...	24

See Notes (10) and (11)

(Notes follow on next page)

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TABLE 19 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) For tolerances, see Section 7.
(2) For facings, see para. 6.4.
(3) For flange bolt holes, see para. 6.5 and Table 17.
(4) For spot facing, see para. 6.6.
(5) For intersecting center lines, center-to-contact surface, and center-to-end dimensions of side outlet fittings, see para. 6.2.4.
(6) For center-to-contact surface and center-to-end dimensions of special degree elbows, see para. 6.2.5.
(7) For reinforcement of certain fittings, see para. 6.1.
(8) For drains, see para. 6.12.
(9) For center-to-contact surface and center-to-end dimensions of reducing fittings, see para. 6.2.3.
(10) For contact surface-to-contact surface and end-to-end dimensions of reducers and eccentric reducers, see para. 6.2.3.
(11) These dimensions apply to straight sizes only. (See paras. 6.2.3 and 6.3.1.3.) For the center-to-end dimensions of reducing fittings or end-to-end dimensions of reducers, use center-to-flange edge or flange edge-to-flange edge dimensions for largest opening, and add the proper height to provide for ring joint groove applying to each flange. See Table 5 for ring joint facing dimensions.
(12) The base dimensions apply to all straight and reducing sizes.
(13) For reducing fittings the size and center-to-face dimensions of base are determined by the size of the largest opening of fitting. In the case of reducing base elbows, orders shall specify whether the base shall be opposite the larger or smaller opening.
(14) Bases shall be plain faced unless otherwise specified, and the center-to-base face dimension R shall be the finished dimensions.
(15) Bases may be cast integral or attached as weldments at the option of the manufacturer.
(16) The bolt hole template for round base is the same as for Class 300 flanges, Table 11, of corresponding outside diameter, except using only four holes in all cases so placed as to straddle center lines. The bases of these fittings are intended for support in compression and are not to be used for anchors or supports in tension or shear.

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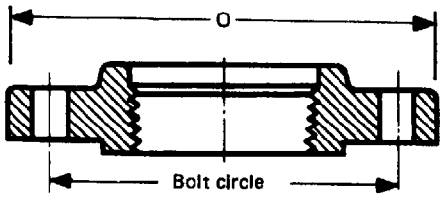
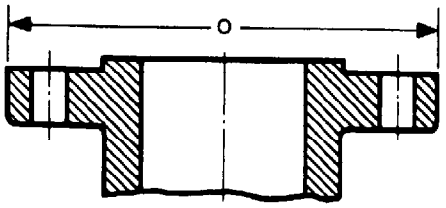
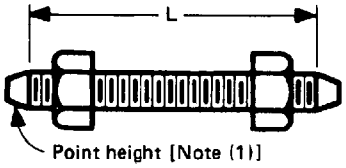
CLASS 900 PIPE FLANGES, AND FLANGED FITTINGS



Flange



Flanged Fitting



Stud Bolt With Nuts

TABLE 20 TEMPLATES FOR DRILLING CLASS 900 FLANGES[2]

1	2	3	4	5	6	7	8	9
		Drilling [(3), (4)]				Length of Bolts [(1), (5)] L		
Nominal Pipe Size	Outside Diameter of Flange O	Diameter of Bolt Circle	Diameter of Bolt Holes	Number of Bolts	Diameter of Bolts	0.25 in. Raised Face	Male and Female; also Tongue and Groove	Ring Joint
½ ¾ 1 1¼ 1½ 2 2½	Use Class 1500 dimensions in these sizes.							
3	9.50	7.50	1.00	8	⅞	5.75	5.50	5.75
4	11.50	9.25	1.25	8	1⅛	6.75	6.50	6.75
5	13.75	11.00	1.38	8	1¼	7.50	7.25	7.50
6	15.00	12.50	1.25	12	1⅛	7.50	7.25	7.75
8	18.50	15.50	1.50	12	1⅜	8.75	8.50	8.75
10	21.50	18.50	1.50	16	1⅜	9.25	9.00	9.25
12	24.00	21.00	1.50	20	1⅜	10.00	9.75	10.00
14	25.25	22.00	1.62	20	1½	10.75	10.50	11.00
16	27.75	24.25	1.75	20	1⅝	11.25	11.00	11.50
18	31.00	27.00	2.00	20	1⅞	12.75	12.50	13.25
20	33.75	29.50	2.12	20	2	13.75	13.50	14.25
24	41.00	35.50	2.62	20	2½	17.25	17.00	18.00

(Notes follow on next page)

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TABLE 20 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) Length of stud bolt does not include the height of the points. See para. 6.10.2.
(2) For other dimensions, see Tables 21 and 22.
(3) For flange bolt holes, see para. 6.5.
(4) For spot facing, see para. 6.6.
(5) Bolt lengths not shown in Table are determined in accordance with Annex F. See para. 6.10.2.

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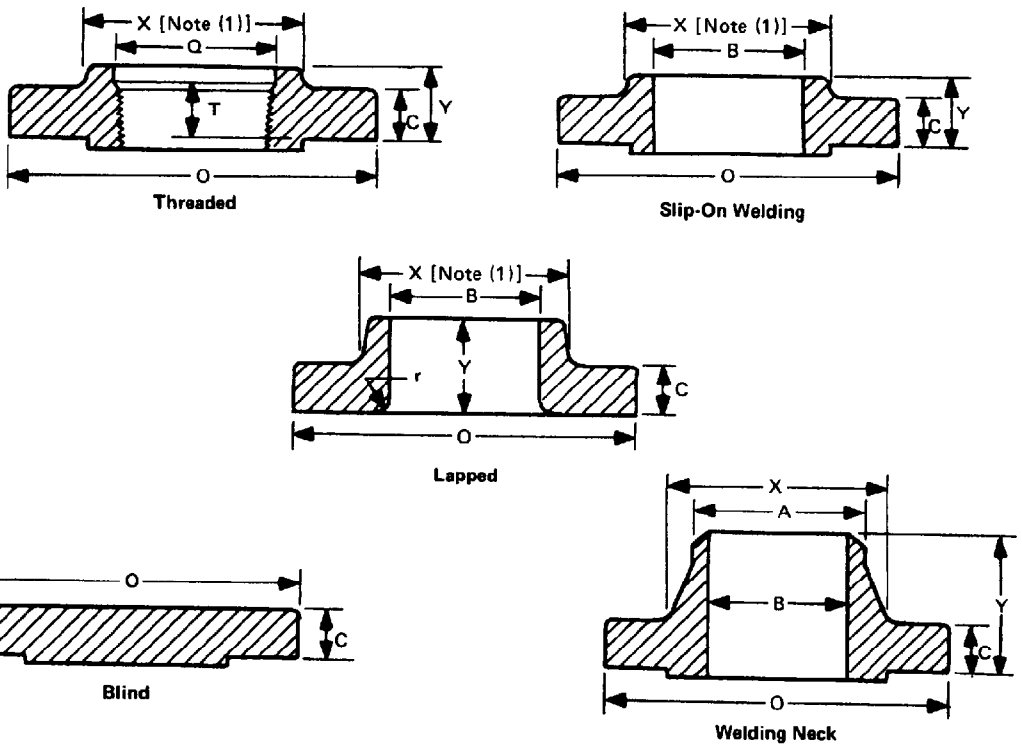

TABLE 21 DIMENSIONS OF CLASS 900 FLANGES[2–8]

1	2	3	4	5	6	7	8	9	10	11	12	13	14
					Length Through Hub				Bore				
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange Min. C	Diameter of Hub X	Hub Diameter Beginning of Chamfer Welding Neck (9) A	Threaded Slip-On Y	Lapped Y	Welding Neck Y	Thread Length Threaded Flange (10), Min. T	Slip-On Min. B	Lapped, Min. B	Welding Neck B	Corner Radius of Bore of Lapped Flange and Pipe r	Counterbore Threaded Flange, Min. Q
½ ¾ 1 1¼ 1½ 2 2½	Use Class 1500 dimensions in these sizes (11).												
3	9.50	1.50	5.00	3.50	2.12	2.12	4.00	1.62	3.57	3.60	To be specified by purchaser.	0.38	3.63
4	11.50	1.75	6.25	4.50	2.75	2.75	4.50	1.88	4.57	4.60		0.44	4.63
5	13.75	2.00	7.50	5.56	3.12	3.12	5.00	2.12	5.66	5.69		0.44	5.69
6	15.00	2.19	9.25	6.63	3.38	3.38	5.50	2.25	6.72	6.75		0.50	6.75
8	18.50	2.50	11.75	8.63	4.00	4.50	6.38	2.50	8.72	8.75		0.50	8.75
10	21.50	2.75	14.50	10.75	4.25	5.00	7.25	2.81	10.88	10.92		0.50	10.88
12	24.00	3.12	16.50	12.75	4.62	5.62	7.88	3.00	12.88	12.92		0.50	12.94
14	25.25	3.38	17.75	14.00	5.12	6.12	8.38	3.25	14.14	14.18		0.50	14.19
16	27.75	3.50	20.00	16.00	5.25	6.50	8.50	3.38	16.16	16.19		0.50	16.19
18	31.00	4.00	22.25	18.00	6.00	7.50	9.00	3.50	18.18	18.20		0.50	18.19
20	33.75	4.25	24.50	20.00	6.25	8.25	9.75	3.62	20.20	20.25		0.50	20.19
24	41.00	5.50	29.50	24.00	8.00	10.50	11.50	4.00	24.25	24.25		0.50	24.19

(Notes follow on next page)

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TABLE 21 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) This dimension is for large end of hub, which may be straight or tapered. Taper shall not exceed 7 deg. on threaded, slip-on, socket welding, and lapped flanges.
(2) For tolerances, see Section 7.
(3) For facings, see para. 6.4.
(4) For flange bolt holes, see para. 6.5 and Table 20.
(5) For spot facing, see para. 6.6.
(6) For reducing threaded and slip-on flanges, see Table 7.
(7) Blind flanges may be made with or without hubs at the manufacturer's option.
(8) For reducing welding neck flanges, see para. 6.8.
(9) For welding end bevel, see para. 6.7.
(10) For threads in threaded flanges, see para. 6.9.
(11) Socket welding flanges may be provided in NPS ½ through 2½ using Class 1500 dimensions.

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Table 22 begins on next page

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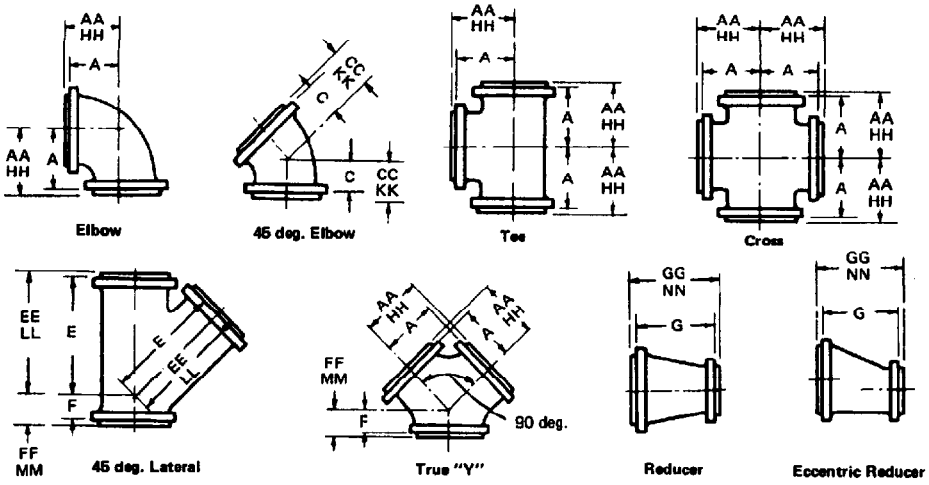

TABLE 22 DIMENSIONS OF CLASS 900 FLANGED FITTINGS[1–8]

1	2	3	4	5	6	7	8	9	10	11	12	13	14
					Flange Edge					0.25 in. Rasied Face (9)			
Nominal Pipe Size	Outside Diameter of Flange D	Thickness of Flange Min. C	Wall Thickness of Fitting, Min. t_m	Inside Diameter of Fitting d	Center-to-Flange Edge Elbow, Tee, Cross, and True "Y" A	Center-to-Flange Edge 45 deg. Elbow C	Long Center-to-Flange Edge Lateral E	Short Center-to-Flange Edge Lateral and True "Y" F	Flange Edge-to-Flange Edge Reducer G	Center-to-Contact Surface of Raised Face Elbow, Tee, Cross, and True "Y" AA	Center-to-Contact Surface of Raised Face 45 deg. Elbow CC	Long Center-to-Contact Surface of Raised Face Lateral EE	Short Center-to-Contact Surface of Raised Face Lateral and True "Y" FF
½	4.75	0.88	0.16	0.50									
¾	5.12	1.00	0.19	0.69									
1	5.88	1.12	0.22	0.88									
1¼	6.25	1.12	0.25	1.12									
					Use Class 1500 dimensions in these sizes.								
1½	7.00	1.25	0.28	1.38									
2	8.50	1.50	0.31	1.88									
2½	9.62	1.62	0.34	2.25									
3	9.50	1.50	0.41	2.88	7.25	5.25	14.25	4.25	7.25	7.50	5.50	14.50	4.50
4	11.50	1.75	0.50	3.88	8.75	6.25	17.25	5.25	8.75	9.00	6.50	17.50	5.50
5	13.75	2.00	0.59	4.75	10.75	7.25	20.75	6.25	10.75	11.00	7.50	21.00	6.50
6	15.00	2.19	0.72	5.75	11.75	7.75	22.25	6.25	11.75	12.00	8.00	22.50	6.50
8	18.50	2.50	0.88	7.50	14.25	8.75	27.25	7.25	14.25	14.50	9.00	27.50	7.50
10	21.50	2.75	1.06	9.38	16.25	9.75	31.25	8.25	16.25	16.50	10.00	31.50	8.50
12	24.00	3.12	1.25	11.12	18.75	10.75	34.25	8.75	17.25	19.00	11.00	34.50	9.00
14	25.25	3.38	1.38	12.25	20.00	11.25	36.25	9.25	18.50	20.25	11.50	36.50	9.50
16	27.75	3.50	1.56	14.00	22.00	12.25	40.50	10.25	20.50	22.25	12.50	40.75	10.25
18	31.00	4.00	1.75	15.75	23.75	13.00	45.25	11.75	24.00	24.00	13.25	45.50	12.00
20	33.75	4.25	1.91	17.50	25.75	14.25	50.00	12.75	26.00	26.00	14.50	50.25	13.00
24	41.00	5.50	2.28	21.00	30.25	17.75	59.75	15.25	30.00	30.50	18.00	60.00	15.50

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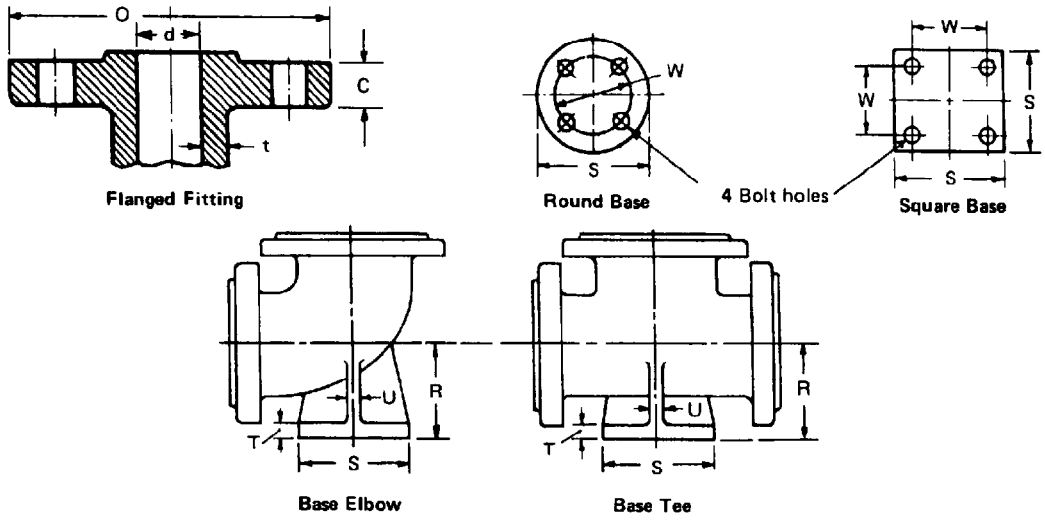

TABLE 22 DIMENSIONS OF CLASS 900 FLANGED FITTINGS[1-8] (CONT'D)

15	16	17	18	19	20	21	22	23	24	25	26	1
0.25 in. Raised Face (9)	Ring Joint (9)									Base Drilling (16)		
Contact Surface-to-Contact Surface of Raised Face Reducer (10) GG	Center-to-End Elbow, Tee, Cross, and True "Y" (11) HH	Center-to-End 45 deg. Elbow (11) KK	Long Center-to-End Lateral (11) LL	Short Center-to-End Lateral and True "Y" (11) MM	End-to-End Reducer NN	Center-to-Base [(12)–(13)] R	Diameter of Round Base or Width of Square Base (14) S	Thickness of Base [(14), (15)] T	Thickness of Ribs (14) U	Bolt Circle or Bolt Spacing W	Diameter of Drilled Holes	Nominal Pipe Size
Use Class 1500 dimensions in these sizes.												½ ¾ 1 1¼ 1½ 2 2½
7.75	7.56	5.56	14.56	4.56	See Notes (10) and (11).	5.75	6.50	0.88	0.75	5.00	0.75	3
9.25	9.06	6.56	17.56	5.56		7.00	7.50	1.00	0.75	5.88	0.88	4
11.25	11.06	7.56	21.06	6.56		8.25	10.00	1.25	0.75	7.88	0.88	5
12.25	12.06	8.06	22.56	6.56		9.00	10.00	1.25	0.75	7.88	0.88	6
14.75	14.56	9.06	27.56	7.56		11.00	12.50	1.44	1.00	10.62	0.88	8
16.75	16.56	10.06	31.56	8.56		12.50	12.50	1.44	1.00	10.62	0.88	10
17.75	19.06	11.06	34.56	9.06		13.25	15.00	1.62	1.12	13.00	1.00	12
19.00	20.44	11.69	36.69	9.69		14.75	15.00	1.62	1.12	13.00	1.00	14
21.00	22.44	12.69	40.94	10.69		16.00	15.00	1.62	1.25	13.00	1.00	16
24.50	24.25	13.50	45.75	12.25		...	...	...	...	...	...	18
26.50	26.25	14.75	50.50	13.25		...	...	...	...	...	...	20
30.50	30.88	18.38	60.38	15.88		...	...	...	...	...	...	24

(Notes follow on next page)

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TABLE 22 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) For tolerances, see Section 7.
(2) For facings, see para. 6.4.
(3) For flange bolt holes, see para. 6.5 and Table 20.
(4) For spot facing, see para. 6.6.
(5) For intersecting center lines, center-to-contact surface, and center-to-end dimensions of side outlet fittings, see para. 6.2.4.
(6) For center-to-contact surface and center-to-end dimensions of special degree elbows, see para. 6.2.5.
(7) For reinforcement of certain fittings, see para. 6.1.
(8) For drains, see para. 6.12.
(9) For center-to-contact surface and center-to-end dimensions of reducing fittings, see para. 6.2.3.
(10) For contact surface-to-contact surface and center-to-end dimensions of reducers and eccentric reducers, see para. 6.2.3.
(11) These dimensions apply to straight sizes only. (See paras. 6.2.3 and 6.3.1.3.) For the center-to-end dimensions of reducing fittings or end-to-end dimensions of reducers, use center-to-flange edge or flange edge-to-flange edge dimensions for largest opening, and add the proper height to provide for ring joint groove applying to each flange. See Table 5 for ring joint facing dimensions.
(12) For reducing fittings, the size and center-to-face dimensions of base are determined by the size of the largest opening of fitting. In the case of reducing base elbows, orders shall specify whether the base shall be opposite the larger or smaller opening.
(13) Bases shall be plain faced unless otherwise specified, and the center-to-base face dimension R shall be the finished dimension.
(14) The base dimensions apply to all straight and reducing sizes.
(15) Bases may be cast integral or attached as weldments at the option of the manufacturer.
(16) The bolt hole template for round base is the same as for Class 300 flanges, Table 11, of corresponding outside diameter, except using only four holes in all cases so placed as to straddle center lines. The bases of these fittings are intended for support in compression and are not to be used for anchors or supports in tension or shear.

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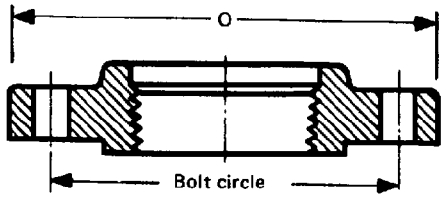
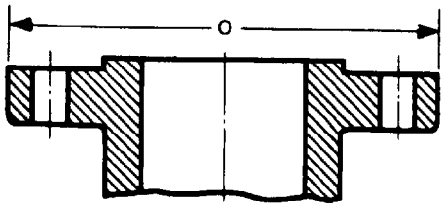
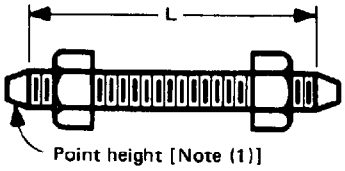
CLASS 1500 PIPE FLANGES, AND FLANGED FITTINGS



Flange



Flanged Fitting



Stud Bolt With Nuts

TABLE 23 TEMPLATES FOR DRILLING CLASS 1500 FLANGES[2]

1	2	3	4	5	6	7	8	9
		Drilling [(3), (4)]				Length of Bolts [(1), (5)] L		
Nominal Pipe Size	Outside Diameter of Flange O	Diameter of Bolt Circle	Diameter of Bolt Holes	Number of Bolts	Diameter of Bolts	0.25 in. Raised Face	Male and Female; also Tongue and Groove	Ring Joint
1/2	4.75	3.25	0.88	4	3/4	4.25	4.00	4.25
3/4	5.12	3.50	0.88	4	3/4	4.50	4.25	4.50
1	5.88	4.00	1.00	4	7/8	5.00	4.75	5.00
1 1/4	6.25	4.38	1.00	4	7/8	5.00	4.75	5.00
1 1/2	7.00	4.88	1.12	4	1	5.50	5.25	5.50
2	8.50	6.50	1.00	8	7/8	5.75	5.50	5.75
2 1/2	9.62	7.50	1.12	8	1	6.25	6.00	6.25
3	10.50	8.00	1.25	8	1 1/8	7.00	6.75	7.00
4	12.25	9.50	1.38	8	1 1/4	7.75	7.50	7.75
5	14.75	11.50	1.62	8	1 1/2	9.75	9.50	9.75
6	15.50	12.50	1.50	12	1 3/8	10.25	10.00	10.50
8	19.00	15.50	1.75	12	1 5/8	11.50	11.25	12.75
10	23.00	19.00	2.00	12	1 7/8	13.25	13.00	13.50
12	26.50	22.50	2.12	16	2	14.75	14.50	15.25
14	29.50	25.00	2.38	16	2 1/4	16.00	15.75	16.75
16	32.50	27.75	2.62	16	2 1/2	17.50	17.25	18.50
18	36.00	30.50	2.88	16	2 3/4	19.50	19.25	20.75
20	38.75	32.75	3.12	16	3	21.25	21.00	22.25
24	46.00	39.00	3.62	16	3 1/2	24.25	24.00	25.50

(Notes follow on next page)

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TABLE 23 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) Length of stud bolt does not include the height of the points. See para. 6.10.2.
(2) For other dimensions, see Tables 24 and 25.
(3) For flange bolt holes, see para. 6.5.
(4) For spot facing, see para. 6.6.
(5) Bolt lengths not shown in Table are determined in accordance with Annex F. See para. 6.10.2.

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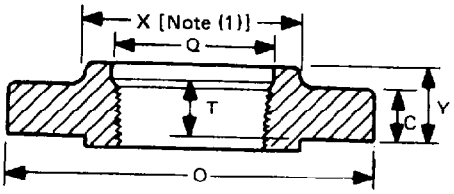
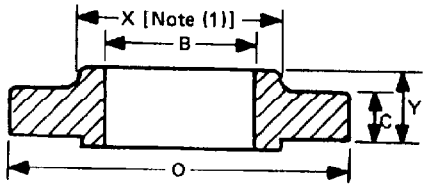
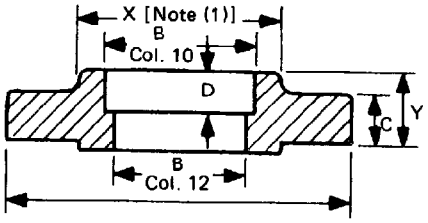


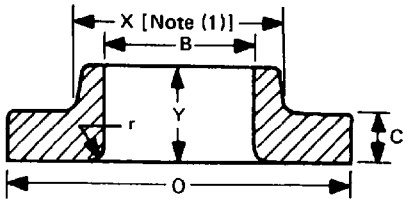
Threaded (1/2 to 2-1/2 only)



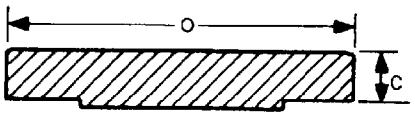
Slip-On-Welding (1/2 to 2-1/2 only)



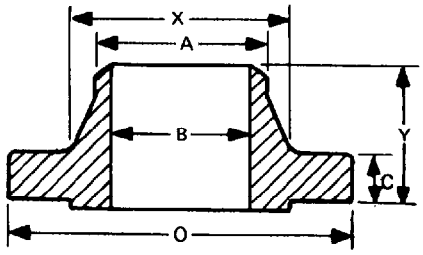
Socket Welding (1/2 to 2-1/2 only)



Lapped



Blind



Welding Neck

TABLE 24 DIMENSIONS OF CLASS 1500 FLANGES[2-8]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
					Length Through Hub				Bore					
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange, Min. C	Diameter of Hub X	Hub Diameter Beginning of Chamfer Welding Neck (9) A	Threaded Slip-On Socket Welding Y	Lapped Y	Welding Neck Y	Thread Length Threaded Flange (10), Min. T	Slip-On Socket Welding, Min. B	Lapped, Min. B	Welding Neck Socket Welding B	Corner Radius of Bore of Lapped Flange and Pipe r	Counterbore Threaded Flange, Min. Q	Depth of Socket D
½	4.75	0.88	1.50	0.84	1.25	1.25	2.38	0.88	0.88	0.90		0.12	0.93	0.38
¾	5.12	1.00	1.75	1.05	1.38	1.38	2.75	1.00	1.09	1.11		0.12	1.14	0.44
1	5.88	1.12	2.06	1.32	1.62	1.62	2.88	1.12	1.36	1.38		0.12	1.41	0.50
1¼	6.25	1.12	2.50	1.66	1.62	1.62	2.88	1.19	1.70	1.72		0.19	1.75	0.56
1½	7.00	1.25	2.75	1.90	1.75	1.75	3.25	1.25	1.95	1.97		0.25	1.99	0.62
2	8.50	1.50	4.12	2.38	2.25	2.25	4.00	1.50	2.44	2.46		0.31	2.50	0.69
2½	9.62	1.62	4.88	2.88	2.50	2.50	4.12	1.88	2.94	2.97		0.31	3.00	0.75
3	10.50	1.88	5.25	3.50	...	2.88	4.62	...	...	3.60		0.38	...	...
4	12.25	2.12	6.38	4.50	...	3.56	4.88	...	...	4.60		0.44	...	...
5	14.75	2.88	7.75	5.56	...	4.12	6.12	...	...	5.69		0.44	...	...
6	15.50	3.25	9.00	6.63	...	4.69	6.75	...	...	6.75		0.50	...	...
8	19.00	3.62	11.50	8.63	...	5.62	8.38	...	...	8.75		0.50	...	...
10	23.00	4.25	14.50	10.75	...	7.00	10.00	...	...	10.92		0.50	...	...
12	26.50	4.88	17.75	12.75	...	8.62	11.12	...	...	12.92		0.50	...	...
14	29.50	5.25	19.50	14.00	...	9.50	11.75	...	...	14.18		0.50	...	...
16	32.50	5.75	21.75	16.00	...	10.25	12.25	...	...	16.19		0.50	...	...
18	36.00	6.38	23.50	18.00	...	10.88	12.88	...	...	18.20		0.50	...	...
20	38.75	7.00	25.25	20.00	...	11.50	14.00	...	...	20.25		0.50	...	...
24	46.00	8.00	30.00	24.00	...	13.00	16.00	...	...	24.25		0.50	...	...

To be specified by purchaser.

(Notes follow on next page)

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TABLE 24 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) This dimension is for large end of hub, which may be straight or tapered. Taper shall not exceed 7 deg. on threaded, slip-on, socket welding, and lapped flanges.
(2) For tolerances, see Section 7.
(3) For facings, see para. 6.4.
(4) For flange bolt holes, see para. 6.5 and Table 23.
(5) For spot facing, see para. 6.6.
(6) For reducing threaded and slip-on flanges, see Table 7.
(7) Blind flanges may be made with or without hubs at the manufacturer's option.
(8) For reducing welding neck flanges, see para. 6.8.
(9) For welding end bevel, see para. 6.7.
(10) For threads in threaded flanges, see para. 6.9.

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Table 25 begins on next page

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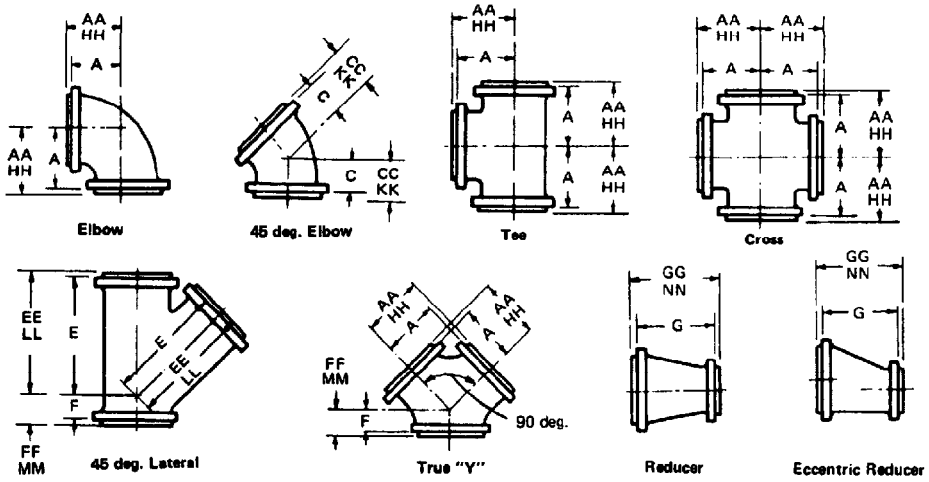

TABLE 25 DIMENSIONS OF CLASS 1500 FLANGED FITTINGS[1-8]

1	2	3	4	5	6	7	8	9	10	11	12	13	14
					Flange Edge					0.25 in. Raised Face (9)			
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange, Min. C	Wall Thickness of Fitting, Min. t_m	Inside Diameter of Fitting, d	Center-to-Flange Edge, Elbow, Tee, Cross, and True "Y" A	Center-to-Flange Edge 45 deg. Elbow C	Long Center-to-Flange Edge Lateral E	Short Center-to-Flange Edge Lateral and True "Y" F	Flange Edge-to-Flange Edge Reducer G	Center-to-Contact Surface of Raised Face Elbow, Tee, Cross, and True "Y" AA	Center-to-Contact Surface of Raised Face 45 deg. Elbow CC	Long Center-to-Contact Surface of Raised Face Lateral EE	Short Center-to-Contact Surface of Raised Face Lateral and True "Y" FF
½	4.75	0.88	0.19	0.50	4.00	2.75	...	...	...	4.25	3.00	...	...
¾	5.12	1.00	0.23	0.69	4.25	3.00	...	...	...	4.50	3.25	...	...
1	5.88	1.12	0.26	0.88	4.75	3.25	8.75	2.25	4.50	5.00	3.50	9.00	2.50
1¼	6.25	1.12	0.31	1.12	5.25	3.75	9.75	2.75	5.25	5.50	4.00	10.00	3.00
1½	7.00	1.25	0.38	1.38	5.75	4.00	10.75	3.25	5.75	6.00	4.25	11.00	3.50
2	8.50	1.50	0.44	1.88	7.00	4.50	13.00	3.75	6.75	7.25	4.75	13.25	4.00
2½	9.62	1.62	0.50	2.25	8.00	5.00	15.00	4.25	7.75	8.25	5.25	15.25	4.50
3	10.50	1.88	0.62	2.75	9.00	5.50	17.00	4.75	8.75	9.25	5.75	17.25	5.00
4	12.25	2.12	0.75	3.62	10.50	7.00	19.00	5.75	10.25	10.75	7.25	19.25	6.00
5	14.75	2.88	0.91	4.38	13.00	8.50	23.00	7.25	13.25	13.25	8.75	23.25	7.50
6	15.50	3.25	1.09	5.38	13.62	9.12	24.62	7.88	14.00	13.88	9.38	24.88	8.12
8	19.00	3.62	1.41	7.00	16.12	10.62	29.62	8.88	16.50	16.38	10.88	29.88	9.12
10	23.00	4.25	1.72	8.75	19.25	11.75	35.75	10.00	19.75	19.50	12.00	36.00	10.25
12	26.50	4.88	2.00	10.38	22.00	13.00	40.50	11.75	22.50	22.25	13.25	40.75	12.00
14	29.50	5.25	2.19	11.38	24.50	14.00	43.75	12.25	25.25	24.75	14.25	44.00	12.50
16	32.50	5.75	2.50	13.00	27.00	16.00	48.00	14.50	27.75	27.25	16.25	48.25	14.75
18	36.00	6.38	2.81	14.62	30.00	17.50	53.00	16.25	31.00	30.25	17.75	53.25	16.50
20	38.75	7.00	3.12	16.38	32.50	18.50	57.50	17.50	33.50	32.75	18.75	57.75	17.75
24	46.00	8.00	3.72	19.62	38.00	20.50	67.00	20.25	39.25	38.75	20.75	67.25	20.50

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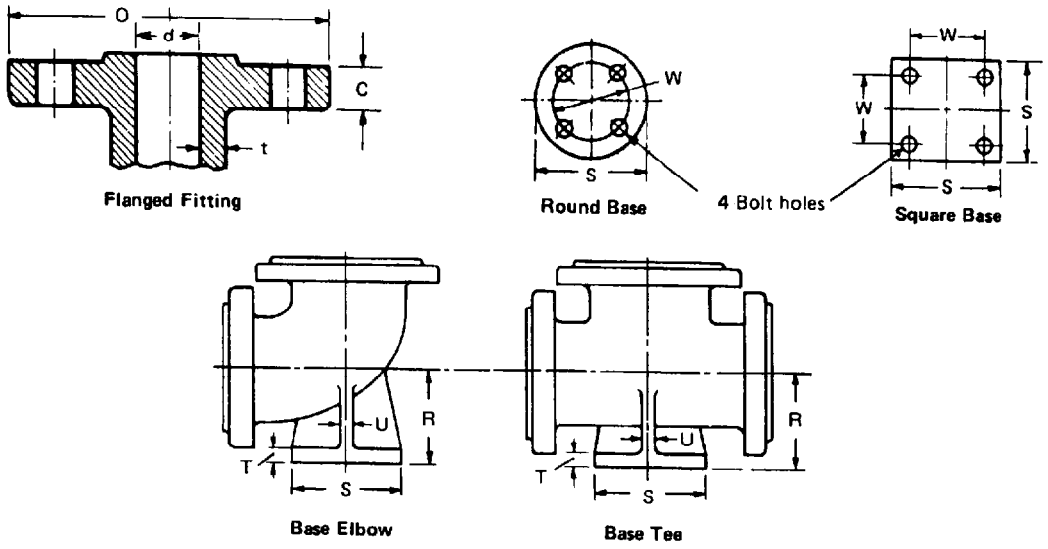

TABLE 25 DIMENSIONS OF CLASS 1500 FLANGED FITTINGS[1–8] (CONT'D)

15	16	17	18	19	20	21	22	23	24	25	26	1
0.25 in. Raised Face (9)	Ring Joint (9)									Base Drilling (16)		
Contact Surface-to-Contact Surface of Raised Face Reducer (10) GG	Center-to-End Elbow Tee Cross and True "Y" (11) HH	Center-to-End 45 deg. Elbow (11) KK	Long Center-to-End Lateral (11) LL	Short Center-to-End Lateral and True "Y" (11) MM	End-to-End Reducer NN	Center-to-Base [(12)–(14)] R	Diameter of Round Base or Width of Square Base (12) S	Thickness of Base [(12), (15)] T	Thickness of Ribs (12) U	Bolt Circle or Bolt Spacing W	Diameter of Drilled Holes	Nominal Pipe Size
...	4.25	3.00	...	...	See Notes (10) and (11)	...	...	...	...	...	...	½
...	4.50	3.25	...	...		...	...	...	...	...	...	¾
5.00	5.00	3.50	9.00	2.50		...	...	...	...	...	...	1
5.75	5.50	4.00	10.00	3.00		...	...	...	...	...	...	1¼
6.25	6.00	4.25	11.00	3.50		...	...	...	...	...	...	1½
7.25	7.31	4.81	13.31	4.06		5.50	6.50	0.88	0.75	5.00	0.75	2
8.25	8.31	5.31	15.31	4.56		6.00	6.50	0.88	0.75	5.00	0.75	2½
9.25	9.31	5.81	17.31	5.06		6.50	7.50	1.00	0.75	5.88	0.88	3
10.75	10.81	7.31	19.31	6.06		7.75	10.00	1.25	0.75	7.88	0.88	4
13.75	13.31	8.81	23.31	7.56		9.00	10.00	1.25	0.75	7.88	0.88	5
14.50	14.00	9.50	25.00	8.25		9.75	12.50	1.44	1.00	10.62	0.88	6
17.00	16.56	11.06	30.06	9.31		11.50	12.50	1.44	1.00	10.62	0.88	8
20.25	19.69	12.19	36.19	10.44		13.75	15.00	1.62	1.12	13.00	1.00	10
23.00	22.56	13.56	41.06	12.31		15.50	15.00	1.62	1.12	13.00	1.00	12
25.75	25.12	14.62	44.38	12.88		17.25	17.50	1.88	1.25	15.25	1.12	14
28.25	27.69	16.69	48.69	15.19		18.75	17.50	1.88	1.25	15.25	1.12	16
31.50	30.69	18.19	53.69	16.94		...	...	...	...	...	...	18
34.00	33.19	19.19	58.19	18.19		...	...	...	...	...	...	20
39.75	38.81	21.31	67.81	21.06		...	...	...	...	...	...	24

(Notes follow on next page)

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TABLE 25 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) For tolerances, see Section 7.
(2) For facings, see para. 6.4.
(3) For flange bolt holes, see para. 6.5 and Table 23.
(4) For spot facing, see para. 6.6.
(5) For intersecting center lines, center-to-contact surface, and center-to-end dimensions of side outlet fittings, see para. 6.2.4.
(6) For center-to-contact surface and center-to-end dimensions of special degree elbows, see para. 6.2.5.
(7) For reinforcement of certain fittings, see para. 6.1.
(8) For drains, see para. 6.12.
(9) For center-to-contact surface and center-to-end dimensions of reducing fittings, see para. 6.2.3.
(10) For contact surface-to-contact surface and end-to-end dimensions of reducers and eccentric reducers, see para. 6.2.3.
(11) These dimensions apply to straight sizes only. (See paras. 6.2.5 and 6.3.1.3.) For the center-to-end dimensions of reducing fittings or end-to-end dimensions of reducers, use center-to-flange edge or flange edge-to-flange edge dimensions for largest opening, and add the proper height to provide for ring joint groove applying to each flange. See Table 5 for ring joint facing dimension.
(12) The base dimensions apply to all straight and reducing sizes.
(13) For reducing fittings, the size and center-to-face dimensions of base are determined by the size of the largest opening of fitting. In the case of reducing base elbows, orders shall specify whether the base shall be opposite the larger or smaller opening.
(14) Bases shall be plain faced unless otherwise specified, and the center-to-base dimension R shall be the finished dimension.
(15) Bases may be cast integral or attached as weldments at the option of the manufacturer.
(16) The bolt hole template for round base is the same as for Class 300 flanges, Table 11, of corresponding outside diameter, except using only four holes in all cases so placed as to straddle center lines. The bases of these fittings are intended for support in compression and are not to be used for anchors or supports in tension or shear.

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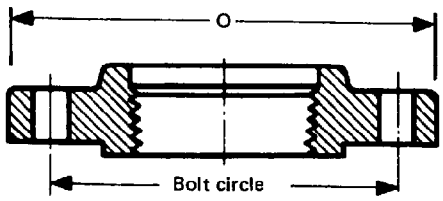
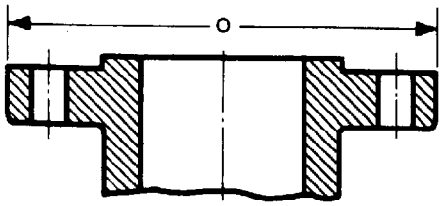
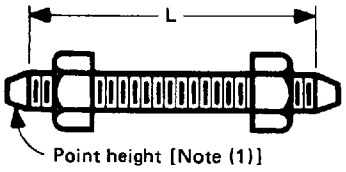
CLASS 2500 PIPE FLANGES, AND FLANGED FITTINGS



Flange



Flanged Fitting



Stud Bolt With Nuts

TABLE 26 TEMPLATES FOR DRILLING CLASS 2500 FLANGES[2]

1	2	3	4	5	6	7	8	9
		Drilling [(3), (4)]				Length of Bolts [(1), (5)] L		
Nominal Pipe Size	Outside Diameter of Flange O	Diameter of Bolt Circle	Diameter of Bolt Holes	Number of Bolts	Diameter of Bolts	0.25 in. Raised Face	Male and Female; also Tongue and Groove	Ring Joint
1/2	5.25	3.50	0.88	4	3/4	4.75	4.50	4.75
3/4	5.50	3.75	0.88	4	3/4	5.00	4.75	5.00
1	6.25	4.25	1.00	4	7/8	5.50	5.25	5.50
1 1/4	7.25	5.12	1.12	4	1	6.00	5.75	6.00
1 1/2	8.00	5.75	1.25	4	1 1/8	6.75	6.50	6.75
2	9.25	6.75	1.12	8	1	7.00	6.75	7.00
2 1/2	10.50	7.75	1.25	8	1 1/8	7.75	7.50	8.00
3	12.00	9.00	1.38	8	1 1/4	8.75	8.50	9.00
4	14.00	10.75	1.62	8	1 1/2	10.00	9.75	10.25
5	16.50	12.75	1.88	8	1 3/4	11.75	11.50	12.25
6	19.00	14.50	2.12	8	2	13.50	13.25	14.00
8	21.75	17.25	2.12	12	2	15.00	14.75	15.50
10	26.50	21.25	2.62	12	2 1/2	19.25	19.00	20.00
12	30.00	24.38	2.88	12	2 3/4	21.25	21.00	22.00

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) Length of stud bolt does not include the height of the points. See para. 6.10.2.
(2) For other dimensions, see Tables 27 and 28.
(3) For flange bolt holes, see para. 6.5.
(4) For spot facing, see para. 6.6.
(5) Bolt lengths not shown in Table are determined in accordance with Annex F. See para. 6.10.2.

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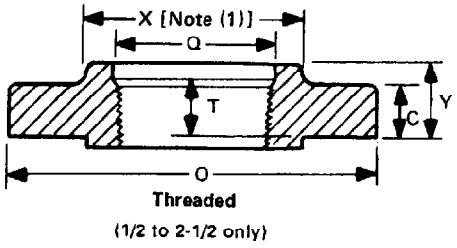
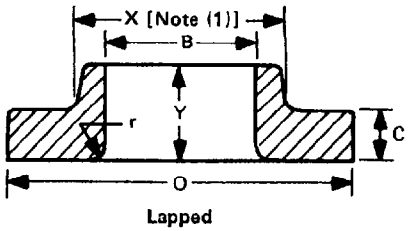
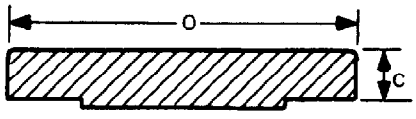


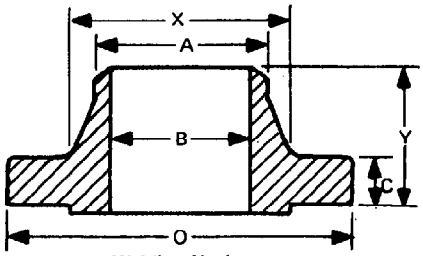
Threaded
(1/2 to 2-1/2 only)



Lapped



Blind



Welding Neck

TABLE 27 DIMENSIONS OF CLASS 2500 FLANGES[2-8]

1	2	3	4	5	6	7	8	9	10	11	12	13
					Length Through Hub				Bore			
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange, Min. C	Diameter of Hub X	Hub Diameter Beginning of Chamfer Welding Neck (9) A	Threaded Y	Lapped Y	Welding Neck Y	Thread Length Threaded Flange (10), Min. T	Lapped, Min. B	Welding, Neck B	Corner Radius of Bore of Lapped Flange and Pipe r	Counterbore Threaded Flange, Min. Q
½	5.25	1.19	1.69	0.84	1.56	1.56	2.88	1.12	0.90		0.12	0.93
¾	5.50	1.25	2.00	1.05	1.69	1.69	3.12	1.25	1.11		0.12	1.14
1	6.25	1.38	2.25	1.32	1.88	1.88	3.50	1.38	1.38		0.12	1.41
1¼	7.25	1.50	2.88	1.66	2.06	2.06	3.75	1.50	1.72		0.19	1.75
1½	8.00	1.75	3.12	1.90	2.38	2.38	4.38	1.75	1.97		0.25	1.99
2	9.25	2.00	3.75	2.38	2.75	2.75	5.00	2.00	2.46		0.31	2.50
2½	10.50	2.25	4.50	2.88	3.12	3.12	5.62	2.25	2.97		0.31	3.00
3	12.00	2.62	5.25	3.50	...	3.62	6.62	...	3.60		0.38	...
4	14.00	3.00	6.50	4.50	...	4.25	7.50	...	4.60		0.44	...
5	16.50	3.62	8.00	5.56	...	5.12	9.00	...	5.69		0.44	...
6	19.00	4.25	9.25	6.63	...	6.00	10.75	...	6.75		0.50	...
8	21 75	5.00	12.00	8.63	...	7.00	12.50	...	8.75		0.50	...
10	26.50	6.50	14.75	10.75	...	9.00	16.50	...	10.92		0.50	...
12	30.00	7.25	17.38	12.75	...	10.00	18.25	...	12.92		0.50	...

To be specified by purchaser.

(Notes follow on next page)

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TABLE 27 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) This dimension is for large end of hub, which may be straight or tapered. Taper shall not exceed 7 deg. on threaded, slip-on, socket welding, and lapped flanges.
(2) For tolerances, see Section 7.
(3) For facings, see para. 6.4.
(4) For flange bolt holes, see para. 6.5 and Table 26.
(5) For spot facing, see para. 6.6.
(6) For reducing threaded and slip-on flanges, see Table 7.
(7) Blind flanges may be made with or without hubs at the manufacturer's option.
(8) For reducing welding neck flanges, see para. 6.8.
(9) For welding end bevel, see para. 6.7.
(10) For threads in threaded flanges, see para. 6.9.

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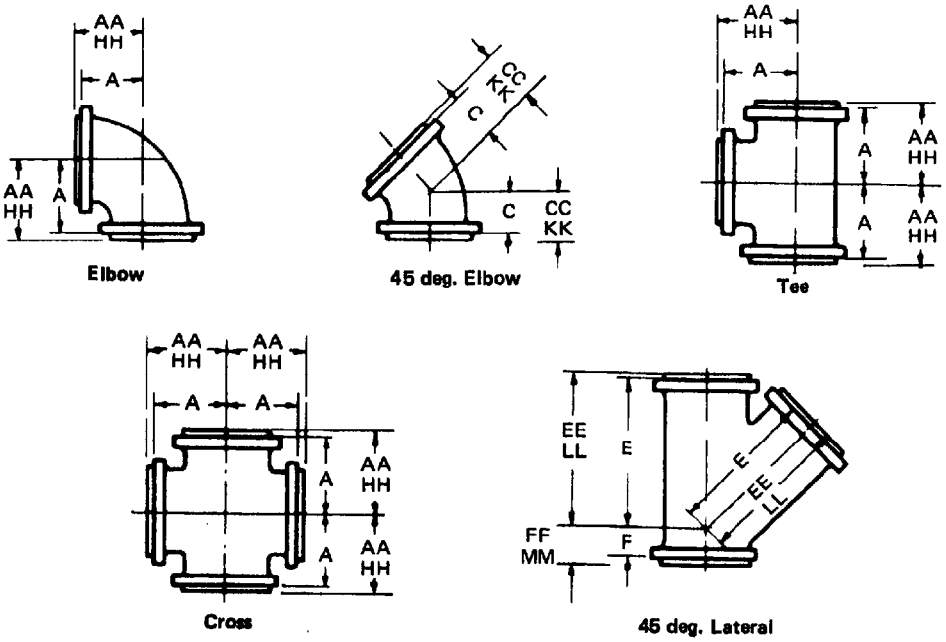

TABLE 28 DIMENSIONS OF CLASS 2500 FLANGED FITTINGS[1-8]

1	2	3	4	5	6	7	8	9	10
					Flange Edge				
Nominal Pipe Size	Outside Diameter of Flange O	Thickness of Flange, Min. C	Wall Thickness of Fitting, Min. t_m	Inside Diameter of Fitting, d	Center-to-Flange Edge, Elbow, Tee, Cross, and True "Y" A	Center-to-Flange Edge 45 deg. Elbow C	Long Center-to-Flange Edge Lateral E	Short Center-to-Flange Edge Lateral and True "Y" F	Flange Edge-to-Flange Edge Reducer G
½	5.25	1.19	0.25	0.44	4.94	...	...	...	...
¾	5.50	1.25	0.28	0.56	5.12	...	...	...	...
1	6.25	1.38	0.34	0.75	5.81	3.75	...	...	...
1¼	7.25	1.50	0.44	1.00	6.62	4.00	...	...	...
1½	8.00	1.75	0.50	1.12	7.31	4.50	...	...	...
2	9.25	2.00	0.62	1.50	8.62	5.50	15.00	5.00	9.00
2½	10.50	2.25	0.75	1.88	9.75	6.00	17.00	5.50	10.00
3	12.00	2.62	0.88	2.25	11.12	7.00	19.50	6.50	11.25
4	14.00	3.00	1.09	2.88	13.00	8.25	22.75	7.50	13.00
5	16.50	3.62	1.34	3.62	15.38	9.75	27.00	9.00	15.25
6	19.00	4.25	1.59	4.38	17.75	11.25	31.00	10.25	17.50
8	21.75	5.00	2.06	5.75	19.88	12.50	35.00	11.50	20.00
10	26.50	6.50	2.59	7.25	24.75	15.75	43.00	14.50	25.00
12	30.00	7.25	3.03	8.62	27.75	17.50	49.00	16.00	28.50

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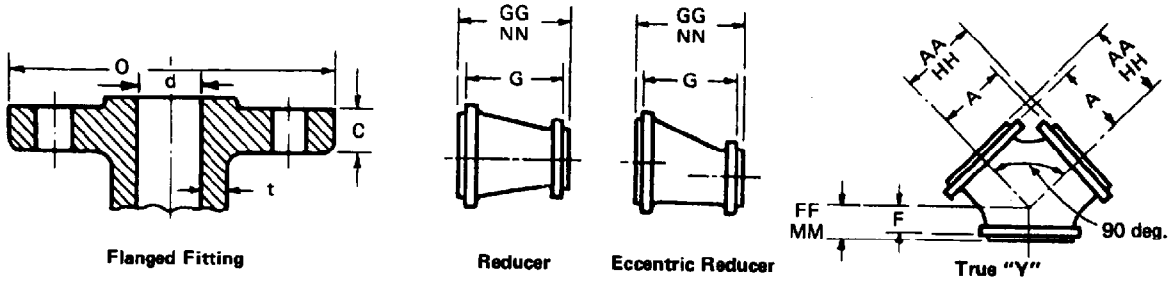

Flanged Fitting | Reducer | Eccentric Reducer | True "Y"

TABLE 28 DIMENSIONS OF CLASS 2500 FLANGED FITTINGS[1-8] (CONT'D)

11	12	13	14	15	16	17	18	19	20	1
0.25 in. Raised Face (9)					Ring Joint (9)					
Center-to-Contact Surface of Raised Face Elbow, Tee, Cross, and True "Y" AA	Center-to-Contact Surface of Raised Face 45 deg. Elbow CC	Long Center-to-Contact Surface of Raised Face Lateral EE	Short Center-to-Contact Surface of Raised Face Lateral and True "Y" FF	Contact Surface-to-Contact Surface of Raised Face Reducer (10) GG	Center-to-End Elbow, Tee Cross, and True "Y" (11) HH	Center-to-End 45 deg. Elbow (11) KK	Long Center-to-End Lateral (11) LL	Short Center-to-End Lateral and True "Y" (11) MM	End-to-End Reducer NN	Nominal Pipe Size
5.19	...	...	...	...	5.19	...	...	...	See Notes (10) and (11)	1/2
5.37	...	...	...	...	5.19	...	...	...		3/4
6.06	4.00	...	...	...	6.06	4.00	...	...		1
6.87	4.25	...	...	...	6.94	4.31	...	...		1 1/4
7.56	4.75	...	...	...	7.62	4.81	...	...		1 1/2
8.87	5.75	15.25	5.25	9.50	8.94	5.81	15.31	5.31		2
10.00	6.25	17.25	5.75	10.50	10.12	6.38	17.38	5.88		2 1/2
11.37	7.25	19.75	6.75	11.75	11.50	7.38	19.88	6.88		3
13.25	8.50	23.00	7.75	13.50	13.44	8.69	23.19	7.94		4
15.62	10.00	27.25	9.25	15.75	15.88	10.25	27.50	9.50		5
18.00	11.50	31.25	10.50	18.00	18.25	11.75	31.50	10.75		6
20.12	12.75	35.25	11.75	20.50	20.44	13.06	35.56	12.06		8
25.00	16.00	43.25	14.75	25.50	25.44	16.44	43.69	15.19		10
28.00	17.75	49.25	16.25	29.00	28.44	18.19	49.69	16.62		12

(Notes follow on next page)

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TABLE 28 (CONT'D)

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) For tolerances, see Section 7.
(2) For facings, see para. 6.4.
(3) For flange bolt holes, see para. 6.5 and Table 26.
(4) For spot facing, see para. 6.6.
(5) For intersecting center lines, center-to-contact surface, and center-to-end dimensions of side outlet fittings, see para. 6.2.4.
(6) For center-to-contact surface and center-to-end dimensions of special degree elbows, see para. 6.2.5.
(7) For reinforcement of certain fittings, see para. 6.1.
(8) For drains, see para. 6.12.
(9) For center-to-contact surface and center-to-end dimensions of reducing fittings, see para. 6.2.3.
(10) For contact surface-to-contact surface and end-to-end dimensions of reducers and eccentric reducers, see para. 6.2.3.
(11) These dimensions apply to straight sizes only. (See paras. 6.2.3 and 6.4.1.3.) For the center-to-end dimensions of reducing fittings or end-to-end dimensions of reducers, use center-to-flange edge or flange edge-to-flange edge dimensions for largest opening, and add the proper height to provide for ring joint groove applying to each flange. See Table 5 for ring joint facing dimensions.

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ANNEX A

THREADING OF PIPE FOR AMERICAN NATIONAL STANDARD THREADED FLANGES

(This Annex is an integral part of ASME B16.5-1996 and is placed after the main text for convenience.)

The length of external taper threads in ASME B1.20.1 is sufficient to provide a satisfactory joint when assembled with corresponding internal taper threads in couplings and fittings. In this Standard, the length of internal thread in Class 150, Class 300, and Class 400 flanges also conforms to ASME B1.20.1.

In Class 600 and higher rated flanges, the length through the hub may exceed the length for internal threads in ASME B1.20.1. Where this occurs, the extended length of internal threads follows the taper of the standard taper threads. Therefore, the diameters of the extra threads are smaller than those shown in ASME B1.20.1.

When threaded flanges conforming to this Standard are assembled with threaded-end pipe, it is intended that the end of the pipe be reasonably close to the mating surface of the flange. To meet this intent, the following requirements are imposed on the mating pipe and external thread.

(1) Pipe to be threaded into flanges of Class 600 or higher rating shall be Schedule 80 or heavier in wall thickness.

(2) The length of external effective thread on the pipe end shall be greater than specified in ASME B1.20.1. When tested with the standard ring gage, the pipe end shall project beyond the gage by the distance specified in Table A1, subject to a tolerance of one thread pitch as provided in ASME B1.20.1.

(3) The extra threads shall continue the taper specified in ASME B1.20.1, so that the pitch diameter of the thread at the pipe end is less than specified therein.

(4) It is recommended that power equipment be used to assemble threaded joints having longer than standard taper threads, in order to bring the pipe end close to the flange face.

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TABLE A1 PROJECTION OF THREADED PIPE END THROUGH RING GAGE BY FLANGE PRESSURE RATING CLASSES

Nominal Pipe Size	150, 300, 400	600		900		1500		2500	
	Number of Turns	Number of Turns	in.	Number of Turns	in.	Number of Turns	in.	Number of Turns	in.
½	...	Use taper pipe thread per ASME B1.20.1 in these sizes.		...	...	3½	0.25	7	0.50
¾	...			...		5	0.35	7	0.50
1	...			...	...	5	0.44	7½	0.65
1¼	...			...	...	5	0.44	7½	0.65
1½	...			...	...	5	0.44	7½	0.65
2	...			...	...	5	0.44	7½	0.65
2½	...			...	...	5	0.62	8	1.00
3	...	1	0.12	3	0.38	6	0.75	10	1.25
3½	...	1	0.12	...	...	...	...	...	...
4	...	1½	0.19	3½	0.44	6½	0.81	10½	1.31
5		1½	0.19	3½	0.44	6½	0.81	10½	1.31
6		1½	0.19	3½	0.44	7½	0.94	11½	1.44
8		2	0.25	4	0.50	8	1.00	14	1.75
10	Use taper pipe thread per ASME B1.20.1.	3	0.38	5	0.62	9	1.12	15	2.00
12		3	0.38	5	0.62	10	1.25	19	2.38
14		3	0.38	6	0.75	...	...	...	...
16		3	0.38	6	0.75	...	...	...	...
18		3	0.38	6	0.75	...	...	...	...
20		3	0.38	6	0.75	...	...	...	...
24		3	0.38	6	0.75	...	...	...	...

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ANNEX B
DIMENSIONS OF STEEL PIPE (TABLE BY WEIGHT CLASS)

(This Annex is not part of ASME B16.5-1996 and is included for information only.)

TABLE B1 DIMENSIONS OF WELDED AND SEAMLESS STEEL PIPE (ASME B36.10M)
Listed as Standard Wall, Extra Strong, and Double Extra Strong Wall

Nominal Pipe Size	Outside Diameter, in.	Wall Thickness, in.		
		Standard Wall	Extra Strong Wall	Double Extra Strong Wall
1/8	0.405	**0.068**	**0.095**	. . .
1/4	0.540	**0.088**	**0.119**	. . .
3/8	0.675	**0.091**	**0.126**	. . .
1/2	0.840	**0.109**	**0.147**	0.294
3/4	1.050	**0.113**	**0.154**	0.308
1	1.315	**0.133**	**0.179**	0.358
1 1/4	1.660	**0.140**	**0.191**	0.362
1 1/2	1.900	**0.145**	**0.200**	0.400
2	2.375	**0.154**	**0.218**	0.436
2 1/2	2.875	**0.203**	**0.276**	0.522
3	3.500	**0.216**	**0.300**	0.600
3 1/2	4.000	**0.226**	**0.318**	. . .
4	4.500	**0.237**	**0.337**	0.674
5	5.563	**0.258**	**0.375**	0.750
6	6.625	**0.280**	**0.432**	0.864
8	8.625	**0.322**	**0.500**	0.875
10	10.750	**0.365**	**0.500**	1.000
12	12.750	0.375	0.500	1.000
14	14.000	**0.375**	0.500	. . .
16	16.000	**0.375**	**0.500**	. . .
18	18.000	0.375	0.500	. . .
20	20.000	**0.375**	**0.500**	. . .
24	24.000	**0.375**	0.500	. . .

GENERAL NOTES:

(a) The decimal thicknesses listed for the respective sizes represent their nominal dimensions as given in ASME B36.10M. For tolerances on wall thicknesses, see appropriate material specifications.

(b) Thicknesses shown in bold face type for Standard Wall are identical with corresponding thicknesses shown in bold face type for Schedules 20, 30, and 40 in Annex C. Those shown in bold face type for Extra Strong Wall are identical with corresponding thicknesses shown in bold face type in Schedules 60 and 80 in Annex C. Double Extra Strong Wall has no corresponding schedule numbers.

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ANNEX C
DIMENSIONS OF STEEL PIPE (TABLE BY SCHEDULES)

(This Annex is not part of ASME B16.5-1996 and is included for information only.)

TABLE C1 DIMENSIONS OF WELDED AND SEAMLESS STEEL PIPE (ASME B36.10M)
Listed by Schedule Numbers

Nominal Pipe Size	Outside Diameter, in.	Schedule 10 in.	Schedule 20 in.	Schedule 30 in.	Schedule 40 in.	Schedule 60 in.	Schedule 80 in.	Schedule 100 in.	Schedule 120 in.	Schedule 140 in.	Schedule 160 in.
1/8	0.405	...	...	...	**0.068**	...	**0.095**	...	...	...	...
1/4	0.540	...	...	...	**0.088**	...	**0.119**	...	...	...	...
3/8	0.675	...	...	...	**0.091**	...	**0.126**	...	...	...	...
1/2	0.840	...	...	...	**0.109**	...	**0.147**	...	...	...	0.188
3/4	1.050	...	...	...	**0.113**	...	**0.154**	...	...	...	0.219
1	1.315	...	...	...	**0.133**	...	**0.179**	...	...	...	0.250
1 1/4	1.660	...	...	...	**0.140**	...	**0.191**	...	...	...	0.250
1 1/2	1.900	...	...	...	**0.145**	...	**0.200**	...	...	...	0.281
2	2.375	...	...	...	**0.154**	...	**0.218**	...	...	...	0.344
2 1/2	2.875	...	...	...	**0.203**	...	**0.276**	...	...	...	0.375
3	3.500	...	...	...	**0.216**	...	**0.300**	...	...	...	0.438
3 1/2	4.000	...	...	...	**0.226**	...	**0.318**	...	...	...	...
4	4.500	...	...	...	**0.237**	...	**0.337**	...	0.438	...	0.531
5	5.563	...	...	...	**0.258**	...	**0.375**	...	0.500	...	0.625
6	6.625	...	...	...	**0.280**	...	**0.432**	...	0.562	...	0.719
8	8.625	...	0.250	0.277	**0.322**	0.406	**0.500**	0.594	0.719	0.812	0.906
10	10.750	...	0.250	0.307	**0.365**	**0.500**	0.594	0.719	0.844	1.000	1.125
12	12.750	...	0.250	0.330	0.406	0.562	0.688	0.844	1.000	1.125	1.312
14	14.000	0.250	0.312	**0.375**	0.438	0.594	0.750	0.938	1.094	1.250	1.406
16	16.000	0.250	0.312	**0.375**	**0.500**	0.656	0.844	1.031	1.219	1.438	1.594
18	18.000	0.250	0.312	0.438	0.562	0.750	0.938	1.156	1.375	1.562	1.781
20	20.000	0.250	**0.375**	**0.500**	0.594	0.812	1.031	1.281	1.500	1.750	1.969
24	24.000	0.250	**0.375**	0.562	0.688	0.969	1.219	1.531	1.812	2.062	2.344
30	30.000	0.312	0.500	0.625	...	...	...	...	...	...	...

GENERAL NOTES:

(a) The decimal thicknesses listed for the respective pipe sizes represent their nominal dimensions as given in ASME B36.10M. For tolerances on wall thicknesses, see appropriate material specifications.

(b) Thicknesses shown in bold face type for Schedules 20, 30, and 40 are identical with thicknesses shown in bold face type for Standard Wall pipe in Annex B. Those in bold face type Schedules 60 and 80 are identical with thicknesses in bold face type for Extra Strong Wall in Annex B.

(c) Some of the larger heavier wall sections are beyond the capabilities of seamless mill production and must be obtained from turned-and-bored billets or other sources.

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ANNEX D
METHODS FOR ESTABLISHING PRESSURE–TEMPERATURE RATINGS

(This Annex is not part of ASME B16.5-1996 and is included for information only.)

D1 GENERAL

D1.1 Introduction

Pressure–temperature ratings in this Standard have been determined by the procedures in this Annex.

The primary consideration in establishing ratings is adequate wall thickness to sustain stresses due to pressure and other loadings. See para. D1.2. Other considerations affecting or limiting the ratings include:

(1) stresses in flanges resulting from bolt-up necessary to maintain gasket seal;

(2) distortion of flanges and flanged fittings due to loadings transmitted through the pipeline; and

(3) limitations applying primarily to valves but imposed also on flanges in order to maintain compatible ratings.

D1.2 Wall Thickness

Wall thickness requirements for flanged fittings are set forth in para. 6.1, and minimum thicknesses t_m are listed in the tables designated in para. 6.1. These values are all greater than those determined by Eq. (1):

$$t = 1.5\ P_c d/(2S - 1.2\ P_c) \qquad (1)$$

where

t = calculated thickness, in.
P_c = pressure rating class designation, psi (e.g., P_c = 150 psi for Class 150)
d = inside diameter of the fitting, in.
S = stress factor of 7000 psi

Equation (1) gives a thickness 50% greater than for a simple cylinder designed for a stress of 7000 psi when subjected to an internal pressure equal to the pressure rating class designation in pounds per square inch. Actual values in the dimension tables listed in para. 6.1 are approximately 0.1 in. to 0.2 in. heavier than those given by the equation.

D1.3 Material Groups

Material groups in Tables 1A are based on identical or closely matched allowable stress and yield strength values. Where they are not identical, the lower value has been applied.

Note that material groups are not numbered consecutively. Some groups are intended for use only in valves. See ASME B16.34.

D1.4 Material Properties

The allowable stress and yield strength values used to calculate the pressure–temperature ratings were taken from the ASME Boiler and Pressure Vessel Code, Section II, Part D. In addition, data has been provided directly by the ASME Boiler and Pressure Vessel Subcommittee on Materials.

D2 RATINGS IN CUSTOMARY UNITS

D2.1 Rating Equation

Ratings given in Table 2 in pounds per square inch (gage) at temperatures expressed in degrees Fahrenheit, for all materials and pressure classes, are established by Eq. (2):

$$P_T = P_r S_1/8750 \le P_c \qquad (2)$$

P_c = ceiling pressure, psig, as specified in D3 at temperature T
P_T = rated working pressure, psig, for the specified material at temperature T
P_r = pressure rating class index, psi[1] (e.g., P_r = 300 psi for Class 300)
S_1 = selected stress, psi, for the specified material at temperature T. See paras. D2.2, D2.3, and D2.4.

[1] This definition of P_r does not apply to Class 150. See para. D2.4.

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D2.2 Ratings for Group No. 1 Materials, Class 300 and Higher

The selected stress S_1 for each Material Group among Group No. 1 materials in Table 1A is determined as follows:

(a) At temperatures below the creep range, S_1 shall be lowest of the following values:

(1) 60% of specified minimum yield strength at 100°F;

(2) 60% of the yield strength at temperature T;

(3) 1.25 times the allowable stress at temperature T as listed for ASME Boiler and Pressure Vessel Code, Section I;

(b) At temperatures in the creep range (defined as those above 700°F for Group No. 1 materials), S_1 shall be the lowest of the following values:

(1) 60% of the yield strength at temperature T;

(2) the allowable stress at Temperature T as listed for ASME Boiler and Pressure Vessel Code, Section I;

(c) In no case shall the value of S_1 increase with increasing temperature.

(d) Yield strength values for determination of values of S_1 shall be obtained from ASME Boiler and Pressure Vessel Code, Section II, Part D.

(e) Where more than one allowable stress value is listed for a material at any temperature, the lower values shall be used. If lower allowable stress values do not appear, and it is noted in the allowable stress table that the allowable stress values exceed two-thirds of the yield strength at temperature, then the allowable stress values shall be determined as two-thirds of the tabulated yield strength at temperature.

(f) Allowable stress values listed for ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, may be used only if the material is not listed for Section I. Allowable stress values listed for ASME Boiler and Pressure Vessel Code, Section III, Classes 2 and 3, may be used only if the material is not listed for either Section I or Section VIII, Division 1.

D2.3 Ratings for Group Nos. 2 and 3 Materials, Class 300 and Higher

The selected stress S_1 for each material group among Group Nos. 2 and 3 materials in Table 1A is determined as follows.

(a) At temperatures below the creep range, S_1 is determined in accordance with para. D2.2(a), except that 70% of yield strength shall be used, instead of 60%, in paras. D2.2(a)(1) and (2).

(b) At temperatures in the creep range (defined as those above 950°F for Group No. 2 materials), S_1 is determined in accordance with para. D2.2(b). For Group No. 3 materials, the creep range temperature limits shall be determined on an individual material basis.

(c) The limitations in paras. D2.2(c), (d), (e), and (f) apply.

D2.4 Ratings for Class 150, All Material Groups

Pressure–temperature ratings for Class 150 flanges and flanged fittings are determined for each Material Group as set forth in paras. D2.1, D2.2, and D2.3, with the following exceptions.

(a) The value of P_r in Eq. (2) (see para. D2.1) shall be 115 psi rather than 150 psi.

(b) The value for S_1 shall be in accordance with the requirements of paras. D2.1, D2.2, and D2.3.

(c) The value for P_T in Eq. (2) at temperature T (degrees Fahrenheit) shall not exceed that given by Eq. (3):

$$P_T = 320 - 0.3T \tag{3}$$

The limits of T in equation (3) are 100°F min. and 1000°F max. For values of T less than 100°F, T equal to 100°F is used.

D3 MAXIMUM RATINGS

D3.1 Maximum Ratings

A set of maximum or ceiling pressure–temperature ratings, P_c, are shown in Table D1. They are imposed to limit deflections.

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TABLE D1 RATING CEILING VALUES

Temperature, °F	Working Pressure, psig. by Classes						
	150	300	400	600	900	1500	2500
−20 to 100	290	750	1000	1500	2250	3750	6250
200	260	750	1000	1500	2250	3750	6250
300	230	730	970	1455	2185	3640	6070
400	200	705	940	1410	2115	3530	5880
500	170	665	885	1330	1995	3325	5540
600	140	605	805	1210	1815	3025	5040
650	125	590	785	1175	1765	2940	4905
700	110	570	755	1135	1705	2840	4730
750	95	530	710	1065	1595	2660	4430
800	80	510	675	1015	1525	2540	4230
850	65	485	650	975	1460	2435	4060
900	50	450	600	900	1350	2245	3745
950	35	385	515	775	1160	1930	3220
1000	20	365	485	725	1090	1820	3030
1050	...	360	480	720	1080	1800	3000
1100	...	325	430	645	965	1610	2685
1150	...	275	365	550	825	1370	2285
1200	...	205	275	410	620	1030	1715
1250	...	180	245	365	545	910	1515
1300	...	140	185	275	410	685	1145
1350	...	105	140	205	310	515	860
1400	...	75	100	150	225	380	630
1450	...	60	80	115	175	290	485
1500	...	40	55	85	125	205	345

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ANNEX E

LIMITING DIMENSIONS OF GASKETS
Other than Ring Joint

(This Annex is an integral part of ASME B16.5-1996 and is placed after the main text for convenience.)

E1 SCOPE

This Annex covers gasket characteristics.

E2 GASKET MATERIALS AND CONSTRUCTION

Classification of gasket materials and types is shown in Fig. E1. Other gaskets, which result in no increase in both loads or flange moment over those resulting from the gaskets included in the respective groups in this Appendix, may be used and warrant the ratings of this Standard with the limiting dimensions of the applicable group. See also para. 5.4 for application of gaskets.

E3 GASKET DIMENSIONS

(a) The actual dimensions of a gasket must be established by the user. Reference to a dimensional standard for gaskets, such as ASME B16.21, is recommended. In any case, selected dimensions should be based on the type of gasket and its characteristics. These characteristics include its density, flexibility, resistance to the fluid and its temperature, and the necessity for satisfactorily compressing the gasket on its inside diameter, its outside diameter, or both. Also to be considered is the question of allowing a "pocket" at the gasket inside diameter (between the flange facings), or of allowing any intrusion of the gasket into the flange bore. Consideration should be given to the service fluid as well as to the possibility of damage which might result from partially disintegrated gaskets.

(b) Limiting gasket dimensions are given in Tables E1, E2, and E3. These dimensions represent approximately the maximum combinations of widths and diameters of the different types of gaskets covered which meet rating requirements. Variations which tend to reduce bolt loads and flange moments (e.g., reducing the gasket width) may be made; however, in departing from the tabulated dimensions, consideration should be given to the stability of the gasket under high bolt loads. As a general rule, the area of unconfined nonmetallic gaskets should not be less that the total bolt area.

(c) Gaskets are divided into three groups based on their gasket loading factors as shown in the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Pressure Vessels.

(d) Gasket contact widths for the three groups are as follows:

Group No. I	Slip-on flange raised face width
Group No. II	Large tongue width
Group No. III	Small tongue width minus 0.03 in., but not less than 0.18 in.

(e) Gaskets of Group No. Ia have inside diameters equal to the outside diameter of the corresponding pipe, which follows the principle established in ASME B16.21. In order to avoid pocketing of fluid handled, Group No. I gaskets may be extended to the inside diameter of valves, pipe, or the bore of integral, welding neck, or socket weld type flanges. Group No. Ia gaskets have outside contact diameters equal to the outside diameter of the raised face.

(f) Gaskets of Groups Nos. IIa and IIIa also have inside diameters equal to the outside diameter of the corresponding pipe. It may be desirable under some conditions to make the inside diameter of these gaskets equal to the inside diameter of valves, pipe, or the bore of integral, welding neck, or socket weld type flanges, and this is permissible provided the gasket contact width does not exceed that shown. This provision affects gaskets shown in Figs. E4, E5, E8, and E9 and requires a reduction in gasket outside diameters as well as inside diameters.

Additional provisions for varying gasket widths in contact with raised face are covered in para. E3(b). Group Nos. IIb and IIIb have outside contact diameters equal to the outside diameter of the raised face.

(g) The outside diameter of gaskets or centering

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rings extending beyond the raised face is equal to the bolt circle minus one bolt diameter. This type gasket is designed to be aligned by the flange bolts.

(h) Group Nos. IIa and IIIa gaskets are designed for those users who prefer that narrow gaskets be located close to the bore, thereby keeping the pressure area to a minimum and giving maximum flexibility to the flanged joint. See para. E3(f). Group Nos. IIb and IIIb gaskets are to be located at the outside of the raised face for ease in aligning the gaskets without a centering ring.

(i) Group No. Ia gaskets with edges extending to the bolts (see Fig. E3) are dimensionally the same as the corresponding flat ring gaskets given in ASME B16.21. See para. E3(c).

E4 TOLERANCES

Gasket contact widths for Group Nos. II and III shall not exceed specified contact width by more than 10%.

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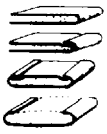
Gasket Group Number	Gasket Material	Sketches
Ia	Self-energizing types: O rings, metallic, elastomer, other gasket types considered as self-sealing	—
	Elastomer without fabric	
	Compressed sheet suitable for the operating conditions	
	Elastomer with cotton fabric insertion	
	Elastomer with or without wire reinforcement	
	Vegetable fiber	
Ib	Spiral-wound metal, with nonmetallic filler	
	Corrugated aluminum, copper or copper alloy or corrugated aluminum, copper or copper alloy double jacketed with nonmetallic filler	
	Corrugated aluminum, copper, or brass	
IIa and IIb	Corrugated metal or corrugated metal double jacketed with nonmetallic filler	
	Corrugated metal	
	Flat metal jacketed with nonmetallic filler	
	Grooved metal	
	Solid flat soft aluminum	
IIa and IIIb	Solid flat metal	
	Ring joint	

FIG. E1 GASKET GROUPS AND TYPICAL MATERIALS

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TABLE E1 GROUP NOS. Ia and Ib GASKETS

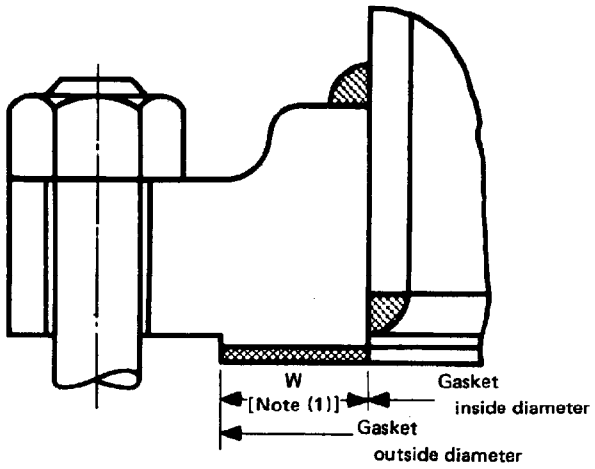

FIG. E2[3] SLIP-ON RAISED FACE WIDTH GASKET

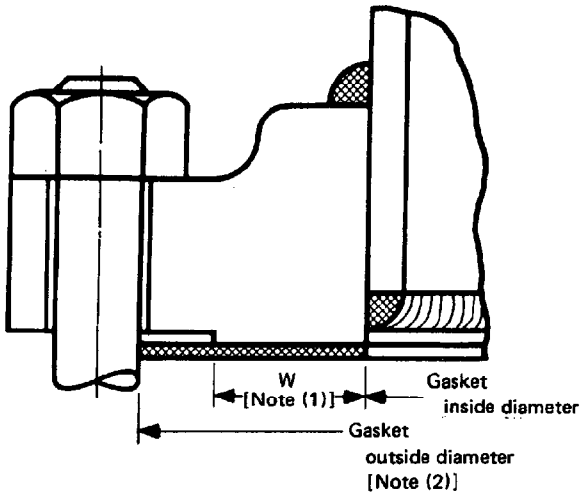

FIG. E3[3] SLIP-ON RAISED FACE WIDTH GASKET WITH EDGES EXTENDING TO THE BOLT

Nominal Size	Gasket Contact Width (1) W	Fig. E2		Fig. E3							
		Inside Diameter	Outside Diameter	Inside Diameter	Outside Diameter (2)						
					150	300	400	600	900	1500	2500
½	0.27	0.84	1.38	0.84	1.88	2.12	2.12	2.12	2.50	2.50	2.75
¾	0.31	1.06	1.69	1.06	2.25	2.62	2.62	2.62	2.75	2.75	3.00
1	0.34	1.31	2.00	1.31	2.62	2.88	2.88	2.88	3.12	3.12	3.38
1¼	0.42	1.66	2.50	1.66	3.00	3.25	3.25	3.25	3.50	3.50	4.12
1½	0.48	1.91	2.88	1.91	3.38	3.75	3.75	3.75	3.88	3.88	4.62
2	0.62	2.38	3.62	2.38	4.12	4.38	4.38	4.38	5.62	5.62	5.75
2½	0.62	2.88	4.12	2.88	4.88	5.12	5.12	5.12	6.50	6.50	6.62
3	0.75	3.50	5.00	3.50	5.38	5.88	5.88	5.88	6.62	6.88	7.75
3½	0.75	4.00	5.50	4.00	6.38	6.50	6.38	6.38	. . .	. . .	. . .
4	0.84	4.50	6.19	4.50	6.88	7.12	7.00	7.62	8.12	8.25	9.25
5	0.88	5.56	7.31	5.56	7.75	8.50	8.38	9.50	9.75	10.00	11.00
6	0.94	6.62	8.50	6.62	8.75	9.88	9.75	10.50	11.38	11.12	12.50
8	1.00	8.62	10.62	8.62	11.00	12.12	12.00	12.62	14.12	13.88	15.25
10	1.00	10.75	12.75	10.75	13.38	14.25	14.12	15.75	17.12	17.12	18.75
12	1.12	12.75	15.00	12.75	16.12	16.62	16.50	18.00	19.62	20.50	21.62
14	1.12	14.00	16.25	14.00	17.75	19.12	19.00	19.38	20.50	22.75	. . .
16	1.25	16.00	18.50	16.00	20.25	21.25	21.12	22.25	22.62	25.25	. . .
18	1.50	18.00	21.00	18.00	21.62	23.50	23.38	24.12	25.12	27.75	. . .
20	1.50	20.00	23.00	20.00	23.88	25.75	25.50	26.88	27.50	29.75	. . .
24	1.62	24.00	27.25	24.00	28.25	30.50	30.25	31.12	33.00	35.50	. . .

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) Applies to both Figs. E2 and E3. Gasket diameters may be varied. See para. E3(b).
(2) Gasket outside diameter may be extended, or an attached centering service may be used. The outside diameter of extended metallic gaskets or of any centering ring may be 0.12 in. less than specified.
(3) Slip-on type flange is shown for illustration purposes only. Gaskets may be used with other types of flange. See para. E3(e).

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TABLE E2A GROUP NO. IIa GASKETS

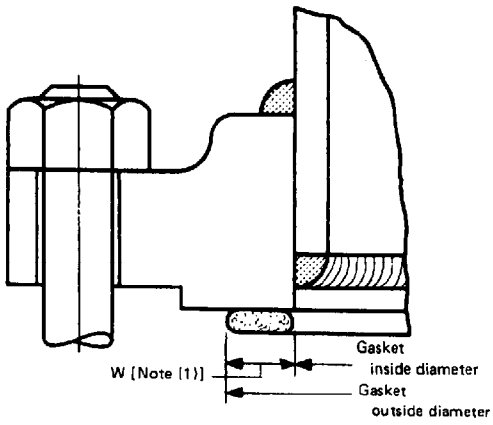

FIG. E4[3] LARGE TONGUE WIDTH GASKET WITH GASKET I.D. EQUAL TO PIPE I.D.

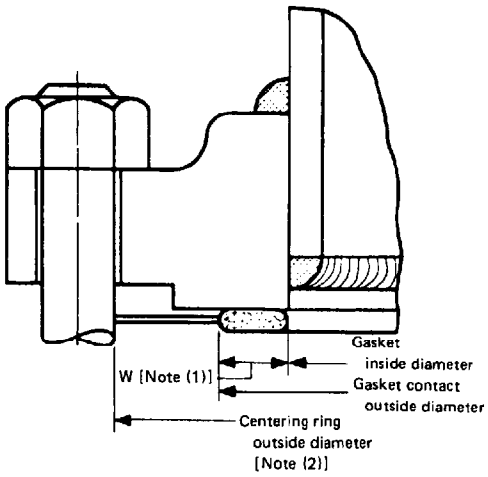

FIG. E5[3] LARGE TONGUE WIDTH GASKET WITH GASKET I.D. EQUAL TO PIPE I.D., WITH CENTERING RING

Nominal Size	Gasket Contact Width (1) W	Fig. E4		Fig. E3								
		Inside Diameter	Outside Diameter	Inside Diameter	Gasket Contact Outside Diameter	Centering Ring Outside Diameter (2)						
						150	300	400	600	900	1500	2500
½	0.19	0.84	1.22	0.84	1.22	1.88	2.12	2.12	2.12	2.50	2.50	2.75
¾	0.19	1.06	1.44	1.06	1.44	2.25	2.62	2.62	2.62	2.75	2.75	3.00
1	0.25	1.31	1.81	1.31	1.81	2.62	2.88	2.88	2.88	3.12	3.12	3.38
1¼	0.31	1.66	2.28	1.66	2.28	3.00	3.25	3.25	3.25	3.50	3.50	4.12
1½	0.38	1.91	2.66	1.91	2.66	3.38	3.75	3.75	3.75	3.88	3.88	4.62
2	0.38	2.38	3.12	2.38	3.12	4.12	4.38	4.38	4.38	5.62	5.62	5.75
2½	0.38	2.88	3.62	2.83	3.62	4.88	5.12	5.12	5.12	6.50	6.50	6.62
3	0.38	3.50	4.25	3.50	4.25	5.38	5.88	5.88	5.83	6.62	6.88	7.75
3½	0.38	4.00	4.75	4.00	4.75	6.38	6.50	6.38	6.38	. . .	. . .	. . .
4	0.50	4.50	5.50	4.50	5.50	6.88	7.12	7.00	7.62	8.12	8.25	9.25
5	0.50	5.56	6.56	5.56	6.56	7.75	8.50	8.38	9.50	9.75	10.00	11.00
6	0.50	6.62	7.62	6.62	7.62	8.75	9.88	9.75	10.50	11.38	11.12	12.50
8	0.62	8.62	9.88	8.62	9.88	11.00	12.12	12.00	12.62	14.12	13.88	15.25
10	0.75	10.75	12.25	10.75	12.25	13.38	14.25	14.12	15.75	17.12	17.12	18.75
12	0.75	12.75	14.25	12.75	14.25	16.12	16.62	16.50	18.00	19.62	20.50	21.62
14	0.75	14.00	15.50	14.00	15.50	17.75	19.12	19.00	19.38	20.50	22.75	. . .
16	0.88	16.00	17.75	16.00	17.75	20.25	21.25	21.12	22.25	22.62	25.25	. . .
18	0.88	18.00	19.75	18.00	19.75	21.62	23.50	23.38	24.12	25.12	27.75	. . .
20	1.00	20.00	22.00	20.00	22.00	23.88	25.75	25.50	26.88	27.50	29.75	. . .
24	1.00	24.00	26.00	24.00	26.00	28.25	30.50	30.25	31.12	33.00	35.50	. . .

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) Applies to both Figs. E4 and E5. Gasket diameters may be varied, provided the gasket contact width does not exceed that shown, subject to tolerances in para. E4. See para. E3(d).

(2) Metallic gaskets may have attached centering device. The outside diameter of any centering ring may be 0.12 in. less than specified.

(3) Slip-on type flange is shown for illustration purposes only. Gaskets may be used with other types of flange. See para. E3(f).

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TABLE E2B GROUP NO. IIb GASKETS

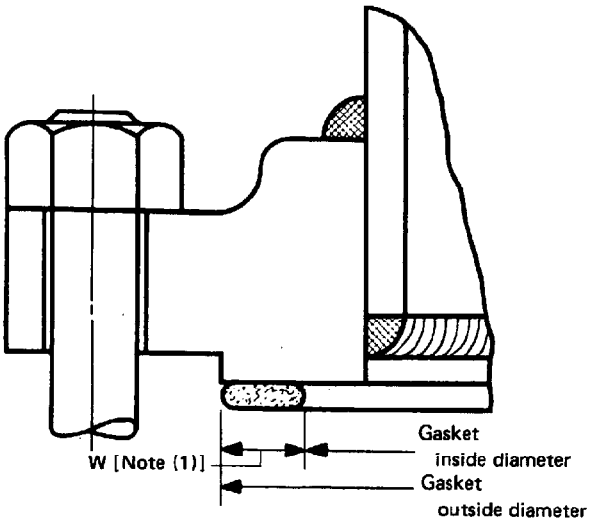

FIG. E6[3] LARGE TONGUE WIDTH GASKET WITH GASKET OUTSIDE DIMENSION EQUAL TO O.D. OF RAISED FACE

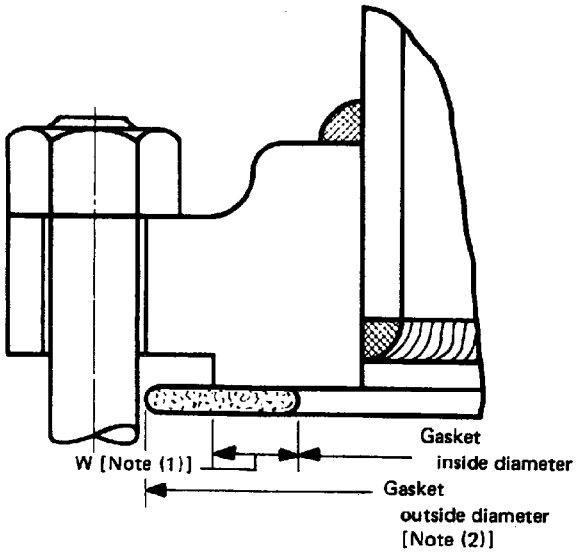

FIG. E7[3] LARGE TONGUE WIDTH GASKET WITH EDGES EXTENDING TO THE BOLT

Nominal Size	Gasket Contact Width (1) W	Fig. E6		Fig. E7							
		Inside Diameter	Outside Diameter	Inside Diameter	Outside Diameter (2)						
					150	300	400	600	900	1500	2500
½	0.19	1.00	1.38	1.00	1.88	2.12	2.12	2.12	2.50	2.50	2.75
¾	0.19	1.31	1.69	1.31	2.25	2.62	2.62	2.62	2.75	2.75	3.00
1	0.25	1.50	2.00	1.50	2.62	2.88	2.88	2.88	3.12	3.12	3.38
1¼	0.31	1.88	2.50	1.88	3.00	3.25	3.25	3.25	3.50	3.50	4.12
1½	0.38	2.12	2.88	2.12	3.38	3.75	3.75	3.75	3.88	3.88	4.62
2	0.38	2.88	3.62	2.88	4.12	4.38	4.38	4.38	5.62	5.62	5.75
2½	0.38	3.38	4.12	3.38	4.88	5.12	5.12	5.12	6.50	6.50	6.62
3	0.38	4.25	5.00	4.25	5.38	5.88	5.88	5.88	6.62	6.88	7.75
3½	0.38	4.75	5.50	4.75	6.38	6.50	6.38	6.38	...	...	...
4	0.50	5.19	6.19	5.19	6.88	7.12	7.00	7.62	8.12	8.25	9.25
5	0.50	6.31	7.31	6.31	7.75	8.50	8.38	9.50	9.75	10.00	11.00
6	0.50	7.50	8.50	7.50	8.75	9.88	9.75	10.50	11.38	11.12	12.50
8	0.62	9.38	10.62	9.38	11.00	12.12	12.00	12.62	14.12	13.88	15.25
10	0.75	11.25	12.75	11.25	13.38	14.25	14.12	15.75	17.12	17.12	18.75
12	0.75	13.50	15.00	13.50	16.12	16.62	16.50	18.00	19.62	20.50	21.62
14	0.75	14.75	16.25	14.75	17.75	19.12	19.00	19.38	20.50	22.75	...
16	0.88	16.75	18.50	16.75	20.25	21.25	21.12	22.25	22.62	25.25	...
18	0.88	19.25	21.00	19.25	21.62	23.50	23.38	24.12	25.12	27.75	...
20	1.00	21.00	23.00	21.00	23.88	25.75	25.50	26.88	27.50	29.75	...
24	1.00	25.25	27.25	25.25	28.25	30.50	30.25	31.12	33.00	35.50	...

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) Applies to both Figs. E6 and E7. Gasket diameters may be varied, provided the gasket contact width does not exceed that shown, subject to tolerances in para. E4. See para. E3(d).

(2) Gasket outside diameter may be extended, or an attached centering device may be used. The outside diameter of extended metallic gasket or of any centering ring may be 0.12 in. less than specified.

(3) Slip-on type flanges are shown for illustration purposes only. Gaskets may be used with other types of flange. See para. E3(f).

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TABLE E3A GROUP NO. IIIa GASKETS

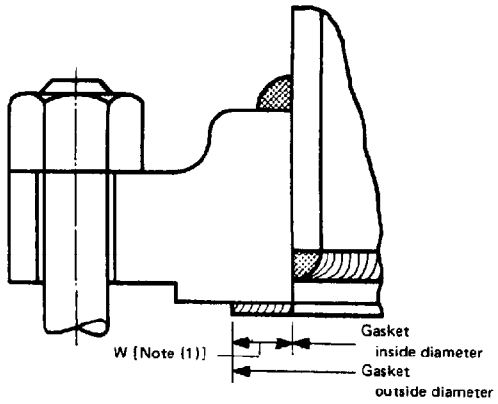

FIG. E8[3] SMALL TONGUE WIDTH GASKET WITH GASKET I.D. EQUAL TO PIPE O.D.

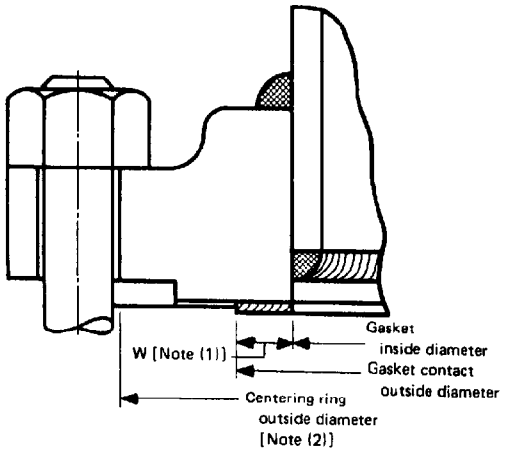

FIG. E9[3] SMALL TONGUE WIDTH GASKET WITH GASKET I.D. EQUAL TO PIPE O.D., WITH CENTERING RING

Nominal Size	Gasket Contact Width (1) W	Fig. E8		Fig. E9								
		Inside Diameter	Outside Diameter	Inside Diameter	Gasket Contact Outside Diameter	Centering Ring Outside Diameter (2)						
						150	300	400	600	900	1500	2500
½	0.19	0.84	1.22	0.84	1.22	1.88	2.12	2.12	2.12	2.50	2.50	2.75
¾	0.19	1.06	1.44	1.06	1.44	2.25	2.62	2.62	2.62	2.75	2.75	3.00
1	0.19	1.31	1.69	1.31	1.69	2.62	2.88	2.88	2.88	3.12	3.12	3.38
1¼	0.19	1.66	2.03	1.66	2.03	3.00	3.25	3.25	3.25	3.50	3.50	4.12
1½	0.19	1.91	2.28	1.91	2.28	3.38	3.75	3.75	3.75	3.88	3.88	4.62
2	0.19	2.38	2.75	2.38	2.75	4.12	4.38	4.38	4.38	5.62	5.62	5.75
2½	0.19	2.88	3.25	2.88	3.25	4.88	5.12	5.12	5.12	6.50	6.50	6.62
3	0.19	3.50	3.88	3.50	3.88	5.38	5.88	5.88	5.88	6.62	6.88	7.75
3½	0.19	4.00	4.38	4.00	4.38	6.38	6.50	6.38	6.38	. . .	. . .	. . .
4	0.22	4.50	4.94	4.50	4.94	6.88	7.12	7.00	7.62	8.12	8.25	9.25
5	0.22	5.56	6.00	5.56	6.00	7.75	8.50	8.38	9.50	9.75	10.00	11.00
6	0.22	6.62	7.06	6.62	7.06	8.75	9.88	9.75	10.50	11.38	11.12	12.50
8	0.28	8.62	9.19	8.62	9.19	11.00	12.12	12.00	12.62	14.12	13.88	15.25
10	0.34	10.75	11.44	10.75	11.44	13.38	14.25	14.12	15.75	17.12	17.12	18.75
12	0.34	12.75	13.44	12.75	13.44	16.12	16.62	16.50	18.00	19.62	20.50	21.62
14	0.34	14.00	14.69	14.00	14.69	17.75	19.12	19.00	19.38	20.50	22.75	. . .
16	0.41	16.00	16.81	16.00	16.81	20.25	21.25	21.12	22.25	22.62	25.25	. . .
18	0.41	18.00	18.81	18.00	18.81	21.62	23.50	23.38	24.12	25.12	27.75	. . .
20	0.47	20.00	20.94	20.00	20.94	23.88	25.75	25.50	26.88	27.50	29.75	. . .
24	0.47	24.00	24.94	24.00	24.94	28.25	30.50	30.25	31.12	33.00	35.50	. . .

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) Applies to both Figs. E8 and E9. Gasket diameters may be varied, provided the gasket contact width does not exceed that shown, subject to tolerances in para. E4. See para. E3(d).

(2) Metallic gaskets may have attached centering device. The outside diameter of any centering ring may be 0.12 in. less than specified.

(3) Slip-on type flanges are shown for illustration purposes only. Gaskets may be used with other types of flange. See para. E3(f).

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TABLE E3B GROUP NO. IIIb GASKETS

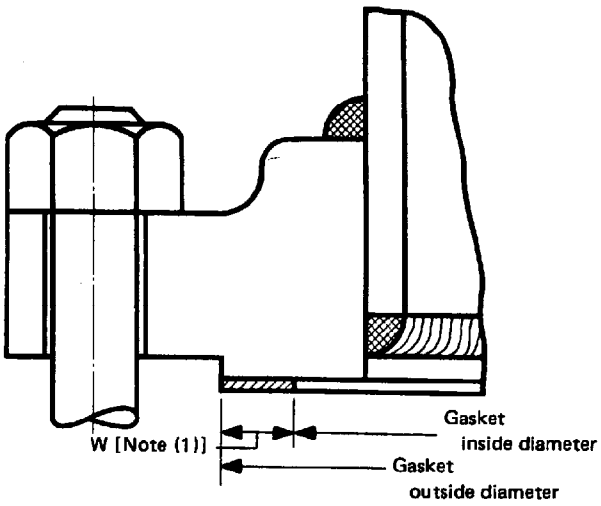

FIG. E10[3] SMALL TONGUE WIDTH GASKET WITH GASKET O.D. EQUAL TO O.D. OF RAISED FACE

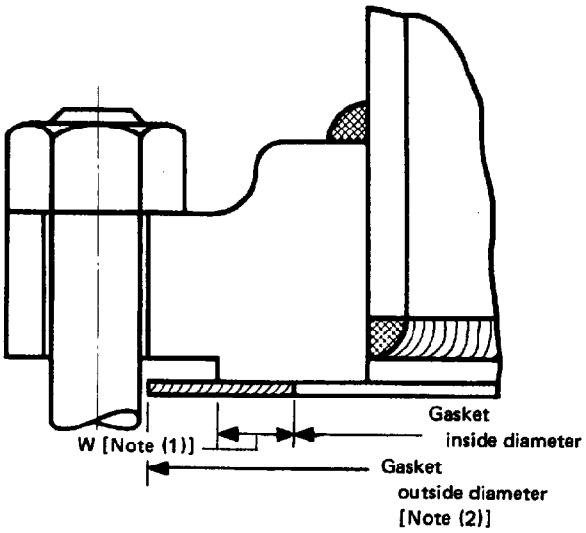

FIG. E11[3] SMALL TONGUE WIDTH GASKET WITH EDGES EXTENDING TO THE BOLT

Nominal Size	Gasket Contact Width (1) W	Fig. E10		Fig. E11							
		Inside Diameter	Outside Diameter	Inside Diameter	Outside Diameter (2)						
					150	300	400	600	900	1500	2500
½	0.19	1.00	1.38	1.00	1.88	2.12	2.12	2.12	2.50	2.50	2.75
¾	0.19	1.31	1.69	1.31	2.25	2.62	2.62	2.62	2.75	2.75	3.00
1	0.19	1.62	2.00	1.62	2.62	2.88	2.88	2.88	3.12	3.12	3.38
1¼	0.19	2.12	2.50	2.12	3.00	3.25	3.25	3.25	3.50	3.50	4.12
1½	0.19	2.50	2.88	2.50	3.38	3.75	3.75	3.75	3.88	3.88	4.62
2	0.19	3.25	3.62	3.25	4.12	4.38	4.38	4.38	5.62	5.62	5.75
2½	0.19	3.75	4.12	3.75	4.88	5.12	5.12	5.12	6.50	6.50	6.62
3	0.19	4.62	5.00	4.62	5.38	5.88	5.88	5.88	6.62	6.88	7.75
3½	0.19	5.12	5.50	5.12	6.38	6.50	6.38	6.38	...	...	...
4	0.22	5.75	6.19	5.75	6.88	7.12	7.00	7.62	8.12	8.25	9.25
5	0.22	6.88	7.31	6.88	7.75	8.50	8.38	9.50	9.75	10.00	11.00
6	0.22	8.06	8.50	8.06	8.75	9.88	9.75	10.50	11.38	11.12	12.50
8	0.28	10.06	10.62	10.06	11.00	12.12	12.00	12.62	14.12	13.88	15.25
10	0.34	12.06	12.75	12.06	13.38	14.25	14.12	15.75	17.12	17.12	18.75
12	0.34	14.31	15.00	14.31	16.12	16.62	16.50	18.00	19.62	20.50	21.62
14	0.34	15.56	16.25	15.56	17.75	19.12	19.00	19.38	20.50	22.75	...
16	0.41	17.69	18.50	17.69	20.25	21.25	21.12	22.25	22.62	25.25	...
18	0.41	20.19	21.00	20.19	21.62	23.50	23.38	24.12	25.12	27.75	...
20	0.47	22.06	23.00	22.06	23.88	25.75	25.50	26.88	27.50	29.75	...
24	0.47	26.31	27.25	26.31	28.25	30.50	30.25	31.12	33.00	35.50	...

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) Applies to both Figs. E10 and E11. Gasket diameters may be varied, provided the gasket contact width does not exceed that shown, subject to tolerances in para. E4. See para. E3(d).

(2) Gasket outside diameter may be extended, or an attached centering device may be used. The outside diameter of extended metallic gasket or of any centering ring may be 0.12 in. less than specified.

(3) Slip-on type flanges are shown for illustration purposes only. Gaskets may be used with other types of flange. See para. E3(f).

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ANNEX F
METHOD FOR CALCULATING BOLT LENGTHS[1]

(This Annex is not part of ASME B16.5-1996 and is included for information only. See para. 6.10.2.)

The following formulas were used in establishing dimension L in Tables 8, 11, 14, 17, 20, 23, and 26. They are given for convenience in determining lengths not given in the tables.

$$L_{CSB} \text{ [See footnote (2)]} = A + n$$

$$L_{CMB} \text{ [See footnote (2)]} = B + n$$

where

A = $2(C + t + d) + G + F - a$, i.e., stud bolt length exclusive of negative length tolerance n

B = $2(C + t) + d + G + F + p - a$, i.e., machine bolt length exclusive of negative tolerance n

C = minimum flange thickness[3] (see Tables 9, 12, 15, 18, 21, 24, and 27)

F = total height of facings or depth of ring joint groove for both flanges (see Table F1)

G = 0.12 in. gasket thickness for raised face, male and female and tongue and groove flanges; also approximate distance between ring joint flanges listed in Table 5

L_{CMB} = calculated machine bolt length as measured from underside of head to end of point

L_{CSB} = calculated stud bolt length (effective thread length, excluding end points)

L_{SMB} = specified machine bolt length (from underhead to end, including end point) which is L_{CMB} rounded off to the nearest 0.25 in. increment (see Fig. F2)

L_{SSB} = specified stud bolt length (effective thread length, excluding end points) which is L_{CSB} rounded off to the nearest 0.25 in. increment (see Fig. F1)

a = zero, except where the small female face is on the end of pipe, a = 0.19 in.

d = heavy nut thickness (equals nominal bolt diameter, see ASME B18.2.2)

n = negative tolerance on bolt length (see Table F2)

p = allowance for height of point of machine bolt (= 1.5 times thread pitch)

t = plus tolerance for flange thickness (see para. 7.3)

[1] The equations used in this Annex are for calculated bolt lengths established to assure full thread engagement of heavy hexagon nuts when worst case tolerances occur on all relevant dimensions of the flanged joint. The use of shorter bolt lengths is acceptable provided that full thread engagement is obtained at assembly (see para. 6.10.2).

[2] For lapped joints calculate stud bolt and machine bolt lengths as follows.

For ring joint groove facing:

$$L_{CSB} = A + \text{(pipe thickness for each lap)} + n$$

$$L_{CMB} = B + \text{(pipe thickness for each lap)} + n$$

For other than ring joint facing:

$$L_{CSB} = A - F + \text{(Table F3 thicknesses)} + n$$

$$L_{CMB} = B - F + \text{(Table F3 thicknesses)} + n$$

[3] 0.06 in. raised face is included in minimum flange thickness for Classes 150 and 300 flanges.

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TABLE F1 *F* VALUES

Flanged Joint Class	Total Height of Facings or Depth of Ring Joint Groove for Both Flanges *F*, in.			
	Type of Flange Facing (1)			
	0.06 in. Raised	0.25 in. Raised	Male and Female or Tongue and Groove	Ring Joint
150 and 300	Zero (2)	0.50	0.25	2 × groove depth
400 to 2500	0.12	0.50	0.25	2 × groove depth

NOTES:
(1) See Fig. 8 and Tables 4 and 5.
(2) Raised face (0.06 in.) is included in minimum flange thickess for Classes 150 and 300 flanges.

TABLE F2 *n* VALUES

Dimension	Negative Tolerance on Bolt Lengths *n*, in.	Length, in.
Stud Bolt		
A		
or	0.06	
[*A* + (pipe thickness for each lap)]	0.12	≤12
or	0.25	>12, ≤18
[*A* − *F* + (Table F3 thicknesses)]		>18
Machine Bolt		
B		
or	For *n* values, use negative length tolerances per ANSI B18.2.1.	. . .
[*B* + (pipe thickness for each lap)]		
or		
[*B* − *F* + (Table F3 thicknesses)]		

TABLE F3 THICKNESSES FOR LAPPED JOINTS

Lap Combination	Classes 150 and 300 Flanges	Classes 400 to 2500 Flanges, inclusive
For lapped to 0.06 in. raised face	One lap	. . .
For lapped to lapped	Both laps	Both laps
For lapped to 0.25 in. male face on flange	. . .	One lap and 0.25 in.
For lapped to female face on flange	. . .	One lap not less than 0.25 in.
For male in lap to female in lap	. . .	2 × pipe wall with lap for male not less than 0.25 in.

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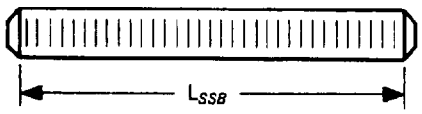

FIG. F1 SPECIFIED STUD BOLT LENGTH

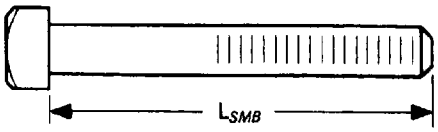

FIG. F2 SPECIFIED MACHINE BOLT LENGTH

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ANNEX G
QUALITY SYSTEM PROGRAM

(This Annex is an integral part of ASME B16.5.1996 and is placed after the main text for convenience.)

The products manufactured in accordance with this Standard shall be produced under a quality system program following the principles of an appropriate standard from the ISO 9000 series.[1] A determination of the need for registration and/or certification of the product manufacturer's quality system program by an independent organization shall be the responsibility of the manufacturer. The detailed documentation demonstrating program compliance shall be available to the purchaser at the manufacturer's facility. A written summary description of the program utilized by the product manufacturer shall be available to the purchaser upon request. The product manufacturer is defined as the entity whose name or trademark appears on the product in accordance with the marking or identification requirements of this Standard.

[1] The series is also available from the American National Standards Institute (ANSI) and the American Society for Quality Control (ASQC) as American National Standards that are identified by a prefix "Q" replacing the prefix "ISO". Each standard of the series is listed under Annex H.

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ANNEX H
REFERENCES

(This Annex is an integral part of ASME B16.5-1996 and is placed after the main text for convenience.)

The following is a list of standards and specifications referenced in this Standard, showing the year of approval. Products covered by each ASTM specification are listed for convenience. (See specifications for exact titles and detailed contents.)

ASME Publications

ASME B1.1-1989	Unified Inch Screw Threads (UN and UNR Thread Form)
ASME B1.20.1-1983(R1992)	Pipe Threads, General Purpose (Inch)
ASME B16.20-1993	Metallic Gaskets for Pipe Flanges — Ring Joint, Spiral-Wound and Jacketed
ASME B16.21-1992	Nonmetallic Flat Gaskets for Pipe Flanges
ASME B16.34-1996	Valves — Flanged, Threaded, and Welding End
ASME B18.2.1-1981(R1992)	Square and Hex Bolts and Screws — Inch Series
ASME B18.2.2-1987(R1993)	Square and Hex Nuts (Inch Series)
ASME B31.3-1992	Chemical Plant and Petroleum Refinery Piping
ASME B36.10M-1985	Welded and Seamless Wrought Steel Pipe
ASME B46.1-1985	Surface Texture (Surface Roughness, Waviness, and Lay)

ASME Boiler and Pressure Vessel Code, 1992 Edition (Including Addenda through 1994)

Section I	Power Boilers
Section II	Materials
Section III	Nuclear Power Plant Components
Section VIII, Div. 1 & 2	Pressure Vessels

ASTM Publications

A 105-95b	Forgings, Carbon Steel, for Piping Components
A 106-95	Seamless Carbon Steel Pipe for High Temperature Service
A 182-95c	Forged or Rolled Alloy Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service
A 193-95a	Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service

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A 194-95a	Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service
A 203-93	Pressure Vessel Plates, Alloy Steel, Nickel
A 204-93	Pressure Vessel Plates, Alloy Steel, Molybdenum
A 216-93	Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
A 217-93	Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service
A 240-95b	Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
A 307-94	Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength
A 320-95$^{\epsilon 1}$	Alloy-Steel Bolting Materials for Low-Temperature Service
A 350-96	Forgings, Carbon and Low-Alloy Steel, Requiring Notch Toughness Testing for Piping Components
A 351-94a	Steel Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts
A 352-93	Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service
A 354-95	Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
A 387-92$^{\epsilon 1}$	Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum
A 449-93	Quenched and Tempered Steel Bolts and Studs
A 453-95	Bolting Materials, High-Temperature, 50 to 120 ksi [345 to 827 Mpa] Yield Strength, With Expansion Coefficients Comparable to Austenitic Steels
A 515-94	Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
A 516-90	Pressure Vessel Plates, Carbon Steel, For Moderate- and Lower-Temperature Service
A 537-91	Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel
A 540-95	Alloy-Steel Bolting Materials for Special Applications
B 127-94a$^{\epsilon 1}$	Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip
B 160-93	Nickel Rod and Bar
B 162-93a$^{\epsilon 1}$	Nickel Plate, Sheet and Strip
B 164-93	Nickel-Copper Alloy Rod, Bar and Wire
B 166-95	Nickel-Chromium-Iron Alloys (UNS N06600, N06601 and N06690) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Rod, Bar and Wire
B 168-95	Nickel-Chromium-Iron Alloys (UNS N06600, N06601, and N06690) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Plate, Sheet and Strip

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B 333-95	Nickel-Molybdenum Alloy Plate, Sheet and Strip
B 335-95	Nickel-Molybdenum Alloy Rod
B 408-95	Nickel-Iron-Chromium Alloy Plate, Sheet and Strip
B 409-95	Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip
B 424-93	Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and N08821) Plate, Sheet and Strip
B 425-93	Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and UNS N08221) Rod and Bar
B 434-95	Nickel-Molybdenum-Chromium-Iron Alloy (UNS N10003) Plate, Sheet and Strip
B 435-94	UNS N06002, UNS N06230, and UNS R30556 Plate, Sheet, and Strip
B 443-93	Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Plate, Sheet, and Strip
B 446-93	Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Rod and Bar
B 462-95	Forged or Rolled UNS N08020, UNS N00824, UNS N08026, and UNS N08367 Alloy Pipe Flanges, Forged Fittings, and Valves and Parts for Corrosive High-Temperature Service
B 463-93	UNS N08020, UNS N08024 and UNS N08026 Alloy Plate Sheet and Strip
B 473-95	UNS N08020, UNS N08026, and UNS N08024 Nickel Alloy Bar and Wire
B 511-93	Nickel-Iron-Chromium-Silicon Alloy Bars and Shapes
B 536-95	Nickel-Iron Chromium-Silicon Alloys (UNS N08830 and N08332) Plate, Sheet, and Strip
B 564-95a$^{\epsilon 1}$	Nickel Alloy Forgings
B 572-94	UNS N06002, UNS N06230, and UNS R30556 Rod
B 573-95	Nickel-Molybdenum-Chromium-Iron Alloy (UNS N10003) Rod
B 574-94$^{\epsilon 1}$	Low-Carbon Nickel-Molybdenum-Chromium and Low-Carbon Nickel-Chromium Molybdenum Alloy Rod
B 575-94	Low-Carbon Nickel-Molybdenum-Chromium and Low-Carbon Nickel-Chromium Molybdenum Alloy Plate, Sheet, and Strip
B 581-94$^{\epsilon 1}$	Nickel-Chromium-Iron-Molybdenum-Copper Alloy Rod
B 582-93	Nickel-Chromium-Iron-Molybdenum-Copper Alloy Plate, Sheet and Strip
B 599-93b	Nickel-Iron-Chromium-Molybdenum-Columbium Stabilized Alloy (UNS N08700) Plate, Sheet and Strip
B 620-93	Nickel-Iron-Chromium-Molybdenum Alloy (UNS N08320) Plate, Sheet, and Strip
B 621-95	Nickel-Iron-Chromium-Molybdenum Alloy (UNS N08320) Rod
B 625-93a	UNS N08904, UNS N08925, UNS N08031, UNS N08932, and UNS N08925 Plate, Sheet and Strip

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B 649-93	Ni-Fe-Cr-Mo-Cu Low Carbon Alloy (UNS N08904) and Ni-Fe-Cr-Mo-Cu-N Low Carbon Alloys (UNS N08925, UNS N08031, and UNS N08926) Bar and Wire
B 672-95	Nickel-Iron-Chromium-Molybdenum Columbium Stabilized Alloy (UNS N08700) Bar and Wire
E 29-93	Using Significant Digits in Test Data to Determine Conformance with Specifications

International Standards Organization (ISO)

ISO 9000-1: 1994	Quality management and quality assurance standards — Part 1: Guidelines for selection and use
ISO 9000-2: 1993	Quality management and quality assurance standard — Part 2: Generic guidelines for the application of ISO 9001, ISO 9002, and ISO 9003
ISO 9000-3: 1991	Quality management and quality assurance standards — Part 3: Guidelines for the application of ISO 9001 to the development, supply and maintenance of software
ISO 9001: 1994	Quality systems — Model for quality assurance in design, development, production, installation, and servicing
ISO 9002: 1994	Quality systems — Model for quality assurance in production and servicing
ISO 9003: 1994	Quality systems — Model for quality assurance in final inspection and test

MSS Publications

MSS SP-9-1992	Spot Facing for Bronze, Iron, and Steel Flanges
MSS SP-25-1978(R1985)	Standard Marking System for Valves, Fittings, Flanges, and Unions
MSS SP-44-1991	Steel Pipe Line Flanges
MSS SP-45-1992	Bypass and Drain Connections
MSS SP-61-1992	Pressure Testing of Steel Valves

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ASQC	American Society for Quality Control P.O. Box 3005, Milwaukee, Wisconsin 53201-3005
ASTM	American Society for Testing and Materials 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959
ISO	International Organization for Standardization 1, rue de Varembé, Case postale 56, CH–1121 Genéve 20, Switzerland/Suisse
MSS	Manufacturers Standardization Society of the Valve & Fittings Industry 127 Park Street, N.E., Vienna, Virginia 22180

ISO documents are available from ANSI. Publications appearing above which have been approved as American National Standards may also be obtained from ANSI.

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ASME B16.9-2001

FACTORY-MADE WROUGHT BUTTWELDING FITTINGS

AN AMERICAN NATIONAL STANDARD

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AN AMERICAN NATIONAL STANDARD

FACTORY-MADE WROUGHT BUTTWELDING FITTINGS

ASME B16.9-2001

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FOREWORD

In 1921, the American Engineering Standards Committee, later American Standards Association (ASA), organized Sectional Committee B16 to unify and further develop national standards for pipe flanges and fittings (and, later, for valves, gaskets, and valve actuators). Cosponsors of the B16 Committee were the American Society of Mechanical Engineers (ASME), the Heating and Piping Contractors National Association [now the Mechanical Contractors Association of America (MCAA)], and the Manufacturers Standardization Society of the Valve and Fittings Industry (MSS). Cosponsors were later designated as cosecretariat organizations.

Standardization of welding fittings was initiated in 1937 by a subgroup (designated Subgroup 6) of Subcommittee 3. After consideration of several drafts, a standard was approved by the Committee, cosponsors, and ASA, and published with the designation ASA B16.9-1940.

Revisions were made in 1950 and 1955 to add sizes up to NPS 24 and to complete coverage of fittings in some sizes. These revisions were approved and published as ASA B16.9-1951 and ASA B16.9-1958. With the subgroup now designated Subcommittee 6 (later Subcommittee F), further revisions were begun to clarify the intent of the standard, to add angularity tolerances, and to include fittings of different types (long radius-reducing elbows and crosses) and smaller sizes (NPS $\frac{1}{4}$ and $\frac{1}{2}$). This revision was published as ASA B16.9-1964 after ASA approval.

After reorganization of ASA, first as the United States of America Standards Institute (USASI), then as the American National Standards Institute (ANSI), with the Sectional Committee being redesignated as an American National Standards Committee, another revision increasing the size range to NPS 48 and revising the text for clarity was approved and published as ANSI B16.9-1971.

In 1975, Subcommittee F began a major revision to bring the standard up to date with current practice and usage. Common fractions were expressed as decimals (but without intending higher precision) and metric dimensional equivalents were added. Provisions for step-wise change of radius for NPS $\frac{3}{4}$ long radius elbows and 180 deg returns were introduced. Following Standards Committee, cosecretariat, and ANSI approval, the revision was published as ANSI B16.9-1978. It was updated by a corrective addendum, B16.9a-1981, issued in February 1982.

In 1982, American National Standards Committee B16 was reorganized as an ASME Committee operating under procedures accredited by ANSI. In this Edition, the text has been revised and inch dimensions are established as the standard. Following approval by the Standards Committee and ASME, approval as an American National Standard was given by ANSI on November 12, 1986 with the new designation ASME/ANSI B16.9-1986.

In 1991 the Subcommittee reviewed the document and made a number of revisions. Dimensions for short pattern lap joints were also added to this 1993 Edition of the Standard.

In this 2001 Edition, short radius elbows and returns were added which includes all dimensions and tolerances of ASME B16.28-1994. This Edition also provides metric units as an independent but parallel alternative standard to U.S. Customary units and a Quality System Program Annex.

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Requests for interpretation or suggestions for revision should be sent to the Secretary, B16 Committee, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016.

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Standardization of Valves, Flanges, Fittings, and Gaskets

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FACTORY-MADE WROUGHT BUTTWELDING FITTINGS

1 SCOPE

1.1 General

This Standard covers overall dimensions, tolerances, ratings, testing, and markings for wrought factory-made buttwelding fittings in sizes NPS ½ through 48 (DN 15 through 1200).

1.2 Special Fittings

Fittings may be made to special dimensions, sizes, shapes, and tolerances by agreement between the manufacturer and the purchaser.

1.3 Fabricated Fittings

Fabricated laterals and other fittings employing circumferential or intersection welds are considered pipe fabrication, and are not within the scope of this Standard.

1.4 Standard Units

The values stated in either metric or U.S. Customary units are to be regarded separately as standard. Within the text, the U.S. Customary units are shown in parentheses. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this Standard.

The designations for pressure rating and size are Class and NPS for both metric and customary dimensioned fittings. The designations PN and DN used in international standards are shown for reference convenience.

1.5 References

1.5.1 Referenced Standards. Standards and specifications adopted by reference in this Standard are shown in Mandatory Appendix II. It is not considered practical to identify the specific edition of each standard and specification in the individual references. Instead, the specific edition reference is identified in Mandatory Appendix II. A product made in conformance with a prior edition of reference standards and in all other respects conforming to this Standard will be considered to be in conformance.

1.5.2 Codes and Regulations. A fitting used under the jurisdiction of the ASME Boiler and Pressure Vessel Code, the ASME Code for Pressure Piping, or a governmental regulation is subject to any limitation of that code or regulation. This includes any maximum temperature limitation, or rule governing the use of a material at low temperature.

1.6 Service Conditions

Criteria for selection of fitting types and materials suitable for particular fluid service are not within the scope of this Standard.

1.7 Welding

Installation welding requirements are outside the scope of this Standard.

1.8 Quality Systems

Nonmandatory requirements relating to the fitting manufacturer's Quality System Program are described in Nonmandatory Appendix A.

1.9 Convention

For the purpose of determining conformance with this Standard, the convention for fixing significant digits where limits, maximum or minimum values, are specified shall be rounded off as defined in ASTM E 29. This requires that an observed or calculated value shall be "rounded off" to the nearest unit in the last right-hand digit used in expressing the limit. Decimal value in the last and tolerances do not imply a particular method of measurement.

2 PRESSURE RATINGS

2.1 Basis of Ratings

The allowable pressure ratings for fittings designed in accordance with this Standard may be calculated as for straight seamless pipe of equivalent material (as shown by comparison of composition and mechanical properties in the respective material specifications) in accordance with the rules established in the applicable

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sections of ASME B31, Code for Pressure Piping. For the calculation, applicable data for the pipe size, wall thickness, and material that is equivalent to that of the fitting shall be used. Pipe size, wall thickness (or schedule number), and material identity on the fittings are in lieu of pressure rating markings.

2.2 Design of Fittings

The design of fittings shall be established by mathematical analyses (e.g. ASME B16.49 for bends) contained in nationally recognized pressure vessel or piping codes or at the manufacturer's option by proof testing in accordance with section 9 of this Standard. In order to meet design or manufacturing requirements, it is expected that some portion of formed fittings may have to be thicker than the pipe wall with which the fittings is intended to be used. The mathematical analyses, if used, may take into account such thicker sections. Records of mathematical analysis and/or successful proof test data shall be available at the manufacturer's facility for inspection by the purchaser.

3 SIZE

NPS, followed by a dimensionless number, is the designation for nominal fitting size. NPS is related to the reference nominal diameter, DN, used in international standards. The relationship is, typically, as follows:

DN	15	20	25	32	40	50	65	80	100
NPS	½	¾	1	1¼	1½	2	2½	3	4

NOTE: For NPS>4, the equivalence is: DN=25 (NPS)

4 MARKING

4.1 Standard Marking

Each fitting shall be permanently marked to show the following:

(a) manufacturer's name or trademark.

(b) material identification, either the ASTM or ASME grade designation.

(c) schedule number[1] or nominal wall thickness in mm.

(d) size — the nominal pipe size (NPS) identification number related to the end connections shall be used.

(e) compliance — see para 4.4 for standard and special fitting marking.

(f) A manufacturer may supplement these mandatory markings with others, including a DN size designation, but confusion with the required marking shall be avoided.

4.2 Exceptions

Where the size of the fitting does not permit complete marking, the identification marks may be omitted in reverse of the order presented above.

4.3 Depth of Stamping

Where steel stamps are used, care shall be taken so that the marking is not deep enough or sharp enough to cause cracks or to reduce the wall thickness of the fitting below the minimum allowed.

4.4 Compliance

4.4.1 Standard Fittings. That the fitting was manufactured in conformance with this Standard, including all dimensional requirements, is certified by a prefix "WP" in the material grade designation marking.

4.4.2 Special Fittings. That the fitting was manufactured in conformance with this Standard except that dimensional requirements are as agreed between the purchaser and the manufacturer, is certified by a supplementary suffix to the material grade designation marking as follows:

(a) S9 applies for fittings in accordance with ASTM A 234 and A 403.

(b) S6 applies for fittings in accordance with ASTM A 420.

(c) S8 applies for fittings in accordance with ASTM A 815.

(d) SPLD applies for fittings in accordance with ASTM B 361, B 363, and B 366.

5 MATERIAL

Wrought fittings covered by this Standard shall be in accordance with ASTM A 234, A 403, A 420, A 815, B 361, B 363, B 366 or the corresponding standard listed in Section II of the ASME Boiler and Pressure Vessel Code. The term *wrought* denotes fittings made of pipe, tubing, plate, or forgings. Fittings made from block forgings may only be supplied subject

[1] Schedule number is a dimensionless number that is widely used as a convenient designation for use in ordering pipe and fittings. It is normally associated with a group of standardized pipe wall thickness. Refer to ASME B36.10 and ASME B36.19 for complete details on pipe schedule numbers.

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agreement between manufacturer and purchaser. Such fittings need not meet the requirements of section 7.

6 FITTINGS DIMENSIONS

6.1 General

This Standard provides for a fixed position for the welding ends with reference to either the center line of the fittings or the overall dimensions. Dimensional requirements for these fittings are to be found in Tables 3 through 12 and Tables I1 through I12 of Mandatory Appendix I.

6.2 Special Dimensions

6.2.1 Fatigue Loading. For applications where fatigue loading is a concern, required minimum dimensions shall be furnished by the purchaser.

6.2.2 Bore Diameter. Bore diameters, away from the ends, are not specified. If special flow path requirements are needed, the bore dimensions shall be specified by the purchaser.

6.2.3 Stub Ends. Service conditions and joint construction often dictate stub end length requirements. Therefore, the purchaser must specify long or short pattern fitting when ordering. (See General Note (c) in Tables 10 and I9.)

7 SURFACE CONTOURS

Where adjacent openings in fittings are not in parallel planes, they shall be joined by a circular arc on the external surfaces. The arc may be terminated in tangents.

8 END PREPARATION

Unless otherwise specified, the details of the welding end preparation shall be in accordance with Table 1. Transitions from the welding bevel to outside surface of the fitting and from the root face to the inside surface of the fitting lying within the maximum envelope shown in Fig. 1 are at the manufacturer's option except as covered in Note (5) of Fig. 1 or unless otherwise specifically ordered.

9 DESIGN PROOF TEST

9.1 Required Tests

Proof tests shall be made as set forth in this Standard when the manufacturer chooses proof testing to qualify the fitting design. Unless otherwise agreed upon between manufacturer and purchaser, the proof test shall be one based on the computed bursting pressure of the fitting and its connecting piping.

9.2 Test Assembly

9.2.1 Representative Components. Fittings that are representative of production and selected for test shall be identified as to material, grade, and lot, including heat treatment. They shall be inspected for dimensional compliance to this Standard.

9.2.2 Other Components. Straight seamless or welded pipe sections whose calculated bursting strength is at least as great as the proof test pressure as calculated in para. 9.3 shall be welded to each end of the fitting to be tested. Any internal misalignment greater than 1.5 mm (0.06 in.) shall be reduced by taper boring at a slope not over 1:3. Length of pipe sections for closures shall be as follows.

(a) Minimum length of pipe shall be one pipe O.D. for NPS 14 (DN 350) and smaller.

(b) Minimum length of pipe shall be one-half pipe O.D. for NPS greater than 14 (DN 350).

9.3 Test Procedure

Test fluid shall be water or other liquid used for hydrostatic testing. Hydrostatic pressure shall be applied to the assembly. The test is successful if the assembly withstands, without rupture, 105% of the computed proof test pressure defined below.

$$P = \frac{2St}{D}$$

where

D = specified outside diameter of pipe

P = computed minimum proof test pressure for fitting

S = actual tensile strength of the test fitting, determined on a specimen representative of the test fitting, which shall meet the tensile strength requirements of the applicable material of section 5.

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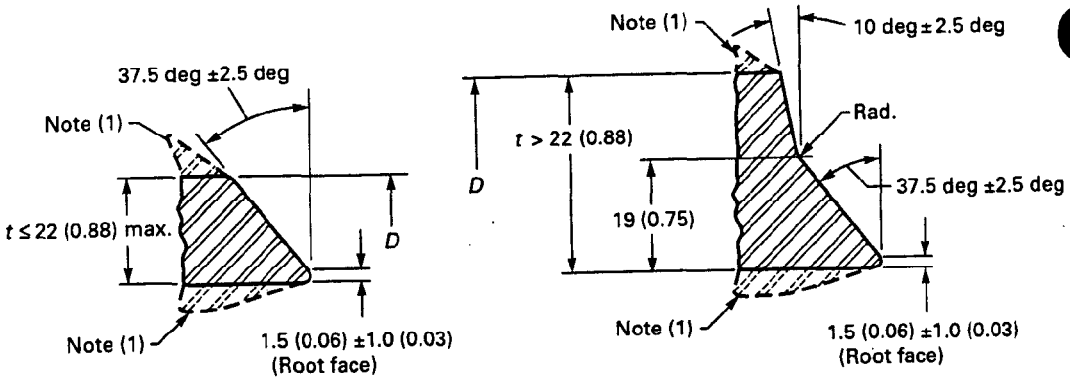

(a) Plain Bevel **(b) Compound Bevel**

TABLE 1 WELDING BEVELS AND ROOT FACE

Nominal Wall Thickness, *t*	End Preparation
Less than *x* [Note (2)]	Cut square or slightly chamfer, at manufacturer's option. (Not illustrated.)
x to 22 (0.88) included	Plain bevel as in sketch (a) above.
More than 22 (0.88)	Compound bevel as in sketch (b) above.

GENERAL NOTES:
(a) Dimensions in parentheses are in inches.
(b) Other dimensions are in millimeters.

NOTES:
(1) See section 8 and Fig. 1 for transition contours.
(2) x = 5 (0.19) for carbon steel or ferritic alloy steel and 3 (0.12) for austenitic alloy steel.

t = nominal pipe wall thickness of the pipe that the fitting marking identifies

NOTE: Any dimensionally consistent system of units may be used.

9.4 Applicability of Test Results

It is not necessary to conduct an individual test of fittings with all combinations of sizes, wall thicknesses, and materials. A successful proof test on one representative fitting may represent others to the extent described in this Standard.

9.4.1 Size Range. One test fitting may be used to qualify similarly proportioned fittings with a size range from one-half to twice that for the tested fitting. The test of a non-reducing fitting qualifies reducing fittings of the same pattern. The test of a reducing fitting qualifies reductions to smaller sizes.

9.4.2 Thickness Range. One test fitting may be used to qualify similarly proportioned fittings with t/D ranges from one-half to three times that for the tested fitting.

9.4.3 Material Grades. The pressure retaining capacity of a geometrically identical fitting made of various grades of steel will be directly proportional to the tensile properties of the various grades; see para 2.1. Therefore, it is necessary to test only a single material grade in a representative fitting to prove the design of the fitting.

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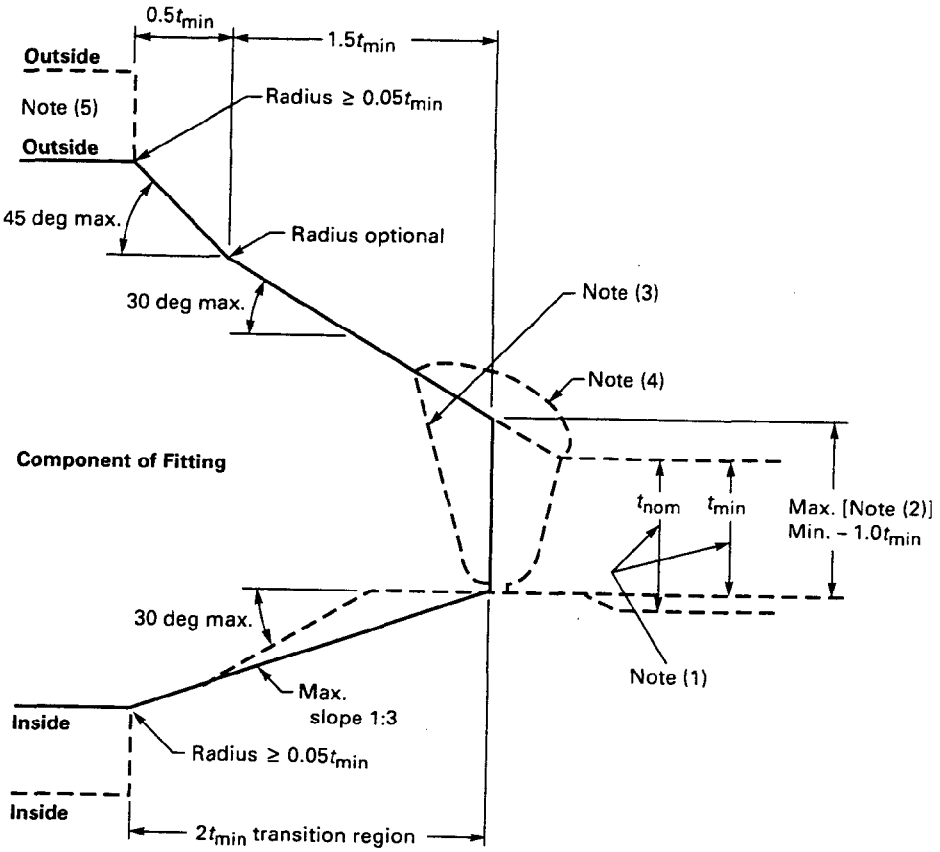

NOTES:
(1) The value of t_{min} is whichever of the following is applicable:
(a) the minimum ordered wall thickness of the pipe;
(b) 0.875 times the nominal wall thickness of pipe ordered to a pipe schedule wall thickness that has an undertolerance of 12.5%.
(2) The maximum thickness at the end of the component is:
(a) the greater of [t_{min} +4mm (0.16 in.)] or 1.15t_{min} when ordered on a minimum wall basis;
(b) the greater of [t_{min} +4mm (0.16 in.)] or 1.10t_{nom} when ordered on a nominal wall basis.
(3) Weld bevel shown is for illustration only.
(4) The weld reinforcement permitted by applicable code may lie outside the maximum envelope.
(5) Where transitions using maximum slope do not intersect outside surface within the transition region, as shown by phantom outline, maximum slopes shown shall be used. Alternately, radii lying within the envelope may be used.

FIG. 1 MAXIMUM ENVELOPE FOR WELDING END TRANSITIONS

10 PRODUCTION TESTS

Hydrostatic testing of wrought fittings is not required by this Standard. All fittings shall be capable of withstanding, without leakage or impairment of serviceability, a hydrostatic test pressure required by the applicable piping code for seamless pipe of material equivalent to the fitting material and of the size and wall thickness the fitting marking identifies.

11 TOLERANCES

Tolerances for fittings are shown in Tables 2 and I1, and apply to the nominal dimensions given in Tables 3 through 12 and Tables I2 through I11. Where given in the tables, the minimum and maximum dimensions are based on these tolerances. The listings with decimals do not imply precision measurement such as use of vernier, micrometer, electronic readout equipment, etc.

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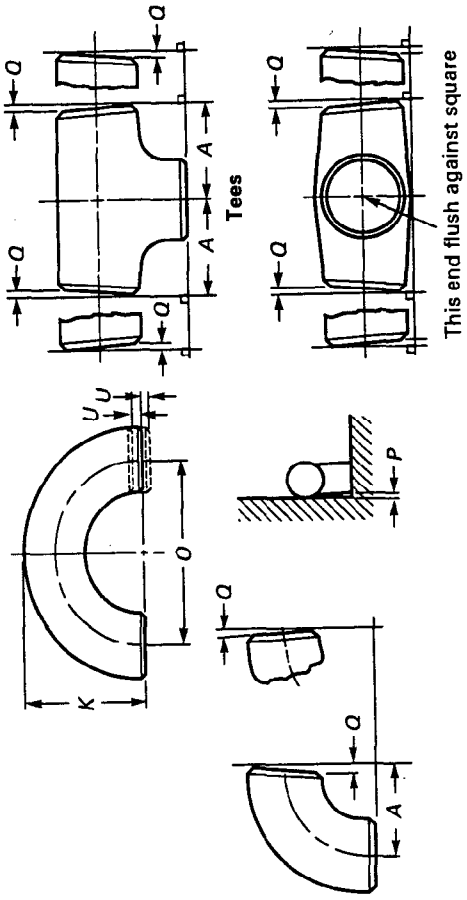

TABLE 2 ILLUSTRATION

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TABLE 2 TOLERANCES

Nominal Pipe Size (NPS)	(DN)	All Fittings: Outside Diameter at Bevel, *D* [Notes (1), and (2)]	All Fittings: Inside Diameter at End [Notes (1),(3), and (4)]	All Fittings: Wall Thickness, *t* [Note (3)]	Center-to-End Dimensions of 90 Deg and 45 Deg Elbows and Tees, *A, B, C, M*	Overall Length of Reducers and Lap Joint Stub Ends, *F, H*	Overall Length of Caps, *E*	180 Deg Returns: Center-to-Center Dimension, *O*	180 Deg Returns: Back-to-Face Dimension, *K*	180 Deg Returns: Alignment of Ends, *U*
½ to 2½	15–65	+1.6–0.8	0.8		2	2	3	6	6	1
3 to 3½	80–90	+1.6	1.6	Not	2	2	3	6	6	1
4	100	+1.6	1.6	Less	2	2	3	6	6	1
5 to 8	125–200	+2.4–1.6	1.6	Than	2	2	6	6	6	1
10 to 18	250–450	+4.0–3.2	3.2	87.5%	2	2	6	10	6	2
20 to 24	500–600	+6.4–4.8	4.8	of	2	2	6	10	6	2
26 to 30	650–750	+6.4–4.8	4.8	Nominal	3	5	10	...	...	...
37 to 48	800–1200	+6.4–4.8	4.8	Thickness	5	5	10	...	...	...

Nominal Pipe Size (NPS)	(DN)	Lap Joint Stub Ends: Outside Diameter of Lap, *G*	Lap Joint Stub Ends: Fillet Radius of Lap, *R*	Lap Joint Stub Ends: Outside Diameter of Barrel	Lap Joint Stub Ends: Lap Thickness
½ to 2½	15–65	+0–1	+0–1		+1.6–0
3 to 3½	80–900	+0–1	+0–1	See	+1.6–0
4	100	+0–1	+0–2	Table 10	+1.6–0
5 to 8	125–200	+0–1	+0–2	For	+1.6–0
10 to 18	250–450	+0–2	+0–2	Limiting	+3.2–0
20 to 24	500–600	+0–2	+0–2	Dimensions	+3.2–0
26 to 30	650–750	...	...		...
37 to 48	800–1200	...	...		...

Nominal Pipe Size (NPS)	(DN)	Angularity Tolerances: Off Angle, *Q*	Angularity Tolerances: Off Plane, *P*
½ to 4	15–100	1	2
5 to 8	125–200	2	4
10 to 12	250–300	2	5
14 to 16	350–400	3	6
18 to 24	450–600	4	10
26 to 30	650–750	5	10
32 to 42	800–1050	5	13
44–48	1100–1200	5	19

GENERAL NOTES:
(a) For reference, see Table 2 Illustration beginning on page 6.
(b) All dimensions are in millimeters.
(c) Tolerances are equal plus and minus except as noted.

NOTES:
(1) Out-of-round is the sum of absolute values of plus and minus tolerances.
(2) This tolerance may not apply in localized areas of formed fittings where increased wall thickness is required to meet design requirements of para. 2.2.
(3) The inside diameter and the nominal wall thicknesses at ends are to be specified by the purchaser.
(4) Unless otherwise specified by the purchaser, these tolerances apply to the nominal inside diameter, which equals the difference between the nominal outside diameter and twice the nominal wall thickness.

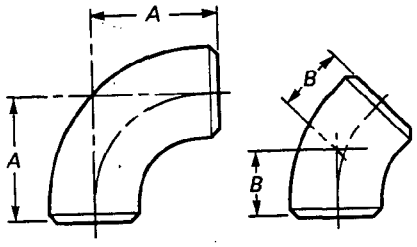

TABLE 3 DIMENSIONS OF LONG RADIUS ELBOWS

Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel	Center-to-End	
			90 Deg Elbows, *A*	45 Deg Elbows, *B*
½	15	21.3	38	16
¾	20 [Note (1)]	26.7	38	19
1	25	33.4	38	22
1¼	32	42.2	48	25
1½	40	48.3	57	29
2	50	60.3	76	35
2½	65	73.0	95	44
3	80	88.9	114	51
3½	90	101.6	133	57
4	100	114.3	152	64
5	125	141.3	190	79
6	150	168.3	229	95
8	200	219.1	305	127
10	250	273.0	381	159
12	300	323.8	457	190
14	350	355.6	533	222
16	400	406.4	610	254
18	450	457	686	286
20	500	508	762	318
22	550	559	838	343
24	600	610	914	381
26	650	660	991	405
28	700	711	1067	438
30	750	762	1143	470
32	800	813	1219	502
34	850	864	1295	533
36	900	914	1372	565
38	950	965	1448	600
40	1000	1016	1524	632
42	1050	1067	1600	660
44	1100	1118	1676	695
46	1150	1168	1753	727
48	1200	1219	1829	759

GENERAL NOTE: All dimensions are in millimeters.

NOTE:
(1) *A* and *B* dimensions of 29 mm and 11 mm, respectively, may be furnished for NPS ¾ (DN20) at the manufacturer's option.

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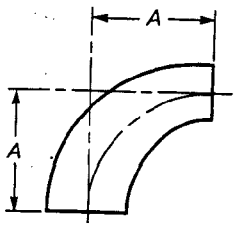

TABLE 4 DIMENSIONS OF LONG RADIUS-REDUCING ELBOWS

Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel		Center-to-End, A	Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel		Center-to-End, A
		Large End	Small End				Large End	Small End	
2 × 1½	50 × 40	60.3	48.3	76	10 × 8	250 × 200	273.0	219.1	381
2 × 1¼	50 × 32	60.3	42.2	76	10 × 6	250 × 150	273.0	168.3	381
2 × 1	50 × 25	60.3	33.4	76	10 × 5	250 × 125	273.0	141.3	381
2½ × 2	65 × 50	73.0	60.3	95	12 × 10	300 × 250	323.8	273.0	457
2½ × 1½	65 × 40	73.0	48.3	95	12 × 8	300 × 200	323.8	219.1	457
2½ × 1¼	65 × 32	73.0	42.2	95	12 × 6	300 × 150	323.8	168.3	457
3 × 2½	80 × 65	88.9	73.0	114	14 × 12	350 × 300	355.6	323.8	533
3 × 2	80 × 50	88.9	60.3	114	14 × 10	350 × 250	355.6	273.0	533
3 × 1½	80 × 40	88.9	48.3	114	14 × 8	350 × 200	355.6	219.1	533
3½ × 3	90 × 80	101.6	88.9	133	16 × 14	400 × 350	406.4	355.6	610
3½ × 2½	90 × 65	101.6	73.0	133	16 × 12	400 × 300	406.4	323.8	610
3½ × 2	90 × 50	101.6	60.3	133	16 × 10	400 × 250	406.4	273.0	610
4 × 3½	100 × 90	114.3	101.6	152	18 × 16	450 × 400	457	406.4	686
4 × 3	100 × 80	114.3	88.9	152	18 × 14	450 × 350	457	355.6	686
4 × 2½	100 × 65	114.3	73.0	152	18 × 12	450 × 300	457	323.8	686
4 × 2	100 × 50	114.3	60.3	152	18 × 10	450 × 250	457	273.0	686
5 × 4	125 × 100	141.3	114.3	190	20 × 18	500 × 450	508	457	762
5 × 3½	125 × 90	141.3	101.6	190	20 × 16	500 × 400	508	406.4	762
5 × 3	125 × 80	141.3	88.9	190	20 × 14	500 × 350	508	355.6	762
5 × 2½	125 × 65	141.3	73.0	190	20 × 12	500 × 300	508	323.8	762
6 × 5	150 × 125	168.3	141.3	229	20 × 10	500 × 250	610	273.0	762
6 × 4	150 × 100	168.3	114.3	229	24 × 22	600 × 550	610	559	914
6 × 3½	150 × 90	168.3	101.6	229	24 × 20	600 × 500	610	508	914
6 × 3	150 × 80	168.3	88.9	229	24 × 18	600 × 450	610	457	914
8 × 6	200 × 150	219.1	168.3	305	24 × 16	600 × 400	610	406.4	914
8 × 5	200 × 125	219.1	141.3	305	24 × 14	600 × 350	610	355.6	914
8 × 4	200 × 100	219.1	114.3	305	24 × 12	600 × 300	610	323.8	914

GENERAL NOTE: All dimensions are in millimeters.

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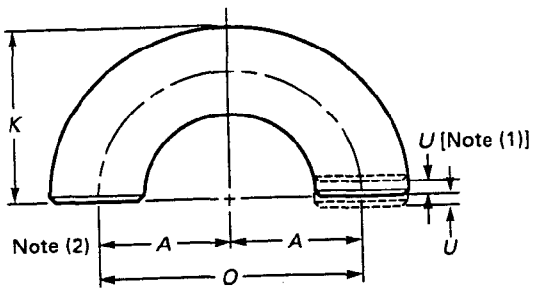

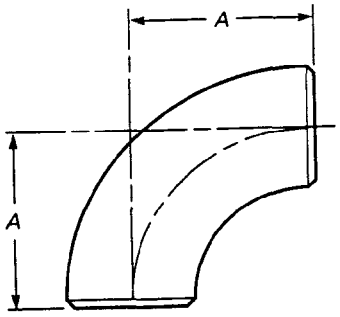

TABLE 5 DIMENSIONS OF LONG RADIUS RETURNS

Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel	Center-to-Center, *D*	Back-to-Face, *K*
½	15	21.3	76	48
¾	20 [Note (3)]	26.7	76	51
1	25	33.4	76	56
1¼	32	42.2	95	70
1½	40	48.3	114	83
2	50	60.3	152	106
2½	65	73.0	190	132
3	80	88.9	229	159
3½	90	101.6	267	184
4	100	114.3	305	210
5	125	141.3	381	262
6	150	168.3	457	313
8	200	219.1	610	414
10	250	273.0	762	518
12	300	323.8	914	619
14	350	355.6	1067	711
16	400	406.4	1219	813
18	450	457	1372	914
20	500	508	1524	1016
22	550	559	1676	1118
24	600	610	1829	1219

GENERAL NOTE: All dimensions are in millimeters.

NOTES:
(1) See Table 2 for tolerance for alignment of ends *U*.
(2) Dimension *A* is equal to one-half of dimension *O*.
(3) *O* and *K* dimentions of 57 mm and 43 mm, respectively, may be furnished for NPS ¾ (DN 20) at the manufacturer's option.

TABLE 6 DIMENSIONS OF SHORT RADIUS ELBOWS

Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel	Center-to-End, *A*
1	25	33.4	25
1¼	32	42.2	32
1½	40	48.3	38
2	50	60.3	51
2½	65	73.0	64
3	80	88.9	76
3½	90	101.6	89
4	100	114.3	102
5	125	141.3	127
6	150	168.3	152
8	200	219.1	203
10	250	273.0	254
12	300	323.8	305
14	350	355.6	356
16	400	406.4	406
18	450	457	457
20	500	508	508
22	550	559	559
24	600	610	610

GENERAL NOTE: All dimensions are in millimeters.

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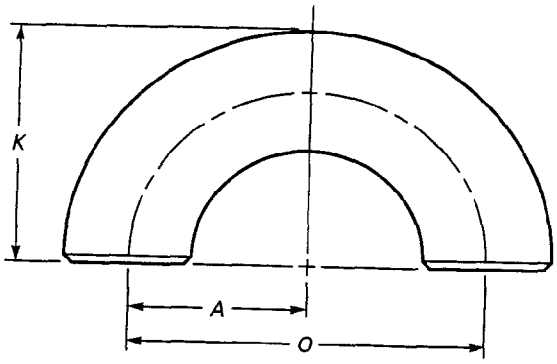

TABLE 7 DIMENSIONS OF SHORT RADIUS 180 deg RETURNS

Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel	Center-to-Center, *O*	Back-to-Face, *K*
1	25	33.4	51	41
1¼	32	42.2	64	52
1½	40	48.3	76	62
2	50	60.3	102	81
2½	65	73.0	127	100
3	80	88.9	152	121
3½	90	101.6	178	140
4	100	114.3	203	159
5	125	141.3	254	197
6	150	168.3	305	237
8	200	219.1	406	313
10	250	273.0	508	391
12	300	323.8	610	467
14	350	355.6	711	533
16	400	406.4	813	610
18	450	457	914	686
20	500	508	1016	762
22	550	559	1118	838
24	600	610	1219	914

GENERAL NOTES:
(a) All dimensions are in millimeters.
(b) Dimension *A* is equal to one-half of dimension *O*.

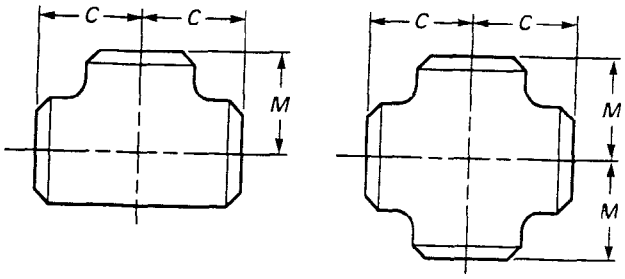

TABLE 8 DIMENSIONS OF STRAIGHT TEES AND CROSSES

Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel	Center-to-End	
			Run, *C*	Outlet, *M* [Notes (1) and (2)]
½	15	21.3	25	25
¾	20	26.7	29	29
1	25	33.4	38	38
1¼	32	42.2	48	48
1½	40	48.3	57	57
2	50	60.3	64	64
2½	65	73.0	76	76
3	80	88.9	86	86
3½	90	101.6	95	95
4	100	114.3	105	105
5	125	141.3	124	124
6	150	168.3	143	143
8	200	219.1	178	178
10	250	273.0	216	216
12	300	323.8	254	254
14	350	355.6	279	279
16	400	406.4	305	305
18	450	457	343	343
20	500	508	381	381
22	550	559	419	419
24	600	610	432	432
26	650	660	495	495
28	700	711	521	521
30	750	762	559	559
32	800	813	597	597
34	850	864	635	635
36	900	914	673	673
38	950	965	711	711
40	1000	1016	749	749
42	1050	1067	762	711
44	1100	1118	813	762
46	1150	1168	851	800
48	1200	1219	889	838

GENERAL NOTE: All dimensions are in millimeters.
NOTES:
(1) Outlet dimension *M* for NPS 26 (DN 650) and larger is recommended but not required.
(2) Dimensions applicable to crosses NPS 24 (DN 600) and smaller.

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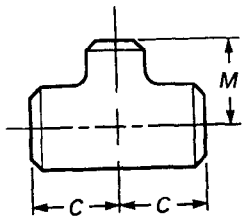

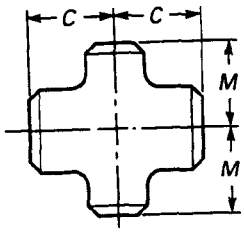

TABLE 9 DIMENSIONS OF REDUCING OUTLET TEES AND REDUCING OUTLET CROSSES

Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel		Center-to-End	
		Run	Outlet	Run, C	Outlet, M [Note (1)]
1/2 × 1/2 × 3/8	15 × 15 × 10	21.3	17.3	25	25
1/2 × 1/2 × 1/4	15 × 15 × 8	21.3	13.7	25	25
3/4 × 3/4 × 1/2	20 × 20 × 15	26.7	21.3	29	29
3/4 × 3/4 × 3/8	20 × 20 × 10	26.7	17.3	29	29
1 × 1 × 3/4	25 × 25 × 20	33.4	26.7	38	38
1 × 1 × 1/2	25 × 25 × 15	33.4	21.3	38	38
1 1/4 × 1 1/4 × 1	32 × 32 × 25	42.2	33.4	48	48
1 1/4 × 1 1/4 × 3/4	32 × 32 × 20	42.2	26.7	48	48
1 1/4 × 1 1/4 × 1/2	32 × 32 × 15	42.2	21.3	48	48
1 1/2 × 1 1/2 × 1 1/4	40 × 40 × 32	48.3	42.2	57	57
1 1/2 × 1 1/2 × 1	40 × 40 × 25	48.3	33.4	57	57
1 1/2 × 1 1/2 × 3/4	40 × 40 × 20	48.3	26.7	57	57
1 1/2 × 1 1/2 × 1/2	40 × 40 × 15	48.3	21.3	57	57
2 × 2 × 1 1/2	50 × 50 × 40	60.3	48.3	64	60
2 × 2 × 1 1/4	50 × 50 × 32	60.3	42.2	64	57
2 × 2 × 1	50 × 50 × 25	60.3	33.4	64	51
2 × 2 × 3/4	50 × 50 × 20	60.3	26.7	64	44
2 1/2 × 2 1/2 × 2	65 × 65 × 50	73.0	60.3	76	70
2 1/2 × 2 1/2 × 1 1/2	65 × 65 × 40	73.0	48.3	76	67
2 1/2 × 2 1/2 × 1 1/4	65 × 65 × 32	73.0	42.2	76	64
2 1/2 × 2 1/2 × 1	65 × 65 × 25	73.0	33.4	76	57
3 × 3 × 2 1/2	80 × 80 × 65	88.9	73.0	86	83
3 × 3 × 2	80 × 80 × 50	88.9	60.3	86	76
3 × 3 × 1 1/2	80 × 80 × 40	88.9	48.3	86	73
3 × 3 × 1 1/4	80 × 80 × 32	88.9	42.2	86	70
3 1/2 × 3 1/2 × 3	90 × 90 × 80	101.6	88.9	95	92
3 1/2 × 3 1/2 × 2 1/2	90 × 90 × 65	101.6	73.0	95	89
3 1/2 × 3 1/2 × 2	90 × 90 × 50	101.6	60.3	95	83
3 1/2 × 3 1/2 × 1 1/2	90 × 90 × 40	101.6	48.3	95	79
4 × 4 × 3 1/2	100 × 100 × 90	114.3	101.6	105	102
4 × 4 × 3	100 × 100 × 80	114.3	88.9	105	98
4 × 4 × 2 1/2	100 × 100 × 65	113.3	73.0	105	95
4 × 4 × 2	100 × 100 × 50	114.3	60.3	105	89
4 × 4 × 1 1/2	100 × 100 × 40	114.3	48.3	105	86
5 × 5 × 4	125 × 125 × 100	141.3	114.3	125	117
5 × 5 × 3 1/2	125 × 125 × 90	141.3	101.6	124	114
5 × 5 × 3	125 × 125 × 80	141.3	88.9	124	111
5 × 5 × 2 1/2	125 × 125 × 65	141.3	73.0	124	108
5 × 5 × 2	125 × 125 × 50	141.3	60.3	124	105

(continued)

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TABLE 9 DIMENSIONS OF REDUCING OUTLET TEES AND REDUCING OUTLET CROSSES (CONT'D)

Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel		Center-to-End	
		Run	Outlet	Run, *C*	Outlet, *M* [Note (1)]
6 × 6 × 5	150 × 150 × 125	168.3	141.3	143	137
6 × 6 × 4	150 × 150 × 100	168.3	114.3	143	130
6 × 6 × 3½	150 × 150 × 90	168.3	101.6	143	127
6 × 6 × 3	150 × 150 × 80	168.3	88.9	143	124
6 × 6 × 2½	150 × 150 × 65	168.3	73.0	143	121
8 × 8 × 6	200 × 200 × 150	219.1	168.3	178	168
8 × 8 × 5	200 × 200 × 125	219.1	141.3	178	162
8 × 8 × 4	200 × 200 × 100	219.1	114.3	178	156
8 × 8 × 3½	200 × 200 × 90	219.1	101.6	178	152
10 × 10 × 8	250 × 250 × 200	273.0	219.1	216	203
10 × 10 × 6	250 × 250 × 150	273.0	168.3	216	194
10 × 10 × 5	250 × 250 × 125	273.0	141.3	216	191
10 × 10 × 4	250 × 250 × 100	273.0	114.3	216	184
12 × 12 × 10	300 × 300 × 250	323.8	273.0	254	241
12 × 12 × 8	300 × 300 × 200	323.8	219.1	254	229
12 × 12 × 6	300 × 300 × 150	323.8	168.3	254	219
12 × 12 × 5	300 × 300 × 125	323.8	141.3	254	216
14 × 14 × 12	350 × 350 × 300	355.6	323.8	279	270
14 × 14 × 10	350 × 350 × 250	355.6	273.0	279	257
14 × 14 × 8	350 × 350 × 200	355.6	219.1	279	248
14 × 14 × 6	350 × 350 × 150	355.6	168.3	279	238
16 × 16 × 14	400 × 400 × 350	406.4	355.6	305	305
16 × 16 × 12	400 × 400 × 300	406.4	323.8	305	295
16 × 16 × 10	400 × 400 × 250	406.4	273.0	305	283
16 × 16 × 8	400 × 400 × 200	406.4	219.1	305	273
16 × 16 × 6	400 × 400 × 150	406.4	168.3	305	264
18 × 18 × 16	450 × 450 × 400	457	406.4	343	330
18 × 18 × 14	450 × 450 × 350	457	355.6	343	330
18 × 18 × 12	450 × 450 × 300	457	323.8	343	321
18 × 18 × 10	450 × 450 × 250	457	273.0	343	308
18 × 18 × 8	450 × 450 × 200	457	219.1	343	298
20 × 20 × 18	500 × 500 × 450	508	457	381	368
20 × 20 × 16	500 × 500 × 400	508	406.4	381	356
20 × 20 × 14	500 × 500 × 350	508	355.6	381	356
20 × 20 × 12	500 × 500 × 300	508	323.8	381	346
20 × 20 × 10	500 × 500 × 250	508	273.0	381	333
20 × 20 × 8	500 × 500 × 200	508	219.1	381	324
22 × 22 × 20	550 × 550 × 500	559	508	419	406
22 × 22 × 18	550 × 550 × 450	559	457	419	394
22 × 22 × 16	550 × 550 × 400	559	406.4	419	381
22 × 22 × 14	550 × 550 × 350	559	355.6	419	381
22 × 22 × 12	550 × 550 × 300	559	323.8	419	371
22 × 22 × 10	550 × 550 × 250	559	273.0	419	359

(continued)

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TABLE 9 DIMENSIONS OF REDUCING OUTLET TEES AND REDUCING OUTLET CROSSES (CONT'D)

Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel		Center-to-End	
		Run	Outlet	Run, *C*	Outlet, *M* [Note (1)]
24 × 24 × 22	600 × 600 × 550	610	559	432	432
24 × 24 × 20	600 × 600 × 500	610	508	432	432
24 × 24 × 18	600 × 600 × 450	610	457	432	419
24 × 24 × 16	600 × 600 × 400	610	406.4	432	406
24 × 24 × 14	600 × 600 × 350	610	355.6	432	406
24 × 24 × 12	600 × 600 × 300	610	323.8	432	397
24 × 24 × 10	600 × 600 × 250	610	273.0	432	384
26 × 26 × 24	650 × 650 × 600	660	610	495	483
26 × 26 × 22	650 × 650 × 550	660	559	495	470
26 × 26 × 20	650 × 650 × 550	660	508	495	457
26 × 26 × 18	650 × 650 × 450	660	457	495	444
26 × 26 × 16	650 × 650 × 400	660	406.4	495	432
26 × 26 × 14	650 × 650 × 350	660	355.6	495	432
26 × 26 × 12	650 × 650 × 300	660	323.8	495	422
28 × 28 × 26	700 × 700 × 650	711	660	521	521
28 × 28 × 24	700 × 700 × 600	711	610	521	508
28 × 28 × 22	700 × 700 × 550	711	559	521	495
28 × 28 × 20	700 × 700 × 500	711	508	521	483
28 × 28 × 18	700 × 700 × 450	711	457	521	470
28 × 28 × 16	700 × 700 × 400	711	406.4	521	457
28 × 28 × 14	700 × 700 × 350	711	355.6	521	457
28 × 28 × 12	700 × 700 × 300	711	323.8	521	448
30 × 30 × 28	750 × 750 × 700	762	711	559	546
30 × 30 × 26	750 × 750 × 650	762	660	559	546
30 × 30 × 24	750 × 750 × 600	762	610	559	533
30 × 30 × 22	750 × 750 × 550	762	559	559	521
30 × 30 × 20	750 × 750 × 500	762	508	559	508
30 × 30 × 18	750 × 750 × 450	762	457	559	495
30 × 30 × 16	750 × 750 × 400	762	406.4	559	483
30 × 30 × 14	750 × 750 × 350	762	355.6	559	483
30 × 30 × 12	750 × 750 × 300	762	323.8	559	473
30 × 30 × 10	750 × 750 × 250	762	273.0	559	460
32 × 32 × 30	800 × 800 × 750	813	762	597	584
32 × 32 × 28	800 × 800 × 700	813	711	597	572
32 × 32 × 26	800 × 800 × 650	813	660	597	572
32 × 32 × 24	800 × 800 × 600	813	610	597	559
32 × 32 × 22	800 × 800 × 550	813	559	597	546
32 × 32 × 20	800 × 800 × 500	813	508	597	533
32 × 32 × 18	800 × 800 × 450	813	457	597	521
32 × 32 × 16	800 × 800 × 400	813	406.4	597	508
32 × 32 × 14	800 × 800 × 350	813	355.6	597	508
34 × 34 × 32	850 × 850 × 800	864	813	635	622
34 × 34 × 30	850 × 850 × 750	864	762	635	610
34 × 34 × 28	850 × 850 × 700	864	711	635	597
34 × 34 × 26	850 × 850 × 650	864	600	635	597
34 × 34 × 24	850 × 850 × 600	864	610	635	584
34 × 34 × 22	850 × 850 × 550	864	559	635	572
34 × 34 × 20	850 × 850 × 500	864	508	635	559

(continued)

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TABLE 9 DIMENSIONS OF REDUCING OUTLET TEES AND REDUCING OUTLET CROSSES (CONT'D)

Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel		Center-to-End	
		Run	Outlet	Run, *C*	Outlet, *M* [Note (1)]
34 × 34 × 18	850 × 850 × 450	864	457	635	546
34 × 34 × 16	850 × 850 × 400	864	406.4	635	533
36 × 36 × 34	900 × 900 × 850	914	864	673	660
36 × 36 × 32	900× 900 × 800	914	813	673	648
36 × 36 × 30	900× 900 × 750	914	762	673	635
36 × 36 × 28	900× 900 × 700	914	711	673	622
36 × 36 × 26	900× 900 × 650	914	660	673	622
36 × 36 × 24	900× 900 × 600	914	610	673	610
36 × 36 × 22	900× 900 × 550	914	559	673	597
36 × 36 × 20	900× 900 × 500	914	508	673	584
36 × 36 × 18	900× 900 × 450	914	457	673	572
36 × 36 × 16	900× 900 × 400	914	406.4	673	559
38 × 38 × 36	950 × 950 × 900	965	914	711	711
38 × 38 × 34	950 × 950 × 850	965	864	711	698
38 × 38 × 32	950 × 950 × 800	965	813	711	686
38 × 38 × 30	950 × 950 × 750	965	762	711	673
38 × 38 × 28	950 × 950 × 700	965	711	711	648
38 × 38 × 26	950 × 950 × 650	965	660	711	648
38 × 38 × 24	950 × 950 × 600	965	610	711	635
38 × 38 × 22	950 × 950 × 550	965	559	711	622
38 × 38 × 20	950 × 950 × 500	965	508	711	610
38 × 38 × 18	950 × 950 × 450	965	457	711	597
40 × 40 × 38	1000 × 1000 × 950	1016	965	749	749
40 × 40 × 36	1000 × 1000 × 900	1016	914	749	737
40 × 40 × 34	1000 × 1000 × 850	1016	864	749	724
40 × 40 × 32	1000 × 1000 × 800	1016	813	749	711
40 × 40 × 30	1000 × 1000 × 750	1016	762	749	698
40 × 40 × 28	1000 × 1000 × 700	1016	711	749	673
40 × 40 × 26	1000 × 1000 × 650	1016	560	749	673
40 × 40 × 24	1000 × 1000 × 600	1016	610	749	660
40 × 40 × 22	1000 × 1000 × 550	1016	559	749	648
40 × 40 × 20	1000 × 1000 × 500	1016	508	749	635
40 × 40 × 18	1000 × 1000 × 450	1016	457	749	622
42 × 42 × 40	1050 × 1050 × 1000	1067	1016	762	711
42 × 42 × 38	1050 × 1050 × 950	1067	968	762	711
42 × 42 × 36	1050 × 1050 × 900	1067	914	762	711
42 × 42 × 34	1050 × 1050 × 850	1067	864	762	711
42 × 42 × 32	1050 × 1050 × 800	1067	813	762	711
42 × 42 × 30	1050 × 1050 × 750	1067	762	762	711
42 × 42 × 28	1050 × 1050 × 700	1067	711	762	698
42 × 42 × 26	1050 × 1050 × 650	1067	660	762	698
42 × 42 × 24	1050 × 1050 × 600	1067	610	762	660
42 × 42 × 22	1050 × 1050 × 550	1067	559	762	660
42 × 42 × 20	1050 × 1050 × 500	1067	508	762	660
42 × 42 × 18	1050 × 1050 × 450	1067	457	762	648
42 × 42 × 16	1050 × 1050 × 400	1067	406.4	762	635
44 × 44 × 42	1100 × 1100 × 1050	1118	1067	813	762
44 × 44 × 40	1100 × 1100 × 1000	1118	1016	813	749

(continued)

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TABLE 9 DIMENSIONS OF REDUCING OUTLET TEES AND REDUCING OUTLET CROSSES (CONT'D)

Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel		Center-to-End	
		Run	Outlet	Run, *C*	Outlet, *M* [Note (1)]
44 × 44 × 38	1100 × 1100 × 950	1118	965	813	737
44 × 44 × 36	1100 × 1100 × 900	1118	914	813	724
44 × 44 × 34	1100 × 1100 × 850	1118	864	813	724
44 × 44 × 32	1100 × 1100 × 800	1118	813	813	711
44 × 44 × 30	1100 × 1100 × 750	1118	762	813	711
44 × 44 × 28	1100 × 1100 × 700	1118	711	813	698
44 × 44 × 26	1100 × 1100 × 650	1118	660	813	698
44 × 44 × 24	1100 × 1100 × 600	1118	610	813	698
44 × 44 × 22	1100 × 1100 × 550	1118	559	813	686
44 × 44 × 20	1100 × 1100 × 500	1118	508	813	686
46 × 46 × 44	1150 × 1150 × 1100	1168	1118	851	800
46 × 46 × 42	1150 × 1150 × 1050	1168	1067	851	787
46 × 46 × 40	1150 × 1150 × 1000	1168	1016	851	775
46 × 46 × 38	1150 × 1150 × 950	1168	965	851	762
46 × 46 × 36	1150 × 1150 × 900	1168	914	851	762
46 × 46 × 34	1150 × 1150 × 850	1168	864	851	749
46 × 46 × 32	1150 × 1150 × 800	1168	813	851	749
46 × 46 × 30	1150 × 1150 × 750	1168	762	851	737
46 × 46 × 28	1150 × 1150 × 700	1168	711	851	737
46 × 46 × 26	1150 × 1150 × 650	1168	660	851	737
46 × 46 × 24	1150 × 1150 × 600	1168	610	851	724
46 × 46 × 22	1150 × 1150 × 550	1168	559	851	724
48 × 48 × 46	1200 × 1200 × 1150	1219	1168	889	838
48 × 48 × 44	1200 × 1200 × 1100	1219	1118	889	838
48 × 48 × 42	1200 × 1200 × 1050	1219	1067	889	813
48 × 48 × 40	1200 × 1200 × 1000	1219	1016	889	813
48 × 48 × 38	1200 × 1200 × 950	1219	965	889	813
48 × 48 × 36	1200 × 1200 × 900	1219	914	889	787
48 × 48 × 34	1200 × 1200 × 850	1219	864	889	787
48 × 48 × 32	1200 × 1200 × 800	1219	813	889	787
48 × 48 × 30	1200 × 1200 × 750	1219	762	889	762
48 × 48 × 28	1200 × 1200 × 700	1219	711	889	762
48 × 48 × 26	1200 × 1200 × 650	1219	660	889	762
48 × 48 × 24	1200 × 1200 × 600	1219	610	889	737
48 × 48 × 22	1200 × 1200 × 550	1219	559	889	737

GENERAL NOTE: All dimensions are in millimeters.

NOTE:
(1) Outlet dimension *M* for run sizes NPS 14 (DN 350) and larger is recommended but not required.

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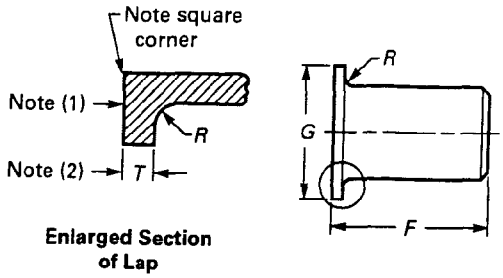

Enlarged Section of Lap

TABLE 10 DIMENSIONS OF LAP JOINT STUB ENDS

Nominal Pipe Size (NPS)	DN	Outside Diameter of Barrel		Long Pattern Length, *F* [Notes (3), (4)]	Short Pattern Length, *F* [Notes (3), (4)]	Radius of Fillet, *R* [Note (5)]	Diameter of Lap, *G* [Note (6)]
		Max.	Min.				
½	15	22.8	20.5	76	51	3	35
¾	20	28.1	25.9	76	51	3	43
1	25	35.0	32.6	102	51	3	51
1¼	32	43.6	41.4	102	51	5	64
1½	40	49.9	47.5	102	51	6	73
2	50	62.4	59.5	152	64	8	92
2½	65	75.3	72.2	152	64	8	106
3	80	91.3	88.1	152	64	10	127
3½	90	104.0	100.8	152	76	10	140
4	100	116.7	113.5	152	76	11	157
5	125	144.3	140.5	203	76	11	185
6	150	171.3	167.5	203	89	13	218
8	200	222.1	218.3	203	102	13	270
10	250	277.2	272.3	254	127	13	324
12	300	328.0	323.1	254	152	13	381
14	350	359.9	354.8	305	152	13	413
16	400	411.0	405.6	305	152	13	470
18	450	462	456	305	152	13	533
20	500	514	507	305	152	13	584
22	550	565	558	305	152	13	641
24	600	616	609	305	152	13	692

GENERAL NOTES:

(a) All dimensions are in millimeters.

(b) See Table 2 for tolerances.

(c) Service conditions and joint construction often dictate stub end length requirements. Therefore, the purchaser must specify long or short pattern fitting when ordering.

NOTES:

(1) Gasket face finish shall be in accordance with ASME B16.5 for raised face flanges.

(2) The lap thickness *T* shall not be less than nominal pipe wall thickness. See Table 2 for maximum tolerance.

(3) When short pattern stub ends are used with larger flanges in Classes 300 and 600, (PN50 & PN110) and with most sizes in Classes 900 (PN150) and higher, and when long pattern stub ends are used with larger flanges in Classes 1500 and 2500, (PN260 AND PN420) it may be necessary to increase the length of the stub ends in order to avoid covering the weld with the flange. Such increases in length shall be a matter of agreement between the manufacturer and purchaser.

(4) When special facings such as tongue and groove, male and female, etc., are employed, additional lap thickness must be provided and such additional thickness shall be in addition to (not included in) the basic length *F*.

(5) These dimensions conform to the radius established for lap joint flanges in ASME B16.5, Pipe Flanges and Flanged Fittings.

(6) This dimension conforms to standard machined facings shown in ASME B16.5. The back face of the lap shall be machined to conform to the surface on which it seats. Where ring joint facings are to be applied, use dimension *K* as given in ASME B16.5.

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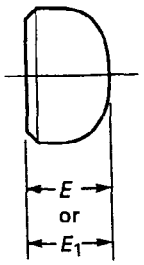

TABLE 11 DIMENSIONS OF CAPS

Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel	Length, *E* [Note (1)]	Limiting Wall Thickness for Length, *E*	Length, *E* [Note (2)]
½	15	21.3	25	4.57	25
¾	20	26.7	25	3.81	25
1	25	33.4	38	4.57	38
1¼	32	42.2	38	4.83	38
1½	40	48.3	38	5.08	38
2	50	60.3	38	5.59	44
2½	65	73.0	38	7.11	51
3	80	88.9	51	7.62	64
3½	90	101.6	64	8.13	76
4	100	114.3	64	8.64	76
5	125	141.3	76	9.65	89
6	150	168.3	89	10.92	102
8	200	219.1	102	12.70	127
10	250	273.0	127	12.70	152
12	300	323.8	152	12.70	178
14	350	355.6	165	12.70	191
16	400	406.4	178	12.70	203
18	450	457	203	12.70	229
20	500	508	229	12.70	254
22	550	559	254	12.70	254
24	600	610	267	12.70	305
26	650	660	267	...	...
28	700	711	267	...	...
30	750	762	267	...	...
32	800	813	267	...	...
34	850	864	267	...	...
36	900	914	267	...	...
38	950	965	305	...	...
40	1000	1016	305	...	...
42	1050	1067	305	...	...
44	1100	1118	343	...	...
46	1150	1168	343	...	...
48	1200	1219	343	...	...

GENERAL NOTES:
(a) All dimensions are in millimeters.
(b) The shape of these caps shall be elipsoidal and shall conform to the shape requirements as given in the ASME Boiler and Pressure Vessel Code.

NOTES:
(1) Length *E* applies for thickness not exceeding that given in column "Limiting Wall Thickness for Length *E*."
(2) Length E_1 applies for thickness greater than that given in column "Limiting Wall Thickness" for NPS 24 (DN 600) and smaller. For NPS 26 (DN 65) and larger, length E_1 shall be by agreement between manufacturer and purchaser.

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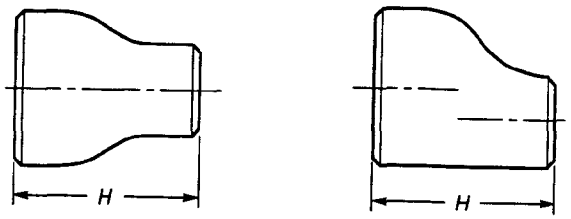

Note (1)

TABLE 12 DIMENSIONS OF REDUCERS

Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel		End-to-End, *H*
		Large End	Small End	
$\frac{3}{4} \times \frac{1}{2}$	20 × 15	26.7	21.3	38
$\frac{3}{4} \times \frac{3}{8}$	20 × 10	26.7	17.3	38
$1 \times \frac{3}{4}$	25 × 20	33.4	26.7	51
$1 \times \frac{1}{2}$	25 × 15	33.4	21.3	51
$1\frac{1}{4} \times 1$	32 × 25	42.2	33.4	51
$1\frac{1}{4} \times \frac{3}{4}$	32 × 20	42.2	26.7	51
$1\frac{1}{4} \times \frac{1}{2}$	32 × 15	42.2	21.3	51
$1\frac{1}{2} \times 1\frac{1}{4}$	40 × 32	48.3	42.2	64
$1\frac{1}{2} \times 1$	40 × 25	48.3	33.4	64
$1\frac{1}{2} \times \frac{3}{4}$	40 × 20	48.3	26.7	64
$1\frac{1}{2} \times \frac{1}{2}$	40 × 15	48.3	21.3	64
$2 \times 1\frac{1}{2}$	50 × 40	60.3	48.3	76
$2 \times 1\frac{1}{4}$	50 × 32	60.3	42.2	76
2×1	50 × 25	60.3	33.4	76
$2 \times \frac{3}{4}$	50 × 20	60.3	26.7	76
$2\frac{1}{2} \times 2$	65 × 50	73.0	60.3	89
$2\frac{1}{2} \times 1\frac{1}{2}$	65 × 40	73.0	48.3	89
$2\frac{1}{2} \times 1\frac{1}{4}$	65 × 32	73.0	42.2	89
$2\frac{1}{2} \times 1$	65 × 25	73.0	33.4	89
$3 \times 2\frac{1}{2}$	80 × 65	88.9	73.0	89
3×2	80 × 50	88.9	60.3	89
$3 \times 1\frac{1}{2}$	80 × 40	88.9	48.3	89
$3 \times 1\frac{1}{4}$	80 × 32	88.9	42.2	89
$3\frac{1}{2} \times 3$	90 × 80	101.6	88.9	102
$3\frac{1}{2} \times 2\frac{1}{2}$	90 × 65	101.6	73.0	102
$3\frac{1}{2} \times 2$	90 × 50	101.6	60.3	102
$3\frac{1}{2} \times 1\frac{1}{2}$	90 × 40	101.6	48.3	102
$3\frac{1}{2} \times 1\frac{1}{4}$	90 × 32	101.6	42.2	102
$4 \times 3\frac{1}{2}$	100 × 90	114.3	101.6	102
4×3	100 × 80	114.3	88.9	102
$4 \times 2\frac{1}{2}$	100 × 65	114.3	73.0	102
4×2	100 × 50	114.3	60.3	102
$4 \times 1\frac{1}{2}$	100 × 40	114.3	48.3	102
5×4	125 × 100	141.3	114.3	127
$5 \times 3\frac{1}{2}$	125 × 90	141.3	101.6	127
5×3	125 × 80	141.3	88.9	127
$5 \times 2\frac{1}{2}$	125 × 65	141.3	73.0	127
5×2	125 × 50	141.3	60.3	127
6×5	150 × 125	168.3	141.3	140
6×4	150 × 100	168.3	114.3	140
$6 \times 3\frac{1}{2}$	150 × 90	168.3	101.6	140
6×3	150 × 80	168.3	88.9	140
$6 \times 2\frac{1}{2}$	150 × 65	168.3	73.0	140
8×6	200 × 150	219.1	168.3	152
8×5	200 × 125	219.1	141.3	152
8×4	200 × 100	219.1	114.3	152
$8 \times 3\frac{1}{2}$	200 × 90	219.1	101.6	152
10×8	250 × 200	273.0	219.1	178
10×6	250 × 150	273.0	168.3	178
10×5	250 × 125	273.0	141.3	178
10×4	250 × 100	273.0	114.3	178
12×10	300 × 250	323.8	273.0	203
12×8	300 × 200	323.8	219.1	203
12×6	300 × 150	323.8	168.3	203
12×5	300 × 125	323.8	141.3	203
14×12	350 × 300	355.6	323.8	330
14×10	350 × 250	355.6	273.0	330
14×8	350 × 200	355.6	219.1	330
14×6	350 × 150	355.6	168.3	330
16×14	400 × 350	406.4	355.6	356
16×12	400 × 300	406.4	323.8	356
16×10	400 × 250	406.4	273.0	356
16×8	400 × 200	406.4	219.1	356
18×16	450 × 400	457	406.4	381
18×14	450 × 350	457	355.6	381
18×12	450 × 300	457	323.8	381
18×10	450 × 250	457	273.0	381

(continued)

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TABLE 12 DIMENSIONS OF REDUCERS (CONT'D)

Nominal Pipe Size (NPS)	DN	Outside Diameter at Bevel, Large End	Outside Diameter at Bevel, Small End	End-to-End, *H*
20 × 18	500 × 450	508	457	508
20 × 16	500 × 400	508	406.4	508
20 × 14	500 × 350	508	355.6	508
20 × 12	500 × 300	508	323.8	508
22 × 20	550 × 500	559	508	508
22 × 18	550 × 450	559	457	508
22 × 16	550 × 400	559	406.4	508
22 × 14	550 × 350	559	355.4	508
24 × 22	600 × 550	610	559	508
24 × 20	600 × 500	610	508	508
24 × 18	600 × 450	610	457	508
24 × 16	600 × 400	610	406.4	508
26 × 24	650 × 600	660	610	610
26 × 22	650 × 550	660	559	610
26 × 20	650 × 500	660	508	610
26 × 18	650 × 450	660	457	610
28 × 26	700 × 650	711	660	610
28 × 24	700 × 600	711	610	610
28 × 22	700 × 550	711	508	610
28 × 20	700 × 500	711	457	610
30 × 28	750 × 700	762	711	610
30 × 26	750 × 650	762	660	610
30 × 24	750 × 600	762	610	610
30 × 22	750 × 550	762	508	610
32 × 30	800 × 750	813	762	610
32 × 28	800 × 700	813	711	610
32 × 26	800 × 650	813	660	610
32 × 24	800 × 600	813	610	610
34 × 32	850 × 800	864	813	610
34 × 30	850 × 750	864	762	610
34 × 28	850 × 700	864	660	610
34 × 26	850 × 650	864	610	610
36 × 34	900 × 850	914	864	610
36 × 32	900 × 800	914	813	610
36 × 30	900 × 750	914	762	610
36 × 28	900 × 700	914	660	610
36 × 26	900 × 650	914	610	610
38 × 36	950 × 900	965	914	610
38 × 34	950 × 850	965	864	610
38 × 32	950 × 800	965	813	610
38 × 30	950 × 750	965	762	610
38 × 28	950 × 700	965	711	610
38 × 26	950 × 650	965	660	610
40 × 38	1000 × 950	1016	965	610
40 × 36	1000 × 900	1016	914	610
40 × 34	1000 × 850	1016	864	610
40 × 32	1000 × 800	1016	813	610
40 × 30	1000 × 750	1016	762	610
42 × 40	1050 × 1000	1067	1016	610
42 × 38	1050 × 950	1067	965	610
42 × 36	1050 × 900	1067	914	610
42 × 34	1050 × 850	1067	864	610
42 × 32	1050 × 800	1067	813	610
42 × 30	1050 × 750	1067	762	610
44 × 42	1100 × 1050	1118	1067	610
44 × 40	1100 × 1000	1118	1016	610
44 × 38	1100 × 950	1118	965	610
44 × 36	1100 × 900	1118	914	610
46 × 44	1150 × 1100	1168	1118	711
46 × 42	1150 × 1050	1168	1067	711
46 × 40	1150 × 1000	1168	1016	711
46 × 38	1150 × 950	1168	965	711
48 × 46	1200 × 1150	1219	1168	711
48 × 44	1200 × 1100	1219	1118	711
48 × 42	1200 × 1050	1219	1067	711
48 × 40	1200 × 1000	1219	1016	711

GENERAL NOTE: All dimensions are in millimeters.

NOTE:
(1) While the figure illustrates a "bell shaped" reducer, the use of conical reducer is not prohibited.

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MANDATORY APPENDIX I
INCH TABLES

This Appendix provides tables of the standard inch dimensions for fittings.

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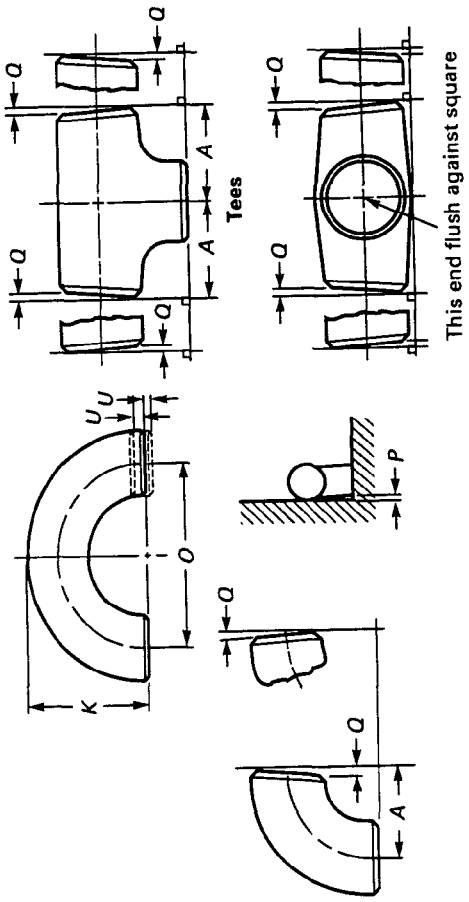

TABLE I1 ILLUSTRATION

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TABLE I1 TOLERANCES

All Fittings				90 Deg and 45 Deg Elbows and Tees	Reducers and Lap Joint Stub Ends		180 Deg Returns			Lap Joint Stub Ends				Angularity Tolerances	
Nominal Pipe Size (NPS)	Outside Diameter at Bevel [Notes(1) and (2)]	Inside Diameter at End [Notes (1), (3), and (4)]	Wall Thickness, *t* [Note (3)]	Center-to-End Dimension, *A,B,C,M*	Overall Length, *F,H*	Overall Length of Cap, *E*	Center-to-Center Dimension, *O*	Back-to-Face Dimension, *K*	Alignment of Ends, *U*	Outside Diameter of Lap, *G*	Fillet Radius of Lap, *R*	Outside Diameter of Barrel	Lap Thickness, *T*	Nominal Pipe Size (NPS)	Off Angle, *Q*	Off Plane, *P*
½ to 2½	+0.06 0.03	0.03		0.06	0.06	0.12	0.25	0.25	0.03	+0	+0		+0.06 0	½ to 4	0.03	0.06
3 to 3½	0.06	0.06		0.06	0.06	0.12	0.25	0.25	0.03	+0 0.03	+0 0.03		+0.06 0	5 to 8	0.06	0.12
4	0.06	0.06	Not less than 87.5% of nominal thickness	0.06	0.06	0.12	0.25	0.25	0.03	+0 0.03	+0 0.06	See Table A9 for limiting dimensions	+0.06 0	10 to 12	0.09	0.19
5 to 8	+0.09 0.06	0.06		0.06	0.06	0.25	0.25	0.25	0.03	+0 0.03	+0 0.06		+0.06 0	14 to 16	0.09	0.25
10 to 18	+0.16 0.12	0.12		0.09	0.09	0.25	0.38	0.25	0.06	+0 0.06	+0 0.06		+0.12 0	18 to 24	0.12	0.38
20 to 24	+0.25 0.19	0.19		0.09	0.09	0.25	0.38	0.25	0.06	+0 0.06	+0 0.06		+0.12 0	26 to 30	0.19	0.38
26 to 30	+0.25 0.19	0.19		0.12	0.19	0.38	...	...	...	...	...	...	...	32 to 42	0.19	0.50
32 to 48	+0.25 0.19	0.19		0.19	0.19	0.38	...	...	...	...	...	...	...	44 to 48	0.19	0.75

GENERAL NOTES:
(a) For reference, see Table I1 Illustration beginning on page 22.
(b) All dimensions are in inches. Tolerances are equal plus and minus except as noted.

NOTES:
(1) Out-of-round is the sum of absolute values of plus and minus tolerance.
(2) This tolerance may not apply in localized areas of formed fittings where increased wall thickness is required to meet design requirements of para. 2.2.
(3) The inside diameter and the nominal wall thicknesses at ends are to be specified by the purchaser.
(4) Unless otherwise specified by the purchaser, these tolerances apply to the nominal inside diameter, which equals the difference between the nominal outside diameter and twice the nominal wall thickness.

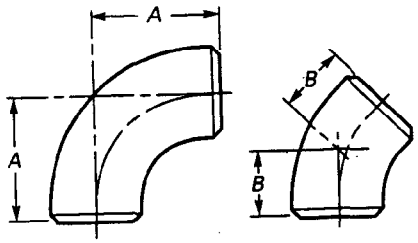

TABLE I2 DIMENSIONS OF LONG RADIUS ELBOWS

Nominal Pipe Size (NPS)	Outside Diameter at Bevel	Center-to-End		Nominal Pipe Size (NPS)	Outside Diameter at Bevel	Center-to-End	
		90 Deg Elbows, *A*	45 Deg Elbows, *B*			90 Deg Elbows, *A*	45 Deg Elbows, *B*
½	0.84	1.50	0.62	16	16.00	24.00	10.00
¾ [Note (1)]	1.05	1.50	0.75	18	18.00	27.00	11.25
1	1.32	1.50	0.88	20	20.00	30.00	12.50
1¼	1.66	1.88	1.00	22	22.00	33.00	13.50
1½	1.90	2.25	1.12	24	24.00	36.00	15.00
2	2.38	3.00	1.38	26	26.00	39.00	16.00
2½	2.88	3.75	1.75	28	28.00	42.00	17.25
3	3.50	4.50	2.00	30	30.00	45.00	18.50
3½	4.00	5.25	2.25	32	32.00	48.00	19.75
4	4.50	6.00	2.50	34	34.00	51.00	21.00
5	5.56	7.50	3.12	36	36.00	54.00	22.25
6	6.62	9.00	3.75	38	38.00	57.00	23.
8	8.62	12.00	5.00	40	40.00	60.00	24.88
10	10.75	15.00	6.25	42	42.00	63.00	26.00
12	12.75	18.00	7.50	44	44.00	66.00	27.38
14	14.00	21.00	8.75	46	46.00	69.00	28.62
				48	48.00	72.00	29.88

GENERAL NOTE: All dimensions are in inches.

NOTE:
(1) *A* and *B* dimensions of 1.12 in. and 0.44 in., respectively, may be furnished for NPS ¾ at the manufacturer's option.

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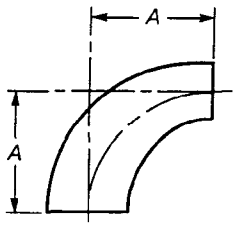

TABKE I3 DIMENSIONS OF LONG RADIUS REDUCING ELBOWS

Nominal Pipe Size (NPS)	Outside Diameter at Bevel		Center-to-End, *A*	Nominal Pipe Size (NPS)	Outside Diameter at Bevel		Center-to-End, *A*
	Large End	Small End			Large End	Small End	
2 × 1½	2.38	1.90	3.00	10 × 8	10.75	8.62	15.00
2 × 1¼	2.38	1.66	3.00	10 × 6	10.75	6.62	15.00
2 × 1	2.38	1.32	3.00	10 × 5	10.75	5.56	15.00
2½ × 2	2.88	2.38	3.75	12 × 10	12.75	10.75	18.00
2½ × 1½	2.88	1.90	3.75	12 × 8	12.75	8.62	18.00
2½ × 1¼	2.88	1.66	3.75	12 × 6	12.75	6.62	18.00
3 × 2½	3.50	2.88	4.50	14 × 12	14.00	12.75	21.00
3 × 2	3.50	2.38	4.50	14 × 10	14.00	10.75	21.00
3 × 1½	3.50	1.90	4.50	14 × 8	14.00	8.62	21.00
3½ × 3	4.00	3.50	5.25	16 × 14	16.00	14.00	24.00
3½ × 2½	4.00	2.88	5.25	16 × 12	16.00	12.75	24.00
3½ × 2	4.00	2.38	5.25	16 × 10	16.00	10.75	24.00
4 × 3½	4.50	4.00	6.00	18 × 16	18.00	16.00	27.00
4 × 3	4.50	3.50	6.00	18 × 14	18.00	14.00	27.00
4 × 2½	4.50	2.88	6.00	18 × 12	18.00	12.75	27.00
4 × 2	4.50	2.38	6.00	18 × 10	18.00	10.75	27.00
5 × 4	5.56	4.50	7.50	20 × 18	20.00	18.00	30.00
5 × 3½	5.56	4.00	7.50	20 × 16	20.00	16.00	30.00
5 × 3	5.56	3.50	7.50	20 × 14	20.00	14.00	30.00
5 × 2½	5.56	2.88	7.50	20 × 12	20.00	12.75	30.00
6 × 5	6.62	5.56	9.00	20 × 10	20.00	10.75	30.00
6 × 4	6.62	4.50	9.00	24 × 22	24.00	22.00	36.00
6 × 3½	6.62	4.00	9.00	24 × 20	24.00	20.00	36.00
6 × 3	6.62	3.50	9.00	24 × 18	24.00	18.00	36.00
8 × 6	8.62	6.62	12.00	24 × 16	24.00	16.00	36.00
8 × 5	8.62	5.56	12.00	24 × 14	24.00	14.00	36.00
8 × 4	8.62	4.50	12.00	24 × 12	24.00	12.75	36.00

GENERAL NOTE: All dimensions are in inches.

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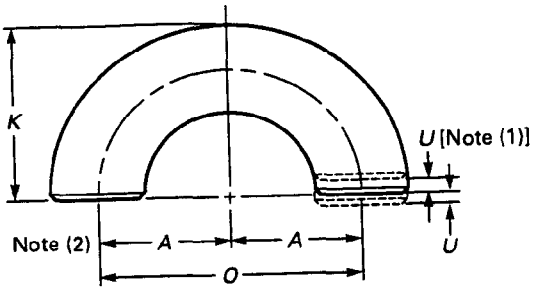

TABLE I4 DIMENSIONS OF LONG RADIUS RETURNS

Nominal Pipe Size (NPS)	Outside Diameter at Bevel	Center-to-Center, *O*	Back-to-Face, *K*
½	0.84	3.00	1.88
¾ [Note (3)]	1.05	3.00	2.00
1	1.32	3.00	2.19
1¼	1.66	3.75	2.75
1½	1.90	4.50	3.25
2	2.38	6.00	4.19
2½	2.88	7.50	5.19
3	3.50	9.00	6.25
3½	4.00	10.50	7.25
4	4.50	12.00	8.25
5	5.56	15.00	10.31
6	6.62	18.00	12.31
8	8.62	24.00	16.31
10	10.75	30.00	20.38
12	12.75	36.00	24.38
14	14.00	42.00	28.00
16	16.00	48.00	32.00
18	18.00	54.00	36.00
20	20.00	60.00	40.00
22	22.00	66.00	44.00
24	24.00	72.00	48.00

GENERAL NOTE: All dimensions are in inches.

NOTES:
(1) See Table I1 for tolerance for alignment of ends, *U*.
(2) Dimension *A* is equal to one-half of dimension *O*.
(3) *O* and *K* dimensions of 2.25 in. and 1.69 in. respectively, may be furnished for NPS ¾ at the manufacturer's option.

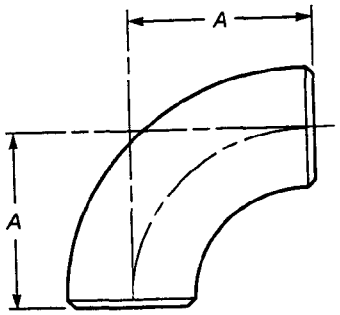

TABLE I5 DIMENSIONS OF SHORT RADIUS ELBOWS

Nominal Pipe Size	Outside Diameter at Bevel	Cent to-End, *A*
1	1.32	1.00
1¼	1.66	1.25
1½	1.90	1.50
2	2.38	2.00
2½	2.88	2.50
3	3.50	3.00
3½	4.00	3.40
4	4.50	4.00
5	5.56	5.00
6	6.62	6.
8	8.62	8.00
10	10.75	10.00
12	12.75	12.00
14	14.00	14.00
16	16.00	16.00
18	18.00	18.00
20	20.00	20.00
22	22.00	22.00
24	24.00	24.00

GENERAL NOTE: All dimensions are in inches.

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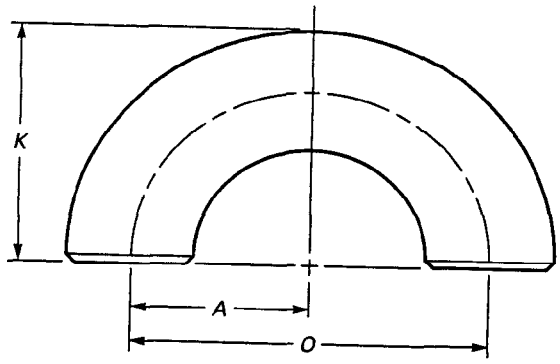

TABLE I6 DIMENSIONS OF SHORT RADIUS 180 deg RETURNS

Nominal Pipe Size	Outside Diameter at Bevel	Center-to-Center, *O*	Back-to-Face, *K*
1	1.32	2.00	1.62
1¼	1.66	2.50	2.06
1½	1.90	3.00	2.44
2	2.38	4.00	3.19
2½	2.88	5.00	3.94
3	3.50	6.00	4.75
3½	4.00	7.00	5.50
4	4.50	8.00	6.25
5	5.56	10.00	7.75
6	6.62	12.00	9.31
8	8.62	16.00	12.31
10	10.75	20.00	15.38
12	12.75	24.00	18.38
14	14.00	28.00	21.00
16	16.00	32.00	24.00
18	18.00	36.00	27.00
20	20.00	40.00	30.00
22	22.00	44.00	33.00
24	24.00	48.00	36.00

GENERAL NOTES:
(a) All dimensions are in inches.
(b) Dimension *A* is equal to one-half of dimension *O*.

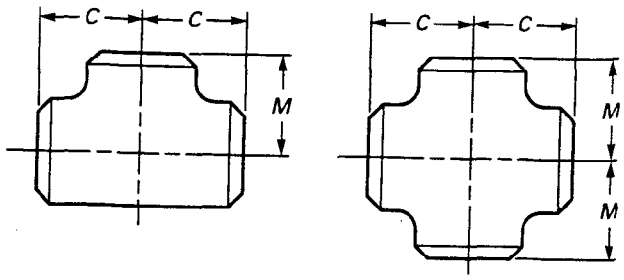

TABLE I7 DIMENSIONS OF STRAIGHT TEES AND CROSSES

Nominal Pipe Size (NPS)	Outside Diameter at Bevel	Center-to-End	
		Run, *C*	Outlet, *M* [Notes (1) and (2)]
½	0.84	1.00	1.00
¾	1.05	1.12	1.12
1	1.32	1.50	1.50
1¼	1.66	1.88	1.88
1½	1.90	2.25	2.25
2	2.38	2.50	2.50
2½	2.88	3.00	3.00
3	3.50	3.38	3.38
3½	4.00	3.75	3.75
4	4.50	4.12	4.12
5	5.56	4.88	4.88
6	6.62	5.62	5.62
8	8.62	7.00	7.00
10	10.75	8.50	8.50
12	12.75	10.00	10.00
14	14.00	11.00	11.00
16	16.00	12.00	12.00
18	18.00	13.50	13.50
20	20.00	15.00	15.00
22	22.00	16.50	16.50
24	24.00	17.00	17.00
26	26.00	19.50	19.50
28	28.00	20.50	20.50
30	30.00	22.00	22.00
32	32.00	23.50	23.50
34	34.00	25.00	25.00
36	36.00	26.50	26.50
38	38.00	28.00	28.00
40	40.00	29.50	29.50
42	42.00	30.00	28.00
44	44.00	32.00	30.00
46	46.00	33.50	31.50
48	48.00	35.00	33.00

GENERAL NOTE: Dimensions are in inches.
NOTES:
(1) Outlet dimension *M* for NPS 26 and larger is recommended but not required.
(2) Dimensions applicable to crosses NPS 24 and smaller.

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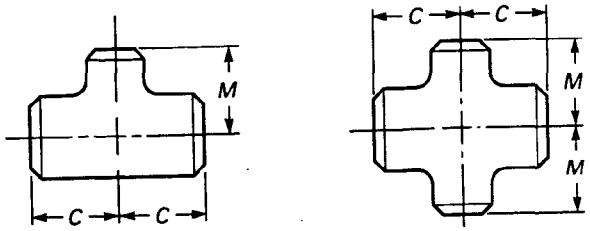

TABLE I8 DIMENSIONS OF REDUCING OUTLET TEES AND REDUCING OUTLET CROSSES

Nominal Pipe Size (NPS)	Outside Diameter at Bevel		Center-to-End	
	Run	Outlet	Run, *C*	Outlet, *M* [Note (1)]
½ × ½ × ⅜	0.84	0.68	1.00	1.00
½ × ½ × ¼	0.84	0.54	1.00	1.00
¾ × ¾ × ½	1.05	0.84	1.12	1.12
¾ × ¾ × ⅜	1.05	0.68	1.12	1.12
1 × 1 × ¾	1.32	1.05	1.50	1.50
1 × 1 × ½	1.32	0.84	1.50	1.50
1¼ × 1¼ × 1	1.66	1.32	1.88	1.88
1¼ × 1¼ × ¾	1.66	1.05	1.88	1.88
1¼ × 1¼ × ½	1.66	0.84	1.88	1.88
1½ × 1½ × 1¼	1.90	1.66	2.25	2.25
1½ × 1½ × 1	1.90	1.32	2.25	2.25
1½ × 1½ × ¾	1.90	1.05	2.25	2.25
1½ × 1½ × ½	1.90	0.84	2.25	2.25
2 × 2 × 1½	2.38	1.90	2.50	2.38
2 × 2 × 1¼	2.38	1.66	2.50	2.25
2 × 2 × 1	2.38	1.32	2.50	2.00
2 × 2 × ¾	2.38	1.05	2.50	1.75
2½ × 2½ × 2	2.88	2.38	3.00	2.75
2½ × 2½ × 1½	2.88	1.90	3.00	2.62
2½ × 2½ × 1¼	2.88	1.66	3.00	2.50
2½ × 2½ × 1	2.88	1.32	3.00	2.25
3 × 3 × 2½	3.50	2.88	3.38	3.25
3 × 3 × 2	3.50	2.38	3.38	3.00
3 × 3 × 1½	3.50	1.90	3.38	2.88
3 × 3 × 1¼	3.50	1.66	3.38	2.75
3½ × 3½ × 3	4.00	3.50	3.75	3.62
3½ × 3½ × 2½	4.00	2.88	3.75	3.50
3½ × 3½ × 2	4.00	2.38	3.75	3.25
3½ × 3½ × 1½	4.00	1.90	3.75	3.12
4 × 4 × 3½	4.50	4.00	4.12	4.00
4 × 4 × 3	4.50	3.50	4.12	3.88
4 × 4 × 2½	4.50	2.88	4.12	3.75
4 × 4 × 2	4.50	2.38	4.12	3.50
4 × 4 × 1½	4.50	1.90	4.12	3.38
5 × 5 × 4	5.56	4.50	4.88	4.62
5 × 5 × 3½	5.56	4.00	4.88	4.50
5 × 5 × 3	5.56	3.50	4.88	4.38
5 × 5 × 2½	5.56	2.88	4.88	4.25
5 × 5 × 2	5.56	2.38	4.88	4.12
6 × 6 × 5	6.62	5.56	5.62	5.38
6 × 6 × 4	6.62	4.50	5.62	5.12
6 × 6 × 3½	6.62	4.00	5.62	5.00
6 × 6 × 3	6.62	3.50	5.62	4.88
6 × 6 × 2½	6.62	2.88	5.62	4.75
8 × 8 × 6	8.62	6.62	7.00	6.62
8 × 8 × 5	8.62	5.56	7.00	6.[illegible]
8 × 8 × 4	8.62	4.50	7.00	[illegible]
8 × 8 × 3½	8.62	4.00	7.00	6.00
10 × 10 × 8	10.75	8.62	8.50	8.00
10 × 10 × 6	10.75	6.62	8.50	7.62
10 × 10 × 5	10.75	5.56	8.50	7.50
10 × 10 × 4	10.75	4.50	8.50	7.25
12 × 12 × 10	12.75	10.75	10.00	9.50
12 × 12 × 8	12.75	8.62	10.00	9.00
12 × 12 × 6	12.75	6.62	10.00	8.62
12 × 12 × 5	12.75	5.56	10.00	8.50
14 × 14 × 12	14.00	12.75	11.00	10.62
14 × 14 × 10	14.00	10.75	11.00	1[illegible]
14 × 14 × 8	14.00	8.62	11.00	[illegible]
14 × 14 × 6	14.00	6.62	11.00	9.38
16 × 16 × 14	16.00	14.00	12.00	12.00
16 × 16 × 12	16.00	12.75	12.00	11.62
16 × 16 × 10	16.00	10.75	12.00	11.12
16 × 16 × 8	16.00	8.62	12.00	10.75
16 × 16 × 6	16.00	6.62	12.00	10.38
18 × 18 × 16	18.00	16.00	13.50	13.00
18 × 18 × 14	18.00	14.00	13.50	13.00
18 × 18 × 12	18.00	12.75	13.50	12.62
18 × 18 × 10	18.00	10.75	13.50	12.12
18 × 18 × 8	18.00	8.62	13.50	11.75

(continued)

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TABLE I8 DIMENSIONS OF REDUCING OUTLET TEES AND REDUCING OUTLET CROSSES

Nominal Pipe Size (NPS)	Outside Diameter at Bevel		Center-to-End	
	Run	Outlet	Run, *C*	Outlet, *M* [Note (1)]
20 × 20 × 18	20.00	18.00	15.00	14.50
20 × 20 × 16	20.00	16.00	15.00	14.00
20 × 20 × 14	20.00	14.00	15.00	14.00
20 × 20 × 12	20.00	12.75	15.00	13.62
20 × 20 × 10	20.00	10.75	15.00	13.12
20 × 20 × 8	20.00	8.62	15.00	12.75
22 × 22 × 20	22.00	20.00	16.50	16.00
22 × 22 × 18	22.00	18.00	16.50	15.50
22 × 22 × 16	22.00	16.00	16.50	15.00
22 × 22 × 14	22.00	14.00	16.50	15.00
22 × 22 × 12	22.00	12.75	16.50	14.62
22 × 22 × 10	22.00	10.75	16.50	14.12
24 × 24 × 22	24.00	22.00	17.00	17.00
24 × 24 × 20	24.00	20.00	17.00	17.00
24 × 24 × 18	24.00	18.00	17.00	16.50
24 × 24 × 16	24.00	16.00	17.00	16.00
24 × 24 × 14	24.00	14.00	17.00	16.00
24 × 24 × 12	24.00	12.75	17.00	15.62
24 × 24 × 10	24.00	10.75	17.00	15.12
26 × 26 × 24	26.00	24.00	19.50	19.00
26 × 26 × 22	26.00	22.00	19.50	18.50
26 × 26 × 20	26.00	20.00	19.50	18.00
26 × 26 × 18	26.00	18.00	19.50	17.50
26 × 26 × 16	26.00	16.00	19.50	17.00
26 × 26 × 14	26.00	14.00	19.50	17.00
26 × 26 × 12	26.00	12.75	19.50	16.62
28 × 28 × 26	28.00	26.00	20.50	20.50
28 × 28 × 24	28.00	24.00	20.50	20.00
28 × 28 × 22	28.00	22.00	20.50	19.50
28 × 28 × 20	28.00	20.00	20.50	19.00
28 × 28 × 18	28.00	18.00	20.50	18.50
28 × 28 × 16	28.00	16.00	20.50	18.00
28 × 28 × 14	28.00	14.00	20.50	18.00
28 × 28 × 12	28.00	12.75	20.50	17.62
30 × 30 × 28	30.00	28.00	22.00	21.50
30 × 30 × 26	30.00	26.00	22.00	21.50
30 × 30 × 24	30.00	24.00	22.00	21.00
30 × 30 × 22	30.00	22.00	22.00	20.50
30 × 30 × 20	30.00	20.00	22.00	20.00
30 × 30 × 18	30.00	18.00	22.00	19.50
30 × 30 × 16	30.00	16.00	22.00	19.00
30 × 30 × 14	30.00	14.00	22.00	19.00
30 × 30 × 12	30.00	12.75	22.00	18.62
30 × 30 × 10	30.00	10.75	22.00	18.12
32 × 32 × 30	32.00	30.00	23.50	23.00
32 × 32 × 28	32.00	28.00	23.50	22.50
32 × 32 × 26	32.00	26.00	23.50	22.50
32 × 32 × 24	32.00	24.00	23.50	22.00
32 × 32 × 22	32.00	22.00	23.50	21.50
32 × 32 × 20	32.00	20.00	23.50	21.00
32 × 32 × 18	32.00	18.00	23.50	20.50
32 × 32 × 16	32.00	16.00	23.50	20.00
32 × 32 × 14	32.00	14.00	23.50	20.00
34 × 34 × 32	34.00	32.00	25.00	24.50
34 × 34 × 30	34.00	30.00	25.00	24.00
34 × 34 × 28	34.00	28.00	25.00	23.50
34 × 34 × 26	34.00	26.00	25.00	23.50
34 × 34 × 24	34.00	24.00	25.00	23.00
34 × 34 × 22	34.00	22.00	25.00	22.50
34 × 34 × 20	34.00	20.00	25.00	22.00
34 × 34 × 18	34.00	18.00	25.00	21.50
34 × 34 × 16	34.00	16.00	25.00	21.00
36 × 36 × 34	36.00	34.00	26.50	26.00
36 × 36 × 32	36.00	32.00	26.50	25.50
36 × 36 × 30	36.00	30.00	26.50	25.00
36 × 36 × 28	36.00	28.00	26.50	24.50
36 × 36 × 26	36.00	26.00	26.50	24.50
36 × 36 × 24	36.00	24.00	26.50	24.00
36 × 36 × 22	36.00	22.00	26.50	23.50
36 × 36 × 20	36.00	20.00	26.50	23.00
36 × 36 × 18	36.00	18.00	26.50	22.50
36 × 36 × 16	36.00	16.00	26.50	22.00
38 × 38 × 36	38.00	36.00	28.00	28.00
38 × 38 × 34	38.00	34.00	28.00	27.50
38 × 38 × 32	38.00	32.00	28.00	27.00
38 × 38 × 30	38.00	30.00	28.00	26.50
38 × 38 × 28	38.00	28.00	28.00	25.50
38 × 38 × 26	38.00	26.00	28.00	25.50
38 × 38 × 24	38.00	24.00	28.00	25.00
38 × 38 × 22	38.00	22.00	28.00	24.50
38 × 38 × 20	38.00	20.00	28.00	24.00
38 × 38 × 18	38.00	18.00	28.00	23.50
40 × 40 × 38	40.00	38.00	29.50	29.50
40 × 40 × 36	40.00	36.00	29.50	29.00
40 × 40 × 34	40.00	34.00	29.50	28.50
40 × 40 × 32	40.00	32.00	29.50	28.00
40 × 40 × 30	40.00	30.00	29.50	27.50
40 × 40 × 28	40.00	28.00	29.50	26.50
40 × 40 × 26	40.00	26.00	29.50	26.50
40 × 40 × 24	40.00	24.00	29.50	26.00
40 × 40 × 22	40.00	22.00	29.50	25.50
40 × 40 × 20	40.00	20.00	29.50	25.00
40 × 40 × 18	40.00	18.00	29.50	24.50
42 × 42 × 40	42.00	40.00	30.00	28.00
40 × 40 × 38	42.00	38.00	30.00	28.00

(continued)

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TABLE I8 DIMENSIONS OF REDUCING OUTLET TEES AND REDUCING OUTLET CROSSES

Nominal Pipe Size (NPS)	Outside Diameter at Bevel		Center-to-End	
	Run	Outlet	Run, *C*	Outlet, *M* [Note (1)]
42 × 42 × 36	42.00	36.00	30.00	28.00
42 × 42 × 34	42.00	34.00	30.00	28.00
42 × 42 × 32	42.00	32.00	30.00	28.00
42 × 42 × 30	42.00	30.00	30.00	28.00
42 × 42 × 28	42.00	28.00	30.00	27.50
42 × 42 × 26	42.00	26.00	30.00	27.50
42 × 42 × 24	42.00	24.00	30.00	26.00
42 × 42 × 22	42.00	22.00	30.00	26.00
42 × 42 × 20	42.00	20.00	30.00	26.00
42 × 42 × 18	42.00	18.00	30.00	25.50
42 × 42 × 16	42.00	16.00	30.00	25.00
44 × 44 × 42	44.00	42.00	32.00	30.00
44 × 44 × 40	44.00	40.00	32.00	29.50
44 × 44 × 38	44.00	38.00	32.00	29.00
44 × 44 × 36	44.00	36.00	32.00	28.50
44 × 44 × 34	44.00	34.00	32.00	28.50
44 × 44 × 32	44.00	32.00	32.00	28.00
44 × 44 × 30	44.00	30.00	32.00	28.00
44 × 44 × 28	44.00	28.00	32.00	27.50
44 × 44 × 26	44.00	26.00	32.00	27.50
44 × 44 × 24	44.00	24.00	32.00	27.50
44 × 44 × 22	44.00	22.00	32.00	27.00
44 × 44 × 20	44.00	20.00	32.00	27.00
46 × 46 × 44	46.00	44.00	33.50	31.50
46 × 46 × 42	46.00	42.00	33.50	31.00
46 × 46 × 40	46.00	40.00	33.50	30.50
46 × 46 × 38	46.00	38.00	33.50	30.00
46 × 46 × 36	46.00	36.00	33.50	30.00
46 × 46 × 34	46.00	34.00	33.50	29.50
46 × 46 × 32	46.00	32.00	33.50	29.50
46 × 46 × 30	46.00	30.00	33.50	29.00
46 × 46 × 28	46.00	28.00	33.50	29.0
46 × 46 × 26	46.00	26.00	33.50	29
46 × 46 × 24	46.00	24.00	33.50	28.5
46 × 46 × 22	46.00	22.00	33.50	28.50
48 × 48 × 46	48.00	46.00	35.00	33.00
48 × 48 × 44	48.00	44.00	35.00	33.00
48 × 48 × 42	48.00	42.00	35.00	32.00
48 × 48 × 40	48.00	40.00	35.00	32.00
48 × 48 × 38	48.00	38.00	35.00	32.00
48 × 48 × 36	48.00	36.00	35.00	31.00
48 × 48 × 34	48.00	34.00	35.00	31.00
48 × 48 × 32	48.00	32.00	35.00	31.00
48 × 48 × 30	48.00	30.00	35.00	30.00
48 × 48 × 28	48.00	28.00	35.00	30.00
48 × 48 × 26	48.00	26.00	35.00	30.00
48 × 48 × 24	48.00	24.00	35.00	29
48 × 48 × 22	48.00	22.00	35.00	29

GENERAL NOTE: All dimensions are in inches.

NOTE:
(1) Outlet dimension *M* for run sizes 14 and larger is recommended but not required.

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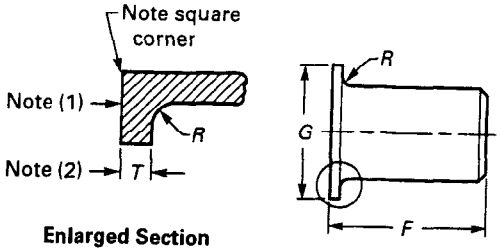

Enlarged Section of Lap

TABLE I9 DIMENSIONS OF LAP JOINT STUB ENDS

Nominal Pipe Size (NPS)	Outside Diameter of Barrel		Long Pattern Length, *F* [Notes (3), (4)]	Short Pattern Length, *F* [Notes (3), (4)]	Radius of Fillet, *R* [Note (5)]	Diameter of Lap, *G* [Note (6)]
	Max.	Min.				
½	0.896	0.809	3.00	2.00	0.12	1.38
¾	1.106	1.019	3.00	2.00	0.12	1.38
1	1.376	1.284	4.00	2.00	0.12	2.00
1¼	1.716	1.629	4.00	2.00	0.19	2.50
1½	1.965	1.869	4.00	2.00	0.25	2.88
2	2.456	2.344	6.00	2.50	0.31	3.62
2½	2.966	2.844	6.00	2.50	0.31	4.12
3	3.596	3.469	6.00	2.50	0.38	5.00
3½	4.096	3.969	6.00	3.00	0.38	5.50
4	4.593	4.469	6.00	3.00	0.44	5.19
5	5.683	5.532	8.00	3.00	0.44	7.31
6	6.743	6.594	8.00	3.50	0.50	8.50
8	8.743	8.594	8.00	4.00	0.50	10.62
10	10.913	10.719	10.00	5.00	0.50	12.75
12	12.913	12.719	10.00	6.00	0.50	15.00
14	14.170	13.969	12.00	6.00	0.50	16.25
16	16.180	15.969	12.00	6.00	0.50	18.50
18	18.190	17.969	12.00	6.00	0.50	21.00
20	20.240	19.969	12.00	6.00	0.50	23.00
22	22.240	21.969	12.00	6.00	0.50	25.25
24	24.240	23.969	12.00	6.00	0.50	27.25

GENERAL NOTES:

(a) All dimensions are in inches.

(b) See Table I1 for tolerances.

(c) Service conditions and joint construction often dictate stub end length requirements. Therefore, the purchaser must specify long or short pattern fitting when ordering.

NOTES:

(1) Gasket face finish shall be in accordance with ASME B16.5 for raised face flanges.

(2) The lap thickness *T* shall not be less than nominal pipe wall thickness. See Table I1 for tolerance.

(3) When short pattern stub ends are used with larger flanges in Classes 300 and 600, and with most sizes in Classes 900 and higher, and when long pattern stub ends are used with larger flanges in Classes 1500 and 2500, it may be necessary to increase the length of the stub ends in order to avoid covering the weld with the flange. Such increases in length shall be a matter of agreement between the manufacturer and the purchaser.

(4) When special facings such as tongue and groove, male and female, etc., are employed, additional lap thickness must be provided and such additional thickness shall be in addition to (not included in) the basic length *F*.

(5) These dimensions conform to the radius established for lap joint flanges in ASME B16.5, Pipe Flanges and Flanged Fittings.

(6) This dimension conforms to standard machine facings shown in ASME B16.5. The back face of the lap shall be machined to conform to the surface on which it seats. Where ring joint facings are to be applied, use dimension *K* as given in ASME B16.5.

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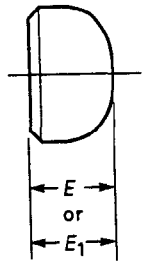

TABLE I10 DIMENSIONS OF CAPS

Nominal Pipe Size (NPS)	Outside Diameter at Bevel	Length, E [Note (1)]	Limiting Wall Thickness for Length E	Length, E_1 [Note (2)]	Nominal Pipe Size (NPS)	Outside Diameter at Bevel	Length, E [Note (1)]	Limiting Wall Thickness for Length E	Length, E_1 [Note (2)]
½	0.84	1.00	0.18	1.00	18	18.00	8.00	0.50	9.00
¾	1.05	1.00	0.15	1.00	20	20.00	9.00	0.50	10.00
1	1.32	1.50	0.18	1.50	22	22.00	10.00	0.50	10.00
1¼	1.66	1.50	0.19	1.50	24	24.00	10.50	0.50	12.00
1½	1.90	1.50	0.20	1.50	26	26.00	10.50	...	...
2	2.38	1.50	0.22	1.75	28	28.00	10.50	...	...
2½	2.88	1.50	0.28	2.00	30	30.00	10.50	...	...
3	3.50	2.00	0.30	2.50	32	32.00	10.50	...	...
3½	4.00	2.50	0.32	3.00	34	34.00	10.50	...	...
4	4.50	2.50	0.34	3.00	36	36.00	10.50	...	...
5	5.56	3.00	0.38	3.50	38	38.00	12.00	...	...
6	6.62	3.50	0.43	4.00	40	40.00	12.00	...	...
8	8.62	4.00	0.50	5.00	42	42.00	12.00	...	...
10	10.75	5.00	0.50	6.00	44	44.00	13.50	...	...
12	12.75	6.00	0.50	7.00	46	46.00	13.50	...	...
14	14.00	6.50	0.50	7.50	48	48.00	13.50	...	...
16	16.00	7.00	0.50	8.00					

GENERAL NOTES:
(a) All dimensions are in inches.
(b) The shape of these caps shall be ellipsoidal and shall conform to the shape requirements asgiven in the ASME Boiler and Pressure Vessel Code.

NOTES:
(1) Length E applies for thickness not exceeding that given in column "Limiting Wall Thickness for Length E."
(2) Length E_1 applies for thickness greater than that given in column "Limiting Wall Thickness" for NPS 24 and smaller. For NPS 26 and larger, length E_1 shall be by agreement between the manufacturer and purchaser.

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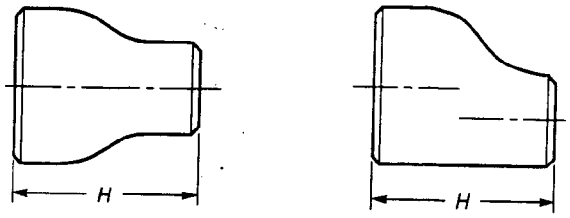

Note (1)

TABLE I11 DIMENSIONS OF REDUCERS

Nominal Pipe Size (NPS)	Outside Diameter at Bevel		End-to-End, *H*
	Large End	Small End	
$\frac{3}{4} \times \frac{1}{2}$	1.05	0.84	1.50
$\frac{3}{4} \times \frac{3}{8}$	1.05	0.68	1.50
$1 \times \frac{3}{4}$	1.32	1.05	2.00
$1 \times \frac{1}{2}$	1.32	0.84	2.00
$1\frac{1}{4} \times 1$	1.66	1.32	2.00
$1\frac{1}{4} \times \frac{3}{4}$	1.66	1.05	2.00
$1\frac{1}{4} \times \frac{1}{2}$	1.66	0.84	2.00
$1\frac{1}{2} \times 1\frac{1}{4}$	1.90	1.66	2.50
$1\frac{1}{2} \times 1$	1.90	1.32	2.50
$1\frac{1}{2} \times \frac{3}{4}$	1.90	1.05	2.50
$1\frac{1}{2} \times \frac{1}{2}$	1.90	0.84	2.50
$2 \times 1\frac{1}{2}$	2.38	1.90	3.00
$2 \times 1\frac{1}{4}$	2.38	1.66	3.00
2×1	2.38	1.32	3.00
$2 \times \frac{3}{4}$	2.38	1.05	3.00
$2\frac{1}{2} \times 2$	2.88	2.38	3.50
$2\frac{1}{2} \times 1\frac{1}{2}$	2.88	1.90	3.50
$2\frac{1}{2} \times 1\frac{1}{4}$	2.88	1.66	3.50
$2\frac{1}{2} \times 1$	2.88	1.32	3.50
$3 \times 2\frac{1}{2}$	3.50	2.88	3.50
3×2	3.50	2.38	3.50
$3 \times 1\frac{1}{2}$	3.50	1.90	3.50
$3 \times 1\frac{1}{4}$	3.50	1.66	3.50
$3\frac{1}{2} \times 3$	4.00	3.50	4.00
$3\frac{1}{2} \times 2\frac{1}{2}$	4.00	2.88	4.00
$3\frac{1}{2} \times 2$	4.00	2.38	4.00
$3\frac{1}{2} \times 1\frac{1}{2}$	4.00	1.90	4.00
$3\frac{1}{2} \times 1\frac{1}{4}$	4.00	1.66	4.00
$4 \times 3\frac{1}{2}$	4.50	4.00	4.00
4×3	4.50	3.50	4.00
$4 \times 2\frac{1}{2}$	4.50	2.88	4.00
4×2	4.50	2.38	4.00
$4 \times 1\frac{1}{2}$	4.50	1.90	4.00
5×4	5.56	4.50	5.00
$5 \times 3\frac{1}{2}$	5.56	4.00	5.00
5×3	5.56	3.50	5.00
$5 \times 2\frac{1}{2}$	5.56	2.88	5.00
5×2	5.56	2.38	5.00
6×5	6.62	5.56	5.50
6×4	6.62	4.50	5.50
$6 \times 3\frac{1}{2}$	6.62	4.00	5.50
6×3	6.62	3.50	5.50
$6 \times 2\frac{1}{2}$	6.62	2.88	5.50
8×6	8.62	6.62	6.00
8×5	8.62	5.56	6.00
8×4	8.62	4.50	6.00
$8 \times 3\frac{1}{2}$	8.62	4.00	6.00
10×8	10.75	8.62	7.00
10×6	10.75	6.62	7.00
10×5	10.75	5.56	7.00
10×4	10.75	4.50	7.00
12×10	12.75	10.75	8.00
12×8	12.75	8.62	8.00
12×6	12.75	6.62	8.00
12×5	12.75	5.56	8.00
14×12	14.00	12.75	13.00
14×10	14.00	10.75	13.00
14×8	14.00	8.62	13.00
14×6	14.00	6.62	13.00
16×14	16.00	14.00	14.00
16×12	16.00	12.75	14.00
16×10	16.00	10.75	14.00
16×8	16.00	8.62	14.00
18×16	18.00	16.00	15.00
18×14	18.00	14.00	15.00
18×12	18.00	12.75	15.00
18×10	18.00	10.75	15.00
20×18	20.00	18.00	20.00
20×16	20.00	16.00	20.00
20×14	20.00	14.00	20.00

(continued)

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TABLE I11 DIMENSIONS OF REDUCERS

Nominal Pipe Size (NPS)	Outside Diameter at Bevel		End-to-End, *H*
	Large End	Small End	
20 × 12	20.00	12.75	20.00
22 × 20	22.00	20.00	20.00
22 × 18	22.00	18.00	20.00
22 × 16	22.00	16.00	20.00
22 × 14	22.00	14.00	20.00
24 × 22	24.00	22.00	20.00
24 × 20	24.00	20.00	20.00
24 × 18	24.00	18.00	20.00
24 × 16	24.00	16.00	20.00
26 × 24	26.00	24.00	24.00
26 × 22	26.00	22.00	24.00
26 × 20	26.00	20.00	24.00
26 × 18	26.00	18.00	24.00
28 × 26	28.00	26.00	24.00
28 × 24	28.00	24.00	24.00
28 × 20	28.00	20.00	24.00
28 × 18	28.00	18.00	24.00
30 × 28	30.00	28.00	24.00
30 × 26	30.00	26.00	24.00
30 × 24	30.00	24.00	24.00
30 × 20	30.00	20.00	24.00
32 × 30	32.00	30.00	24.00
32 × 28	32.00	28.00	24.00
32 × 26	32.00	26.00	24.00
32 × 24	32.00	24.00	24.00
34 × 32	34.00	32.00	24.00
34 × 30	34.00	30.00	24.00
34 × 26	34.00	26.00	24.00
34 × 24	34.00	24.00	24.00
36 × 34	36.00	34.00	24.00
36 × 32	36.00	32.00	24.00
36 × 30	36.00	30.00	24.00
36 × 26	36.00	26.00	24.00
36 × 24	36.00	24.00	24.00
38 × 36	38.00	36.00	24.00
38 × 34	38.00	34.00	24.00
38 × 32	38.00	32.00	24.00
38 × 30	38.00	30.00	24.00
38 × 28	38.00	28.00	24.00
38 × 26	38.00	26.00	24.00
40 × 38	40.00	38.00	24.00
40 × 36	40.00	36.00	24.00
40 × 34	40.00	34.00	24.00
40 × 32	40.00	32.00	24.00
40 × 30	40.00	30.00	24.00
42 × 40	42.00	40.00	24.00
42 × 38	42.00	38.00	24.00
42 × 36	42.00	36.00	24.00
42 × 34	42.00	34.00	24.00
42 × 32	42.00	32.00	24.00
42 × 30	42.00	30.00	24.00
44 × 42	44.00	42.00	24.00
44 × 40	44.00	40.00	24.00
44 × 38	44.00	38.00	24.00
44 × 36	44.00	36.00	24.00
46 × 44	46.00	44.00	28.00
46 × 42	46.00	42.00	28.00
46 × 40	46.00	40.00	28.00
46 × 38	46.00	38.00	28.00
48 × 46	48.00	46.00	28.00
48 × 44	48.00	44.00	28.00
48 × 42	48.00	42.00	28.00
48 × 40	48.00	40.00	28.00

GENERAL NOTES:
(a) All dimensions are in inches.

NOTE:
(1) While the figure illustrates a "bell shaped" reducer, the use of conical reducer is not prohibited.

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MANDATORY APPENDIX II
REFERENCES

The following is a list of standards and specifications referenced in this Standard showing the year of approval.

ASME B16.5-1996, Pipe Flanges and Flanged Fittings
ASME B16.25-1997, Buttwelding Ends
ASME B16.49-2000, Factory-Made Wrought Steel Buttwelding Induction Bends for Transportation and Distribution Systems
ASME B31, Code for Pressure Piping
ASME B36.10M-1996, Welded and Seamless Wrought Steel Pipes
ASME B36.19M-1985(R1994), Stainless Steel Pipe
ASME BPVC-1995, ASME Boiler and Pressure Vessel Code

Publisher: American Society of Mechanical Engineers (ASME International), Three Park Avenue, New York, NY 10016; Order Department: 22 Law Drive, Box 2300, Fairfield, NJ 07007

ASTM A 234-00, Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
ASTM A 403-00b, Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
ASTM A 420-00a, Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service
ASTM A 815/A 815M-00, Standard Specification for Wrought Ferritic, Ferritic/Austenitic and Martensitic Stainless Steel Piping Fittings
ASTM B 361-95, Standard Specification for Factory-Made Wrought Aluminum and Aluminum-Alloy Welding Fittings
ASTM B 363-00, Standard Specification for Seamless and Welded Unalloyed Titanium and Titanium Alloy Welding Fittings
ASTM B 366-00, Standard Specifications for Factory-Made Wrought Nickel and Nickel Alloy Fittings
ASTM E 29-93a, Standard Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications

Publisher: American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428

ISO 6708:1995, Pipework Components — Definition and Selecton of DN (Nominal Size)
ISO 9000-1:1994, Quality Management and Quality Assurance Standards — Part 1: Guidelines for Selection and Use
ISO 9000-2:1997, Quality Management and Quality Assurance Standards — Part 2: Generic Guidelines for the Application of ISO 9001, ISO 9002, and ISO 9003
ISO 9000-3:1997, Quality Management and Quality Assurance Standards — Part 3: Guidelines for the Application of ISO 9001:1994 to the Development, Supply, Installation and Maintenance of Computer Software
ISO 9001:1994, Quality Systems — Model for Quality Assurance in Design, Development, Production, Installation and Servicing
ISO 9002:1994, Quality Systems — Model for Quality Assurance in Production, Installation and Servicing
ISO 9003:1994, Quality Systems — Model for Quality Assurance in Final Inspection and Test

Publisher: International Organization for Standaridization (ISO), 1 rue de Varembé, Case Postale 131, CH-1211, Genève 20, Switzerland/Suisse

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NONMANDATORY APPENDIX A
QUALITY SYSTEM PROGRAM

The products manufactured in accordance with this Standard shall be produced under a quality system program following the principles of an appropriate standard from the ISO 9000 series[1]. A determination of the need for registration and/or certification of the product manufacturer's quality system by an independent organization shall be the responsibility of the manufacturer. The detailed documentation demonstrating program compliance shall be available to the purchaser at the manufacturer's facility. A written summary description of the program utilized by the product manufacturer shall be available to the purchaser upon request. The product manufacturer is defined as the entity whose name or trademark appears on the product in accordance with the marking or identification requirements of this Standard.

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[1] The series is also available from the American National Standards Institute (ANSI) and the American Society for Quality Control (ASQC) as American National Standards that are identified by a prefix "Q" replacing the prefix "ISO". Each standard of the series is listed under references.

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ASME B16.11-1996
(Revision of ASME B16.11-1991)

FORGED FITTINGS, SOCKET-WELDING AND THREADED

AN AMERICAN NATIONAL STANDARD

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The American Society of Mechanical Engineers

AN AMERICAN NATIONAL STANDARD

FORGED FITTINGS, SOCKET-WELDING AND THREADED

ASME B16.11-1996
(Revision of ASME B16.11-1991)

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Date of Issuance: April 16, 1997

The 1996 edition of this Standard is being issued with an automatic addenda subscription service. The use of an addenda allows revisions made in response to public review comments or committee actions to be published as necessary; revisions published in addenda will become effective 6 months after the Date of Issuance of the addenda. The next edition of this Standard is scheduled for publication in 2001.

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FOREWORD

(This Foreword is not part of ASME B16.11-1996.)

The Sectional Committee on the Standardization of Pipe Flanges and Fittings, B16, organized in 1920 under the procedure of the American Standards Association (ASA) appointed a subgroup of Subcommittee No. 3 (now Subcommittee F) to initiate the standardization of welding fittings in May, 1937. The first meeting of this group was held later that month, and at its meeting in December, 1938, in New York, it was agreed to undertake the standardization of dimensions of socket-welding fittings and to refer this project to a new drafting subgroup. One of the most important dimensions of this type of fitting requiring standardization was considered to be the dimension from the centerline of the fitting to the bottom of the socket, since from the stand-point of the designing engineer, this dimension governs the location of adjacent pipe with reference to the entire piping layout. Another important item for consideration was the welding fillet dimensions.

The drafting subgroup held meetings in Chicago, Detroit, and New York in March, 1939, and May and October, 1940, respectively, and at the last named meeting the completed draft of the proposed standard was discussed and further revisions were suggested. When applied to the September, 1940, draft, these changes produced the May, 1941, draft which was prepared for distribution to industry for criticism and comment.

This distribution resulted in a number of helpful comments. The members of the subgroup agreed by mail that many of the changes suggested should be incorporated in the revised draft (December, 1941). Progress on the approval of the standard was delayed by the war after which a few more changes were added to make the proposal acceptable to all concerned. The revised draft (April, 1946) was then submitted to the members of the sectional committee for letter ballot vote.

Following the approval of the sectional committee, the proposed standard was next approved by the sponsor bodies, and presented to the ASA with recommendation for approval as an American Standard. This designation was given on December 9, 1946.

In 1960, it was agreed that the standard needed a complete revision and simultaneously that it should be expanded to cover threaded fittings and plugs, then covered by MSS SP-49 and SP-50. A Task Force worked diligently for four years before arriving at a draft which it felt was acceptable. They also found that ratings were outdated and eliminated the 4000 lb classes of threaded fittings, assigned pressure-temperature ratings for a number of materials, and converted the socket weld fitting ratings to 3000 and 6000 lb. Following approval by the Sectional Committee and Sponsors, ASA approval was granted on January 28, 1966.

Following designation changes of ASA to ANSI and Sectional Committee to Standards Committee, Subcommittee No. 6 began consideration of changes in 1969. Early in 1972, changes in the pressure class designations, materials, and clarification of wording were agreed upon and submitted for approval. This approach was granted on June 20, 1973.

The work of development of the 1980 edition of B16.11 began in 1975 when the committee began consideration of comments and proposals for change, which had been received. The development procedure was arduous in that a number of ballots were taken which elicited many additional comments and counter proposals. The major changes included

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an expanded scope for better definition, requirements for conformance marking, a nonmandatory annex with provisions for proof or burst testing and the inclusion of metric equivalents. Following approval by the Standards Committee and Co-Secretariat, final approval by ANSI was granted on October 6, 1980.

In 1982, American National Standards Committee B16 was reorganized as an ASME Committee operating under procedures accredited by ANSI. The 1991 edition of the standard, re-titled "Forged Fittings, Socket-Welding and Threaded," incorporated forging material listed in Table 1 of ASME/ANSI B16.34-1988, including Group 3 material which was not previously covered in B16.11. The 1991 edition established U.S. customary units as the standard. Other clarifying and editorial revisions were made in order to improve the text. Following approval by the Standards Committee and ASME, final approval by ANSI was granted on March 4, 1991.

In this 1996 Edition, metric dimensions were added as an independent but equal standard to the inch units. Following approval by the Standards Committee and ASME, this revision to the 1991 edition of this Standard was approved as an American National Standard by ANSI on December 16, 1996, with the new deSignation ASME B16.11-1996.

All requests for interpretations or suggestions for revisions should be sent to the Secretary, B16 Committee, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017.

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Standardization of Valves, Flanges, Fittings, Gaskets, and Valve Actuators

(The following is a roster of the Committee at the time of approval of this Standard.)

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FORGED FITTINGS, SOCKET-WELDING AND THREADED

1 SCOPE

1.1 General

This Standard covers ratings, dimensions, tolerances, marking and material requirements for forged fittings, both socket-welding and threaded, as illustrated in Tables 4 through 7 and A4 through A7, inclusive.

1.1.1 Fitting Types/Configuration. Types of fittings covered by this Standard are shown in Tables 1A and 1B, by class and size range. Fittings shown in Tables 4 through 7 and A4 through A7 may also be made with combinations of socket-welding and threaded ends.

1.1.2 Partial Compliance Fittings. Fittings with special dimensions, threads or counterbores, and fittings made from nonstandard materials may be made by agreement between the manufacturer and the purchaser (see para. 5.2). When such fittings meet all other stipulations of this Standard, they shall be considered in partial compliance therewith, provided they are appropriately marked (see para. 4).

1.1.3 Quality Systems. Nonmandatory requirements relating to the product manufacturer's Quality System Program are described in Annex C.

1.2 References

1.2.1 Referenced Standards. Standards and specifications adopted by reference in this Standard are shown in Annex D, which is part of this Standard. It is not considered practical to identify the specific edition of each standard and specification in the individual references. Instead, the specific edition reference is identified in Annex D. A fitting made in conformance and conforming to this Standard, in all other respects, will be considered to be in conformance to the Standard, even though the edition reference may be changed in a subsequent addendum to or revision of the Standard.

1.2.2 Codes and Regulations. A fitting used under the jurisdiction of the ASME Boiler and Pressure Vessel Code, the ASME Code for Pressure Piping, or a governmental regulation is subject to any limitation of that code or regulation. This includes any maximum temperature limitation, or rule governing the use of a material at low temperature, or provisions for operation at a pressure exceeding the ratings in this Standard.

1.3 Service Conditions

Criteria for selection of fitting types and materials suitable for particular fluid service are not within the scope of this Standard.

1.4 Welding

Installation welding requirements are not within the scope of this Standard. Installation welding shall be done in accordance with the applicable piping Code or regulation covering the piping system into which the fittings are installed.

1.5 Standard Units

The values stated in either metric units or inch units are to be regarded separately as standard. Within the text, the inch units are shown in parentheses. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

Tables 4 through 7 show fittings dimensional requirements in millimeters. Tables A4 through A7 show the dimensional requirements for inch dimensioned fittings.

2 PRESSURE RATINGS

2.1 General

These fittings shall be designated as Class 2000, 3000, and 6000 for threaded end fittings and Class 3000, 6000, and 9000 for socket-weld end fittings.

2.1.1 Basis of Rating. The schedule of pipe corresponding to each Class of fitting for rating purposes is shown in Table 2. Design temperature and other service conditions shall be limited as provided by the applicable piping code or regulation for the material of construction of the fitting. Within these limits the maximum allowable pressure of a fitting shall be that computed for straight seamless pipe of equivalent material (as shown by comparison of composition and mechanical properties in the respective material specifications). The wall thickness used in such computation shall be that tabu-

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TABLE 1A TYPES OF FITTINGS BY CLASS DESIGNATION AND DN (NOMINAL SIZE) RANGE

Description	Socket-Weld			Threaded		
	Class Designation			Class Designation		
	3000	6000	9000	2000	3000	6000
45 deg., 90 deg. Elbows	DN6-DN100	DN6-DN50	DN15-DN50	DN6-DN100	DN6-DN100	DN6-DN100
Tees, Crosses	DN6-DN100	DN6-DN50	DN15-DN50	DN6-DN100	DN6-DN100	DN6-DN100
Coupling, Half-Coupling	DN6-DN100	DN6-DN50	DN15-DN50	...	DN6-DN100	DN6-DN100
Cap	DN6-DN100	DN6-DN100	DN15-DN50	...	DN6-DN100	DN6-DN100
Square, Hex, Round Plug	...	...	...	DN6-DN100 [See Note (1)]		
Hex and Flush Bushing	...	...	...	DN6-DN100 [See Note (1)]		

NOTE:
(1) Plugs and bushings are not identified by Class Designation. They may be used for ratings up through Class 6000 designation.

TABLE 1B TYPES OF FITTINGS BY CLASS DESIGNATION AND NPS SIZE RANGE

Description	Socket-Weld			Threaded		
	Class Designation			Class Designation		
	3000	6000	9000	2000	3000	6000
45 deg., 90 deg. Elbows	1/8-4	1/8-2	1/2-2	1/8-4	1/8-4	1/8-4
Tees, Crosses	1/8-4	1/8-2	1/2-2	1/8-4	1/8-4	1/8-4
Coupling, Half-Coupling	1/8-4	1/8-2	1/2-2	...	1/8-4	1/8-4
Cap	1/8-4	1/8-4	1/2-2	...	1/8-4	1/8-4
Square, Hex, Round Plug	...	...	...	1/8-4 [See Note (1)]		
Hex and Flush Bushing	...	...	...	1/8-4 [See Note (1)]		

NOTE:
(1) Plugs and bushings are not identified by Class Designation. They may be used for ratings up through Class 6000 designation.

lated in ANSI/ASME B36.10M for the size and applicable schedule of pipe reduced by applicable manufacturing tolerances and other allowances (e.g., threaded allowances).

Any corrosion allowance and any variation in allowable stress due to temperature or other design shall be applied to the pipe and fitting alike.

2.1.2 Nonstandard Pipe Wall Thickness. Since ANSI/ASME B36.10M does not include Schedule 160 nor Double Extra Strong thickness for DN6, 8, and 10 (NPS 1/8, 1/4, and 3/8), the values in Table 3 may be used as the nominal wall thicknesses of the pipe for rating purposes.

2.1.3 Combination End Fittings. The Class for fittings made with combinations of socket-welding and threaded ends shall be based on the end configuration that has the lowest rating from Table 2.

2.2 Pressure Test Capability

Pressure testing is not required by this Standard but the fittings shall be capable of withstanding a hydrostatic test pressure required by the applicable piping code for seamless pipe of material equivalent to the fitting forging and of the schedule or wall thickness correlated with the fitting Class and end connection of Table 2.

3 SIZE AND TYPE

3.1 General

The following table shows nominal pipe size (NPS) used for inch dimensioned fittings versus nominal diameter (DN), used for millimeter dimensioned fittings.

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NPS VERSUS DN

NPS	1/8	1/4	3/8	1/2	3/4	1
DN	6	8	10	15	20	25

NPS	1 1/4	1 1/2	2	2 1/2	3	4
DN	32	40	50	65	80	100

3.2 Reducing Fitting Size

In the case of reducing tees and crosses, the size of the largest run opening shall be given first, followed by the size of the opening at the opposite end of the run. Where the fitting is a tee, the size of the branch is given last. Where the fitting is a cross, the largest side-outlet is the third dimension given, followed by the opening opposite. The line sketches, Fig. 1, illustrate how the reducing fittings are read.

4 MARKING

4.1 General

Each fitting shall be permanently marked with the required identification by raised lettering and/or by stamping, electro-etching, or vibro-tool marking on the collar portion, raised pad or raised boss portion of the forging. Cylindrical fittings shall be marked on the O.D. or on the end of the fitting in a location such that the marking will not be obliterated as a result of welding installation. The marking of bushings and plugs is not required by this Standard.

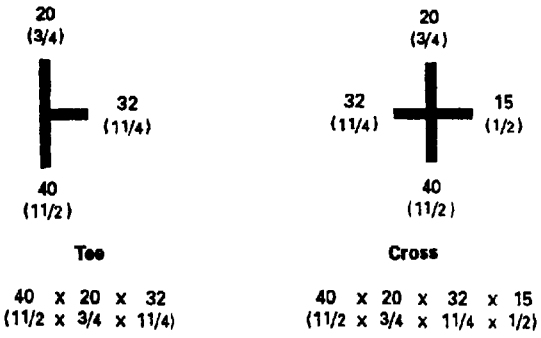

FIG. 1 METHOD OF DESIGNATING OUTLETS OF REDUCING TEES AND CROSSES (See para. 3.2)

TABLE 2 CORRELATION OF FITTINGS CLASS WITH SCHEDULE NUMBER OR WALL DESIGNATION OF PIPE FOR CALCULATION OF RATINGS

Class Designation of Fitting	Type of Fitting	Pipe Used For Rating Basis [Note (1)]	
		Schedule No.	Wall Designation
2000	Threaded	80	XS
3000	Threaded	160	...
6000	Threaded	...	XXS
3000	Socket-Welding	80	XS
6000	Socket-Welding	160	...
9000	Socket-Welding	...	XXS

NOTE:
(1) This table is not intended to restrict the use of pipe of thinner or thicker wall with fittings. Pipe actually used may be thinner or thicker in nominal wall than that shown in Table 2. When thinner pipe is used, its strength may govern the rating. When thicker pipe is used (e.g., for mechanical strength), the strength of the fitting governs the rating.

TABLE 3 NOMINAL WALL THICKNESS OF SCHEDULE 160 AND DOUBLE EXTRA STRONG PIPE

DN	NPS	Schedule 160		XXS	
		mm	in.	mm	in.
6	1/8	3.15	0.124	4.83	0.190
8	1/4	3.68	0.145	6.05	0.238
10	3/8	4.01	0.158	6.40	0.252

4.1.1 Specific Marking. The marking shall include (but is not limited to) the following:

(a) Manufacturer's Name or Trademark

(b) Material Identification. Material shall be identified in accordance with the marking requirements of either the appropriate ASTM Fittings Specifications A 234, A 403, A 420, or B 366, or the appropriate ASTM Forging Specifications A 105, A 182, A 350 B 160, B 164, or other applicable forging Specification of Table 1, ASME/ANSI B16.34 (see para. 5.1).

(c) Product Conformance. Fittings covered under para. 1.1.1 shall be marked with either the ASTM Fittings Specification material identification (e.g.,

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"WP ____") or the symbol "B16" to denote conformance to this Standard.

Partial compliance fittings covered in para. 1.1.2 marked with ASTM forging identification (A 105, A 182, A 350, etc.) shall not be marked B16.

Partial compliance fittings covered in para. 1.1.2 marked with ASTM Fitting Specification (A 234, A 403, A 420, and B 366) shall be marked with the number of the applicable ASTM Specification Supplementary Requirement covering special or nonstandard fittings.

(d) Class Designation. 2000, 3000, 6000, or 9000, as applicable. Alternatively, the designation 2M, 3M, 6M, or 9M, as applicable, may be used where M stands for 1000.

(e) Size. The nominal pipe size related to the end connections.

4.1.2 Omission of Markings. Where size and shape of fittings do not permit all of the above markings, they may be omitted in the reverse order given above.

5 MATERIAL

5.1 Standard Materials

The material for fittings shall consist of forgings, bars, seamless pipe, or tubular products which conform to the requirements for melting process, chemical composition requirements, and mechanical property requirements of the forging product form listed in Table 1, ASME B16.34, including notes.

5.2 Nonstandard Materials

When fittings made of other materials reference this Standard for nonstandard coverage, they should be marked as agreed upon by manufacturer and purchaser, and shall not include the identification specified in paras. 4.1.1(b) and 4.1.1(c) of this Standard (see Annex B).

6 DIMENSIONS

6.1 General

Unless otherwise noted, the dimensions for socket-welding fittings given in Tables 4 and A4 and the dimensions for threaded fittings given in Tables 5, 6, 7, A5, A6, and A7 are nominal values and subject to the designated manufacturing tolerance.

6.2 Socket Fittings

6.2.1 Body Wall Thickness. The body wall thickness of socket-welding fittings shall be equal to or greater than the values, G, shown in Tables 4 and A4.

6.2.2 Socket Wall Thickness. The socket wall average thickness and minimum thickness shall be no less than the corresponding values, C, shown in Tables 4 and A4.

6.2.3 Socket Position. The fixed position for the bottom of the socket with reference to the centerline of the socket-welding fitting shall be maintained as required by the dimensions, A, of Tables 4 and A4. For reducing fittings, see para. 6.5.

6.2.4 Socket Depth. The socket depth shall be no less than the minimum values, J, shown in Tables 4 and A4.

6.2.5 Socket Bore. The inside surface of the socket bore shall present a good workmanlike finish that is free of burrs.

6.2.6 Perpendicularity. The end flats of socket-welding fittings shall be at right angles to the socket axis.

6.2.7 Width. The forging radius shall not reduce the width of the flat welding surface to less than the value shown in Fig. 2.

6.3 Threaded Fittings

6.3.1 Wall Thickness. The body or end wall thickness of threaded fittings shall be equal to or greater than the minimum values, G, as shown in Tables 5, A5, or A6.

6.3.2 Internal Threading. All fittings with internal threads shall be threaded with American National Standard Taper Pipe Threads (ANSI/ASME B1.20.1). Variations in threading shall be limited to one turn large or one turn small from the gaging notch when using working gages. The reference point for gaging is the starting end of the fitting, providing the chamfer does not exceed the major diameter of the internal thread. When a chamfer on the internal thread exceeds this limit, the reference point becomes the last thread scratch on the chamfer cone.

6.3.3 External Threads. All externally threaded fittings shall be threaded with American National Standard Taper Pipe Threads (ANSI/ASME B1.20.1) and the variation in threading shall be limited to one turn large or one turn small from the gage face of ring

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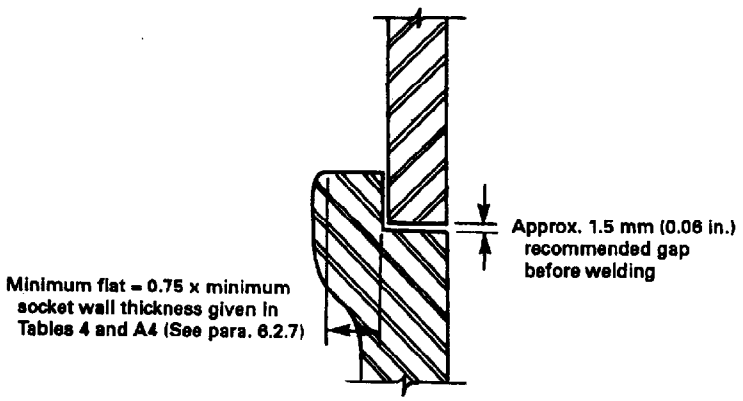

FIG. 2 WELDING GAP AND MINIMUM FLAT DIMENSIONS FOR SOCKET-WELDING FITTINGS

when using working gages. The reference point for gaging is the end of the thread.

6.3.4 Countersink or Chamfer. All internal threads shall be countersunk a distance not less than one-half the pitch of the thread at an angle of approximately 45 deg. with the axis of the thread, and all external threads shall be chamfered at an angle of 30 deg. to 45 deg. from the axis, for the purpose of easier entrance in making a joint and for protection of the thread. Countersinking and chamfering shall be concentric with the threads. The length of threads specified in all tables shall be measured to include the countersink or chamfer.

6.4 Collars

End collars of both socket-welding and threaded fittings shall be such that they overlap the crotch area as illustrated in the sketches in Tables 4, A4, and A5.

6.5 Reducing Fittings

Reducing fittings shall have the same center-to-end, center-to-bottom of socket, band diameter, and outside diameters as the uniform size fitting corresponding to the largest size end connection of the reducing fitting.

7 TOLERANCES

7.1 Additional Tolerances

Tolerances in addition to those listed in Tables 4, 5, 6, 7, A4, A5, A6, and A7.

7.1.1 Concentricity of Bores. The socket and fitting bores shall be concentric within a tolerance of 0.8 mm (0.03 in.) for all sizes. Opposite socket bores shall be concentric within a tolerance of 1.5 mm (0.06 in.) for all sizes.

7.1.2 Coincidence of Axes. The maximum allowable variation in the alignment of the fitting bore and socket bore axes shall be 1.0 mm in 200 mm (0.06 in. in 1 ft). The maximum allowable variation in alignment of threads shall be 1.0 mm in 200 mm (0.06 in. in 1 ft).

8 TESTING

8.1 Proof Testing

Proof testing for fittings made from standard materials is not required by this Standard.

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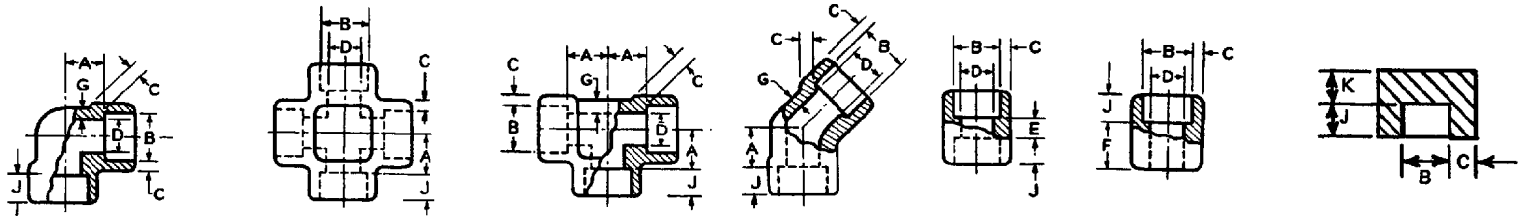
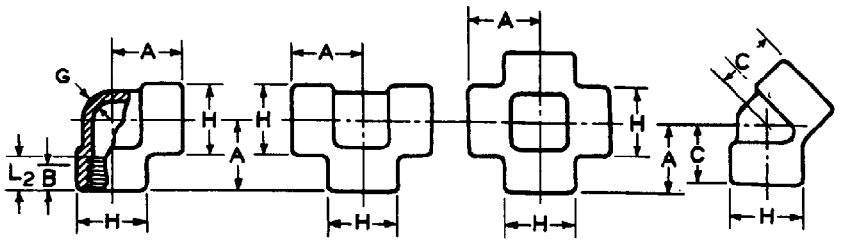


TABLE 4 SOCKET-WELDING FITTINGS

DN	Nom. Pipe Size	Socket Bore Dia. (2) B	Bore Diameter of Fittings (2) D			Socket Wall Thickness (1) C						Body Wall G			Depth of Socket J Min.	Center to Bottom of Socket — A						Laying Lengths		Tolerances ±			End Wall Thickness $K_{min.}$		
			Class Designation			Class Designation						Class Designation				90° Elbows, Tees, and Crosses			45° Elbows								Class Designation		
						3000		6000		9000		3000	6000	9000		Class Designation						Couplings E	Half Couplings F	A	E	F	3000	6000	9000
			3000	6000	9000	Ave.	Min.	Ave.	Min.	Ave.	Min.	Min.	Min.	Min.	Min.	3000	6000	9000	3000	6000	9000								
6	⅛	11.2 10.8	7.6 6.1	4.8 3.2		3.18	3.18	3.96	3.43			2.41	3.15		9.5	11.0	11.0		8.0	8.0		6.5	16.0	1.0	1.5	1.0	4.8	6.4	
8	¼	14.6 14.2	10.0 8.5	7.1 5.6		3.78	3.30	4.60	4.01			3.02	3.68		9.5	11.0	13.5		8.0	8.0		6.5	16.0	1.0	1.5	1.0	4.8	6.4	
10	⅜	18.0 17.6	13.3 11.8	9.9 8.4		4.01	3.50	5.03	4.37			3.20	4.01		9.5	13.5	15.5		8.0	11.0		6.5	17.5	1.5	3.0	1.5	4.8	6.4	
15	½	22.2 21.8	16.6 15.0	12.5 11.0	7.2 5.6	4.67	4.09	5.97	5.18	9.35	8.18	3.73	4.78	7.47	9.5	15.5	19.0	25.5	11.0	12.5	15.5	9.5	22.5	1.5	3.0	1.5	6.4	7.9	11.2
20	¾	27.6 27.2	21.7 20.2	16.3 14.8	11.8 10.3	4.90	4.27	6.96	6.04	9.78	8.56	3.91	5.56	7.82	12.5	19.0	22.5	28.5	13.0	14.0	19.0	9.5	24.0	1.5	3.0	1.5	6.4	7.9	12.7
25	1	34.3 33.9	27.4 25.9	21.5 19.9	16.0 14.4	5.69	4.98	7.92	6.93	11.38	9.96	4.55	6.35	9.09	12.5	22.5	27.0	32.0	14.0	17.5	20.5	12.5	28.5	2.0	4.0	2.0	9.6	11.2	14.2
32	1¼	43.1 42.7	35.8 34.3	30.2 28.7	23.5 22.0	6.07	5.28	7.92	6.93	12.14	10.62	4.85	6.35	9.70	12.5	27.0	32.0	35.0	17.5	20.5	22.5	12.5	30.0	2.0	4.0	2.0	9.6	11.2	14.2
40	1½	49.2 48.8	41.6 40.1	34.7 33.2	28.7 27.2	6.35	5.54	8.92	7.80	12.70	11.12	5.08	7.14	10.15	12.5	32.0	38.0	38.0	20.5	25.5	25.5	12.5	32.0	2.0	4.0	2.0	11.2	12.7	15.7
50	2	61.7 61.2	53.3 51.7	43.6 42.1	38.9 37.4	6.93	6.04	10.92	9.50	13.84	12.12	5.54	8.74	11.07	16.0	38.0	41.0	54.0	25.5	28.5	28.5	19.0	41.0	2.0	4.0	2.0	12.7	15.7	19.0
65	2½	74.4 73.9	64.2 61.2			8.76	7.67					7.01			16.0	41.0			28.5			19.0	43.0	2.5	5.0	2.5	15.7	19.0	
80	3	90.3 89.8	79.4 76.4			9.52	8.30					7.62			16.0	57.0			32.0			19.0	44.5	2.5	5.0	2.5	19.0	22.4	
100	4	115.7 115.2	103.8 100.7			10.69	9.35					8.56			19.0	66.5			41.0			19.0	48.0	2.5	5.0	2.5	22.4	28.4	

GENERAL NOTE: Dimensions are in millimeters.

NOTES:
(1) Average of Socket Wall Thickness around periphery shall be no less than listed values. The minimum values are permitted in localized areas.
(2) Upper and lower values for each size are the respective maximum and minimum dimensions.



90 deg. Elbow Tee Cross 45 deg. Elbow

TABLE 5 FORGED THREADED FITTINGS

DN	Nom. Pipe Size	Center to End Elbows, Tees, Crosses A			Center to End 45° Elbow C			Outside Diameter of Band H			Minimum Wall Thickness G			Length of Thread Min. (1)	
		2000	3000	6000	2000	3000	6000	2000	3000	6000	2000	3000	6000	B	L_2
6	1/8	21	21	25	17	17	19	22	22	25	3.18	3.18	6.35	6.4	6.7
8	1/4	21	25	28	17	19	22	22	25	33	3.18	3.30	6.60	8.1	10.2
10	3/8	25	28	33	19	22	25	25	33	38	3.18	3.51	6.98	9.1	10.4
15	1/2	28	33	38	22	25	28	33	38	46	3.18	4.09	8.15	10.9	13.6
20	3/4	33	38	44	25	28	33	38	46	56	3.18	4.32	8.53	12.7	13.9
25	1	38	44	51	28	33	35	46	56	62	3.68	4.98	9.93	14.7	17.3
32	1 1/4	44	51	60	33	35	43	56	62	75	3.89	5.28	10.59	17.0	18.0
40	1 1/2	51	60	64	35	43	44	62	75	84	4.01	5.56	11.07	17.8	18.4
50	2	60	64	83	43	44	52	75	84	102	4.27	7.14	12.09	19.0	19.2
65	2 1/2	76	83	95	52	52	64	92	102	121	5.61	7.65	15.29	23.6	28.9
80	3	86	95	106	64	64	79	109	121	146	5.99	8.84	16.64	25.9	30.5
100	4	106	114	114	79	79	79	146	152	152	6.55	11.18	18.67	27.7	33.0

GENERAL NOTE: Dimensions are in millimeters.

NOTES:

(1) Dimension B is minimum length of perfect thread. The length of useful thread (B plus threads with fully formed roots and flat crests) shall not be less than L_2 (effective length of external thread) required by American National Standard for Pipe Threads (ANSI/ASME B1.20.1). See Section 6.3

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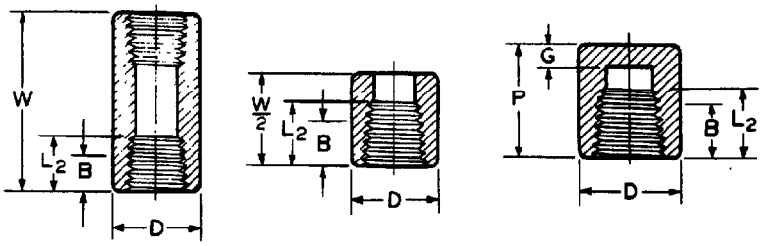

Coupling **Half-Coupling** **Cap**

TABLE 6 THREADED FITTINGS[1]

DN	Nom. Pipe Size	End to End Couplings W	End to End Caps P		Outside Diameter D		End Wall Thickness Min. G		Length of Thread Min. (2)	
		3000 and 6000	3000	6000	3000	6000	3000	6000	B	L_2
6	1/8	32	19	...	16	22	4.8	...	6.4	6.7
8	1/4	35	25	27	19	25	4.8	6.4	8.1	10.2
10	3/8	38	25	27	22	32	4.8	6.4	9.1	10.4
15	1/2	48	32	33	28	38	6.4	7.9	10.9	13.6
20	3/4	51	37	38	35	44	6.4	7.9	12.7	13.9
25	1	60	41	43	44	57	9.7	11.2	14.7	17.3
32	1 1/4	67	44	46	57	64	9.7	11.2	17.0	18.0
40	1 1/2	79	44	48	64	76	11.2	12.7	17.8	18.4
50	2	86	48	51	76	92	12.7	15.7	19.0	19.2
65	2 1/2	92	60	64	92	108	15.7	19.0	23.6	28.9
80	3	108	65	68	108	127	19.0	22.4	25.9	30.5
100	4	121	68	75	140	159	22.4	28.4	27.7	33.0

GENERAL NOTE: Dimensions are in millimeters.

NOTES:

(1) Class 2000 and DN6 Class 6000 couplings, half couplings, and caps are not included in this Standard.

(2) Dimension B is minimum length of perfect thread. The length of useful thread (B plus threads with fully formed roots and flat crests) shall not be less than L_2 (effective length of external thread) required by American National Standard for Pipe Threads (ANSI/ASME B1.20.1). See Section 6.3.

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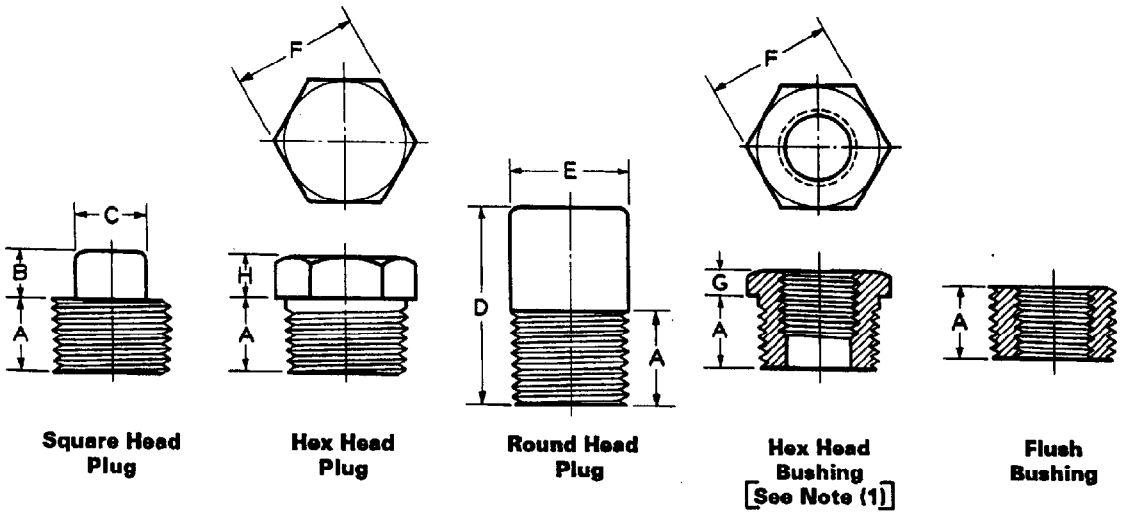

Square Head Plug | Hex Head Plug | Round Head Plug | Hex Head Bushing [See Note (1)] | Flush Bushing

TABLE 7 PLUGS AND BUSHINGS

DN	Nominal Pipe Size	Length (Minimum) A	Plugs Square Head		Plugs Round Head		Hex Plugs and Bushings		
			Height of Square (Minimum) B	Width Flats (Minimum) C	Nominal Diameter of Head E	Length (Minimum) D	Width Flats (Nominal) F	Hex Height (Min.)	
								Bushing G	Plug H
6	1/8	10	6	7	10	35	11	...	6
8	1/4	11	6	10	14	41	16	3	6
10	3/8	13	8	11	18	41	18	4	8
15	1/2	14	10	14	21	44	22	5	8
20	3/4	16	11	16	27	44	27	6	10
25	1	19	13	21	33	51	36	6	10
32	1 1/4	21	14	24	43	51	46	7	14
40	1 1/2	21	16	28	48	51	50	8	16
50	2	22	18	32	60	64	65	9	18
65	2 1/2	27	19	36	73	70	75	10	19
80	3	28	21	41	89	70	90	10	21
100	4	32	25	65	114	76	115	13	25

GENERAL NOTE: Dimensions are in millimeters.

NOTE:

(1) *Cautionary Note Regarding Hex Bushings.* Hex Head Bushings of one-size reduction should not be used in services wherein they might be subject to harmful loads and forces other than internal pressures.

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ANNEX A
INCH TABLES

(This Annex is an integral part of ASME B16.11-1996 and is placed after the main text for convenience. See para. 1.5.)

This Annex provides tables of the standard inch dimensions for fittings.

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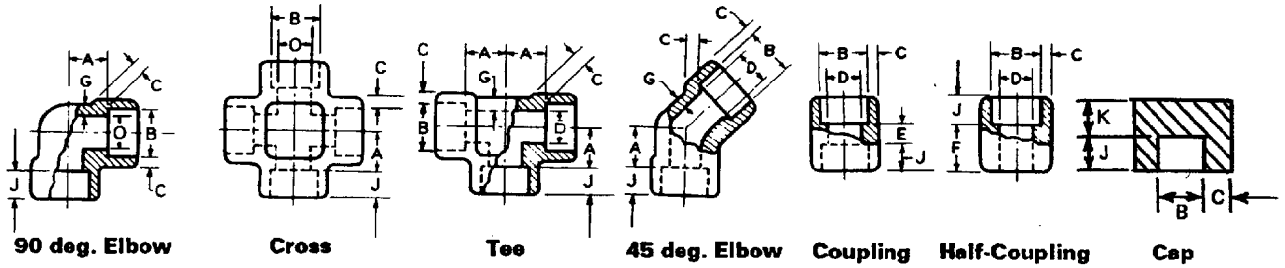
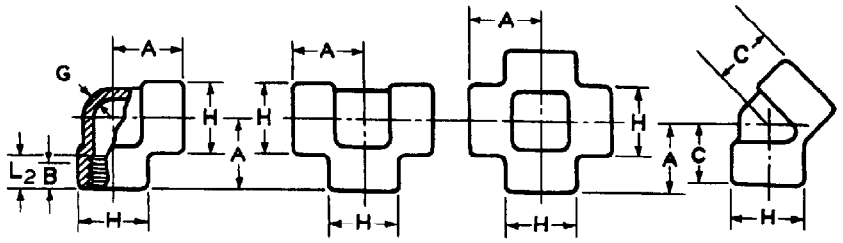


TABLE A4 SOCKET-WELDING FITTINGS

Nom. Pipe Size	Socket Bore Dia. (2) B	Bore Diameter of Fittings (2) D — Class Designation			Socket Wall Thickness (1) C — Class Designation						Body Wall G — Class Designation			Depth of Socket J Min.	Center to Bottom of Socket — A: 90° Elbows, Tees, and Crosses — Class Designation			Center to Bottom of Socket — A: 45° Elbows — Class Designation			Laying Lengths		Tolerances ±			End Wall Thickness $K_{min.}$ — Class Designation		
					3000		6000		9000													Couplings E	Half Couplings F						
		3000	6000	9000	Ave.	Min.	Ave.	Min.	Ave.	Min.	Min.	Min.	Min.		3000	6000	9000	3000	6000	9000			A	E	F	3000	6000	9000
⅛	0.440	0.299	0.189		0.125	0.125	0.156	0.135			0.095	0.124		0.38	0.44	0.44		0.31	0.31		0.25	0.62	0.03	0.06	0.03	0.19	0.25	
	0.420	0.239	0.126																									
¼	0.575	0.394	0.280		0.149	0.130	0.181	0.158			0.119	0.145		0.38	0.44	0.53		0.31	0.31		0.25	0.62	0.03	0.06	0.03	0.19	0.25	
	0.555	0.334	0.220																									
⅜	0.710	0.523	0.389		0.158	0.138	0.198	0.172			0.126	0.158		0.38	0.53	0.62		0.31	0.44		0.25	0.69	0.06	0.12	0.06	0.19	0.25	
	0.690	0.463	0.329																									
½	0.875	0.652	0.494	0.282	0.184	0.161	0.235	0.204	0.368	0.322	0.147	0.188	0.294	0.38	0.62	0.75	1.00	0.44	0.50	0.62	0.38	0.88	0.06	0.12	0.06	0.25	0.31	0.44
	0.855	0.592	0.434	0.222																								
¾	1.085	0.854	0.642	0.464	0.193	0.168	0.274	0.238	0.385	0.337	0.154	0.219	0.308	0.50	0.75	0.88	1.12	0.50	0.56	0.75	0.38	0.94	0.06	0.12	0.06	0.25	0.31	0.50
	1.065	0.794	0.582	0.404																								
1	1.350	1.079	0.845	0.629	0.224	0.196	0.312	0.273	0.448	0.392	0.179	0.250	0.358	0.50	0.88	1.06	1.25	0.56	0.69	0.81	0.50	1.12	0.08	0.16	0.08	0.38	0.44	0.56
	1.330	1.019	0.785	0.569																								
1¼	1.695	1.410	1.190	0.926	0.239	0.208	0.312	0.273	0.478	0.418	0.191	0.250	0.382	0.50	1.06	1.25	1.38	0.69	0.81	0.88	0.50	1.19	0.08	0.16	0.08	0.38	0.44	0.56
	1.675	1.350	1.130	0.866																								
1½	1.935	1.640	1.368	1.130	0.250	0.218	0.351	0.307	0.500	0.438	0.200	0.281	0.400	0.50	1.25	1.50	1.50	0.81	1.00	1.00	0.50	1.25	0.08	0.16	0.08	0.44	0.50	0.62
	1.915	1.580	1.308	1.070																								
2	2.426	2.097	1.717	1.533	0.273	0.238	0.430	0.374	0.545	0.477	0.218	0.344	0.436	0.62	1.50	1.62	2.12	1.00	1.12	1.12	0.75	1.62	0.08	0.16	0.08	0.50	0.62	0.75
	2.406	2.037	1.657	1.473																								
2½	2.931	2.529			0.345	0.302					0.276			0.62	1.62			1.12			0.75	1.69	0.10	0.20	0.10	0.62	0.75	
	2.906	2.409																										
3	3.560	3.128			0.375	0.327					0.300			0.62	2.25			1.25			0.75	1.75	0.10	0.20	0.10	0.75	0.88	
	3.535	3.008																										
4	4.570	4.086			0.421	0.368					0.337			0.75	2.62			1.62			0.75	1.88	0.10	0.20	0.10	0.88	1.12	
	4.545	3.966																										

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) Average of Socket Wall Thickness around periphery shall be no less than listed values. The minimum values are permitted in localized areas.
(2) Upper and lower values for each size are the respective maximum and minimum dimensions.



90 deg. Elbow Tee Cross 45 deg. Elbow

TABLE A5 FORGED THREADED FITTINGS

Nom. Pipe Size	Center to End Elbows, Tees, Crosses A			Center to End 45° Elbow C			Outside Diameter of Band H			Minimum Wall Thickness G			Length of Thread Min. (1)	
	2000	3000	6000	2000	3000	6000	2000	3000	6000	2000	3000	6000	B	L_2
1/8	0.81	0.81	0.97	0.69	0.69	0.75	0.88	0.88	1.00	0.125	0.125	0.250	0.25	0.2639
1/4	0.81	0.97	1.12	0.69	0.75	0.88	0.88	1.00	1.31	0.125	0.130	0.260	0.32	0.4018
3/8	0.97	1.12	1.31	0.75	0.88	1.00	1.00	1.31	1.50	0.125	0.138	0.275	0.36	0.4078
1/2	1.12	1.31	1.50	0.88	1.00	1.12	1.31	1.50	1.81	0.125	0.161	0.321	0.43	0.5337
3/4	1.31	1.50	1.75	1.00	1.12	1.31	1.50	1.81	2.19	0.125	0.170	0.336	0.50	0.5457
1	1.50	1.75	2.00	1.12	1.31	1.38	1.81	2.19	2.44	0.145	0.196	0.391	0.58	0.6828
1 1/4	1.75	2.00	2.38	1.31	1.38	1.69	2.19	2.44	2.97	0.153	0.208	0.417	0.67	0.7068
1 1/2	2.00	2.38	2.50	1.38	1.69	1.72	2.44	2.97	3.31	0.158	0.219	0.436	0.70	0.7235
2	2.38	2.50	3.25	1.69	1.72	2.06	2.97	3.31	4.00	0.168	0.281	0.476	0.75	0.7565
2 1/2	3.00	3.25	3.75	2.06	2.06	2.50	3.62	4.00	4.75	0.221	0.301	0.602	0.93	1.138
3	3.38	3.75	4.19	2.50	2.50	3.12	4.31	4.75	5.75	0.236	0.348	0.655	1.02	1.200
4	4.19	4.50	4.50	3.12	3.12	3.12	5.75	6.00	6.00	0.258	0.440	0.735	1.09	1.300

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) Dimension B is minimum length of perfect thread. The length of useful thread (B plus threads with fully formed roots and flat crests) shall not be less than L_2 (effective length of external thread) required by American National Standard for Pipe Threads (ANSI/ASME B1.20.1). See Section 6.3

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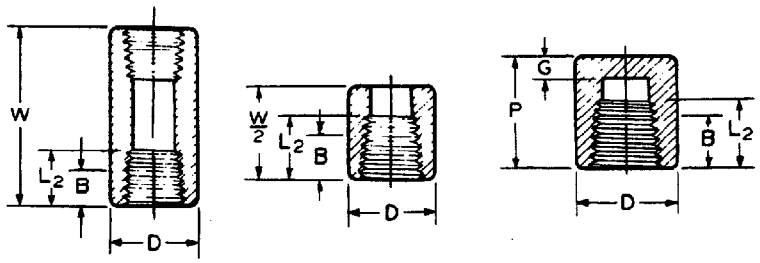

Coupling **Half-Coupling** **Cap**

TABLE A6 THREADED FITTINGS (1)

Nom. Pipe Size	End to End Couplings W	End to End Caps P		Outside Diameter D		End Wall Thickness Min. G		Length of Thread Min. (2)	
	3000 and 6000	3000	6000	3000	6000	3000	6000	B	L_2
1/8	1.25	0.75	. . .	0.62	0.88	0.19	. . .	0.25	0.2639
1/4	1.38	1.00	1.06	0.75	1.00	0.19	0.25	0.32	0.4018
3/8	1.50	1.00	1.06	0.88	1.25	0.19	0.25	0.36	0.4078
1/2	1.88	1.25	1.31	1.12	1.50	0.25	0.31	0.43	0.5337
3/4	2.00	1.44	1.50	1.38	1.75	0.25	0.31	0.50	0.5457
1	2.38	1.62	1.69	1.75	2.25	0.38	0.44	0.58	0.6828
1 1/4	2.62	1.75	1.81	2.25	2.50	0.38	0.44	0.67	0.7068
1 1/2	3.12	1.75	1.88	2.50	3.00	0.44	0.50	0.70	0.7235
2	3.38	1.88	2.00	3.00	3.62	0.50	0.62	0.75	0.7565
2 1/2	3.62	2.38	2.50	3.62	4.25	0.62	0.75	0.93	1.138
3	4.25	2.56	2.69	4.25	5.00	0.75	0.88	1.02	1.200
4	4.75	2.69	2.94	5.50	6.25	0.88	1.12	1.09	1.300

GENERAL NOTE: Dimensions are in inches.

NOTES:

(1) Class 2000 and DN6 Class 6000 couplings, half couplings, and caps are not included in this Standard.

(2) Dimension B is minimum length of perfect thread. The length of useful thread (B plus threads with fully formed roots and flat crests) shall not be less than L_2 (effective length of external thread) required by American National Standard for Pipe Threads (ANSI/ASME B1.20.1). See Section 6.3

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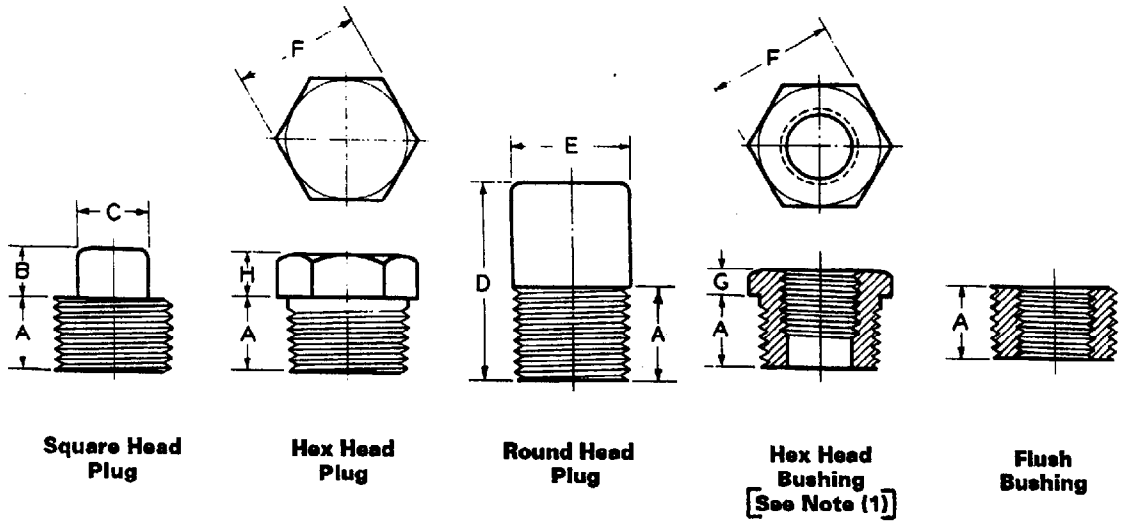

Square Head Plug | **Hex Head Plug** | **Round Head Plug** | **Hex Head Bushing [See Note (1)]** | **Flush Bushing**

TABLE A7 PLUGS AND BUSHINGS

Nominal Pipe Size	Length (Minimum) A	Plugs Square Head		Plugs Round Head		Hex Plugs and Bushings		
		Height of Square (Minimum) B	Width Flats (Minimum) C	Nominal Diameter of Head E	Length (Minimum) D	Width Flats (Nominal) F	Hex Height (Min.)	
							Bushing G	Plug H
1/8	0.38	0.25	0.28	0.41	1.38	0.44	. . .	0.25
1/4	0.44	0.25	0.38	0.53	1.62	0.62	0.12	0.25
3/8	0.50	0.31	0.44	0.69	1.62	0.69	0.16	0.31
1/2	0.56	0.38	0.56	0.84	1.75	0.88	0.19	0.31
3/4	0.62	0.44	0.62	1.06	1.75	1.06	0.22	0.38
1	0.75	0.50	0.81	1.31	2.00	1.38	0.25	0.38
1 1/4	0.81	0.56	0.94	1.69	2.00	1.75	0.28	0.56
1 1/2	0.81	0.62	1.12	1.91	2.00	2.00	0.31	0.62
2	0.88	0.69	1.31	2.38	2.50	2.50	0.34	0.69
2 1/2	1.06	0.75	1.50	2.88	2.75	3.00	0.38	0.75
3	1.12	0.81	1.69	3.50	2.75	3.50	0.41	0.81
4	1.25	1.00	2.50	4.50	3.00	4.62	0.50	1.00

GENERAL NOTE: Dimensions are in inches.

NOTE:

(1) *Cautionary Note Regarding Hex Bushings.* Hex Head Bushings of one-size reduction should not be used in services wherein they might be subject to harmful loads and forces other than internal pressures.

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ANNEX B
METHOD FOR BURST TESTING FITTINGS

(This Annex is an integral part of ASME B16.11-1996 and is placed after the main text for convenience. See para. 5.2.)

B1 This Annex is included to provide documentation of design requirements for nonstandard materials as a service to users of this Standard (see para. 5.2).

B2 Such fittings whose design cannot be established by mathematical analyses contained in nationally recognized pressure vessel or piping codes may be established by proof testing in accordance with Section B3.

B3 To insure adequacy of fittings design, the actual bursting strength of fittings shall not be less than the computed bursting strength of the pipe of the designated schedule number and material. To determine the relative strength of the fitting, straight pipe of the designated wall thickness and material shall be welded to each end of the socket-welding fitting or threaded into each end of the threaded end fitting, 153 mm (6.0 in.) in length but not less than twice the outside diameter of the pipe, and with proper end closures applied beyond the minimum length of straight pipe. Hydrostatic pressure shall be applied until at least the computer bursting pressure is achieved.

The computed bursting strength of pipe shall be determined on the basis of the following formula:

$$P = \frac{2SFt}{D}$$

where

P = computed bursting strength of pipe gage pressure

S = specification minimum ultimate tensile strength of pipe material

F = 1.125, which is a factor to adjust test pressure for the actual tensile strength of the test piece

t = pipe wall thickness
= 0.90 × nominal thickness in sizes DN 32 (1¼ in.) and less
= 0.93 × nominal thickness in sizes DN 40 (1½ in.) and larger

D = outside diameter of pipe

(NOTE: Any dimensionally consistent system may be used.)

Since the above formula is applicable only to straight pipe it cannot be used for a direct computation of the bursting strength of fittings. The fittings ability to withstand bursting shall be gaged only by comparing their behavior on test with the calculated bursting strength of straight pipe of the designated wall thickness and material.

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ANNEX C
QUALITY SYSTEM PROGRAM

(This Annex is not a part of ASME B16.11-1996 and is included for information purposes only.)

The products manufactured in accordance with this Standard shall be produced under a quality system program following the principles of an appropriate standard from the ISO 9000 series[1]. A determination of the need for registration and/or certification of the product manufacturer's quality system program by an independent organization shall be the responsibility of the manufacturer. The detailed documentation demonstrating program compliance shall be available to the purchaser at the manufacturer's facility. A written summary description of the program utilized by the product manufacturer shall be available to the purchaser upon request. The product manufacturer is defined as the entity whose name or trademark appears on the product in accordance with the marking or identification requirements of this Standard.

---

[1] The series is also available from the American National Standards Institute (ANSI) and the American Society for Quality Control (ASQC) as American National Standards that are identified by a prefix "Q" replacing the prefix "ISO". Each standard of the series is listed under references.

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ANNEX D
REFERENCES

(This Annex is an integral part of ASME B16.11-1996 and is placed after the main text for convenience.)

List of standards and specifications referenced in this Standard showing the year of approval.

ASME Publications

ANSI/ASME B1.20.1-1983 (R1993)	Pipe Threads, General Purpose (Inch)
ANSI/ASME B36.10M-1985	Welded and Seamless Wrought Steel Pipe
ANSI/ASME B16.34-1988	Valves — Flanged, Threaded, and Welding End

ASTM Publications

ASTM A 105/A 105M-94	Specification for Forgings, Carbon Steel, for Piping Components
ASTM A 182/A 182M-94C	Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
ASTM A 234/A 234M-94	Specification for Pipe Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures
ASTM A 350/A 350M-94	Specification for Forgings, Carbon and Low-Alloy Steel, Requiring Notch Toughness Testing for Piping Components
ASTM A 403/A 403M-94A	Specification for Wrought Austenitic Stainless Steel Pipe Fittings
ASTM A 420/A 420M-94A	Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service
ASTM B 366-95	Specification for Factory-Made Wrought Nickel and Nickel Alloy Welding Fittings
ASTM B 160-93	Specification for Nickel Rod and Bar
ASTM B 164-93	Specification for Nickel-Copper Alloy Rod, Bar and Wire

ISO Publications

ISO 9000–1 1994. Quality Management and Quality Assurance Standards–Part 1: Guidelines for Selection and Use

ISO 9000–2 1993. Quality Management and Quality Assurance Standards–Part 2: Generic Guidelines for the Application of ISO 9001, ISO 9002, and ISO 9003

ISO 9000–3 1991. Quality Management and Quality Assurance Standards–Part 3: Guidelines for the Application of ISO 9001 to the Development, Supply, and Maintenance of Software

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ISO 9001–1994. Quality Systems: Model for Quality Assurance in Design, Development, Production, Installation, and Servicing

ISO 9002–1994. Quality Systems: Model for Quality Assurance in Production and Servicing

ISO 9003–1994. Quality Systems: Model for Quality Assurance in Final Inspection and Test

Publications of the following organizations appear on the above list:

ASME	The American Society of Mechanical Engineers 345 East 47th Street, New York, NY 10017
ASTM	American Society for Testing and Materials 100 Barr Harbor Drive, West Conshohocken, PA 19428
ISO	ISO Central Secretariat Case Postale 56 CH-1211 Geneva 20 Switzerland/Suisse

Publications appearing above which have been approved as American National Standards may also be obtained from:

ANSI	American National Standards Institute, Inc. 11 West 42nd Street, New York, NY 10036

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AMERICAN NATIONAL STANDARDS FOR PIPING, PIPE FLANGES, FITTINGS, AND VALVES

Scheme for the Identification of Piping Systems A13.1-1996
Pipe Threads, General Purpose (Inch) ..... B1.20.1-1983(R1992)
Dryseal Pipe Threads (Inch) ..... B1.20.3-1976(R1991)
Cast Iron Pipe Flanges and Flanged Fittings B16.1-1989
Malleable Iron Threaded Fittings B16.3-1992
Gray Iron Threaded Fittings B16.4-1992
Pipe Flanges and Flanged Fittings (NPS ½ Through NPS 24) B16.5-1996
Factory-Made Wrought Steel Buttwelding Fittings B16.9-1993
Face-to-Face and End-to-End Dimensions of Valves B16.10-1992
Forged Fittings, Socket-Welding and Threaded B16.11-1996
Cast Iron Threaded Drainage Fittings B16.12-1991
Ferrous Pipe Plugs, Bushings, and Locknuts with Pipe Threads B16.14-1991
Cast Bronze Threaded Fittings, Classes 125 and 250 ..... B16.15-1985
Cast Copper Alloy Solder Joint Pressure Fittings B16.18-1984
Metallic Gaskets for Pipe Flanges — Ring-Joint, Spiral-Wound, and Jacketed B16.20-1993
Nonmetallic Flat Gaskets for Pipe Flanges B16.21-1992
Wrought Copper and Copper Alloy Solder Joint Pressure Fittings B16.22-1995
Cast Copper Alloy Solder Joint Drainage Fittings — DWV B16.23-1992
Cast Copper Alloy Pipe Flanges and Flanged Fittings, Class 150, 300, 400, 600, 900, 1500, and 2500 ..... B16.24-1991
Buttwelding Ends B16.25-1992
Cast Copper Alloy Fittings for Flared Copper Tubes B16.26-1988
Wrought Steel Buttwelding Short Radius Elbows and Returns B16.28-1994
Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings — DWV B16.29-1986
Cast Copper Alloy Solder Joint Fittings for Sovent Drainage Systems B16.32-1992
Manually Operated Metallic Gas Valves for Use in Gas Piping Systems Up to 125 psig (Sizes ½ Through 2) B16.33-1990
Valves — Flanged, Threaded, and Welding End B16.34-1996
Orifice Flanges B16.36-1996
Large Metallic Valves for Gas Distribution (Manually Operated, NPS 2½ to 12, 125 psig Maximum) B16.38-1985
Malleable Iron Threaded Pipe Unions, Classes 150, 250, and 300 ..... B16.39-1986
Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems B16.40-1985
Functional Qualification Requirements for Power Operated Active Valve Assemblies for Nuclear Power Plants ..... B16.41-1983(R1989)
Ductile Iron Pipe Flanges and Flanged Fittings, Class 150 and 300 ..... B16.42-1987
Wrought Copper and Copper Alloy Solder Joint Fittings for Sovent® Drainage Systems B16.43-1982
Manually Operated Metallic Gas Valves for Use in House Piping Systems B16.44-1995
Cast Iron Fittings for Sovent® Drainage Systems B16.45-1987
Large Diameter Steel Flanges (NPS 26 Through NPS 60) B16.47-1996
Power Piping B31.1-1995
Fuel Gas Piping B31.2-1968
Process Piping B31.3-1996
Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols B31.4-1992
Refrigeration Piping B31.5-1992
Gas Transmission and Distribution Piping Systems B31.8-1995
Building Services Piping B31.9-1988
Slurry Transportation Piping Systems B31.11-1989
ASME Guide for Gas Transmission and Distribution Piping Systems — 1986 (not an ANSI Standard) .....
Manual for Determining the Remaining Strength of Corroded Pipelines (not an ANSI Standard) B31G-1991
Welded and Seamless Wrought Steel Pipe B36.10M-1995
Stainless Steel Pipe B36.19M-1985
Self-Operated and Power-Operated Safety-Related Valves Functional Specification Standard ..... N278.1-1975(R1984)

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AN AMERICAN NATIONAL STANDARD

ASME B16.20a-2000

ADDENDA

to

ASME B16.20-1998
METALLIC GASKETS FOR PIPE FLANGES
Ring-Joint, Spiral-Wound, and Jacketed

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ASME B16.20a-2000

Following approval by the ASME B16 Committee and ASME, and after public review, ASME B16.20a-2000 was approved by the American National Standards Institute on May 3, 2000.

Addenda to the 1998 edition of ASME B16.20 are issued in the form of replacement pages. Revisions, additions, and deletions are incorporated directly into the affected pages. It is advisable, however, that this page, the Addenda title and copyright pages, and all replaced pages be retained for reference.

SUMMARY OF CHANGES

This is the first Addenda to be published to ASME B16.20-1998.

Replace or insert the pages listed. Changes given below are identified on the pages by a margin note, **(a)**, placed next to the affected area. The pages not listed are the reverse sides of the listed pages and contain no changes.

Page	*Location*	*Change*
v	Committee Roster	Updated to reflect Addenda
xi	Contents	Updated to reflect Addenda
2, 2.1	Paragraph 3.2.5	Revised
21	Table 12	Notes (1) and (3) revised
23	Table 14	General Note (c) and Notes (1) and (2) revised
24	Table 15	(1) Title revised (2) General Notes added
28	Table 19	Revised
35	Mandatory Annex I	Revised

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ASME B16 COMMITTEE (a)
Standardization of Valves, Flanges, Fittings, Gaskets, and Valve Actuators

(The following is the roster of the Committee at the time of approval of this Standard.)

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METALLIC GASKETS FOR PIPE FLANGES

Ring-Joint, Spiral-Wound, and Jacketed

1 SCOPE

1.1 General

This Standard covers materials, dimensions, tolerances, and markings for metal ring joint gaskets, spiral-wound metal gaskets, metal-jacketed gaskets, and filler material. These gaskets are dimensionally suitable for use with flanges described in reference flange standards ASME B16.5, ASME B16.47, and API Specification 6A. This Standard covers spiral-wound metal gaskets and metal-jacketed gaskets for use with raised-face and flat-face flanges.

1.2 Quality Systems

Requirements relating to the product manufacturers' quality system programs are described in Annex A.

1.3 References

Standards and specifications adopted by reference in this Standard are shown in Annex I, which is part of this Standard.

2 RING-JOINT GASKETS

2.1 Types

Ring-joint gaskets shall be either octagonal or oval in cross section.

2.2 Size

Ring-joint gaskets shall be identified by an R, RX, or BX number that relates to flange size (NPS), pressure class, and the appropriate flange standards (ASME B16.5, ASME B16.47, or API Specification 6A).

2.3 Materials

2.3.1 General. Ring-joint gasket materials, some of which are listed in Table 1, shall be selected by the user based on suitability for the service conditions.

TABLE 1 MAXIMUM HARDNESS FOR RING GASKETS

Ring Gasket Material	Maximum Hardness	
	Brinell	Rockwell "B" Scale
Soft iron (1)	90	56
Low-carbon steel	120	68
4–6 chrome ½Mo	130	72
Type 410	170	86
Type 304	160	83
Type 316	160	83
Type 347	160	83

NOTE:
(1) May be low-carbon steel, not to exceed maximum hardness of 90 Brinell—56 Rockwell "B."

It is recommended that ring-joint gaskets be of a lesser hardness than that of the mating flanges.

2.3.2 Hardness. Ring-joint gaskets of materials listed in Table 1 shall have a hardness equal to or less than that shown in Table 1.

2.4 Marking

The outer surface of each gasket shall carry the manufacturer's name or identification trademark and gasket number prefixed by the letters R, RX, or BX followed by the gasket material identification. Materials shall be identified as shown in Table 2. The gasket shall also be marked with an ASME B16.20 designation. The marking shall be applied so as not to harmfully distort the gasket or affect the integrity of the seal.

2.5 Dimensions and Tolerances

Dimensions and tolerances for ring-joint gaskets shall be as shown in Tables 3 through 8.

2.6 Surface Finish

Types R and RX gaskets shall have a finish not rougher than 63 μin. roughness. Type BX gaskets shall have a finish not rougher than 32 μin. roughness. Surface finishes shall pertain to the gasket-sealing surfaces.

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STD.ASME B16.20A-ENGL 2000 ■ 0759670 0617683 177 ■

TABLE 2 RING GASKET MARKINGS

Ring Gasket Material	Identification	Marking Example (1)
Soft iron (2)	D	R51D
Low-carbon steel	S	R51S
4–6 chrome ½Mo	F5 (3)	R51F5
Type 410	S 410	R51S410
Type 304	S 304	R51S304
Type 316	S 316	R51S316
Type 347	S 347	R51S347

NOTES:
(1) This number shall be preceded by the manufacturer's name or identification trademark.
(2) May be low-carbon steel, not to exceed maximum hardness of 90 Brinell—56 Rockwell "B."
(3) F5 identification designates ASTM Specification A 182-72 chemical composition requirements only.

2.7 Identification Number

Dimensional reference identification numbers are assigned to ring-joint gaskets and are shown in Tables 3 through 8.

3 SPIRAL-WOUND GASKETS

3.1 Size and Class

Spiral-wound gaskets, including centering ring and inner ring (paras. 3.2.4 and 3.2.5), are identified by flange size (NPS), pressure class, and the appropriate flange standard (ASME B16.5 or ASME B16.47).

3.2 Dimensions and Tolerances

3.2.1 General. Dimensions and tolerances for spiral-wound gaskets, centering rings, and inner rings shall be in accordance with Tables 9 through 11 and as specified in this section.

3.2.2 Construction. Spiral-wound gaskets shall be constructed as alternate plies (circular layers counted as revolutions) of preformed metal windings and plaint fillers that are spirally wound. For the finished gasket, the filler shall be essentially flush with, but not below, the metal winding on both contact faces of the gasket. The metal strip in the winding shall be 0.006 in. to 0.009 in. thick. The filler material thickness shall be determined by the manufacturer.

3.2.3 Metal Joining. The inner windings shall have a minimum of three plies of preformed metal strip without filler. The initial two plies shall be spot-welded circumferentially with a minimum of three welds spaced at a maximum distance of 3 in. The outer windings, which shall have a minimum of three plies of preformed metal without filler, shall be spot-welded circumferentially with a minimum of three welds, the last of which shall be the terminal weld.

The distance of the first weld from the terminal weld shall be no greater than 1.5 in. Up to four additional loose preformed metal windings beyond the terminal weld may be used to retain the gasket into the centering ring.

3.2.4 Centering Ring. All spiral-wound gaskets shall be furnished assembled into a centering ring. The centering ring thickness shall be from 0.117 in. to 0.131 in. and suitably grooved on the inside diameter so as to retain the gasket.

3.2.5 Inner Ring. Inner rings shall be furnished with all spiral-wound gaskets having PTFE (polytetrafluoroethylene) filler material. It is recommended that inner rings be specified by the user for flexible graphite and other filler materials (if appropriate for flanges and bore sizes used), particularly where experience has demonstrated inward buckling of the gaskets to be a problem. Inner rings shall be furnished in spiral-wound gaskets for flanges NPS 24 and larger in Class 900, NPS 12 and larger in Class 1500, and NPS 4 and larger in Class 2500. Gaskets with inner rings should be used only with socket welding, lapped, welding neck, and integral flanges. (a)

The inner-ring thickness shall be from 0.117 in. to 0.131 in. Tables 12 through 14 show inner-ring inside diameters that may extend a maximum of 0.06 in. into the flange bore under the worst combination of flange bore, eccentric installation, and tolerance. Reference Table 15 for minimum pipe wall thickness for use with gaskets with inner rings. Reference Tables 16, 17, and 18 for maximum allowable bore for use with gaskets without inner rings.

3.2.6 Gasket Compression. Spiral-wound gaskets NPS ½, NPS ¾, and NPS 1 in Classes 150, 300, and 600 shall be designed so that a uniform bolt stress of 25,000 psi, based on the nominal bolt root diameter, will compress the gasket to a thickness of 0.130 in. ±0.005 in. All other gasket sizes and classes shall be designed so that a uniform bolt stress of 30,000 psi will compress the gasket to a thickness of 0.130 in. ±0.005 in.

3.3 Materials

Metal windings and filler materials shall be in accordance with Table 19. The inner ring shall be of a material

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that has corrosion resistant characteristics equivalent to or better than that of the metal winding. The centering ring may be carbon steel that is painted, metal plated, or otherwise coated to inhibit atmospheric corrosion.

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TABLE 12 INNER-RING INSIDE DIAMETERS FOR SPIRAL-WOUND GASKETS (a)

Flange Size (NPS)	Pressure Class						
	150	300	400 (1)	600	900 (1, 2)	1500 (2, 3)	2500 (1–3)
½	0.56	0.56	...	0.56	...	0.56	0.56
¾	0.81	0.81	...	0.81	...	0.81	0.81
1	1.06	1.06	...	1.06	...	1.06	1.06
1¼	1.50	1.50	...	1.50	...	1.31	1.31
1½	1.75	1.75	...	1.75	...	1.63	1.63
2	2.19	2.19	...	2.19	...	2.06	2.06
2½	2.62	2.62	...	2.62	...	2.50	2.50
3	3.19	3.19	...	3.10	3.10	3.10	3.10
4	4.19	4.19	4.04	4.04	4.04	3.85	3.85
5	5.19	5.19	5.05	5.05	5.05	4.90	4.90
6	6.19	6.19	6.10	6.10	6.10	5.80	5.80
8	8.50	8.50	8.10	8.10	7.75	7.75	7.75
10	10.56	10.56	10.05	10.05	9.69	9.69	9.69
12	12.50	12.50	12.10	12.10	11.50	11.50	11.50
14	13.75	13.75	13.50	13.50	12.63	12.63	...
16	15.75	15.75	15.35	15.35	14.75	14.50	...
18	17.69	17.69	17.25	17.25	16.75	16.75	...
20	19.69	19.69	19.25	19.25	19.00	18.75	...
24	23.75	23.75	23.25	23.25	23.25	22.75	...

GENERAL NOTES:

(a) The inner-ring thickness shall be 0.117 in. to 0.131 in.

(b) For sizes NPS 1¼ through NPS 3, the inside diameter tolerance is ±0.03 in.; for larger sizes the inside diameter tolerance is ±0.06 in. See Table 15 for minimum pipe wall thicknesses that are suitable for use with standard inner rings.

NOTES:

(1) There are no
  (a) NPS ½ through NPS 3 Class 400 flanges; therefore, use Class 600 flanges
  (b) NPS ½ through NPS 2½ Class 900 flanges; therefore, use Class 1500 flanges
  (c) NPS 14 and larger Class 2500 flanges

(2) Inner rings are required for Class 900, NPS 24 gaskets; Class 1500, NPS 12 through NPS 24 gaskets; and Class 2500, NPS 4 through NPS 12 gaskets.

(3) Refer to para. 3.2.5 for required use of inner rings.

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TABLE 13 INNER-RING INSIDE DIAMETERS FOR SPIRAL-WOUND GASKETS USED BETWEEN ASME B16.47 SERIES A FLANGES

Flange Size (NPS)	Pressure Class				
	150	300	400	600	900 (1, 2)
26	25.75	25.75	26.00	25.50	26.00
28	27.75	27.75	28.00	27.50	28.00
30	29.75	29.75	29.75	29.75	30.25
32	31.75	31.75	32.00	32.00	32.00
34	33.75	33.75	34.00	34.00	34.00
36	35.75	35.75	36.13	36.13	36.25
38	37.75	37.50	37.50	37.50	39.75
40	39.75	39.50	39.38	39.75	41.75
42	41.75	41.50	41.38	42.00	43.75
44	43.75	43.50	43.50	43.75	45.50
46	45.75	45.38	46.00	45.75	48.00
48	47.75	47.63	47.50	48.00	50.00
50	49.75	49.00	49.50	50.00	...
52	51.75	52.00	51.50	52.00	...
54	53.50	53.25	53.25	54.25	...
56	55.50	55.25	55.25	56.25	...
58	57.50	57.00	57.25	58.00	...
60	59.50	60.00	59.75	60.25	...

GENERAL NOTES:
(a) The inner-ring thickness shall be 0.117 in. to 0.131 in.
(b) The inside diameter tolerance is ±0.12 in.
(c) These inner rings are suitable for use with pipe walls 0.38 in. or thicker.

NOTES:
(1) Inner rings are required for Class 900 gaskets.
(2) There are no Class 900 flanges NPS 50 and larger.

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TABLE 14 INNER-RING INSIDE DIAMETERS FOR SPIRAL-WOUND GASKETS USED BETWEEN ASME B16.47 SERIES B FLANGES (a)

Flange Size (NPS)	Pressure Class				
	150	300	400	600	900 (1, 2)
26	25.75	25.75	25.75	25.38	26.25
28	27.75	27.75	27.63	27.00	28.25
30	29.75	29.75	29.63	29.63	30.75
32	31.75	31.75	31.50	31.25	33.00
34	33.75	33.75	33.50	33.50	35.25
36	35.75	35.75	35.38	35.50	36.25
38	37.75	38.25	37.50	37.50	39.75
40	39.75	40.25	39.38	39.75	41.75
42	41.75	42.75	41.38	42.00	43.75
44	43.75	44.25	43.50	43.75	45.50
46	45.75	46.38	46.00	45.75	48.00
48	47.75	48.50	47.50	48.00	50.00
50	49.75	49.88	49.50	50.00	...
52	51.75	51.88	51.50	52.00	...
54	53.75	53.75	53.25	54.25	...
56	56.00	56.25	55.25	56.25	...
58	58.19	58.44	57.25	58.00	...
60	60.44	61.31	59.75	60.25	...

GENERAL NOTES:
(a) The inner-ring thickness shall be 0.117 in. to 0.131 in.
(b) The inside diameter tolerance is ±0.12 in.
(c) These inner rings are suitable for use with pipe walls 0.375 in. or thicker.

NOTES:
(1) Inner rings are required for Class 900 gaskets. Refer to para. 3.2.5 for required use of inner rings.
(2) There are no NPS 50 and larger Class 900 flanges.

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(a) **TABLE 15 MINIMUM PIPE WALL THICKNESS SUITABLE FOR USE OF SPIRAL-WOUND GASKETS WITH INNER RINGS FOR ASME B16.5 FLANGES**

Flange Size (NPS)	Pressure Class						
	150	300	400	600	900	1500	2500
1/2, 3/4, 1	Schedule 80						
1 1/4, 1 1/2, 2, 2 1/2, 3	Schedule 40						
4, 5, 6	Schedule 40					Schedule 80	
8, 10, 12, 14, 16, 18, 20, 24	Schedule 10S		Schedule 30		Schedule 80		

GENERAL NOTES:
(a) The pipe wall schedules identified represent the minimum recommended pipe wall thickness suitable for use with inner rings for ASME B16.5 flanges. (Reference ASME B36.10M and B36.19M.)
(b) Gaskets with inner rings should be used only with socket welding, lapped, welding neck, and integral flanges.

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TABLE 18 MAXIMUM BORE OF ASME B16.47 SERIES B FLANGES FOR USE WITH SPIRAL-WOUND GASKETS

Flange Size (NPS)	Pressure Class				
	150	300	400	600	900 (1)
26	Welding neck and integral flanges having maximum inside diameters as described in ASME B16.47				
28					
30					
32					
34					
36					
38					
40					
44					
46					
48					
50					(2)
52					(2)
54					(2)
56					(2)
58					(2)
60					(2)

GENERAL NOTE: This table shows the maximum bore of flanges for which the spiral-wound gasket dimensions shown in Table 11 are recommended, considering the tolerances involved, the possibility of eccentric installation, and the possibility that the gasket may extend into the assembled flange bore.

NOTES:

(1) Inner rings are required for Class 900 gaskets, NPS 26 through NPS 48 (see para. 3.2.5).

(2) There are no Class 900 flanges NPS 50 and larger.

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(a) **TABLE 19 COLOR CODING AND ABBREVIATIONS FOR SPIRAL-WOUND GASKET MATERIALS**

Metallic Winding Materials		
Material	**Abbreviation**	**Color Code**
Carbon steel	CRS	Silver
304 SS	304	Yellow
304 L SS	304 L	No color
309 SS	309	No color
310 SS	310	No color
316 L SS	316 L	Green
317 L SS	317 L	Maroon
347 SS	347	Blue
321 SS	321	Turquoise
430 SS	430	No color
Ni–Cu	...	...
Monel 400	MON	Orange
Grade 400	...	...
Nickel 200	NI	Red
Titanium	TI	Purple
20Cb-3 alloy	A-20	Black
Ni–Mo	...	...
Hastelloy B	HAST B	Brown
Grade B2	...	...
Ni–Mo–Cr	...	...
Hastelloy C	HAST C	Beige
Grade C-276	...	...
Ni–Cr–Fe	...	...
Inconel 600	INC 600	Gold
Grade 600	...	...
Ni–Cr–Fe–Cb	...	...
Inconel 625	INC 625	Gold
Grade 625	...	...
Ni–Cr–Fe–Ti	...	...
Inconel X-750	INX	No color
Grade X-750	...	...
Ni–Fe–Cr	...	...
Incoloy 800	IN 800	White
Grade 800	...	...
Ni–Fe–Cr–Mo–Cu	...	...
Incoloy 825	IN 825	White
Grade 825	...	...
Zirconium	ZIRC	No color

(*continued*)

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MANDATORY ANNEX I
REFERENCES

(a)

The following is a list of publications referenced in this Standard.

API Specification 6A — 17th Edition — 1996, Specification for Valves and Wellhead Equipment

Publisher: American Petroleum Institute (API), 1220 L Street, NW, Washington, DC 20005

ASME B16.5-1996, Pipe Flanges and Flanged Fittings[1]

ASME B16.47-1996, Large Diameter Steel Flanges: NPS 26 through NPS 60[1]

ASME B36.10M-1996, Welded and Seamless Wrought Steel Pipe[1]

ASME B36.19M-1985 (R1994), Stainless Steel Pipe[1]

Publisher: American Society of Mechanical Engineers (ASME), Three Park Ave., New York, NY 10016; Order Department: 22 Law Drive, Box 2300, Fairfield, NJ 07007

ISO 9000-1: 1994, Quality management and quality assurance standards — Part 1: Guidelines for selection and use

ISO 9000-2: 1997, Quality management and quality assurance standards — Part 2: Generic guidelines for the application of ISO 9001, ISO 9002, and ISO 9003

ISO 9000-3: 1997, Quality management and quality assurance standards — Part 3: Guidelines for the application of ISO 9001 to the development, supply, installation, and maintenance of computer software

ISO 9001: 1994, Quality systems — Model for quality assurance in design, development, production, installation, and servicing

ISO 9002: 1994, Quality systems — Model for quality assurance in production, installation, and servicing

ISO 9003: 1994, Quality systems — Model for quality assurance in final inspection and test

Publisher: International Organization for Standardization (ISO), 1 rue de Varembé, Case postale 56, CH-1211 Genève 20, Switzerland/Suisse

[1] May also be obtained from the American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036.

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AMERICAN NATIONAL STANDARDS FOR PIPING, PIPE FLANGES, FITTINGS, AND VALVES

Scheme for the Identification of Piping Systems A13.1-1996
Pipe Threads, General Purpose (Inch) ..... B1.20.1-1983(R1992)
Dryseal Pipe Threads (Inch) ..... B1.20.3-1976(R1998)
Cast Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250 ..... B16.1-1998
Malleable Iron Threaded Fittings: Classes 150 and 300 ..... B16.3-1998
Gray Iron Threaded Fittings: Classes 125 and 250 ..... B16.4-1998
Pipe Flanges and Flanged Fittings (NPS ½ Through NPS 24) B16.5-1996
Factory-Made Wrought Steel Buttwelding Fittings B16.9-1993
Face-to-Face and End-to-End Dimensions of Valves B16.10-1992
Forged Fittings, Socket-Welding and Threaded B16.11-1996
Cast Iron Threaded Drainage Fittings B16.12-1998
Ferrous Pipe Plugs, Bushings, and Locknuts with Pipe Threads B16.14-1991
Cast Bronze Threaded Fittings: Classes 125 and 250 ..... B16.15-1985(R1994)
Cast Copper Alloy Solder Joint Pressure Fittings ..... B16.18-1984(R1994)
Metallic Gaskets for Pipe Flanges: Ring-Joint, Spiral-Wound, and Jacketed B16.20-1998
Nonmetallic Flat Gaskets for Pipe Flanges B16.21-1992
Wrought Copper and Copper Alloy Solder Joint Pressure Fittings B16.22-1995
Cast Copper Alloy Solder Joint Drainage Fittings — DWV B16.23-1992
Cast Copper Alloy Pipe Flanges and Flanged Fittings: Classes 150, 300, 400, 600, 900, 1500, and 2500 ..... B16.24-1991(R1998)
Buttwelding Ends B16.25-1997
Cast Copper Alloy Fittings for Flared Copper Tubes B16.26-1988
Wrought Steel Buttwelding Short Radius Elbows and Returns B16.28-1994
Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings — DWV B16.29-1994
Manually Operated Metallic Gas Valves for Use in Gas Piping Systems up to 125 psig (Sizes ½ Through 2) B16.33-1990
Valves — Flanged, Threaded, and Welding End B16.34-1996
Orifice Flanges B16.36-1996
Large Metallic Valves for Gas Distribution (Manually Operated, NPS 2½ to 12, 125 psig Maximum) ..... B16.38-1985(R1994)
Malleable Iron Threaded Pipe Unions B16.39-1998
Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems ..... B16.40-1985(R1994)
Ductile Iron Pipe Flanges and Flanged Fittings, Classes 150 and 300 ..... B16.42-1998
Manually Operated Metallic Gas Valves for Use in House Piping Systems B16.44-1995
Cast Iron Fittings for Sovent® Drainage Systems B16.45-1998
Large Diameter Steel Flanges (NPS 26 Through NPS 60) B16.47-1996
Steel Line Blanks B16.48-1997
Factory-Made Wrought Steel Buttwelding Induction Bends for Transportation and Distribution Systems B16.49-2000
Power Piping B31.1-1998
Fuel Gas Piping (not an ANSI standard) B31.2-1968
Process Piping B31.3-1999
Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids B31.4-1998
Refrigeration Piping B31.5-1992
Gas Transmission and Distribution Piping Systems B31.8-1999
Building Services Piping B31.9-1996
Slurry Transportation Piping Systems B31.11-1989
Manual for Determining the Remaining Strength of Corroded Pipelines B31G-1991
Welded and Seamless Wrought Steel Pipe B36.10M-1996
Stainless Steel Pipe ..... B36.19M-1985(R1994)
Self-Operated and Power-Operated Safety-Related Valves Functional Specification Standard ..... N278.1-1975(R1992)

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METALLIC GASKETS FOR PIPE FLANGES

Ring-Joint, Spiral-Wound, and Jacketed

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AN AMERICAN NATIONAL STANDARD

METALLIC GASKETS FOR PIPE FLANGES

Ring-Joint, Spiral-Wound, and Jacketed

ASME B16.20-1998
(Revision of ASME B16.20-1993)

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FOREWORD

Ring-joint gaskets and grooves probably originated in the boiler field, where they were used in various forms for manhole covers, autoclaves, and other closures; however, it was in the oil industry (both in the production and refining of oil) that they received the greatest recognition and were developed into their present form. Their use expanded steadily as temperatures and pressures were increased in steam plants. Tests examining their application in flanges and valves were conducted as early as 1928.

In June 1936, the American Petroleum Institute (API) issued Tentative Standard 5-G-3 on Ring-Joints for Steel Flanges and Flange Unions for use with API Tubular Goods. This standard was known as API Specification 6B, Ring-Joint Flanges. Following the acceptance of ring-joints for flanges and valves by API and the issuance of their standard, ASA B16e on Steel Pipe Flanges and Flanged Fittings was revised to include them, and the 1939 edition included standard dimensions for a full line of ring-joint flanges based on the API standard. Development work continued, and API formulated Standard 6E, Specification for Wellhead Equipment, which included ring-joints not covered in ASA B16e-1939.

In 1949, the American Standards Association (ASA), Sectional Committee B16, Subcommittee 3, Steel Flanges and Flanged Fittings, assembled the available information on ring-joint gaskets into a single standard. ASA approval was granted on April 30, 1952, with the designation ASA B16.20-1952.

Ring gaskets for Class 900 (900 lb at that time) in sizes NPS 26 through 36 were added, and ASA approval was granted on April 30, 1952.

An updated version was submitted, and ASA approval was granted on April 4, 1955, with the designation ASA B16.20-1955. The standard was reviewed, and reaffirmation approval was granted by the ASA on April 25, 1963.

The standard was reviewed, and reaffirmation approval was granted by the American National Standards Institute (ANSI) on April 25, 1973, with the designation of an American National Standard.

API requested that ASME convert their gasket standard, API 601, into an ASME American National Standard. As a result of that request, this edition was expanded to include requirements for spiral-wound and jacketed gaskets that were formerly listed in API 601, 7th edition, 1988. Also, ring-joint groove dimensions are not included in this edition because they are included in ASME/ANSI B16.5-1988, titled Pipe Flanges and Flanged Fittings, and ASME B16.47-1990, titled Large Diameter Steel Flanges.

The 1993 edition was approved by the B16 Standards Committee. Following approval by ASME, approval by ANSI was given on January 22, 1993, with the designation ASME B16.20-1993.

In the 1998 edition of ASME B16.20, reference standards are updated, a quality system program annex is added, inner ring inside diameters for spiral-wound gaskets are revised, and several editorial revisions are made. Following approval by ASME B16 Subcommittee B and the B16 Main Committee, ANSI approved this American National Standard on November 20, 1998.

Requests for interpretations or suggestions for revision should be sent to The American Society of Mechanical Engineers; Secretary, B16 Committee; Three Park Avenue, New York, New York 10016-5990.

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Standardization of Valves, Flanges, Fittings, Gaskets, and Valve Actuators

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CORRESPONDENCE WITH THE B16 COMMITTEE

General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Standard may interact with the Committee by requesting interpretations, proposing revisions, and attending Committee meetings. Correspondence should be addressed to:

Secretary, B16 Main Committee
The American Society of Mechanical Engineers
Three Park Avenue
New York, NY 10016-5990

Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Interpretations. Upon request, the B16 Committee will render an interpretation of any requirement of the Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the B16 Main Committee.

The request for interpretation should be clear and unambiguous. It is further recommended that the inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. The inquirer may also include any plans or drawings, which are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in this format will be rewritten in this format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME Committee or Subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

Attending Committee Meetings. The B16 Main Committee regularly holds meetings, which are open to the public. Persons wishing to attend any meeting should contact the Secretary of the B16 Main Committee.

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IMPORTANT INFORMATION CONCERNING USE OF ASBESTOS OR ALTERNATIVE MATERIALS

Asbestos is referenced for use as a filler material in metallic gaskets. It has served as a universal sealing material, compatible with most fluid services. It has been of extreme usefulness in minimizing fire hazards.

Certain serious adverse health effects are associated with asbestos, among them the serious and often fatal diseases of lung cancer, asbestosis, and mesothelioma (a cancer of the chest and abdominal linings). The degree of exposure to asbestos varies with the product and the work practices involved.

Consult the most recent edition of the Occupational Safety and Health Administration, U.S. Department of Labor, Occupational Safety and Health Standard for Asbestos, Tremolite, Anthophyllite, and Actinolite, 29 Code of Federal Regulations Section 1910.1001; the U.S. Environmental Protection Agency, National Emission Standard for Asbestos, 40 Code of Federal Regulations Sections 61.140 through 61.156; and the proposed rule by the U.S. Environmental Protection Agency proposing labeling requirements and phased banning of asbestos products, published at 51 Federal Register 3738-3759 (January 29, 1986).

There are currently in use and under development a number of substitute materials to replace asbestos in certain applications. Manufacturers and users are encouraged to develop and use effective substitute materials that can meet the specifications for, and operating requirements of, the equipment to which they would apply.

Information concerning safety and health risks and proper precautions with respect to particular materials and conditions should be obtained from one's employer, the manufacturer or supplier of that material, or the Material Safety Data Sheet.

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METALLIC GASKETS FOR PIPE FLANGES

Ring-Joint, Spiral-Wound, and Jacketed

1 SCOPE

1.1 General

This Standard covers materials, dimensions, tolerances, and markings for metal ring-joint gaskets, spiral-wound metal gaskets, metal-jacketed gaskets, and filler material. These gaskets are dimensionally suitable for use with flanges described in reference flange standards ASME B16.5, ASME B16.47, and API Specification 6A. This Standard covers spiral-wound metal gaskets and metal-jacketed gaskets for use with raised-face and flat-face flanges.

1.2 Quality Systems

Requirements relating to the product manufacturers' quality system programs are described in Annex A.

1.3 References

Standards and specifications adopted by reference in this Standard are shown in Annex I, which is part of this Standard.

2 RING-JOINT GASKETS

2.1 Types

Ring-joint gaskets shall be either octagonal or oval in cross section.

2.2 Size

Ring-joint gaskets shall be identified by an R, RX, or BX number that relates to flange size (NPS), pressure class, and the appropriate flange standards (ASME B16.5, ASME B16.47, or API Specification 6A).

2.3 Materials

2.3.1 General. Ring-joint gasket materials, some of which are listed in Table 1, shall be selected by the user based on suitability for the service conditions.

TABLE 1 MAXIMUM HARDNESS FOR RING GASKETS

Ring Gasket Material	Maximum Hardness	
	Brinell	Rockwell "B" Scale
Soft iron (1)	90	56
Low-carbon steel	120	68
4–6 chrome ½Mo	130	72
Type 410	170	86
Type 304	160	83
Type 316	160	83
Type 347	160	83

NOTE:
(1) May be low-carbon steel, not to exceed maximum hardness of 90 Brinell—56 Rockwell "B."

It is recommended that ring-joint gaskets be of a lesser hardness than that of the mating flanges.

2.3.2 Hardness. Ring-joint gaskets of materials listed in Table 1 shall have a hardness equal to or less than that shown in Table 1.

2.4 Marking

The outer surface of each gasket shall carry the manufacturer's name or identification trademark and gasket number prefixed by the letters R, RX, or BX followed by the gasket material identification. Materials shall be identified as shown in Table 2. The gasket shall also be marked with an ASME B16.20 designation. The marking shall be applied so as not to harmfully distort the gasket or affect the integrity of the seal.

2.5 Dimensions and Tolerances

Dimensions and tolerances for ring-joint gaskets shall be as shown in Tables 3 through 8.

2.6 Surface Finish

Types R and RX gaskets shall have a finish not rougher than 63 μin. roughness. Type BX gaskets shall have a finish not rougher than 32 μin. roughness. Surface finishes shall pertain to the gasket-sealing surfaces.

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TABLE 2 RING GASKET MARKINGS

Ring Gasket Material	Identification	Marking Example (1)
Soft iron (2)	D	R51D
Low-carbon steel	S	R51S
4–6 chrome ½Mo	F5 (3)	R51F5
Type 410	S 410	R51S410
Type 304	S 304	R51S304
Type 316	S 316	R51S316
Type 347	S 347	R51S347

NOTES:
(1) This number shall be preceded by the manufacturer's name or identification trademark.
(2) May be low-carbon steel, not to exceed maximum hardness of 90 Brinell—56 Rockwell "B."
(3) F5 identification designates ASTM Specification A 182-72 chemical composition requirements only.

2.7 Identification Number

Dimensional reference identification numbers are assigned to ring-joint gaskets and are shown in Tables 3 through 8.

3 SPIRAL-WOUND GASKETS

3.1 Size and Class

Spiral-wound gaskets, including centering ring and inner ring (paras. 3.2.4 and 3.2.5), are identified by flange size (NPS), pressure class, and the appropriate flange standard (ASME B16.5 or ASME B16.47).

3.2 Dimensions and Tolerances

3.2.1 General. Dimensions and tolerances for spiral-wound gaskets, centering rings, and inner rings shall be in accordance with Tables 9 through 11 and as specified in this section.

3.2.2 Construction. Spiral-wound gaskets shall be constructed as alternate plies (circular layers counted as revolutions) of preformed metal windings and plaint fillers that are spirally wound. For the finished gasket, the filler shall be essentially flush with, but not below, the metal winding on both contact faces of the gasket. The metal strip in the winding shall be 0.006 in. to 0.009 in. thick. The filler material thickness shall be determined by the manufacturer.

3.2.3 Metal Joining. The inner windings shall have a minimum of three plies of preformed metal strip without filler. The initial two plies shall be spot-welded circumferentially with a minimum of three welds spaced at a maximum distance of 3 in. The outer windings, which shall have a minimum of three plies of preformed metal without filler, shall be spot-welded circumferentially with a minimum of three welds, the last of which shall be the terminal weld.

The distance of the first weld from the terminal weld shall be no greater than 1.5 in. Up to four additional loose preformed metal windings beyond the terminal weld may be used to retain the gasket into the centering ring.

3.2.4 Centering Ring. All spiral-wound gaskets shall be furnished assembled into a centering ring. The centering ring thickness shall be from 0.117 in. to 0.131 in. and suitably grooved on the inside diameter so as to retain the gasket.

3.2.5 Inner Ring. Inner rings shall be furnished with all spiral-wound gaskets having PTFE (polytetrafluoroethylene) filler material. It is recommended that inner rings be specified by the user for flexible graphite and other filler materials (if appropriate for flanges and bore sizes used), particularly where experience has demonstrated inward buckling of the gaskets to be a problem. Inner rings shall be furnished in spiral-wound gaskets for flanges NPS 24 and larger in Class 900, NPS 12 and larger in Class 1500, and NPS 4 and larger in Class 2500. Gaskets with inner rings should be used only with socket welding, lapped, welding neck, and integral flanges.

The inner-ring thickness shall be from 0.117 in. to 0.131 in. Tables 12 through 14 show inner-ring inside diameters that may extend a maximum of 0.06 in. into the flange bore under the worst combination of flange bore, eccentric installation, and tolerance.

3.2.6 Gasket Compression. Spiral-wound gaskets NPS ½, NPS ¾, and NPS 1 in Classes 150, 300, and 600 shall be designed so that a uniform bolt stress of 25,000 psi, based on the nominal bolt root diameter, will compress the gasket to a thickness of 0.130 in. ±0.005 in. All other gasket sizes and classes shall be designed so that a uniform bolt stress of 30,000 psi will compress the gasket to a thickness of 0.130 in. ±0.005 in.

3.3 Materials

Metal windings and filler materials shall be in accordance with Table 19. The inner ring shall be of a material that has corrosion resistant characteristics equivalent to or better than that of the metal winding. The centering ring may be carbon steel that is painted, metal plated, or otherwise coated to inhibit atmospheric corrosion.

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3.4 Marking

3.4.1 General. The centering ring of each spiral-wound gasket shall be permanently marked. The lettering height shall be a minimum of 0.1 in. The following information shall be included with the centering ring markings:

(a) Manufacturer's name or trademark.

(b) Flange size (NPS).

(c) Pressure class.

(d) Winding metal abbreviation (Table 19), except that the abbreviation may be omitted when 304 stainless steel is used.

(e) Filler material abbreviation (Table 19).

(f) Centering and inner ring metal abbreviation (Table 19), except that the abbreviation may be omitted when carbon steel is used for the outer ring and 304 stainless steel is used for the inner ring.

(g) Flange identification. Gaskets intended for ASME B16.47 flanges shall be marked B16.47 A or B16.47 B, as applicable. Gaskets intended for ASME B16.5 flanges need not be so marked. Illustrative marking examples are shown in Table 20.

(h) ASME B16.20 designation.

3.4.2 Pressure Class. Gaskets suitable for more than one pressure class shall be marked with all applicable classes, as shown in Table 20.

3.4.3 Color Coding. Spiral-wound gaskets shall be marked with a color code that identifies the windings and filler materials. A continuous color around the outer edge of the centering ring shall identify the winding metal. The color identifying the filler material for NPS $1\frac{1}{2}$ and larger shall have four intermittent stripes spaced approximately 90 deg apart on the outer edge of the centering ring. Smaller size gaskets shall have a minimum of two stripes 180 deg apart. The colors shall conform to those listed in Table 19.

4 JACKETED GASKETS

4.1 Size and Pressure Class

Jacketed gaskets are identified by flange size (NPS), pressure class, and the appropriate flange standard (ASME B16.5 or ASME B16.47).

4.2 Design

4.2.1 General. Jacketed gaskets shall be made with a filler material enclosed in a metal jacket.

4.2.2 Jacket Thickness. The jacket metal thickness shall be a minimum of 0.015 in.

4.2.3 Filler Thickness. The filler thickness shall be a minimum of 0.06 in.

4.2.4 Miscellaneous. Other design details, including the density of the filler, shall be the gasket manufacturer's responsibility.

4.3 Dimensions and Tolerances

Gasket dimensions and tolerances shall be in accordance with Tables 21, 22, or 23.

4.4 Materials

Metal jacket and filler material shall be selected from Table 24. For jacketed gasket limitations related to ASME B16.5 applications, see Annex E of ASME B16.5.

4.5 Marking

4.5.1 Applied Marking. Jacketed gaskets shall be marked with waterproof ink or equivalent. Where gasket size does not permit such markings, a separate attached marking tag may be used. The lettering height shall be a minimum of 0.2 in. The following information shall be included with the markings:

(a) Manufacturer's name or trademark.

(b) Flange size (NPS).

(c) Pressure class.

(d) Jacketed material abbreviation (Table 24), except that the abbreviation may be omitted when soft carbon steel is used.

(e) Filler material abbreviation (Table 24).

(f) Flange identification. Gaskets intended for ASME B16.47 flanges shall be marked B16.47 A or B16.47 B, as applicable. Gaskets intended for ASME B16.5 flanges need not be so marked. Illustrative marking examples are shown in Table 25.

(g) ASME B16.20 designation.

4.5.2 Pressure Class. Gaskets suitable for more than one pressure class shall be marked with all applicable classes.

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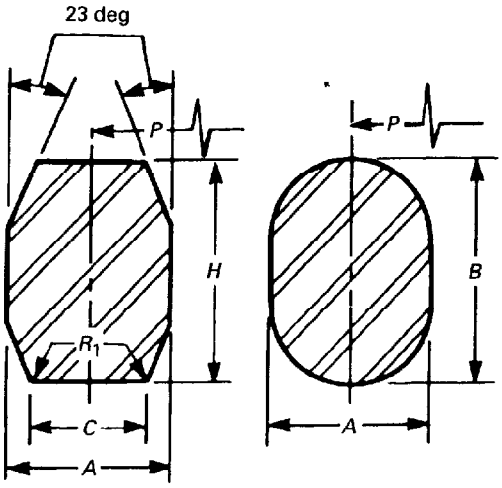

Octagonal Oval

TABLE 3 TYPE R RING GASKET DIMENSIONS AND TOLERANCES

Ring Number	Pitch Diameter of Ring, *P*	Width of Ring, *A*	Height of Ring		Width of Flat on Octagonal Ring, *C*	Radius in Octagonal Ring, R_1
			Oval, *B*	Octagonal, *H*		
R-11	1.344	0.250	0.44	0.38	0.170	0.06
R-12	1.563	0.313	0.56	0.50	0.206	0.06
R-13	1.688	0.313	0.56	0.50	0.206	0.06
R-14	1.750	0.313	0.56	0.50	0.206	0.06
R-15	1.875	0.313	0.56	0.50	0.206	0.06
R-16	2.000	0.313	0.56	0.50	0.206	0.06
R-17	2.250	0.313	0.56	0.50	0.206	0.06
R-18	2.375	0.313	0.56	0.50	0.206	0.06
R-19	2.563	0.313	0.56	0.50	0.206	0.06
R-20	2.688	0.313	0.56	0.50	0.206	0.06
R-21	2.844	0.438	0.69	0.63	0.305	0.06
R-22	3.250	0.313	0.56	0.50	0.206	0.06
R-23	3.250	0.438	0.69	0.63	0.305	0.06
R-24	3.750	0.438	0.69	0.63	0.305	0.06
R-25	4.000	0.313	0.56	0.50	0.206	0.06
R-26	4.000	0.438	0.69	0.63	0.305	0.06
R-27	4.250	0.438	0.69	0.63	0.305	0.06
R-28	4.375	0.500	0.75	0.69	0.341	0.06
R-29	4.500	0.313	0.56	0.50	0.206	0.06
R-30	4.625	0.438	0.69	0.63	0.305	0.06
R-31	4.875	0.438	0.69	0.63	0.305	0.06
R-32	5.000	0.500	0.75	0.69	0.341	0.06
R-33	5.188	0.313	0.56	0.50	0.206	0.06
R-34	5.188	0.438	0.69	0.63	0.305	0.06
R-35	5.375	0.438	0.69	0.63	0.305	0.06

(continued)

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TABLE 3 TYPE R RING GASKET DIMENSIONS AND TOLERANCES (CONT'D)

Ring Number	Average Pitch Diameter of Ring, *P*	Width of Ring, *A*	Height of Ring		Width of Flat on Octagonal Ring, *C*	Radius in Octagonal Ring, R_1
			Oval, *B*	Octagonal, *H*		
R-36	5.875	0.313	0.56	0.50	0.206	0.06
R-37	5.875	0.438	0.69	0.63	0.305	0.06
R-38	6.188	0.625	0.88	0.81	0.413	0.06
R-39	6.375	0.438	0.69	0.63	0.305	0.06
R-40	6.750	0.313	0.56	0.50	0.206	0.06
R-41	7.125	0.438	0.69	0.63	0.305	0.06
R-42	7.500	0.750	1.00	0.94	0.485	0.06
R-43	7.625	0.313	0.56	0.50	0.206	0.06
R-44	7.625	0.438	0.69	0.63	0.305	0.06
R-45	8.313	0.438	0.69	0.63	0.305	0.06
R-46	8.313	0.500	0.75	0.69	0.341	0.06
R-47	9.000	0.750	1.00	0.94	0.485	0.06
R-48	9.750	0.313	0.56	0.50	0.206	0.06
R-49	10.625	0.438	0.69	0.63	0.305	0.06
R-50	10.625	0.625	0.88	0.81	0.413	0.06
R-51	11.000	0.875	1.13	1.06	0.583	0.06
R-52	12.000	0.313	0.56	0.50	0.206	0.06
R-53	12.750	0.438	0.69	0.63	0.305	0.06
R-54	12.750	0.625	0.88	0.81	0.413	0.06
R-55	13.500	1.125	1.44	1.38	0.780	0.09
R-56	15.000	0.313	0.56	0.50	0.206	0.06
R-57	15.000	0.438	0.69	0.63	0.305	0.06
R-58	15.000	0.875	1.13	1.06	0.583	0.06
R-59	15.625	0.313	0.56	0.50	0.206	0.06
R-60	16.000	1.250	1.56	1.50	0.879	0.09
R-61	16.500	0.438	0.69	0.63	0.305	0.06
R-62	16.500	0.625	0.88	0.81	0.413	0.06
R-63	16.500	1.000	1.31	1.25	0.681	0.09
R-64	17.875	0.313	0.56	0.50	0.206	0.06
R-65	18.500	0.438	0.69	0.63	0.305	0.06
R-66	18.500	0.625	0.88	0.81	0.413	0.06
R-67	18.500	1.125	1.44	1.38	0.780	0.09
R-68	20.375	0.313	0.56	0.50	0.206	0.06
R-69	21.000	0.438	0.69	0.63	0.305	0.06
R-70	21.000	0.750	1.00	0.94	0.485	0.06
R-71	21.000	1.125	1.44	1.38	0.780	0.09
R-72	22.000	0.313	0.56	0.50	0.206	0.06
R-73	23.000	0.500	0.75	0.69	0.341	0.06
R-74	23.000	0.750	1.00	0.94	0.485	0.06
R-75	23.000	1.250	1.56	1.50	0.879	0.09
R-76	26.500	0.313	0.56	0.50	0.206	0.06
R-77	27.250	0.625	0.88	0.81	0.413	0.06
R-78	27.250	1.000	1.31	1.25	0.681	0.09
R-79	27.250	1.375	1.75	1.63	0.977	0.09
R-80	24.250	0.313	...	0.50	0.206	0.06

(continued)

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TABLE 3 TYPE R RING GASKET DIMENSIONS AND TOLERANCES (CONT'D)

Ring Number	Average Pitch Diameter of Ring, *P*	Width of Ring, *A*	Height of Ring		Width of Flat on Octagonal Ring, *C*	Radius in Octagonal Ring, R_1
			Oval, *B*	Octagonal, *H*		
R-81	25.000	0.563	...	0.75	0.377	0.06
R-82	2.250	0.438	...	0.63	0.305	0.06
R-84	2.500	0.438	...	0.63	0.305	0.06
R-85	3.125	0.500	...	0.69	0.341	0.06
R-86	3.563	0.625	...	0.81	0.413	0.06
R-87	3.938	0.625	...	0.81	0.413	0.06
R-88	4.875	0.750	...	0.94	0.485	0.06
R-89	4.500	0.750	...	0.94	0.485	0.06
R-90	6.125	0.875	...	1.06	0.583	0.06
R-91	10.250	1.250	...	1.50	0.879	0.09
R-92	9.000	0.438	0.69	0.63	0.305	0.06
R-93	29.500	0.750	...	0.94	0.485	0.06
R-94	31.500	0.750	...	0.94	0.485	0.06
R-95	33.750	0.750	...	0.94	0.485	0.06
R-96	36.000	0.875	...	1.06	0.583	0.06
R-97	38.000	0.875	...	1.06	0.583	0.06
R-98	40.250	0.875	...	1.06	0.583	0.06
R-99	9.250	0.438	...	0.63	0.305	0.06
R-100	29.500	1.125	...	1.38	0.780	0.09
R-101	31.500	1.250	...	1.50	0.879	0.09
R-102	33.750	1.250	...	1.50	0.879	0.09
R-103	36.000	1.250	...	1.50	0.879	0.09
R-104	38.000	1.375	...	1.63	0.977	0.09
R-105	40.250	1.375	...	1.63	0.977	0.09

GENERAL NOTE: All dimensions are in inches.

TOLERANCES:

P = average pitch diameter of ring, ±0.007
A = width of ring, ±0.008
B, H = height of ring, +0.05, −0.02
Variation in height throughout the entire circumference of any given ring shall not exceed 0.02 within these tolerances.
C = width of flat on octagonal ring, ±0.008
R_1 = radius in ring, ±0.02
23 deg = angle, ±½ deg

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TABLE 4 PIPE SIZES FOR TYPE R RING GASKETS SUITABLE FOR REFERENCED STANDARDS

Ring Number	Pressure Classes											
	ASME B16.5					API 6B				ASME B16.47 Series A		
	150	300–600	900	1500	2500	720–960 (1)	2000	3000	5000	150	300–600	900
R-11	...	1/2	...	...	...	...	...	...	...	...	...	...
R-12	...	...	1/2	1/2	...	...	...	...	...	...	...	...
R-13	...	3/4	...	...	1/2	...	...	...	...	...	...	...
R-14	...	...	3/4	3/4	...	...	...	...	...	...	...	...
R-15	1	...	...	...	...	...	...	...	...	...	...	...
R-16	...	1	1	1	3/4	1	1	1	1	...	...	...
R-17	1 1/4	...	...	...	...	...	...	...	...	...	...	...
R-18	...	1 1/4	1 1/4	1 1/4	1	1 1/4	1 1/4	1 1/4	1 1/4	...	...	...
R-19	1 1/2	...	...	...	...	...	...	...	...	...	...	...
R-20	...	1 1/2	1 1/2	1 1/2	...	1 1/2	1 1/2	1 1/2	1 1/2	...	...	...
R-21	...	...	...	...	1 1/4	...	...	...	...	...	...	...
R-22	2	...	...	...	...	...	...	...	...	...	...	...
R-23	...	2	...	...	1 1/2	2	2	...	...	...	...	...
R-24	...	...	2	2	...	...	...	2	2	...	...	...
R-25	2 1/2	...	...	...	...	...	...	...	...	...	...	...
R-26	...	2 1/2	...	...	2	2 1/2	2 1/2	...	...	...	...	...
R-27	...	...	2 1/2	2 1/2	...	...	...	2 1/2	2 1/2	...	...	...
R-28	...	...	...	...	2 1/2	...	...	...	...	...	...	...
R-29	3	...	...	...	...	...	...	...	...	...	...	...
R-30 (2)	...	3	...	...	...	...	...	...	...	...	...	...
R-31	...	3	3	...	...	3	3	3	...	...	...	...
R-32	...	...	...	...	3	...	...	...	...	...	...	...
R-33	3 1/2	...	...	...	...	...	...	...	...	...	...	...
R-34	...	3 1/2	...	...	...	...	...	...	...	...	...	...
R-35	...	...	...	3	...	...	...	...	3	...	...	...
R-36	4	...	...	...	...	...	...	...	...	...	...	...
R-37	...	4	4	...	...	4	4	4	3 1/2	...	...	...
R-38	...	...	...	...	4	...	...	...	...	...	...	...
R-39	...	...	...	4	...	...	...	...	4	...	...	...
R-40	5	...	...	...	...	...	...	...	...	...	...	...
R-41	...	5	5	...	...	5	5	5	...	...	...	...
R-42	...	...	...	...	5	...	...	...	...	...	...	...
R-43	6	...	...	...	...	...	...	...	...	...	...	...
R-44	...	...	...	5	...	...	...	...	5	...	...	...
R-45	...	6	6	...	...	6	6	6	...	...	...	...
R-46	...	...	...	6	...	...	...	...	6	...	...	...
R-47	...	...	...	...	6	...	...	...	...	...	...	...
R-48	8	...	...	...	...	...	...	...	...	...	...	...
R-49	...	8	8	...	...	8	8	8	...	...	...	...
R-50	...	...	...	8	...	...	...	...	8	...	...	...
R-51	...	...	...	...	8	...	...	...	...	...	...	...
R-52	10	...	...	...	...	...	...	...	...	...	...	...
R-53	...	10	10	...	...	10	10	10	...	...	...	...
R-54	...	...	...	10	...	...	...	...	10	...	...	...

(continued)

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TABLE 4 PIPE SIZES FOR TYPE R RING GASKETS SUITABLE FOR REFERENCED STANDARDS (CONT'D)

Ring Number	Pressure Classes											
	ASME B16.5					API 6B				ASME B16.47 Series A		
	150	300–600	900	1500	2500	720–960 (1)	2000	3000	10000 (1)	150	300–600	900
R-55	...	...	...	...	10	...	...	...	...	...	...	...
R-56	12	...	...	...	...	...	...	...	...	...	...	...
R-57	...	12	12	...	...	12	12	12	...	...	12	12
R-58	...	...	...	12	...	...	...	...	...	...	...	...
R-59	14	...	...	...	...	...	...	...	...	...	...	...
R-60	...	...	...	...	12	...	...	...	...	...	...	...
R-61	...	14	...	...	...	14	14	14	...	...	14	...
R-62	...	...	14	...	...	...	...	...	...	...	...	14
R-63	...	...	...	14	...	...	...	...	...	...	...	...
R-64	16	...	...	...	...	...	...	...	...	...	...	...
R-65	...	16	...	...	...	16	16	...	...	...	16	...
R-66	...	...	16	...	...	...	...	16	...	...	...	16
R-67	...	...	...	16	...	...	...	...	...	...	...	...
R-68	18	...	...	...	...	...	...	...	...	...	...	...
R-69	...	18	...	...	...	18	18	...	...	...	18	...
R-70	...	...	18	...	...	...	...	18	...	...	...	18
R-71	...	...	...	18	...	...	...	...	...	...	...	...
R-72	20	...	...	...	...	...	...	...	...	...	...	...
R-73	...	20	...	...	...	20	20	...	...	...	20	...
R-74	...	...	20	...	...	...	...	20	...	...	...	20
R-75	...	...	...	20	...	...	...	...	...	...	...	...
R-76	24	...	...	...	...	...	...	...	...	...	...	...
R-77	...	24	...	...	...	...	...	...	...	...	24	...
R-78	...	...	24	...	...	...	...	...	...	...	...	24
R-79	...	...	...	24	...	...	...	...	...	...	...	...
R-80	...	...	...	...	...	...	...	...	...	22	...	...
R-81	...	...	...	...	...	...	...	...	...	...	22	...
R-82	...	...	...	...	...	...	...	...	1	...	...	...
R-84	...	...	...	...	...	...	...	...	1½	...	...	...
R-85	...	...	...	...	...	...	...	...	2	...	...	...
R-86	...	...	...	...	...	...	...	...	2½	...	...	...
R-87	...	...	...	...	...	...	...	...	3	...	...	...
R-88	...	...	...	...	...	...	...	...	4	...	...	...
R-89	...	...	...	...	...	...	...	...	3½	...	...	...
R-90	...	...	...	...	...	...	...	...	5	...	...	...
R-91	...	...	...	...	...	...	...	...	10	...	...	...
R-92	...	...	...	...	...	...	...	...	...	...	...	...
R-93	...	...	...	...	...	...	...	...	...	...	26	...
R-94	...	...	...	...	...	...	...	...	...	...	28	...
R-95	...	...	...	...	...	...	...	...	...	...	30	...

(continued)

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TABLE 4 PIPE SIZES FOR TYPE R RING GASKETS SUITABLE FOR REFERENCED STANDARDS (CONT'D)

Ring Number	Pressure Classes											
	ASME B16.5					API 6B				ASME B16.47 Series A		
	150	300–600	900	1500	2500	720–960 (1)	2000	3000	10000 (1)	150	300–600	900
R-96	...	...	...	...	...	...	...	...	...	...	32	...
R-97	...	...	...	...	...	...	...	...	...	...	34	...
R-98	...	...	...	...	...	...	...	...	...	...	36	...
R-99	...	...	...	...	...	...	8	8	...	...	...	...
R-100	...	...	...	...	...	...	...	...	...	...	...	26
R-101	...	...	...	...	...	...	...	...	...	...	...	28
R-102	...	...	...	...	...	...	...	...	...	...	...	30
R-103	...	...	...	...	...	...	...	...	...	...	...	32
R-104	...	...	...	...	...	...	...	...	...	...	...	34
R-105	...	...	...	...	...	...	...	...	...	...	...	36

GENERAL NOTE: End flanges to API 6D and API 600 use gaskets for equivalent pipe size under ASME B16.5 or ASME B16.47 series A.

NOTES:
(1) Class 720, 960, and 10000 flanges to API 6B are obsolete. Data are for information only.
(2) R-30 is for lapped joint only.

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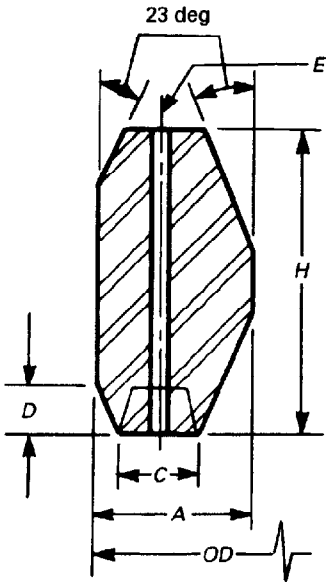

TABLE 5 TYPE RX RING GASKET DIMENSIONS AND TOLERANCES

Ring Number	Outside Diameter of Ring, *OD*	Width of Ring, *A*	Width of Flat, *C*	Height of Outside Bevel, *D*	Height of Ring, *H*	Radius of Ring, R_1	Hole Size, *E* (1)
RX-20	3.000	0.344	0.182	0.125	0.750	0.06	...
RX-23	3.672	0.469	0.254	0.167	1.000	0.06	...
RX-24	4.172	0.469	0.254	0.167	1.000	0.06	...
RX-25	4.313	0.344	0.182	0.125	0.750	0.06	...
RX-26	4.406	0.469	0.254	0.167	1.000	0.06	...
RX-27	4.656	0.469	0.254	0.167	1.000	0.06	...
RX-31	5.297	0.469	0.254	0.167	1.000	0.06	...
RX-35	5.797	0.469	0.254	0.167	1.000	0.06	...
RX-37	6.297	0.469	0.254	0.167	1.000	0.06	...
RX-39	6.797	0.469	0.254	0.167	1.000	0.06	...
RX-41	7.547	0.469	0.254	0.167	1.000	0.06	...
RX-44	8.047	0.469	0.254	0.167	1.000	0.06	...
RX-45	8.734	0.469	0.254	0.167	1.000	0.06	...
RX-46	8.750	0.531	0.263	0.188	1.125	0.06	...
RX-47	9.656	0.781	0.407	0.271	1.625	0.09	...
RX-49	11.047	0.469	0.254	0.167	1.000	0.06	...
RX-50	11.156	0.656	0.335	0.208	1.250	0.06	...
RX-53	13.172	0.469	0.254	0.167	1.000	0.06	...
RX-54	13.281	0.656	0.335	0.208	1.250	0.06	...
RX-57	15.422	0.469	0.254	0.167	1.000	0.06	...
RX-63	17.391	1.063	0.582	0.333	2.000	0.09	...
RX-65	18.922	0.469	0.254	0.167	1.000	0.06	...
RX-66	18.031	0.656	0.335	0.208	1.250	0.06	...
RX-69	21.422	0.469	0.254	0.167	1.000	0.06	...
RX-70	21.656	0.781	0.407	0.271	1.625	0.09	...

(continued)

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TABLE 5 TYPE RX RING GASKET DIMENSIONS AND TOLERANCES (CONT'D)

Ring Number	Outside Diameter of Ring, *OD*	Width of Ring, *A*	Width of Flat, *C*	Height of Outside Bevel, *D*	Height of Ring, *H*	Radius of Ring, R_1	Hole Size, *E* (1)
RX-73	23.469	0.531	0.263	0.208	1.250	0.06	...
RX-74	23.656	0.781	0.407	0.271	1.625	0.09	...
RX-82	2.672	0.469	0.254	0.167	1.000	0.06	0.06
RX-84	2.922	0.469	0.254	0.167	1.000	0.06	0.06
RX-85	3.547	0.531	0.263	0.167	1.000	0.06	0.06
RX-86	4.078	0.594	0.335	0.188	1.125	0.06	0.09
RX-87	4.453	0.594	0.335	0.188	1.125	0.06	0.09
RX-88	5.484	0.688	0.407	0.208	1.250	0.06	0.12
RX-89	5.109	0.719	0.407	0.208	1.250	0.06	0.12
RX-90	6.875	0.781	0.479	0.292	1.750	0.09	0.12
RX-91	11.297	1.188	0.780	0.297	1.781	0.09	0.12
RX-99	9.672	0.469	0.254	0.167	1.000	0.06	...
RX-201	2.026	0.226	0.126	0.057	0.445	0.02 (3)	...
RX-205	2.453	0.219	0.120	0.072 (2)	0.437	0.02 (3)	...
RX-210	3.844	0.375	0.213	0.125 (2)	0.750	0.03 (3)	...
RX-215	5.547	0.469	0.210	0.167 (2)	1.000	0.06 (3)	...

GENERAL NOTE: All dimensions are in inches.

NOTES:

(1) Rings RX-82 through RX-91 only require one pressure passage hole as illustrated. The center line of the hole shall be located at the midpoint of dimension *C*.

(2) Tolerance on these dimensions is +0, −0.015.

(3) Tolerance on these dimensions is +0.02, −0.

TOLERANCES:

OD = outside diameter of ring, +0.020, −0

A = width of ring, +0.008, −0
Variation in width throughout the entire circumference of any ring shall not exceed 0.004 within these tolerances.

C = width of flat, +0.006, −0

D = height of outside bevel, +0, −0.03

H = height of ring, +0.008, −0
Variation in height throughout the entire circumference of any ring shall not exceed 0.004 within these tolerances.

R_1 = radius of ring, ±0.02

23 deg = angle, $\pm\frac{1}{2}$ deg

E = hole size, ±0.02

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TABLE 6 PIPE SIZES FOR TYPE RX RING GASKETS SUITABLE FOR REFERENCED STANDARDS

	Pressure Classes			
	API 6B			
Ring Number	720–960 2000 (1)	2900 (1)	3000	5000
RX-20	1½	...	1½	1½
RX-23	2	...	...	...
RX-24	...	...	2	2
RX-25	...	...	...	3⅛
RX-26	2½	...	...	...
RX-27	...	...	2½	2½
RX-31	3	...	3	...
RX-35	...	...	...	3
RX-37	4	...	4	...
RX-39	...	...	...	4
RX-41	5	...	5	...
RX-44	...	...	...	5
RX-45	6	...	6	...
RX-46	...	...	...	6
RX-47	...	...	...	8 (2)
RX-49	8	...	8	...
RX-50	...	...	...	8
RX-53	10	...	10	...
RX-54	...	...	...	10
RX-57	12	...	12	...
RX-63	...	...	...	14
RX-65	16	...	...	...
RX-66	...	...	16	...
RX-69	18	...	...	...
RX-70	...	...	18	...
RX-73	20	...	...	...
RX-74	...	...	20	...
RX-82	...	1	...	...
RX-84	...	1½	...	...
RX-85	...	2	...	...
RX-86	...	2½	...	...
RX-87	...	3	...	...
RX-88	...	4	...	...
RX-89	...	3½	...	...
RX-90	...	5	...	...
RX-91	...	10	...	...
RX-99	8 (2)	...	8 (2)	...
RX-201	...	...	...	1⅜
RX-205	...	...	...	1 13/16
RX-210	...	...	...	2 9/16
RX-215	...	...	...	4 1/16

NOTES:
(1) Class 720, 960, and 2900 flanges to API 6B are obsolete. Data are for information only.
(2) Crossover flange connection.

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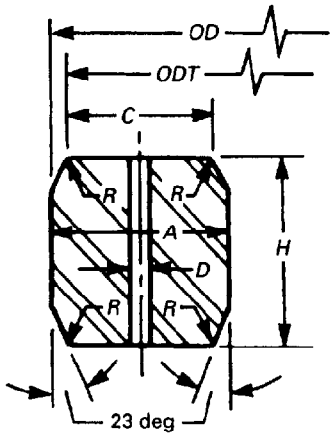

TABLE 7 TYPE BX RING GASKET DIMENSIONS AND TOLERANCES

Ring Number	Nominal Size, in.	Outside Diameter of Ring, *OD*	Height of Ring, *H*	Width of Ring, *A*	Outside Diameter of Flat, *ODT*	Width of Flat, *C*	Hole Size, *D* (1)
BX-150	1 11/16	2.842	0.366	0.366	2.790	0.314	0.06
BX-151	1 13/16	3.008	0.379	0.379	2.954	0.325	0.06
BX-152	2 1/16	3.334	0.403	0.403	3.277	0.346	0.06
BX-153	2 9/16	3.974	0.448	0.448	3.910	0.385	0.06
BX-154	3 1/16	4.600	0.488	0.488	4.531	0.419	0.06
BX-155	4 1/16	5.825	0.560	0.560	5.746	0.481	0.06
BX-156	7 1/16	9.367	0.733	0.733	9.263	0.629	0.12
BX-157	9	11.593	0.826	0.826	11.476	0.709	0.12
BX-158	11	13.860	0.911	0.911	13.731	0.782	0.12
BX-159	13 5/8	16.800	1.012	1.012	16.657	0.869	0.12
BX-160	13 5/8	15.850	0.938	0.541	15.717	0.408	0.12
BX-161	16 5/8	19.347	1.105	0.638	19.191	0.482	0.12
BX-162	16 5/8	18.720	0.560	0.560	18.641	0.481	0.06
BX-163	18 3/4	21.896	1.185	0.684	21.728	0.516	0.12
BX-164	18 3/4	22.463	1.185	0.968	22.295	0.800	0.12
BX-165	21 1/4	24.595	1.261	0.728	24.417	0.550	0.12
BX-166	21 1/4	25.198	1.261	1.029	25.020	0.851	0.12
BX-167	26 3/4	29.896	1.412	0.516	29.696	0.316	0.06
BX-168	26 3/4	30.128	1.412	0.632	29.928	0.432	0.06
BX-169	5 1/8	6.831	0.624	0.509	6.743	0.421	0.06
BX-170	6 5/8	8.584	0.560	0.560	8.505	0.481	0.06
BX-171	8 9/16	10.529	0.560	0.560	10.450	0.481	0.06
BX-172	11 5/32	13.113	0.560	0.560	13.034	0.481	0.06
BX-303	30	33.573	1.494	0.668	33.361	0.457	0.06

GENERAL NOTES:
(a) All dimensions are in inches.
(b) Radius *R* shall be 8% to 12% of the gasket height *H*.

(continued)

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NOTES TO TABLE 7 (CONT'D)

NOTE:
(1) One pressure passage hole is required per gasket as illustrated. The center line of the hole shall be located at the midpoint of dimension *C*.

TOLERANCES:
OD = (outside diameter of ring) +0, −0.005
H = (height of ring) +0.008, −0
Variation in height throughout the entire circumference of any ring shall not exceed 0.004 within these tolerances.
A = (width of ring) +0.008, −0
Variation in width throughout the entire circumference of any ring shall not exceed 0.004 within these tolerances.
ODT = (outside diameter of flat) ±0.002
C = (width of flat) +0.006, −0
D = (hole size) ±0.02
R = (radius of ring) see General Note (b)
23 deg = (angle) ±1/4 deg

TABLE 8 PIPE SIZES FOR TYPE BX RING GASKETS SUITABLE FOR REFERENCED STANDARDS

Ring Number	Pressure Classes					
	API 6BX					
	2000	3000	5000	10000	15000	20000
BX-150	...	...	...	1 11/16	1 11/16	...
BX-151	...	...	...	1 13/16	1 13/16	1 13/16
BX-152	...	...	...	2 1/16	2 1/16	2 1/16
BX-153	...	...	...	2 9/16	2 9/16	2 9/16
BX-154	...	...	...	3 1/16	3 1/16	3 1/16
BX-155	...	...	...	4 1/16	4 1/16	4 1/16
BX-156	...	...	...	7 1/16	7 1/16	7 1/16
BX-157	...	...	...	9	9	9
BX-158	...	...	...	11	11	11
BX-159	...	...	...	13 5/8	13 5/8	13 5/8
BX-160	...	...	13 5/8	...	...	...
BX-161	...	...	16 3/4	...	...	...
BX-162	...	...	16 3/4	16 3/4	16 3/4	...
BX-163	...	...	18 3/4	...	...	...
BX-164	...	...	...	18 3/4	18 3/4	...
BX-165	...	...	21 1/4	...	...	...
BX-166	...	...	...	21 1/4	...	...
BX-167	26 3/4	...	...	...	...	...
BX-168	...	26 3/4	...	...	...	...
BX-169	...	...	...	5 1/8	...	...
BX-170	...	...	...	6 5/8	6 5/8	...
BX-171	...	...	...	8 9/16	8 9/16	...
BX-172	...	...	...	11 5/32	11 5/32	...
BX-303	30	30	...	...	...	...

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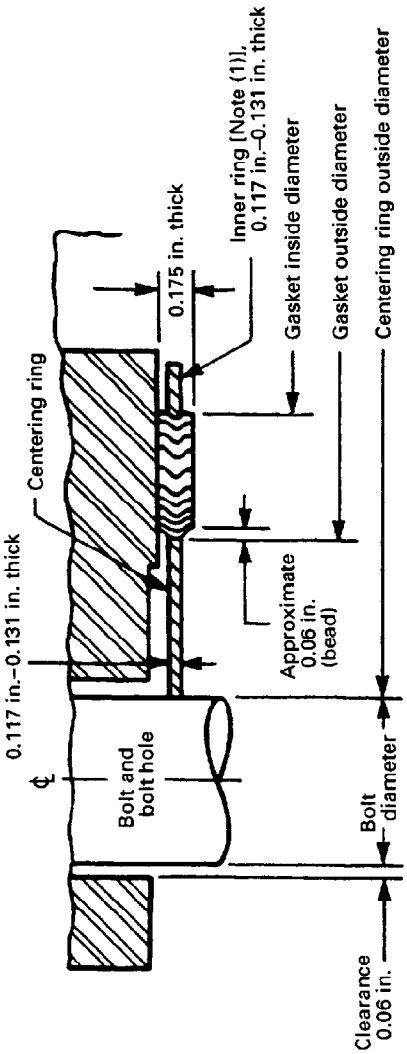

TABLE 9 ILLUSTRATION

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TABLE 9 DIMENSIONS FOR SPIRAL-WOUND GASKETS USED WITH ASME B16.5 FLANGES

Flange Size (NPS)	Outside Diameter of Gasket (2)		Inside Diameter of Gasket by Class (3)							Outside Diameter of Centering Ring by Class (4)						
	Classes 150, 300, 400, 600	Classes 900, 1500, 2500	150	300	400 (5)	600	900 (1, 5)	1500 (1)	2500 (1, 5)	150	300	400 (5)	600	900 (5)	1500	2500 (5)
½	1.25	1.25	0.75	0.75	...	0.75	...	0.75	0.75	1.88	2.13	...	2.13	...	2.50	2.75
¾	1.56	1.56	1.00	1.00	...	1.00	...	1.00	1.00	2.25	2.63	...	2.63	...	2.75	3.00
1	1.88	1.88	1.25	1.25	...	1.25	...	1.25	1.25	2.63	2.88	...	2.88	...	3.13	3.38
1¼	2.38	2.38	1.88	1.88	...	1.88	...	1.56	1.56	3.00	3.25	...	3.25	...	3.50	4.13
1½	2.75	2.75	2.13	2.13	...	2.13	...	1.88	1.88	3.38	3.75	...	3.75	...	3.88	4.63
2	3.38	3.38	2.75	2.75	...	2.75	...	2.31	2.31	4.13	4.38	...	4.38	...	5.63	5.75
2½	3.88	3.88	3.25	3.25	...	3.25	...	2.75	2.75	4.88	5.13	...	5.13	...	6.50	6.63
3	4.75	4.75	4.00	4.00	...	4.00	3.75	3.63	3.63	5.38	5.88	...	5.88	6.63	6.88	7.75
4	5.88	5.88	5.00	5.00	4.75	4.75	4.75	4.63	4.63	6.88	7.13	7.00	7.63	8.13	8.25	9.25
5	7.00	7.00	6.13	6.13	5.81	5.81	5.81	5.63	5.63	7.75	8.50	8.38	9.50	9.75	10.00	11.00
6	8.25	8.25	7.19	7.19	6.88	6.88	6.88	6.75	6.75	8.75	9.88	9.75	10.50	11.38	11.13	12.50
8	10.38	10.13	9.19	9.19	8.88	8.88	8.75	8.50	8.50	11.00	12.13	12.00	12.63	14.13	13.88	15.25
10	12.50	12.25	11.31	11.31	10.81	10.81	10.88	10.50	10.63	13.38	14.25	14.13	15.75	17.13	17.13	18.75
12	14.75	14.50	13.38	13.38	12.88	12.88	12.75	12.75	12.50	16.13	16.63	16.50	18.00	19.63	20.50	21.63
14	16.00	15.75	14.63	14.63	14.25	14.25	14.00	14.25	...	17.75	19.13	19.00	19.38	20.50	22.75	...
16	18.25	18.00	16.63	16.63	16.25	16.25	16.25	16.00	...	20.25	21.25	21.13	22.25	22.63	25.25	...
18	20.75	20.50	18.69	18.69	18.50	18.50	18.25	18.25	...	21.63	23.50	23.38	24.13	25.13	27.75	...
20	22.75	22.50	20.69	20.69	20.50	20.50	20.50	20.25	...	23.88	25.75	25.50	26.88	27.50	29.75	...
24	27.00	26.75	24.75	24.75	24.75	24.75	24.75	24.25	...	28.25	30.50	30.25	31.13	33.00	35.50	...

GENERAL NOTES:
(a) For reference, see Table 9 illustration beginning on previous page.
(b) The gasket–thickness tolerance is ±0.005 in. measured across the metallic portion of the gasket not including the filler, which may protrude slightly beyond the metal.
(c) For limitations on the maximum flange bore for use with these spiral-wound gaskets, see Table 16.

NOTES:
(1) Inner rings are required for all PTFE filled gaskets and for Class 900 gaskets, NPS 24; Class 1500 gaskets, NPS 12 through NPS 24; and Class 2500 gaskets, NPS 4 through NPS 12 (see para. 3.2.5 and Table 12).
(2) The gasket outside diameter tolerance for NPS ½ through NPS 8 is ±0.03 in.; for NPS 10 through NPS 24, +0.06 in., −0.03 in.
(3) The gasket inside diameter tolerance for NPS ½ through NPS 8 is ±0.016 in.; for NPS 10 through NPS 24, ±0.03 in.
(4) The centering ring outside diameter tolerance is ±0.03 in.
(5) There are no Class 400 flanges in NPS ½ through NPS 3 (use Class 600), Class 900 flanges in NPS ½ through NPS 2½ (use Class 1500), or Class 2500 flanges NPS 14 and larger.

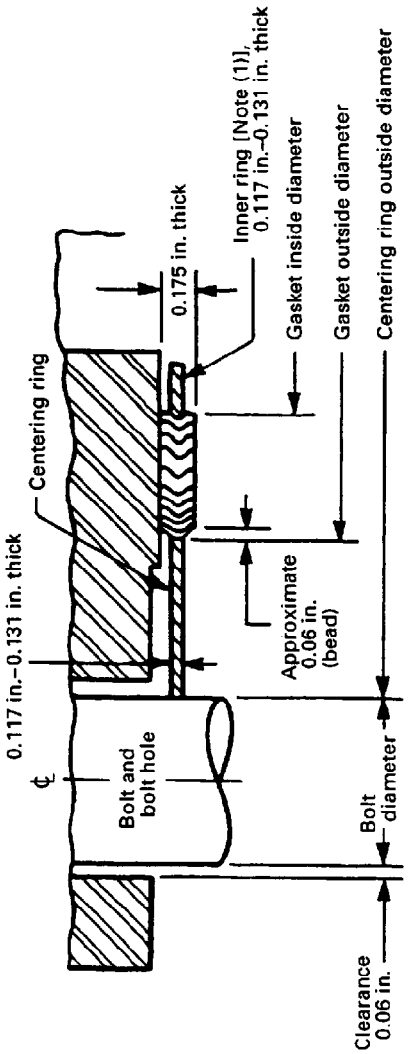

TABLE 10 ILLUSTRATION

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TABLE 10 DIMENSIONS FOR SPIRAL-WOUND GASKETS USED WITH ASME B16.47 SERIES A FLANGES

	Class 150			Class 300			Class 400			Class 600			Class 900 (1)		
	Gasket		Centering Ring	Gasket		Centering Ring	Gasket		Centering Ring	Gasket		Centering Ring	Gasket		Centering Ring
Flange Size (NPS)	Inside Diameter (2)	Outside Diameter (3)	Outside Diameter (4)	Inside Diameter (2)	Outside Diameter (3)	Outside Diameter (4)	Inside Diameter (2)	Outside Diameter (3)	Outside Diameter (4)	Inside Diameter (2)	Outside Diameter (3)	Outside Diameter (4)	Inside Diameter (2, 5)	Outside Diameter (3, 5)	Outside Diameter (4, 5)
26	26.50	27.75	30.50	27.00	29.00	32.88	27.00	29.00	32.75	27.00	29.00	34.13	27.00	29.00	34.75
28	28.50	29.75	32.75	29.00	31.00	35.38	29.00	31.00	35.13	29.00	31.00	36.00	29.00	31.00	37.25
30	30.50	31.75	34.75	31.25	33.25	37.50	31.25	33.25	37.25	31.25	33.25	38.25	31.25	33.25	39.75
32	32.50	33.88	37.00	33.50	35.50	39.63	33.50	35.50	39.50	33.50	35.50	40.25	33.50	35.50	42.25
34	34.50	35.88	39.00	35.50	37.50	41.63	35.50	37.50	41.50	35.50	37.50	42.25	35.50	37.50	44.75
36	36.50	38.13	41.25	37.63	39.63	44.00	37.63	39.63	44.00	37.63	39.63	44.50	37.75	39.75	47.25
38	38.50	40.13	43.75	38.50	40.00	41.50	38.25	40.25	42.25	39.00	41.00	43.50	40.75	42.75	47.25
40	40.50	42.13	45.75	40.25	42.13	43.88	40.38	42.38	44.38	41.25	43.25	45.50	43.25	45.25	49.25
42	42.50	44.25	48.00	42.25	44.13	45.88	42.38	44.38	46.38	43.50	45.50	48.00	45.25	47.25	51.25
44	44.50	46.38	50.25	44.50	46.50	48.00	44.50	46.50	48.50	45.75	47.75	50.00	47.50	49.50	53.88
46	46.50	48.38	52.25	46.38	48.38	50.13	47.00	49.00	50.75	47.75	49.75	52.25	50.00	52.00	56.50
48	48.50	50.38	54.50	48.63	50.63	52.13	49.00	51.00	53.00	50.00	52.00	54.75	52.00	54.00	58.50
50	50.50	52.50	56.50	51.00	53.00	54.25	51.00	53.00	55.25	52.00	54.00	57.00	...	...	...
52	52.50	54.50	58.75	53.00	55.00	56.25	53.00	55.00	57.25	54.00	56.00	59.00	...	...	...
54	54.50	56.50	61.00	55.25	57.25	58.75	55.25	57.25	59.75	56.25	58.25	61.25	...	...	...
56	56.50	58.50	63.25	57.25	59.25	60.75	57.25	59.25	61.75	58.25	60.25	63.50	...	...	...
58	58.50	60.50	65.50	59.50	61.50	62.75	59.25	61.25	63.75	60.50	62.50	65.50	...	...	...
60	60.50	62.50	67.50	61.50	63.50	64.75	61.75	63.75	66.25	62.75	64.75	68.25	...	...	...

GENERAL NOTES:
(a) For reference, see Table 10 illustration beginning on previous page.
(b) The gasket-thickness tolerance is ±0.005 in. measured across the metallic portion of the gasket not including the filler, which may protrude slightly beyond the metal.
(c) For limitations on the maximum flange bore for use with these spiral-wound gaskets, see Table 17.
(d) ASME B16.47 Series A flanges NPS 12 through NPS 24 have the same raised face dimensions as ASME B16.5 flanges.

NOTES:
(1) Inner rings are required for all PTFE gaskets and Class 900 gaskets, NPS 26 through NPS 48 (see para. 3.2.5 and Table 13).
(2) The gasket inside diameter tolerance for NPS 26 through NPS 34 is ±0.03 in., and the tolerance for NPS 36 through NPS 60 is ±0.05 in.
(3) The gasket outside diameter tolerance for NPS 26 through NPS 60 is ±0.06 in.
(4) The centering ring outside diameter tolerance is ±0.03 in.
(5) There are no Class 900 flanges NPS 50 and larger.

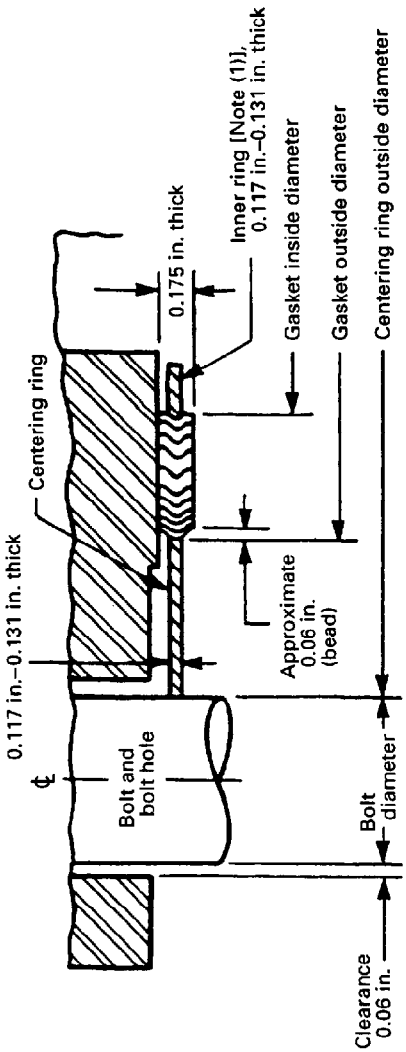

TABLE 11 ILLUSTRATION

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TABLE 11 DIMENSIONS FOR SPIRAL-WOUND GASKETS USED WITH ASME B16.47 SERIES B FLANGES

	Class 150			Class 300			Class 400			Class 600			Class 900 (1)		
	Gasket		Centering Ring	Gasket		Centering Ring	Gasket		Centering Ring	Gasket		Centering Ring	Gasket		Centering Ring
Flange Size (NPS)	Inside Diameter (2)	Outside Diameter (3)	Outside Diameter (4)	Inside Diameter (2)	Outside Diameter (3)	Outside Diameter (4)	Inside Diameter (2)	Outside Diameter (3)	Outside Diameter (4)	Inside Diameter (2)	Outside Diameter (3)	Outside Diameter (4)	Inside Diameter (2, 5)	Outside Diameter (3, 5)	Outside Diameter (4, 5)
26	26.50	27.50	28.56	26.50	28.00	30.38	26.25	27.50	29.38	26.13	28.13	30.13	27.25	29.50	33.00
28	28.50	29.50	30.56	28.50	30.00	32.50	28.13	29.50	31.50	27.75	29.75	32.25	29.25	31.50	35.50
30	30.50	31.50	32.56	30.50	32.00	34.88	30.13	31.75	33.75	30.63	32.63	34.63	31.75	33.75	37.75
32	32.50	33.50	34.69	32.50	34.00	37.00	32.00	33.88	35.88	32.75	34.75	36.75	34.00	36.00	40.00
34	34.50	35.75	36.81	34.50	36.00	39.13	34.13	35.88	37.88	35.00	37.00	39.25	36.25	38.25	42.25
36	36.50	37.75	38.88	36.50	38.00	41.25	36.13	38.00	40.25	37.00	39.00	41.25	37.25	39.25	44.25
38	38.37	39.75	41.13	39.75	41.25	43.25	38.25	40.25	42.25	39.00	41.00	43.50	40.75	42.75	47.25
40	40.25	41.88	43.13	41.75	43.25	45.25	40.38	42.38	44.38	41.25	43.25	45.50	43.25	45.25	49.25
42	42.50	43.88	45.13	43.75	45.25	47.25	42.38	44.38	46.38	43.50	45.50	48.00	45.25	47.25	51.25
44	44.25	45.88	47.13	45.75	47.25	49.25	44.50	46.50	48.50	45.75	47.75	50.00	47.50	49.50	53.88
46	46.50	48.19	49.44	47.88	49.38	51.88	47.00	49.00	50.75	47.75	49.75	52.25	50.00	52.00	56.50
48	48.50	50.00	51.44	49.75	51.63	53.88	49.00	51.00	53.00	50.00	52.00	54.75	52.00	54.00	58.50
50	50.50	52.19	53.44	51.88	53.38	55.88	51.00	53.00	55.25	52.00	54.00	57.00	...	...	...
52	52.50	54.19	55.44	53.88	55.38	57.88	53.00	55.00	57.25	54.00	56.00	59.00	...	...	...
54	54.50	56.00	57.63	55.25	57.25	60.25	55.25	57.25	59.75	56.25	58.25	61.25	...	...	...
56	56.88	58.18	59.63	58.25	60.00	62.75	57.25	59.25	61.75	58.25	60.25	63.50	...	...	...
58	59.07	60.19	62.19	60.44	61.94	65.19	59.25	61.25	63.75	60.50	62.50	65.50	...	...	...
60	61.31	62.44	64.19	62.56	64.19	67.19	61.75	63.75	66.25	62.75	64.75	68.25	...	...	...

GENERAL NOTES:
(a) For reference, see Table 11 illustration beginning on previous page.
(b) The gasket-thickness tolerance is ±0.005 in. measured across the metallic portion of the gasket not including the filler, which may protrude slightly beyond the metal.
(c) For limitations on the maximum flange bore for use with these spiral-wound gaskets, see Table 18.

NOTES:
(1) Inner rings are required for all PTFE gaskets and for Class 900 gaskets, NPS 26 through NPS 48 (see para. 3.2.5 and Table 14).
(2) The gasket inside diameter tolerance for NPS 26 through NPS 34 is ±0.03 in., and the tolerance for NPS 36 through NPS 60 is ±0.05 in.
(3) The gasket outside diameter tolerance for NPS 26 through NPS 60 is ±0.06 in.
(4) The centering ring outside diameter tolerance is ±0.03 in.
(5) There are no Class 900 flanges NPS 50 and larger.

TABLE 12 INNER-RING INSIDE DIAMETERS FOR SPIRAL-WOUND GASKETS

Flange Size (NPS)	Pressure Class						
	150	300	400 (1)	600	900 (1, 2)	1500 (2, 3)	2500 (1–3)
½	0.56	0.56	...	0.56	...	0.56	0.56
¾	0.81	0.81	...	0.81	...	0.81	0.81
1	1.06	1.06	...	1.06	...	1.06	1.06
1¼	1.50	1.50	...	1.50	...	1.31	1.31
1½	1.75	1.75	...	1.75	...	1.63	1.63
2	2.19	2.19	...	2.19	...	2.06	2.06
2½	2.62	2.62	...	2.62	...	2.50	2.50
3	3.19	3.19	...	3.10	3.10	3.10	3.10
4	4.19	4.19	4.04	4.04	4.04	3.85	3.85
5	5.19	5.19	5.05	5.05	5.05	4.90	4.90
6	6.19	6.19	6.10	6.10	6.10	5.80	5.80
8	8.50	8.50	8.10	8.10	7.75	7.75	7.75
10	10.56	10.56	10.05	10.05	9.69	9.69	9.69
12	12.50	12.50	12.10	12.10	11.50	11.50	11.50
14	13.75	13.75	13.50	13.50	12.63	12.63	...
16	15.75	15.75	15.35	15.35	14.75	14.50	...
18	17.69	17.69	17.25	17.25	16.75	16.75	...
20	19.69	19.69	19.25	19.25	19.00	18.75	...
24	23.75	23.75	23.25	23.25	23.25	22.75	...

GENERAL NOTES:

(a) The inner-ring thickness shall be 0.117 in. to 0.131 in.

(b) For sizes NPS 1¼ through NPS 3, the inside diameter tolerance is ±0.03 in.; for larger sizes the inside diameter tolerance is ±0.06 in. See Table 15 for minimum pipe wall thicknesses that are suitable for use with standard inner rings.

NOTES:

(1) There are no Class 400 flanges NPS ½ through NPS 3 (use Class 600), Class 900 flanges NPS ½ through NPS 2½ (use Class 1500), or Class 2500 flanges NPS 14 and larger.

(2) Inner rings are required for Class 900, NPS 24 gaskets; Class 1500, NPS 12 through NPS 24 gaskets; and Class 2500, NPS 4 through NPS 12 gaskets.

(3) The inner-ring inside diameters shown for NPS 1¼ through NPS 2½ in Class 1500 and 2500 will produce inner-ring widths of 0.12 in., a practical minimum for production purposes.

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TABLE 13 INNER-RING INSIDE DIAMETERS FOR SPIRAL-WOUND GASKETS USED BETWEEN ASME B16.47 SERIES A FLANGES

Flange Size (NPS)	Pressure Class				
	150	300	400	600	900 (1, 2)
26	25.75	25.75	26.00	25.50	26.00
28	27.75	27.75	28.00	27.50	28.00
30	29.75	29.75	29.75	29.75	30.25
32	31.75	31.75	32.00	32.00	32.00
34	33.75	33.75	34.00	34.00	34.00
36	35.75	35.75	36.13	36.13	36.25
38	37.75	37.50	37.50	37.50	39.75
40	39.75	39.50	39.38	39.75	41.75
42	41.75	41.50	41.38	42.00	43.75
44	43.75	43.50	43.50	43.75	45.50
46	45.75	45.38	46.00	45.75	48.00
48	47.75	47.63	47.50	48.00	50.00
50	49.75	49.00	49.50	50.00	...
52	51.75	52.00	51.50	52.00	...
54	53.50	53.25	53.25	54.25	...
56	55.50	55.25	55.25	56.25	...
58	57.50	57.00	57.25	58.00	...
60	59.50	60.00	59.75	60.25	...

GENERAL NOTES:
(a) The inner-ring thickness shall be 0.117 in. to 0.131 in.
(b) The inside diameter tolerance is ±0.12 in.
(c) These inner rings are suitable for use with pipe walls 0.38 in. or thicker.

NOTES:
(1) Inner rings are required for Class 900 gaskets.
(2) There are no Class 900 flanges NPS 50 and larger.

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TABLE 14 INNER-RING INSIDE DIAMETERS FOR SPIRAL-WOUND GASKETS USED BETWEEN ASME B16.47 SERIES B FLANGES

Flange Size (NPS)	Pressure Class				
	150	300	400	600	900 (1, 2)
26	25.75	25.75	25.75	25.38	26.25
28	27.75	27.75	27.63	27.00	28.25
30	29.75	29.75	29.63	29.63	30.75
32	31.75	31.75	31.50	31.25	33.00
34	33.75	33.75	33.50	33.50	35.25
36	35.75	35.75	35.38	35.50	36.25
38	37.75	38.25	37.50	37.50	39.75
40	39.75	40.25	39.38	39.75	41.75
42	41.75	42.75	41.38	42.00	43.75
44	43.75	44.25	43.50	43.75	45.50
46	45.75	46.38	46.00	45.75	48.00
48	47.75	48.50	47.50	48.00	50.00
50	49.75	49.88	49.50	50.00	...
52	51.75	51.88	51.50	52.00	...
54	53.75	53.75	53.25	54.25	...
56	56.00	56.25	55.25	56.25	...
58	58.19	58.44	57.25	58.00	...
60	60.44	61.31	59.75	60.25	...

GENERAL NOTES:
(a) The inner-ring thickness shall be 0.117 in. to 0.131 in.
(b) The inside diameter tolerance is ±0.12 in.
(c) These inner rings are suitable for use with pipe walls 0.38 in. or thicker.

NOTES:
(1) Inner rings are required for Class 900 gaskets.
(2) There are no Class 900 flanges NPS 50 and larger.

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TABLE 15 MINIMUM PIPE WALL THICKNESS SUITABLE FOR USE WITH INNER RINGS FOR ASME B16.5 FLANGES

Flange Size (NPS)	Pressure Class						
	150	300	400	600	900	1500	2500
½ ¾ 1	Schedule 80						
1¼ 1½ 2 2½ 3	Schedule 40						
4 5 6	Schedule 40					Schedule 80	
8 10 12 14 16 18 20 24	Schedule 10S		Schedule 30		Schedule 80		

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TABLE 16 MAXIMUM BORE OF ASME B16.5 FLANGES FOR USE WITH SPIRAL-WOUND GASKETS

<table>
<tr><th rowspan="2">Flange Size (NPS)</th><th colspan="8">Pressure Class</th></tr>
<tr><th>75</th><th>150</th><th>300</th><th>400</th><th>600</th><th>900 (1)</th><th>1500 (1)</th><th>2500 (1)</th></tr>
<tr><td>½
¾
1</td><td rowspan="12">No flanges</td><td colspan="2" rowspan="2">WN flange only (2)</td><td rowspan="3">No flanges
Use Class 600</td><td>WN flange only (2)</td><td rowspan="3">No flanges
Use Class 1500</td><td colspan="2" rowspan="3">WN flange only (2)</td></tr>
<tr><td>1¼
1½</td><td colspan="2">SO flange (3)
WN flange (2)</td><td>SO flange (3)
WN flange (2)</td></tr>
<tr><td>2
2½</td><td colspan="2">SO flange (3)
WN flange, any bore</td><td>SO flange (3)
WN flange, any bore</td></tr>
<tr><td>3</td><td colspan="3" rowspan="9">SO flange
WN flange, any bore</td><td>SO flange (3)
WN flange, any bore</td><td rowspan="2">WN flange with SW bore [includes nozzle (4) but excludes SO flange]</td></tr>
<tr><td>4
6</td><td colspan="2">WN flange with Schedule 10S bore described in ASME B36.19M [includes nozzle (4) but excludes SO flange]</td><td rowspan="3">WN flange with Schedule 80 bore [excludes nozzle (4) and SO flange] (5)</td></tr>
<tr><td>8
10
12</td><td rowspan="4">No flanges</td></tr>
<tr><td>14
16
18
20
24</td><td colspan="2">WN flange with Schedule 10S bore described in ASME B36.19M [excludes nozzle (4) and SO flange] (5)</td></tr>
</table>

GENERAL NOTES:
(a) This table shows the maximum bore of flanges for which the spiral-wound gasket dimensions shown in Table 9 are recommended considering the tolerances involved, possible eccentric installation, and the possibility that the gasket may extend into the assembled flange bore.
(b) For maximum permissible flange bores for nonmandatory inner rings, see Table 15.
(c) Abbreviations: SO = slip on and threaded WN = welding neck SW = standard wall

NOTES:
(1) Inner rings are required for Class 900 gaskets, NPS 24; Class 1500 gaskets, NPS 12 through NPS 24; and Class 2500 gaskets, NPS 4 through NPS 12 (see para. 3.2.5). These inner rings may extend into the pipe bore a maximum of 0.06 in. under the worst combination of maximum bore, eccentric installation, and additive tolerances.
(2) In these sizes the gasket is suitable for a welding neck flange with a standard wall bore, if the gasket and the flanges are assembled concentrically. This also applies to a nozzle. It is the user's responsibility to determine if the gasket is satisfactory for a flange of any larger bore.
(3) Gaskets in these sizes are suitable for slip-on flanges only if the gaskets and flanges are assembled concentrically.
(4) A *nozzle* is a long welding neck; the bore equals the flange NPS.
(5) An NPS 24 gasket is suitable for nozzles.

TABLE 17 MAXIMUM BORE OF ASME B16.47 SERIES A FLANGES FOR USE WITH SPIRAL-WOUND GASKETS

Flange Size (NPS)	Pressure Class				
	150	300	400	600	900 (1)
26	(2)	(3)	(3)	(3)	(3)
28	(2)	(3)	(3)	(3)	(3)
30	(2)	(3)	(3)	(3)	(3)
32	(2)	(3)	(3)	(3)	(3)
34	(2)	(3)	(3)	(3)	(3)
36	(2)	(3)	(3)	(3)	(3)
38	(2)	(3)	(3)	(3)	(3)
40	(2)	(3)	(3)	(3)	(3)
42	(2)	(3)	(3)	(3)	(3)
44	(2)	(3)	(3)	(3)	(3)
46	(2)	(3)	(3)	(3)	(3)
48	(2)	(3)	(3)	(3)	(3)
50	(2)	(3)	(3)	(3)	(4)
52	(2)	(3)	(3)	(3)	(4)
56	(2)	(3)	(3)	(3)	(4)
58	(2)	(3)	(3)	(3)	(4)
60	(2)	(3)	(3)	(3)	(4)

GENERAL NOTE: This table shows the maximum bore of flanges for which the spiral-wound gasket dimensions shown in Table 10 are recommended, considering the tolerances involved, the possibility of eccentric installation, and the possibility that the gasket may extend into the assembled flange bore.

NOTES:

(1) Inner rings are required for Class 900 gaskets, NPS 26 through NPS 48 (see para. 3.2.5).

(2) Applies only to welding neck flanges with a bore not larger than the inside diameter of a 0.187-in. wall pipe. Larger bores must be checked individually.

(3) Applies only to welding neck flanges with a bore not larger than the inside diameter of a 0.25-in. wall pipe, except that NPS 38, Class 300, is not suitable for a bore larger than the inside diameter of a 0.30-in. wall pipe. Larger bores must be checked individually.

(4) There are no Class 900 flanges in NPS 50 through 60.

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TABLE 18 MAXIMUM BORE OF ASME B16.47 SERIES B FLANGES FOR USE WITH SPIRAL-WOUND GASKETS

Flange Size (NPS)	Pressure Class				
	150	300	400	600	900 (1)
26	Welding neck and integral flanges having maximum inside diameters as described in ASME B16.47				
28					
30					
32					
34					
36					
38					
40					
44					
46					
48					
50					(2)
52					(2)
54					(2)
56					(2)
58					(2)
60					(2)

GENERAL NOTE: This table shows the maximum bore of flanges for which the spiral-wound gasket dimensions shown in Table 11 are recommended, considering the tolerances involved, the possibility of eccentric installation, and the possibility that the gasket may extend into the assembled flange bore.

NOTES:

(1) Inner rings are required for Class 900 gaskets, NPS 26 through NPS 48 (see para. 3.2.5).

(2) There are no Class 900 flanges NPS 50 and larger.

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TABLE 19 COLOR CODING AND ABBREVIATIONS FOR SPIRAL-WOUND GASKET MATERIALS

Metallic Winding Materials		
Material	**Abbreviation**	**Color Code**
Carbon steel	CRS	Silver
304 SS	304	Yellow
304 L SS	304 L	No color
309 SS	309	No color
310 SS	310	No color
316 L SS	316 L	Green
347 SS	347	Blue
321 SS	321	Turquoise
430 SS	430	No color
Ni–Cu	...	...
Monel 400	MON	Orange
Grade 400	...	...
Nickel 200	NI	Red
Titanium	TI	Purple
20Cb-3 alloy	A-20	Black
Ni–Mo	...	...
Hastelloy B	HAST B	Brown
Grade B2	...	...
Ni–Mo–Cr	...	...
Hastelloy C	HAST C	Beige
Grade C-276	...	...
Ni–Cr–Fe	...	...
Inconel 600	INC 600	Gold
Grade 600	...	...
Ni–Cr–Fe–Cb	...	...
Inconel 625	INC 625	Gold
Grade 625	...	...
Ni–Cr–Fe–Ti	...	...
Inconel X-750	INX	No color
Grade X-750	...	...
Ni–Fe–Cr	...	...
Incoloy 800	IN 800	White
Grade 800	...	...
Ni–Fe–Cr–Mo–Cu	...	...
Incoloy 825	IN 825	White
Grade 825	...	...
Zirconium	ZIRC	No color

(*continued*)

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TABLE 19 COLOR CODING AND ABBREVIATIONS FOR SPIRAL-WOUND GASKET MATERIALS (CONT'D)

Nonmetallic Filler Materials		
Material	**Abbreviation**	**Color Code**
Chrysotile asbestos	ASB	No stripe
Polytetrafluoroethylene	PTFE	White stripe
Mica-graphite	Mfr.'s designation	Pink stripe
Flexible-graphite	F.G.	Gray stripe
Ceramic	CER	Light green stripe

TABLE 20 EXAMPLE MARKINGS FOR SPIRAL-WOUND GASKETS

Description	Marking
NPS 3, Class 300 and 600 ASME B16.5 gasket having a Type 304 metal winding and a flexible graphite filler material	3–300/600—F.G. (Manufacturer's trademark) ASME B16.20
NPS 36, Class 300 ASME B16.47 Series A gasket having a Type 304 metal winding and a ceramic filler material	36–300—CER ASME B16.47 A (Manufacturer's trademark) ASME B16.20
NPS 12, Class 1500 ASME B16.5 gasket having an inconel metal winding, PTFE filler material, and an inconel inner ring	12–1500 INC 600—PTFE INC 600 I.R. (Manufacturer's trademark) ASME B16.20

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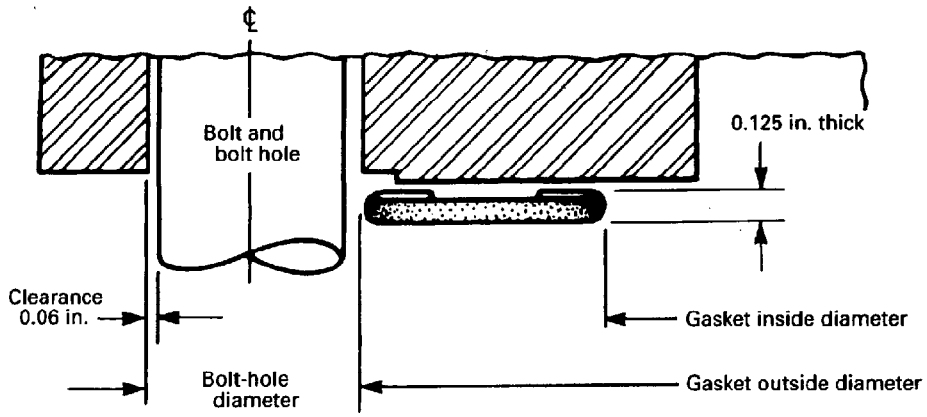

TABLE 21 JACKETED GASKET DIMENSIONS FOR ASME B16.5 FLANGES

Flange Size (NPS)	Gasket Inside Diameter (1)	Gasket Outside Diameter by Class (1)						
		150	300	400 (2)	600	900 (3)	1500	2500 (4)
½	0.88	1.75	2.00	...	2.00	...	2.38	2.63
¾	1.13	2.13	2.50	...	2.50	...	2.63	2.88
1	1.50	2.50	2.75	...	2.75	...	3.00	3.25
1¼	1.88	2.88	3.13	...	3.13	...	3.38	4.00
1½	2.13	3.25	3.63	...	3.63	...	3.75	4.50
2	2.88	4.00	4.25	...	4.25	...	5.50	5.63
2½	3.38	4.75	5.00	...	5.00	...	6.38	6.50
3	4.25	5.25	5.75	...	5.75	6.50	6.75	7.63
4	5.19	6.75	7.00	6.88	7.50	8.00	8.13	9.13
5	6.00	7.63	8.38	8.25	9.38	9.63	9.88	10.88
6	7.50	8.63	9.75	9.63	10.38	11.25	11.00	12.38
8	9.38	10.88	12.00	11.88	12.50	14.00	13.75	15.13
10	11.25	13.25	14.13	14.00	15.63	17.00	17.00	18.63
12	13.50	16.00	16.50	16.38	17.88	19.50	20.38	21.50
14	14.75	17.63	19.00	18.88	19.25	20.38	22.63	...
16	16.75	20.13	21.13	21.00	22.13	22.50	25.13	...
18	19.25	21.50	23.38	23.25	24.00	25.00	27.63	...
20	21.00	23.75	25.63	25.38	26.75	27.38	29.63	...
24	25.25	28.13	30.38	30.13	31.00	32.88	35.38	...

GENERAL NOTE: The gasket-thickness tolerance is +0.03 in., −0.000 in.

NOTES:

(1) For gaskets NPS ½ through NPS 24, the outside and inside diameter tolerances are +0.06 in., −0.000 in.

(2) There are no Class 400 flanges NPS ½ through NPS 3 (use Class 600).

(3) There are no Class 900 flanges NPS ½ through NPS 2½ (use Class 1500).

(4) There are no Class 2500 flanges NPS 14 and larger.

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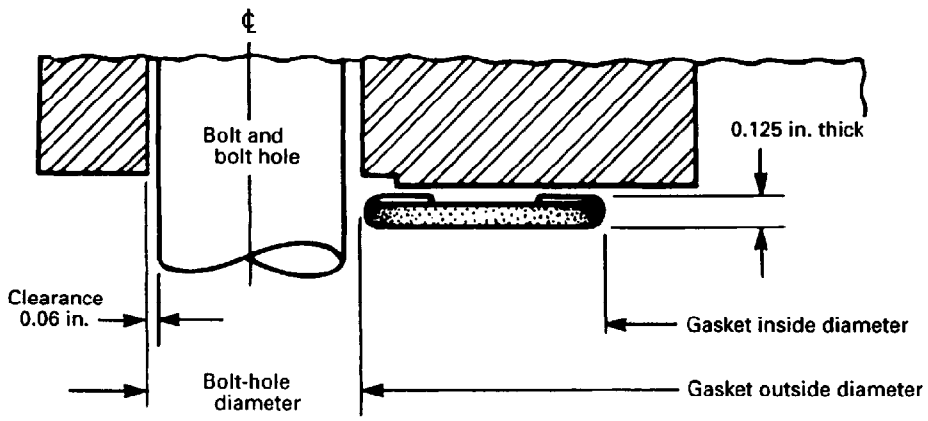

TABLE 22 JACKETED GASKET DIMENSIONS FOR ASME B16.47 SERIES A FLANGES

Flange Size (NPS)	Gasket Inside Diameter (1)	Gasket Outside Diameter by Class (1)				
		150	300	400	600	900 (2)
26	26.50	30.38	32.75	32.63	34.00	34.63
28	28.50	32.63	35.25	35.00	35.88	37.13
30	30.50	34.63	37.38	37.13	38.13	39.63
32	32.50	36.88	39.50	39.38	40.13	42.13
34	34.50	38.88	41.50	41.38	42.13	44.63
36	36.50	41.13	43.88	43.88	44.38	47.13
38	38.50	43.63	41.38	42.13	43.38	47.13
40	40.50	45.63	43.75	44.25	45.38	49.13
42	42.50	47.88	45.75	46.25	47.88	51.13
44	44.50	50.13	47.88	48.38	49.88	53.75
46	46.50	52.13	50.00	50.63	52.13	56.38
48	48.50	54.38	52.00	52.88	54.63	58.38
50	50.50	56.38	54.13	55.13	56.88	...
52	52.50	58.63	56.13	57.13	58.88	...
54	54.50	60.88	58.63	59.63	61.13	...
56	56.50	63.13	60.63	61.63	63.13	...
58	58.50	65.38	62.63	63.63	65.38	...
60	60.50	67.38	64.63	66.13	68.13	...

GENERAL NOTE: The gasket–thickness tolerance is +0.03 in., −0.000 in.

NOTES:

(1) For gaskets NPS 26 through NPS 60, the outside diameter and inside diameter tolerances are +0.13 in., −0.000 in.

(2) There are no Class 900 flanges NPS 50 and larger.

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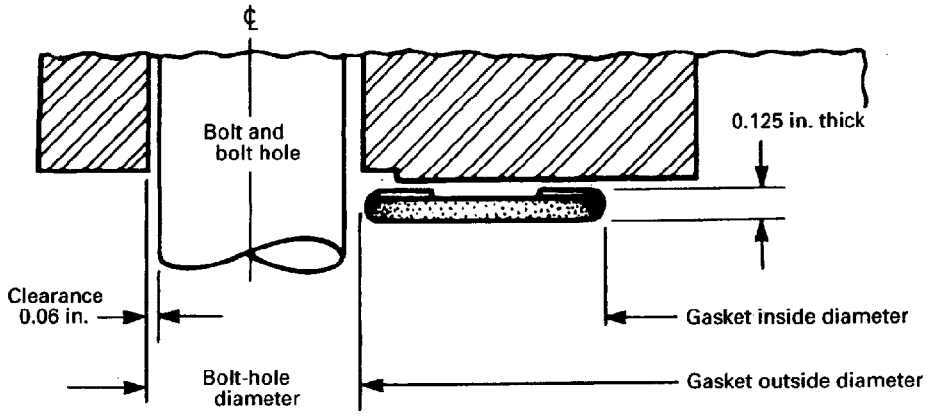

TABLE 23 JACKETED GASKET DIMENSIONS FOR ASME B16.47 SERIES B FLANGES

Flange Size (NPS)	Gasket Inside Diameter (1)	Gasket Outside Diameter by Class (1)				
		150	300	400	600	900 (2)
26	26.50	28.44	30.25	29.25	30.00	32.88
28	28.50	30.44	32.38	31.38	32.13	35.38
30	30.50	32.44	34.75	33.63	34.50	37.63
32	32.50	34.56	36.88	35.75	36.63	39.88
34	34.50	36.69	39.00	37.75	39.13	42.13
36	36.50	38.75	41.13	40.13	41.13	44.13
38	38.50	41.00	43.13	42.13	43.38	47.13
40	40.50	43.00	45.13	44.25	45.38	49.13
42	42.50	45.00	47.13	46.25	47.88	51.13
44	44.50	47.00	49.13	48.38	49.88	53.75
46	46.50	49.31	51.75	50.63	52.13	56.38
48	48.50	51.31	53.75	52.88	54.63	58.38
50	50.50	53.31	55.75	55.13	56.88	...
52	52.50	55.31	57.75	57.13	58.88	...
54	54.50	57.50	60.13	59.63	61.13	...
56	56.50	59.50	62.63	61.63	63.13	...
58	58.50	62.06	65.06	63.63	65.38	...
60	60.50	64.06	67.06	66.13	68.13	...

GENERAL NOTE: The gasket-thickness tolerance is +0.03 in., −0.000 in.

NOTES:

(1) For gaskets NPS 26 through NPS 60, the outside diameter and inside diameter tolerances are +0.13 in., −0.000 in.

(2) There are no Class 900 flanges NPS 50 and larger.

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TABLE 24 ABBREVIATIONS FOR IDENTIFYING MATERIALS FOR JACKETED GASKETS

Material		Abbreviation
	Metals	
Al	Aluminum	AL
CRS	Carbon steel	CS
Cu	Copper	CU
Ni–Mo (grade B2)	Hastelloy B	HAST B
Ni–Mo–Cr (grade C-276)	Hastelloy C	HAST C
Ni–Cr–Fe (grade 600)	Inconel 600	INC 600
Ni–Cr–Fe–Cb (grade 625)	Inconel 625	INC 625
Ni–Fe–Cr (grade 800)	Incoloy 800	IN 800
Ni–Cr–Fe–Ti (grade X-750)	Inconel X-750	INX
Ni–Cu (grade 400)	Monel	MON
Nickel 200	Nickel	NI
Soft iron	Soft iron	Soft iron
Ni–Cr	Stainless steels	3-digit
Ta	Tantalum	TANT
Ti	Titanium	TI
	Fillers	
	Asbestos	ASB
	Ceramic	CER
	Flexible graphite	F.G.
	Polytetrafluoroethylene	PTFE

TABLE 25 EXAMPLE MARKINGS FOR JACKETED GASKETS

Description	Marking
NPS 2½, Class 150 ASME B16.5 gasket having a Type 304 metal jacket and a flexible graphite filler material	2½–150—304/F.G. (Manufacturer's trademark) ASME B16.20
NPS 30, Class 300 ASME B16.47 Series B gasket having a carbon-steel jacket and a ceramic filler material	30–300—CS/CER ASME B16.47 B (Manufacturer's trademark) ASME B16.20

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MANDATORY ANNEX I
REFERENCES

The following is a list of publications referenced in this Standard.

ASME B16.5-1996, Pipe Flanges and Flanged Fittings[1]

ASME B16.47-1996, Large Diameter Steel Flanges: NPS 26 through NPS 60[1]

ASME B36.10M-1996, Welded and Seamless Wrought Steel Pipe[1]

ASME B36.19M-1985 (R1994), Stainless Steel Pipe[1]

Publisher: American Society of Mechanical Engineers (ASME), Three Park Ave., New York, NY 10016; Order Department: 22 Law Drive, Box 2300, Fairfield, NJ 07007

ISO 9000-1: 1994, Quality management and quality assurance standards — Part 1: Guidelines for selection and use

ISO 9000-2: 1997, Quality management and quality assurance standards — Part 2: Generic guidelines for the application of ISO 9001, ISO 9002, and ISO 9003

ISO 9000-3: 1991, Quality management and quality assurance standards — Part 3: Guidelines for the application of ISO 9001 to the development, supply, installation, and maintenance of computer software

ISO 9001: 1994, Quality systems — Model for quality assurance in design, development, production, installation, and servicing

ISO 9002: 1994, Quality systems — Model for quality assurance in production, installation, and servicing

ISO 9003: 1994, Quality systems — Model for quality assurance in final inspection and test

Publisher: International Organization for Standardization (ISO), 1 rue de Varembé, Case postale 56, CH-1121 Genève 20, Switzerland/Suisse

API Specification 6A — 17th Edition — 1996, Specification for Valves and Wellhead Equipment

Publisher: American Petroleum Institute (API), 1220 L Street, NW, Washington, DC 20005

[1] May also be obtained from the American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036.

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NONMANDATORY ANNEX A
QUALITY SYSTEM PROGRAM

The products manufactured in accordance with this Standard shall be produced under a quality system program following the principles of an appropriate standard from the ISO 9000 series.[1] A determination of the need for registration and/or certification of the product manufacturer's quality system program by an independent organization shall be the responsibility of the manufacturer. Detailed documentation demonstrating program compliance shall be available to the purchaser at the manufacturer's facility. A written, summarized description of the program used by the product manufacturer shall be available to the purchaser upon request. The product manufacturer is defined as the entity whose name or trademark appears on the product in accordance with the marking or identification requirements of this Standard.

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[1] The series is also available from the American National Standards Institute (ANSI) and the American Society for Quality (ASQ) as American National Standards that are identified by a prefix "Q" replacing the prefix "ISO". Each standard of the series is listed in Annex I.

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AMERICAN NATIONAL STANDARDS FOR PIPING, PIPE FLANGES, FITTINGS, AND VALVES

Scheme for the Identification of Piping Systems A13.1-1996
Pipe Threads, General Purpose (Inch) ..... B1.20.1-1983(R1992)
Dryseal Pipe Threads (Inch) ..... B1.20.3-1976(R1991)
Cast Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250 ..... B16.1-1998
Malleable Iron Threaded Fittings: Classes 150 and 300 ..... B16.3-1998
Gray Iron Threaded Fittings: Classes 125 and 250 ..... B16.4-1998
Pipe Flanges and Flanged Fittings (NPS ½ Through NPS 24) B16.5-1996
Factory-Made Wrought Steel Buttwelding Fittings B16.9-1993
Face-to-Face and End-to-End Dimensions of Valves B16.10-1992
Forged Fittings, Socket-Welding and Threaded B16.11-1996
Cast Iron Threaded Drainage Fittings B16.12-1998
Ferrous Pipe Plugs, Bushings, and Locknuts with Pipe Threads B16.14-1991
Cast Bronze Threaded Fittings: Classes 125 and 250 ..... B16.15-1985(R1994)
Cast Copper Alloy Solder Joint Pressure Fittings ..... B16.18-1984(R1994)
Metallic Gaskets for Pipe Flanges: Ring-Joint, Spiral-Wound, and Jacketed B16.20-1998
Nonmetallic Flat Gaskets for Pipe Flanges B16.21-1992
Wrought Copper and Copper Alloy Solder Joint Pressure Fittings B16.22-1995
Cast Copper Alloy Solder Joint Drainage Fittings — DWV B16.23-1992
Cast Copper Alloy Pipe Flanges and Flanged Fittings: Classes 150, 300, 400, 600, 900, 1500, and 2500 ..... B16.24-1991(R1998)
Buttwelding Ends B16.25-1997
Cast Copper Alloy Fittings for Flared Copper Tubes B16.26-1988
Wrought Steel Buttwelding Short Radius Elbows and Returns B16.28-1994
Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings — DWV B16.29-1994
Manually Operated Metallic Gas Valves for Use in Gas Piping Systems up to 125 psig (Sizes ½ Through 2) B16.33-1990
Valves — Flanged, Threaded, and Welding End B16.34-1996
Orifice Flanges B16.36-1996
Large Metallic Valves for Gas Distribution (Manually Operated, NPS 2½ to 12, 125 psig Maximum) ..... B16.38-1985(R1994)
Malleable Iron Threaded Pipe Unions B16.39-1998
Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems ..... B16.40-1985(R1994)
Ductile Iron Pipe Flanges and Flanged Fittings, Classes 150 and 300 ..... B16.42-1998
Manually Operated Metallic Gas Valves for Use in House Piping Systems B16.44-1995
Cast Iron Fittings for Sovent® Drainage Systems B16.45-1998
Large Diameter Steel Flanges (NPS 26 Through NPS 60) B16.47-1996
Steel Line Blanks B16.48-1997
Power Piping B31.1-1995
Fuel Gas Piping (not an ANSI standard) B31.2-1968
Process Piping B31.3-1999
Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids B31.4-1992
Refrigeration Piping B31.5-1992
Gas Transmission and Distribution Piping Systems B31.8-1995
Building Services Piping B31.9-1996
Slurry Transportation Piping Systems B31.11-1989
Manual for Determining the Remaining Strength of Corroded Pipelines B31G-1991
Welded and Seamless Wrought Steel Pipe B36.10M-1996
Stainless Steel Pipe ..... B36.19M-1985(R1994)
Self-Operated and Power-Operated Safety-Related Valves Functional Specification Standard ..... N278.1-1975(R1992)

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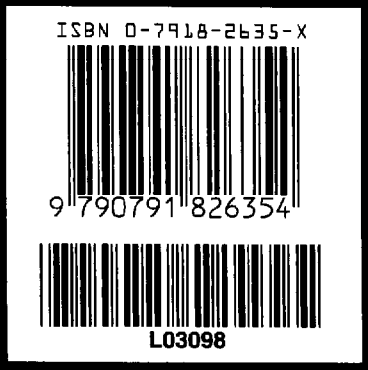

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ASME B16.21 92 ■ 0759670 0528728 0T1 ■

ASME B16.21-1992

(REVISION OF ANSI B16.21-1978)

Nonmetallic Flat Gaskets for Pipe Flanges

AN AMERICAN NATIONAL STANDARD

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ASME-B16.21

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AN AMERICAN NATIONAL STANDARD

Nonmetallic Flat Gaskets for Pipe Flanges

ASME B16.21-1992

(REVISION OF ANSI B16.21-1978)

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FOREWORD

(This Foreword is not part of ASME B16.21-1992.)

Several years ago the Standards and Specifications Committee of the Mechanical Packing Association started work on a standard for nonmetallic or cut gaskets for bronze, iron, and steel pipe flanges. Up to that time the individual sizes of gaskets were made to many different sets of dimensions, based on different concepts of adaption and functional use on the part of consumers as well as manufacturers. In some cases dimensions were shown in American Standards.

Dimensions of gaskets being used were collected, and a basic design philosophy for sizing was formulated by the committee. This was the result of extensive field research experience and accepted standard user requirements. The procedure followed was to dimension the gasket for each type and size of flange so as to prevent the gasket from projecting into the line of flow. Dimensional tolerances of standard pipe flanges and fittings as to ID, OD, and bolting were all considered.

Suggested dimensional standards were tabulated and distributed for industry comment. After several revisions a final draft, dated September 15, 1948, was approved by the Mechanical Packing Association for submission as an American Standard.

Sectional Committee (B16) on the Standardization of Pipe Flanges and Fittings was organized in 1921 under the procedure of the American Standards Association, with the Heating, Piping, and Air Conditioning Contractors' National Association, Manufacturers' Standardization Society of the Valve and Fittings Industry, and The American Society of Mechanical Engineers as joint sponsors.

Sectional Committee B16 received the proposal on May 9, 1949, and assigned it to a joint group of Subcommittees 1 and 3. The Manufacturers' Standardization Society was also consulted as the proposal included gaskets for bronze flanges made to their Standard Practice SP-2. This joint group offered a revision of the original design concept for sizing which was acceptable to the Mechanical Packing Association's Committee (now the Fluid Sealing Association). The standard was approved as an American Standard on December 5, 1951, with the designation ASA B16.21-1951.

In 1961, the standard was reviewed by the members of Subcommittee No. 7 on Gaskets and proposals for revision and updating the standard were agreed upon. The American Standards Assocation granted approval of the revision on March 20, 1962 following sectional committee and sponsor approval.

In the mid-1960's work was begun on a revision. The revision became a complete rewrite and included gaskets for API Std 605, MSS SP-44 and SP-51 as well as complete metric equivalents for all dimensions. Following its approval by the B16 Standards Committee and Co-Secretariat organizations, this Standard was approved as an American National Standard by ANSI on May 2, 1978.

In 1982, American National Standards Committee B16 was reorganized as an ASME Committee operating under procedures accredited by ANSI.

In 1989, general revisions were begun to reflect the current size ranges covered by the corresponding flange standards. Gasket dimensions for tongue and groove, male and

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female and Rating Classes above 900 were deleted because a survey indicated these nonmetallic gaskets were almost never used for these joints. Tolerances to the dimensions were added.

Following approval by the Standards Committee and ASME, approval as an American National Standard was given by ANSI on March 16, 1992, with the new designation ASME B16.21-1992.

All requests for interpretations or suggestions for revisions should be sent to the Administrative Secretary B16, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.

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Standardization of Valves, Flanges, Fittings, Gaskets, and Valve Actuators

(The following is the roster of the Committee at the time of approval of this Standard.)

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NONMETALLIC FLAT GASKETS FOR PIPE FLANGES

1 SCOPE

This Standard for nonmetallic flat gaskets for bolted flanged joints in piping includes:

(*a*) types and sizes;
(*b*) materials;
(*c*) dimensions and allowable tolerances.

2 TYPES

Dimensions are provided for the following types of gaskets which are suitable for use with the flange facings indicated:

Gasket Type	Flange Facing
full face	flat face flanges
flat ring	raised face

3 SIZES

The sizes of flanges for which dimensions are given in the tables are included in the standards listed under para. 5.3.[1] Those sizes are expressed in nominal pipe size (NPS) as described in ANSI/ASME B36.10 M.

4 MATERIALS

4.1 Composition

Gaskets shall be made of resilient or pliable materials. Metal may be incorporated as reinforcing or filler material.

4.2 Service Requirements

Selection of a suitable material for a given service is the responsibility of the user, subject to the requirements of the referenced standard (see para. 5.3) and any applicable code or government regulation. The material selected shall be compatible with the fluid and suitable for the pressure-temperature conditions of the service.

5 DIMENSIONS

5.1 Thickness

Selection of gasket thickness is the responsibility of the user, considering the properties of the gasket material as well as the intended service application.

5.2 Diameters

The tabulated diameters are based on the following:

(*a*) The outside diameter of flat ring gaskets is equal to the bolt circle diameter minus the bolt diameter so that the gasket is centered in the flange bolts.

(*b*) The outside diameter of full face gaskets is equal to the flange outside diameter.

(*c*) The inside diameter of all gaskets is equal to the outside diameter of pipe required by ANSI/ASME B36.10M.[2]

5.3 Dimensional Tables

Tables are provided for each of the following referenced flange standards.

5.3.1 ASME/ANSI B16.1 Cast Iron Pipe Flanges and Flanged Fittings

(*a*) Table 1 (Class 25) and Table 2 (Class 125) provide dimensions for flat rung and full face gaskets.

(*b*) Table 3 (Class 250) provides dimensions for flat ring gaskets.

[1] Standards and specifications referenced in this Standard are listed in Annex A. The specific edition is not identified in text references. Instead, the edition reference is specified in Annex A.

[2] The user may require that the inside diameter of the gasket matches the inside diameter of the pipe.

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TABLE 1 GASKET DIMENSIONS FOR ASME/ANSI B16.1 CLASS 25 CAST IRON PIPE FLANGES AND FLANGED FITTINGS

			Full Face Gasket			
Nominal Pipe Size	Gasket ID	Flat Ring OD	OD	Number of Holes	Hole Diameter	Bolt Circle Diameter
4	4.50	6.88	9.00	8	0.75	7.50
5	5.56	7.88	10.00	8	0.75	8.50
6	6.62	8.88	11.00	8	0.75	9.50
8	8.62	11.12	13.50	8	0.75	11.75
10	10.75	13.62	16.00	12	0.75	14.25
12	12.75	16.38	19.00	12	0.75	17.00
14	14.00	18.00	21.00	12	0.88	18.75
16	16.00	20.50	23.50	16	0.88	21.25
18	18.00	22.00	25.00	16	0.88	22.75
20	20.00	24.25	27.50	20	0.88	25.00
24	24.00	28.75	32.00	20	0.88	29.50
30	30.00	35.12	38.75	28	1.00	36.00
36	36.00	41.88	46.00	32	1.00	42.75
42	42.00	48.50	53.00	36	1.12	49.50
48	48.00	55.00	59.50	44	1.12	56.00
54	54.00	61.75	66.25	44	1.12	62.75
60	60.00	68.12	73.00	52	1.25	69.25
72	72.00	81.38	86.50	60	1.25	82.50
84	84.00	94.25	99.75	64	1.38	95.50
96	96.00	107.25	113.25	68	1.38	108.50

GENERAL NOTE: Dimensions are in inches.

5.3.2 ASME/ANSI B16.5 Pipe Flanges and Flanged Fittings

(*a*) Dimensions in Tables 4 and 5 also apply to flanged valves (ASME/ANSI B16.34).

(*b*) Table 4 (Class 150) provides dimensions for flat ring and full face gaskets.

(*c*) Table 5 (Classes 300, 400, 600, and 900) provides dimensions for flat ring gaskets.

5.3.3 ASME B16.24 Cast Copper Alloy Pipe Flanges and Flanged Fittings. Table 6 provides dimensions for full face gaskets.

5.3.4 ASME B16.47 Large Diameter Steel Flanges

(*a*) Table 7 provides flat ring gasket dimensions for Series A (formerly MSS SP-44) flanges, Classes 150, 300, 400, and 600.

(*b*) Table 8 provides flat ring gasket dimensions for Series B (formerly API Standard 605) flanges, Classes 75, 150, 300, 400, and 600.

5.3.5 MSS SP-51 Class 150 LW Corrosion Resistant Cast Flanges and Flanged Fittings

(*a*) Table 9 provides dimensions for full face gaskets.

(*b*) These dimensions apply also to MSS SP-42 valves.

6 TOLERANCES

Outside diameter
NPS 12 and smaller: +zero, −0.06 in.
NPS 14 and larger: +zero, −0.12 in.

Inside diameter
NPS 12 and smaller: ±0.06 in.
NPS 14 and larger: ±0.12 in.

Bolt circle diameter: ±0.06 in.

Center-to-center of adjacent bolt holes: ±0.03 in.

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TABLE 2 GASKET DIMENSIONS FOR ASME/ANSI B16.1 CLASS 125 CAST IRON PIPE FLANGES AND FLANGED FITTINGS

			Full Face Gasket			
Nominal Pipe Size	Gasket ID	Flat Ring OD	OD	Number of Holes	Hole Diameter	Bolt Circle Diameter
1	1.31	2.62	4.25	4	0.62	3.12
1¼	1.66	3.00	4.62	4	0.62	3.50
1½	1.91	3.38	5.00	4	0.62	3.88
2	2.38	4.12	6.00	4	0.75	4.75
2½	2.88	4.88	7.00	4	0.75	5.50
3	3.50	5.38	7.50	4	0.75	6.00
3½	4.00	6.38	8.50	8	0.75	7.00
4	4.50	6.88	9.00	8	0.75	7.50
5	5.56	7.75	10.00	8	0.88	8.50
6	6.62	8.75	11.00	8	0.88	9.50
8	8.62	11.00	13.50	8	0.88	11.75
10	10.75	13.88	16.00	12	1.00	14.25
12	12.75	16.12	19.00	12	1.00	17.00
14	14.00	17.75	21.00	12	1.12	18.75
16	16.00	20.25	23.50	16	1.12	21.25
18	18.00	21.62	25.00	16	1.25	22.75
20	20.00	23.88	27.50	20	1.25	25.00
24	24.00	28.25	32.00	20	1.38	29.50
30	30.00	34.75	38.75	28	1.38	36.00
36	36.00	41.25	46.00	32	1.62	42.75
42	42.00	48.00	53.00	36	1.62	49.50
48	48.00	54.50	59.50	44	1.62	56.00

GENERAL NOTE: Dimensions are in inches.

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TABLE 3 FLAT RING GASKET DIMENSIONS FOR ASME/ANSI B16.1 CLASS 250 CAST IRON PIPE FLANGES AND FLANGED FITTINGS

Nominal Pipe Size	Gasket ID	Flat Ring OD	Nominal Pipe Size	Gasket ID	Flat Ring OD
1	1.31	2.88	12	12.75	16.62
1¼	1.66	3.25	14	14.00	19.12
1½	1.91	3.75	16	16.00	21.25
2	2.38	4.38	18	18.00	23.50
2½	2.88	5.12	20	20.00	25.75
3	3.50	5.88	24	24.00	30.50
3½	4.00	6.50	30	30.00	37.50
4	4.50	7.12	36	36.00	44.00
5	5.56	8.50	42	42.00	50.75
6	6.62	9.88	48	48.00	58.75
8	8.62	12.12			
10	10.75	14.25			

GENERAL NOTE: Dimensions are in inches.

TABLE 4 GASKET DIMENSIONS FOR ASME/ANSI B16.5 CLASS 150 PIPE FLANGES AND FLANGED FITTINGS

Nominal Pipe Size	Gasket ID	Flat Ring OD	Full Face Gasket OD	No. of Holes	Hole Diameter	Bolt Circle Diameter	Nominal Pipe Size	Gasket ID	Flat Ring OD	Full Face Gasket OD	No. of Holes	Hole Diameter	Bolt Circle Diameter
½	0.84	1.88	3.50	4	0.62	2.38	8	8.62	11.00	13.50	8	0.88	11.75
¾	1.06	2.25	3.88	4	0.62	2.75	10	10.75	13.38	16.00	12	1.00	14.25
1	1.31	2.62	4.25	4	0.62	3.12	12	12.75	16.13	19.00	12	1.00	17.00
1¼	1.66	3.00	4.63	4	0.62	3.50	14	14.00	17.75	21.00	12	1.12	18.75
1½	1.91	3.38	5.00	4	0.62	3.88	16	16.00	20.25	23.50	16	1.12	21.25
2	2.38	4.12	6.00	4	0.75	4.75	18	18.00	21.62	25.00	16	1.25	22.75
2½	2.88	4.88	7.00	4	0.75	5.50	20	20.00	23.88	27.50	20	1.25	25.00
3	3.50	5.38	7.50	4	0.75	6.00	24	24.00	28.25	32.00	20	1.38	29.50
3½	4.00	6.38	8.50	8	0.75	7.00							
4	4.50	6.88	9.00	8	0.75	7.50							
5	5.56	7.75	10.00	8	0.88	8.50							
6	6.62	8.75	11.00	8	0.88	9.50							

GENERAL NOTE: Dimensions are in inches.

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TABLE 5 FLAT RING GASKET DIMENSIONS FOR ASME/ANSI B16.5 PIPE FLANGES AND FLANGED FITTINGS, CLASSES 300, 400, 600, AND 900

Nominal Pipe Size	Gasket ID	Gasket OD			
		Class 300	Class 400	Class 600	Class 900
½	0.84	2.12	2.12	2.12	2.50
¾	1.06	2.62	2.62	2.62	2.75
1	1.31	2.88	2.88	2.88	3.12
1¼	1.66	3.25	3.25	3.25	3.50
1½	1.91	3.75	3.75	3.75	3.88
2	2.38	4.38	4.38	4.38	5.62
2½	2.88	5.12	5.12	5.12	6.50
3	3.50	5.88	5.88	5.88	6.62
3½	4.00	6.50	6.38	6.38	...
4	4.50	7.12	7.00	7.62	8.12
5	5.56	8.50	8.38	9.50	9.75
6	6.62	9.88	9.75	10.50	11.38
8	8.62	12.12	12.00	12.62	14.12
10	10.75	14.25	14.12	15.75	17.12
12	12.75	16.62	16.50	18.00	19.62
14	14.00	19.12	19.00	19.38	20.50
16	16.00	21.25	21.12	22.25	22.62
18	18.00	23.50	23.38	24.12	25.12
20	20.00	25.75	25.50	26.88	27.50
24	24.00	30.50	30.25	31.12	33.00

GENERAL NOTE: Dimensions are in inches.

TABLE 6 FULL FACE GASKET DIMENSIONS FOR ASME B16.24 CAST COPPER ALLOY PIPE FLANGES AND FLANGED FITTINGS, CLASSES 150 AND 300

Nominal Pipe Size	Gasket ID	Class 150 Gaskets				Class 300 Gaskets			
		OD	Number of Holes	Hole Diameter	Bolt Circle Diameter	OD	Number of Holes	Hole Diameter	Bolt Circle Diameter
½	0.84	3.50	4	0.62	2.38	3.75	4	0.62	2.62
¾	1.06	3.88	4	0.62	2.75	4.62	4	0.75	3.25
1	1.31	4.25	4	0.62	3.12	4.88	4	0.75	3.50
1¼	1.66	4.62	4	0.62	3.50	5.25	4	0.75	3.88
1½	1.91	5.00	4	0.62	3.88	6.12	4	0.88	4.50
2	2.38	6.00	4	0.75	4.75	6.50	8	0.75	5.00
2½	2.88	7.00	4	0.75	5.50	7.50	8	0.88	5.88
3	3.50	7.50	4	0.75	6.00	8.25	8	0.88	6.62
3½	4.00	8.50	8	0.75	7.00	9.00	8	0.88	7.25
4	4.50	9.00	8	0.75	7.50	10.00	8	0.88	7.88
5	5.56	10.00	8	0.88	8.50	11.00	8	0.88	9.25
6	6.62	11.00	8	0.88	9.50	12.50	12	0.88	10.63
8	8.62	13.50	8	0.88	11.75	15.00	12	1.00	13.00
10	10.75	16.00	12	1.00	14.25	...	...	...	...
12	12.75	19.00	12	1.00	17.00	...	...	...	...

GENERAL NOTE: Dimensions are in inches.

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TABLE 7 FLAT RING GASKET DIMENSIONS FOR ASME B16.47 SERIES A LARGE DIAMETER STEEL FLANGES, CLASSES 150, 300, 400, AND 600

Nominal Pipe Size	ID	OD			
		Class 150	Class 300	Class 400	Class 600
22 (1)	22.00	26.00	27.75	27.63	28.88
26	26.00	30.50	32.88	32.75	34.12
28	28.00	32.75	35.38	35.12	36.00
30	30.00	34.75	37.50	37.25	38.25
32	32.00	37.00	39.62	39.50	40.25
34	34.00	39.00	41.62	41.50	42.25
36	36.00	41.25	44.00	44.00	44.50
38	38.00	43.75	41.50	42.26	43.50
40	40.00	45.75	43.88	44.58	45.50
42	42.00	48.00	45.88	46.38	48.00
44	44.00	50.25	48.00	48.50	50.00
46	46.00	52.25	50.12	50.75	52.26
48	48.00	54.50	52.12	53.00	54.75
50	50.00	56.50	54.25	55.25	57.00
52	52.00	58.75	56.25	57.26	59.00
54	54.00	61.00	58.75	59.75	61.25
56	56.00	63.25	60.75	61.75	63.50
58	58.00	65.50	62.75	63.75	65.50
60	60.00	67.50	64.75	66.25	67.75

GENERAL NOTE: Dimensions are in inches.

NOTE:
(1) NPS 22 for reference only. Size not listed in ASME B16.47.

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TABLE 8 FLAT RING GASKET DIMENSIONS FOR ASME B16.47 SERIES B LARGE DIAMETER STEEL FLANGES, CLASSES 75, 150, 300, 400, AND 600

Nominal Pipe Size	Gasket ID	Gasket OD				
		Class 75	Class 150	Class 300	Class 400	Class 600
26	26.00	27.88	28.56	30.38	29.38	30.12
28	28.00	29.88	30.56	32.50	31.50	32.25
30	30.00	31.88	32.56	34.88	33.75	34.62
32	32.00	33.88	34.69	37.00	35.88	36.75
34	34.00	35.88	36.81	39.12	37.88	39.25
36	36.00	38.31	38.88	41.25	40.25	41.25
38	38.00	40.31	41.12	43.25	...	...
40	40.00	42.31	43.12	45.25	...	...
42	42.00	44.31	45.12	47.25	...	...
44	44.00	46.50	47.12	49.25	...	...
46	46.00	48.50	49.44	51.88	...	...
48	48.00	50.50	51.44	53.88	...	...
50	50.00	52.50	53.44	55.88	...	...
52	52.00	54.62	55.44	57.88	...	...
54	54.00	56.62	57.62	61.25	...	...
56	56.00	58.88	59.62	62.75	...	...
58	58.00	60.88	62.19	65.19	...	...
60	60.00	62.88	64.19	67.12	...	...

GENERAL NOTE: Dimensions are in inches.

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TABLE 9 FULL FACE GASKET DIMENSIONS FOR MSS SP-51 CLASS 150LW CORROSION RESISTANT CAST FLANGES AND FLANGED FITTINGS

Nominal Pipe Size	Gasket ID	Gasket OD	Number of Holes	Hole Diameter	Bolt Circle Diameter
¼	0.56	2.50	4	0.44	1.69
⅛	0.69	2.50	4	0.44	1.69
½	0.84	3.50	4	0.62	2.38
¾	1.06	3.88	4	0.62	2.75
1	1.31	4.25	4	0.62	3.12
1¼	1.66	4.62	4	0.62	3.50
1½	1.91	5.00	4	0.62	3.88
2	2.38	6.00	4	0.75	4.75
2½	2.88	7.00	4	0.75	5.50
3	3.50	7.50	4	0.75	6.00
4	4.50	9.00	8	0.75	7.50
5	5.56	10.00	8	0.88	8.50
6	6.62	11.00	8	0.88	9.50
8	8.62	13.60	8	0.88	11.75
10	10.75	16.00	12	1.00	14.25
12	12.75	19.00	12	1.00	17.00
14	14.00	21.00	12	1.12	18.75
16	16.00	23.50	16	1.12	21.25
18	18.00	25.00	16	1.25	22.75
20	20.00	27.50	20	1.25	25.00
24	24.00	32.00	20	1.38	29.50

GENERAL NOTE: Dimensions are in inches.

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ASME B16.21 92 ■ 0759670 0528744 244 ■

ANNEX A
REFERENCES

(This Annex is an integral part of ASME B16.21, which is placed after the main text for convenience.)

The following is a list of standards and specifications referenced in this Standard, showing the year of approval.

ASME Publications (Approved as American National Standards)

ASME/ANSI B16.1-1989	Cast Iron Pipe Flanges and Flanged Fittings
ASME/ANSI B16.5-1988	Pipe Flanges and Flanged Fittings
ASME B16.24-1991	Cast Copper Alloy Pipe Flanges and Flanged Fittings
ASME/ANSI B16.34-1988	Valves — Flanged, Threaded, and Welding End
ASME B16.47-1990	Large Diameter Steel Flanges
ANSI/ASME B36.10M-1985	Welded and Seamless Wrought Steel Pipe

API Standards

API Std 605-1980	Large Diameter Carbon Steel Flanges

MSS Standards

MSS SP-42-1985	Class 150 Corrosion Resistant Gate, Globe, Angle, and Check Valves with Flanged and Butt Weld Ends
MSS SP-44-1990	Steel Pipe Line Flanges
MSS SP-51-1986	Class 150LW Corrosion Resistant Cast Flanges and Flanged Fittings

Publications of the following organization appear on the above list:

ASME	The American Society of Mechanical Engineers 345 East 47th Street New York, New York 10017
API	American Petroleum Institute 1220 L Street, N.W. Washington, D.C. 20005
MSS	Manufacturers' Standardization Society of the Valve and Fittings Industry, Inc. 127 Park Street, N.E. Vienna, Virginia 22180

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Publications appearing above which have been approved as American National Standards may also be obtained from:

ANSI American National Standards Institute, Inc.
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AMERICAN NATIONAL STANDARDS FOR PIPING, PIPE FLANGES, FITTINGS, AND VALVES

Scheme for the Identification of Piping Systems ..... A13.1-1981(R1985)
Pipe Threads, General Purpose (Inch) ..... B1.20.1-1983(R1992)
Dryseal Pipe Threads (Inch) ..... B1.20.3-1976(R1991)
Cast Iron Pipe Flanges and Flanged Fittings B16.1-1989
Malleable Iron Threaded Fittings, Class 150 and 300 ..... B16.3-1985
Cast Iron Threaded Fittings, Classes 125 and 250 ..... B16.4-1985
Pipe Flanges and Flanged Fittings B16.5-1988
Factory-Made Wrought Steel Buttwelding Fittings B16.9-1986
Face-to-Face and End-to-End Dimensions of Valves B16.10-1986
Forged Fittings, Socket-Welding and Threaded B16.11-1991
Cast Iron Threaded Drainage Fittings B16.12-1991
Ferrous Pipe Plugs, Bushings, and Locknuts with Pipe Threads B16.14-1991
Cast Bronze Threaded Fittings, Class 125 and 250 ..... B16.15-1985
Cast Copper Alloy Solder Joint Pressure Fittings B16.18-1984
Ring-Joint Gaskets and Grooves for Steel Pipe Flanges B16.20-1973
Nonmetallic Flat Gaskets for Pipe Flanges B16.21-1992
Wrought Copper and Copper Alloy Solder Joint Pressure Fittings B16.22-1989
Cast Copper Alloy Solder Joint Drainage Fittings — DWV B16.23-1992
Cast Copper Alloy Pipe Flanges and Flanged Fittings, Class 150, 300, 400, 600, 900, 1500, and 2500 ..... B16.24-1991
Buttwelding Ends B16.25-1986
Cast Copper Alloy Fittings for Flared Copper Tubes B16.26-1988
Wrought Steel Buttwelding Short Radius Elbows and Returns B16.28-1986
Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings — DWV B16.29-1986
Cast Copper Alloy Solder Joint Fittings for Sovent® Drainage Systems B16.32-1992
Manually Operated Metallic Gas Valves for Use in Gas Piping Systems Up to 125 psig (Sizes ½ Through 2) B16.33-1990
Valves — Flanged, Threaded, and Welding End B16.34-1988
Orifice Flanges B16.36-1988
Large Metallic Valves for Gas Distribution (Manually Operated, NPS 2½ to 12, 125 psig Maximum) ... B16.38-1985
Malleable Iron Threaded Pipe Unions, Classes 150, 250, and 300 ..... B16.39-1986
Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems B16.40-1985
Functional Qualification Requirements for Power Operated Active Valve Assemblies for Nuclear Power Plants ..... B16.41-1983(R1989)
Ductile Iron Pipe Flanges and Flanged Fittings, Class 150 and 300 ..... B16.42-1987
Wrought Copper and Copper Alloy Solder Joint Fittings for Sovent® Drainage Systems B16.43-1982
Cast Iron Fittings for Sovent® Drainage Systems B16.45-1987
Large Diameter Steel Flanges (NPS 26 Through NPS 60) B16.47-1990
Power Piping B31.1-1989
Fuel Gas Piping B31.2-1968
Chemical Plant and Petroleum Refinery Piping B31.3-1990
Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols B31.4-1989
Refrigeration Piping B31.5-1987
Gas Transmission and Distribution Piping Systems B31.8-1989
Building Services Piping B31.9-1988
Slurry Transportation Piping Systems B31.11-1989
ASME Guide for Gas Transmission and Distribution Piping Systems — 1986 (not an ANSI Standard) .....
Manual for Determining the Remaining Strength of Corroded Pipelines (not an ANSI Standard) B31G-1991
Welded and Seamless Wrought Steel Pipe B36.10M-1985
Stainless Steel Pipe B36.19M-1985
Self-Operated and Power-Operated Safety-Related Valves Functional Specification Standard .. N278.1-1975(R1984)

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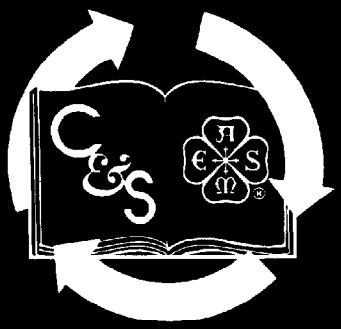

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ASME B16.24 91 ■ 0759670 0543169 479 ■

ASME B16.24-1991
(REVISION OF ANSI B16.24-1979)

Cast Copper Alloy Pipe Flanges and Flanged Fittings

Class 150, 300, 400, 600, 900, 1500, and 2500

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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ASME-B16.24

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ERRATA

to

ASME B16.24-1991
CAST COPPER ALLOY PIPE FLANGES AND FLANGED FITTINGS, Class 150, 300, 400, 600, 900, 1500, and 2500

Title — *Correct title of document to read:*

Cast Copper Alloy Pipe Flanges, Class 150, 300, 400, 600, 900, 1500, and 2500, and Flanged Fittings, Class 150 and 300

Page 1, para. 2.1 — *Correct as follows:*

(1) In first sentence, correct Tables 1 and 2 *to read* Table 1

(2) In second sentence, correct Table 1 *to read* Table 2

JUNE 1991

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AN AMERICAN NATIONAL STANDARD

Cast Copper Alloy Pipe Flanges and Flanged Fittings

Class 150, 300, 400, 600, 900, 1500, and 2500

ASME B16.24-1991

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Date of Issuance: April 15, 1991

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FOREWORD

(This Foreword is not part of ASME B16.24-1991.)

The development of the first Bronze Flanged Standard was started in 1910 to eliminate the confusion prevailing in the trade with respect to bronze flange dimensions and service ratings. The work culminated and was published in 1914 under the title "1914 Brass Standard Flange Dimensions" for 150 and 250 lb steam pressures.

This was superseded in 1928 by the Manufacturers Standardization Society of Valves and Fittings Industry (MSS) "Standard Practice" SP-2 which contained changes to provide interchangeability with the American Cast-Iron Flange Standards for 125 lb and 250 lb steam pressures. Subsequent revisions were issued in 1930 and 1936. In the latter a new column of thickness for 300 lb flanges was added.

In the 1937 edition, illustrations and dimensions of bronze flanged fittings were added. This was edited and reprinted in 1943 to make it conform in effect to U.S. Department of Commerce, National Bureau of Standards, Simplified Practice Recommendation R-183-42 and to the War Production Board Limitation Order L-252, dated January 23, 1943.

In the 1946 edition, the pressure-temperature ratings were added for the 150 lb and 300 lb standards and the dimensions for and reference to the 250 lb standard were omitted. Limitation Order L-252 was cancelled on April 28, 1945. The period of Government prohibition of manufacture and civilian use of the 250 lb standard, during the life of Order L-252, caused no hardship on the part of either the manufacturer or the consumer, indicating that this pressure class in bronze products does not warrant being recognized as a standard.

This standard which has been kept up-to-date and in constant use since 1910, was reviewed and reaffirmed in 1949. In October, 1951, MSS presented it to Sectional Committee B16 on Pipe Flanges and Flanged Fittings for review and possible approval as an American Standard.

Following approval of the sectional committee and sponsor organizations, it was presented to the American Standards Association (ASA), now the American National Standards Institute (ANSI), for approval and designation as an American Standard. This was granted on February 27, 1953.

In 1961, following the organization of Subcommittee No. 11 (now J), work was begun on revision of the 1953 edition. Chief among the changes recommended was the deletion of reference to brass. This resulted from an action by the ASTM of redefining the alloys which could properly be called bronze. Several other changes which brought the standard up-to-date were also approved by the Sectional Committee and sponsor organizations, with approval designation as an American Standard being granted on July 20, 1962.

Subcommittee J, in keeping with regulations of ANSI began a review of the document in 1969. Only minor changes were found necessary. Among these were the presentation of ratings in tabular form, and the gasket retaining grooves being made permissible rather than recommended. Final approval to the changes was granted by ANSI on January 27, 1971.

A revision was undertaken in 1977 and several changes were proposed. Chief among

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these was the addition of metric equivalents and the elimination of the optional gasket retaining grooves. In addition, the standard was extensively revised editorially. Following approvals by Subcommittee J, the Standards Committee and Co-Secretariat, ANSI granted its approval on June 26, 1979.

In 1982 American National Standards Committee B16 was reorganized as an ASME Committee operating under procedures accredited by ANSI.

This 1991 edition of the standard changes the scope of the standard from bronze pipe flanges and fittings to cast copper alloy flanges and flanged fittings. The scope of the flanges now covered in this document was expanded to include classes 150, 300, 400, 600, 900, 1500 and 2500. This edition establishes U.S. customary units as the standard. Other clarifying and editorial revisions were made in order to improve the text.

Following approval by the Standards Committee and ASME, this revision to the 1979 edition of the Standard was approved as an American National Standard by ANSI on February 1, 1991, with the new designation ASME B16.24-1991 and the new title "Cast Copper Alloy Pipe Flanges and Flanged Fittings."

Request for interpretations or suggestions for revisions should be sent to the Secretary B16 Committee, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.

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Standardization of Valves, Flanges, Fittings, Gaskets, and Valve Actuators

(The following is the roster of the Committee at the time of approval of this Standard.)

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CAST COPPER ALLOY PIPE FLANGES, FLANGED FITTINGS, CLASS 150, 300, 400, 600, 900, 1500 AND 2500

1 SCOPE

1.1 General

This Standard for Cast Copper Alloy Pipe Flanges and Flanged Fittings covers:

(a) pressure temperature ratings;
(b) sizes and methods of designating openings for reduced fittings;
(c) marking;
(d) materials;
(e) dimensions;
(f) bolts, nuts, and gaskets;
(g) tolerances; and
(h) tests.

1.2 Codes and Regulations

A flange or flanged fitting used under the jurisdiction of the ASME Boiler and Pressure Vessel Code, the ASME Code for Pressure Piping or a governmental regulation is subject to any limitation of that code or regulation. This includes any maximum temperature limitation, or rule governing the use of a material at low temperature, or provisions for operating at a pressure exceeding the pressure–temperature ratings in this Standard.

1.3 Units of Measurement

U.S. customary units are the standard. For conversion to metric units use the following:

(a) 1 in. = 25.4 mm
(b) 1 psi = 0.069 bar = 6.9 kPa
(c) °F = 1.8°C + 32

2 PRESSURE–TEMPERATURE RATINGS

2.1 General

The tabulated pressure–temperature ratings shown in Tables 1 and 2 apply to the materials designated in paras. 5.2.1, 5.2.2, 5.3.1, and 5.3.2, and to the dimensions prescribed in Tables 3, 4, 5, and 6. The tabulated pressure–temperature ratings shown in Table 1 apply to the materials designated in para. 5.2.3 and to the dimensions prescribed in ASME/ANSI B16.5. All ratings are independent of the contained fluid and are the maximum non-shock pressures at the tabulated temperatures. Pressure ratings at temperatures intermediate to those tabulated may be obtained by linear interpolation.

2.2 Ratings of Flanged Joints

Ratings in this Standard apply to flanged joints which conform to the limitations on bolting in paras. 5.4 and 8(a), and on gaskets in paras. 5.5 and 8(b) and which are made up in accordance with good practice for alignment and assembly. Use of the ratings for flanged joints not conforming to these limitations is the sole responsibility of the user. Requirements for alignment and assembly of joints and consideration of leakage due to forces and moments developed in the connected piping or equipment are not covered in this Standard. If the two flanges in a flanged joint do not have the same pressure–temperature ratings, the rating of the joint at any temperature is the lower of the two flange ratings at that temperature.

2.3 Rating Temperature

The temperature shown for a corresponding pressure rating is the temperature of the pressure-containing shell of the flange or flanged fitting. In general, this temperature is the same as that of the contained fluid. Use of a pressure rating corresponding to a temperature other than that of the contained fluid is the responsibility of the user, subject to the applicable code or regulation. For any temperature below −20°F, the rating shall be no greater than the rating for −20°F.

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2.4 Low Temperature Service

When assembled with suitable bolting and gaskets, and subject to the applicable code or regulations, copper alloy flanges and flanged fittings, in accordance with this Standard, may be used at temperatures down to −325°F.

2.5 System Hydrostatic Test

Flanged joints and flanged fittings may be subjected to system hydrostatic tests at pressures not to exceed 1.5 times the tabulated working pressure at 100°F. System testing at higher pressures is the responsibility of the user, subject to the requirements of the applicable code or regulation.

3 SIZES AND METHOD OF DESIGNATING OPENINGS

3.1 The size of a regular flange or fitting is identified by the corresponding nominal pipe size, NPS.

3.2 Reduced fittings shall be designated by the size of the openings in their proper sequence as indicated in Fig. 1.

4 MARKING

4.1 General

Except as modified herein, flanges and flanged fittings shall be marked as required in MSS SP-25.

4.1.1 Name. The manufacturer's name or trademark shall be applied.

4.1.2 Material. All flanges and flanged fittings shall be marked with the ASTM specification number. In addition, the grade identification symbol, 952, is required for flanges cast to ASTM B 148.

4.1.3 Rating Class. Numerals shall be applied giving the pressure rating class for which the product is designed.

4.1.4 Designation. The designation "B16" shall be applied, preferably located adjacent to the Class designation, to indicate conformance to this Standard.

4.1.5 Size. The nominal pipe size shall be applied but may be omitted from reducing flanges and reducing flanged fittings.

5 MATERIALS

5.1 General

Products covered by this Standard shall be made of castings produced to the requirements of para. 5.2 or 5.3.

5.2 Flanges

Flanges shall be in accordance with one of the material requirements listed below.

5.2.1 Alloy C83600. Castings shall meet the requirements of ASTM B62.

5.2.2 Alloy C92200. Castings shall meet the requirements of ASTM B61.

5.2.3 Alloy C95200. Castings shall meet the requirements of ASTM B148 and the additional requirements listed below.

5.2.3.1 Ordering Information. Ordering information shall include tests on each lot and the form of the test bar.

5.2.3.2 Sampling. The sample for chemical analysis shall be taken from the test bar casting or other casting sample in such a manner as to be representative of each casting lot.

5.2.3.3 Test Bars. A minimum of three test bars shall be poured from each lot of cast metal.

5.2.3.4 Weld Repair Approval. A flange casting shall not be repaired, plugged, welded, or burned-in unless permission from the user of the flange has been previously secured. This will be requested of the user upon the manufacturer's determination that casting defects are such that after the approved repair the usefulness and the strength of the casting will not be impaired.

5.2.3.5 Weld Repair. Preparation for repair welding shall include inspection to assure complete removal of the defect. Repairs shall be made utilizing welding procedures qualified in accordance with Section XI of the ASME Boiler and Pressure Vessel Code. Repair welding shall be done by welders or welding operators meeting the qualification requirements of that Code.

5.3 Flanged Fittings

Flanged fittings shall be in accordance with one of the material requirements listed below.

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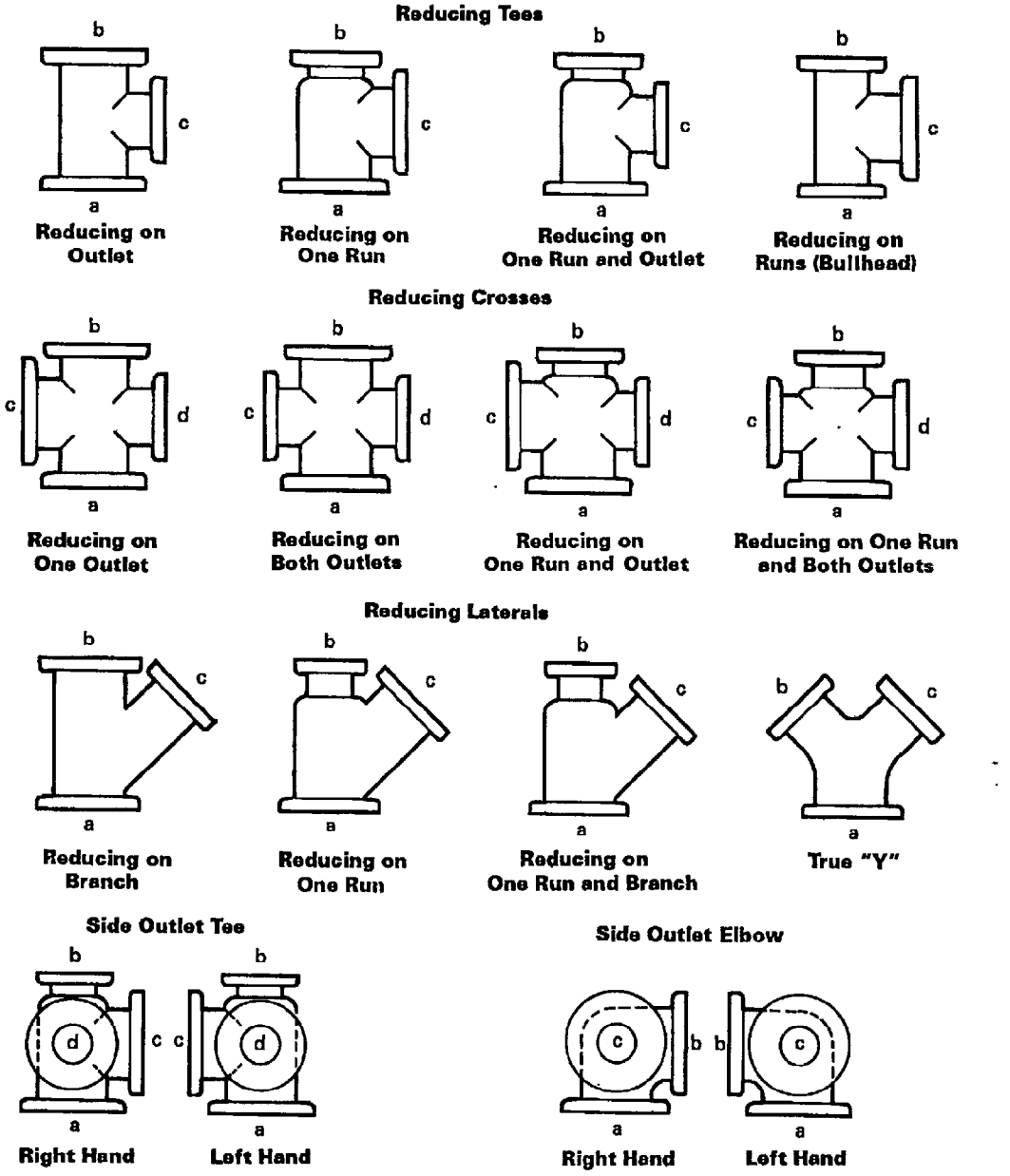

FIG. 1 METHOD OF DESIGNATING OUTLETS OF REDUCING FITTINGS

GENERAL NOTES:

(a) In designating the openings of reducing fittings they should be read in the order indicated by the sequence of the letters a, b, c, and d. In designating the outlets of side outlet reducing fittings, the side outlet is named last and in the case of the cross which is not shown, the side outlet is designated by the letter e.

(b) The largest opening establishes the basic size of a reducing fitting. The largest opening is named first, except for bullhead tees which are reducing on both runs and for double branch elbows where both branches are reducing, the outlet is the largest opening and named last in both cases. (Double branch elbows are not included in this Standard.)

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5.3.1 Alloy C83600. Castings shall meet the requirements of ASTM B62.

5.3.2 Alloy C92200. Castings shall meet the requirements of ASTM B61.

5.4 Bolting

Bolting materials recommended for use with copper alloy flanges and flanged fittings are described in the following paragraphs.

5.4.1 Steel Bolting. Bolting material having allowable stresses not less than those for ASTM A193 Gr B7 are listed as high strength in Table 1B in ASME/ANSI B16.5. These and other materials of comparable strength may be used in any flanged joint. Carbon steel bolting conforming to ASTM A307 shall not be used below −20°F nor above 400°F and is limited for use with Class 150 and 300.

5.4.2 Nonferrous Boltings. The following nonferrous materials may be used for Class 150 and 300 within the temperature limitation stated. Other bolting materials that have at least a 30 ksi specified minimum yield strength may be used when permitted by the applicable code or regulations.

ASTM Spec.	Alloy UNS No.	Condition	Notes
B98	C65100	Half Hard	(1)
	C65500	Half Hard	(1)
	C66100	Half Hard	(1)
B150	C61400		(2)
	C63000		(2)
	C64200		(2)
B164	N04400	Hot Finish	
	N04400	Cold Drawn	(2)
	N04400	Cold Drawn, Stress Relieved	(2)
	N04400	Cold Drawn, Stress Equalized	(2)
	N04405	Hot Finish	
	N04405	Cold Drawn	(2)

NOTES:
(1) Maximum operating temperature 350°F
(2) Maximum operating temperature 550°F

5.5 Gaskets

Materials for gaskets are described in Annex E of ASME/ANSI B16.5. The user is responsible for selection of gasket materials which will withstand the expected bolt loading without injurious crushing and which are suitable for the service conditions. Particular attention needs to be given to gasket selection if the user elects to use a hydrostatic test pressure that exceeds the test pressure specified in para. 2.5.

5.6 Materials Selection

Criteria for the selection of materials are not within the scope of this Standard. The possibility of material deterioration in service should be considered by the user. A discussion of precautionary considerations can be found in Appendix F of ASME B31.3.

6 FLANGE DIMENSIONS

6.1 Flange dimensions are dependent upon the flange casting material.

6.1.1 Alloys C83600 and C92200. The flange dimensions shall be in accordance with Tables 3 and 5 with alternative facings as permitted in para. 6.2.

6.1.2 Alloy C95200. The flange dimensions shall be in accordance with the dimensional requirements of ASME/ANSI B16.5.

6.2 End Flange Facings

Class 150 and 300 blind and companion flanges are regularly furnished with a flat face. Class 400 and higher companion flanges are regularly furnished with a 0.25 in. raised face, with the exception of the small male face (on end of pipe) and the small female face (on end of pipe). When using straight pipe threads, any of the flange pipe threads shown in ASME/ANSI B16.5 may be used with copper alloy flanges. When flanges of alloy C83600 or alloy C92200 are furnished with one of the alternative ASME/ANSI B16.5 facings, any required raised face dimension shall be in addition to the basic flange thickness, "C", of Tables 3 and 5.

6.3 Threaded Flanges

Threaded flanges shall have a taper pipe thread in accordance with ANSI/ASME B1.20.1. Variations in alignment of the thread with the axis of the flange shall not exceed 0.06 in./ft.

6.4 Thread Chamfer

All flanges of alloy C83600 and C92200 shall be made without a counterbore. The threads shall be

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chamfered approximately to the major diameter of the thread at the pipe end of the flange at an angle approximately 45 deg. with the axis of the thread. The chamfer shall be concentric with the thread and shall be included in the measurement of the thread length.

6.5 Thread Length

The length of the thread shall include the chamfer.

6.6 Thread Gaging

The gaging notch of the thread gage shall come flush with the bottom of the chamfer in all threaded flanges, and shall be considered as being the intersection of the chamfer cone and the pitch cone of the thread. This depth of chamfer is approximately equal to one-half the pitch of the thread. The maximum allowable thread variation is one turn large or small from the gaging notch.

6.7 Threaded Flange Assembly

External pipe threads used with higher pressure flanges must be longer than normal to bring the end of the pipe close to the face of the flange when parts are assembled by power equipment. The additional length and number of turns are shown in Annex A of ASME/ANSI B16.5 for ANSI/ASME B1.20.1 threads.

6.8 Integral Flanges

When flanges are integral with fittings or valves, pairs of bolt holes shall straddle the center line.

6.9 Spot and Back Facing

Flanges and flanged fittings covered by this Standard shall have bearing surfaces for bolting which shall be parallel to the flange face within 1 deg. Any spot or back facing shall not reduce the flange thickness, "C," below the dimension required by para. 6.1. The spot facing diameter shall be in accordance with MSS-SP-9. When cutting into the hub of flanges or flanged fittings with back facing tools, the intersection shall have a radius of not less than 0.06 in.

7 FITTING DIMENSIONS

7.1 Center-to-Face Dimensions

7.1.1 Side Outlet Fittings. Side outlet elbows and side outlet tees shall have all openings on intersecting center lines.

7.1.2 Elbows

(a) The center-to-face dimensions for straight size 90 deg. elbows, 90 deg. long radius elbows, 45 deg. elbows, and side outlet 90 deg. elbows are shown in Tables 4 and 6.

(b) Reducing 90 deg. elbows and reducing side outlet 90 deg. elbows shall have the same center-to-face dimensions as straight size fittings shown in Tables 4 and 6, corresponding to the size of the largest opening.

(c) Special degree elbows ranging from 1 to 45 deg., inclusive, shall have the same center-to-face dimensions given for 45 deg. elbows and those over 45 deg. and up to 90 deg., inclusive, shall have the same center-to-face dimensions given for 90 deg. elbows. The angle designation of an elbow is its deflection from straight line flow and is the angle between the flange faces.

7.1.3 Tees, Crosses, and Laterals

(a) The center-to-face dimensions for straight size tees, with or without side outlet, crosses, and laterals are shown in Tables 4 and 6.

(b) Reducing tees, with or without side outlet, reducing crosses, and reducing laterals shall have the same center-to-face dimensions as straight size fittings shown in Tables 4 and 6, corresponding to the size of the largest opening. Tees, crosses, and laterals, reducing on the run only, shall have the same center-to-face dimensions as straight size fittings shown in Tables 4 and 6, corresponding to the size of the largest opening.

(c) Tees reducing on both runs are generally known as bullhead tees and have the same center-to-face dimensions as straight size fittings corresponding to the size of the outlet.

7.1.4 True Ys. Center-to-face dimensions for straight size true Ys are shown in Tables 4 and 6. Reducing sizes are considered special and should be made to suit conditions.

7.1.5 Reducers and Eccentric Reducers. The face-to-face dimensions for all combinations of reducers and eccentric reducers shall be the same as given in Tables 4 and 6 for the larger opening.

7.1.6 Interchangeability. Class 150 flanged fittings in NPS 1 and larger have a bolting pattern that is dimensionally interchangeable with Class 125 Cast Iron Flanged Fittings (ASME/ANSI B16.1), Class

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150 Steel Flanged Fittings (ASME/ANSI B16.5), and Class 150 Ductile Iron Flanged Fittings (ASME/ANSI B16.42). Class 300 flanged fittings in NPS 1 and larger have a bolting pattern that is dimensionally interchangeable with Class 250 Cast Iron Flanged Fittings (ASME/ANSI B16.1), Class 300 Steel Flanged Fittings (ASME/ANSI B16.5), and Class 300 Ductile Iron Flanged Fittings (ASME/ANSI B16.42).

7.2 Wall Thickness

For inspection purposes, the minimum wall thickness, "t," of flanged fittings at the time of manufacture shall be as shown in Tables 4 and 6, except as provided in para. 9.1. Additional metal thickness needed to withstand assembly stresses, shapes other than circular, and stress concentrations must be determined by the manufacturer. In particular, 45 deg. laterals, true Ys, and crosses may require additional reinforcement to compensate for inherent weaknesses in these shapes.

8 BOLTING, NUTS, AND GASKETS

(a) For carbon steel and nonferreous bolting smaller than three-quarter inch, ANSI Standard Square Heads, ANSI Standard Heavy Hex Heads (ANSI B18.2.1), or ANSI Standard Heavy Hex Nuts (ANSI B18.2.2) are recommended. For carbon steel and nonferrous bolting three-quarter inch and larger, ANSI Standard Heads, ANSI Standard Hex Heads (ANSI B18.2.1), ANSI Standard Hex Nuts, or ANSI Heavy Hex Nuts (ANSI B18.2.2) are recommended.

All bolting and nuts shall be threaded in accordance with ANSI Standard Unified Screw Threads (ANSI B1.1), Coarse Thread Series, Class 2A and Class 2B.

(b) Full faced gaskets extending to the flange edge as given in ANSI B16.21, are required for flat faced surfaces such as shown in Tables 3 and 5. Metallic gaskets shall not be used with flat faced flanges.

If bolting material is either carbon steel or nonferrous, compressed sheet gaskets that are less than 0.12 in. thick should not be used.

9 TOLERANCES[1]

9.1 Wall Thickness

Fittings with local areas having less than minimum wall thickness will be acceptable provided that:

(a) the area of subminimum thickness can be enclosed by a circle whose diameter is no greater than $0.35\sqrt{dt}$ where d is the inside diameter and t is the minimum wall thickness as shown in Tables 4 and 6;

(b) measured thickness is not less than $0.9t$;

(c) enclosure circles are separated from each other by an edge-to-edge distance of not less than $1.75\sqrt{dt}$.

9.2 Center-to-Face

The following tolerances shall be permitted on all center-to-contact surface dimensions of fittings:

Nominal Pipe Size	Plus or Minus
10 and smaller	0.03 in.
12	0.06 in.

Tolerances for contact surface-to-contact surface dimensions shall be twice those given above. The largest opening in the fitting governs the tolerance to be applied to all openings.

9.3 Facings

9.3.1 Outside Diameter, 0.25 in. raised face, 0.02 in.

9.4 Flange Thickness

Sizes NPS 12 and smaller — +0.12 in.
−zero

9.5 Counterbore, Threaded Flanges

Sizes NPS 10 and smaller — +0.03 in.
−zero
Sizes NPS 12 and larger — +0.06 in.
−zero

9.6 Drilling and Facing

9.6.1 Bolt Circle Diameter ±0.06 in.

9.6.2 Center-to-Center of adjacent bolt holes ±0.03 in.

10 TESTS

10.1 Flange Testing

Flanges are not required to be pressure tested.

[1]Unless otherwise stated, tolerances are equal, plus and minus.

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10.2 Flanged Fitting Testing

Each flanged fitting shall be given a shell test in accordance with para. 10.2.1 or 10.2.2.

10.2.1 Class 150 fitting made from alloys C83600 or C92200 in sizes ½ in. through 4 in. may be pneumatically tested at 80 psi (minimum) while under water for a minimum of 2 minutes. No visible leakage is permitted through the pressure boundary wall.

10.2.2 Hydrostatic Shell Test. The hydrostatic shell test for flanged fittings shall be no less than 1.5 times the 100°F rating rounded off to the next higher 25 psi increment. Test pressures are shown in Tables 1 and 2.

(a) The test shall be made with water, which may contain a corrosion inhibitor, with kerosene, or with another suitable fluid, provided its viscosity is no greater than that of water, at a test temperature not above 125°F.

(b) The test duration shall be a minimum of 1 minute for fittings NPS 2 and smaller, 2 minutes for fittings NPS 2½ to 8, and 3 minutes for NPS 10 and 12.

(c) No visible leakage is permitted through the pressure boundary wall.

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TABLE 1 PRESSURE–TEMPERATURE RATINGS FOR ALLOYS C83600 AND C92200

Service Temperature, °F	Working Pressure, psig			
	Class 150		Class 300	
	ASTM B 62 C83600	ASTM B 61 C92200	ASTM B 62 C83600	ASTM B 61 C92200
−20 to 150	225	225	500	500
175	220	220	480	490
200	210	215	465	475
225	205	210	445	465
250	195	205	425	460
275	190	200	410	440
300	180	195	390	425
350	165	180	350	400
400	...	170	...	375
406	150	...	...	...
450	135 (1)	160	280 (1)	350
500	...	150	...	325
550	...	140	...	300
Test Pressure	350	350	750	750

NOTE:
(1) Some codes (e.g., ASME Boiler and Pressure Vessel Code, Section I; ASME B31.1; ASME B31.5) limit the rating temperature of the indicated material to 406°F.

TABLE 2 PRESSURE–TEMPERATURE RATINGS FOR ASTM B 148, ALLOY C95200

Service Temperature, °F	Working Pressure, psig						
	Class 150	Class 300	Class 400	Class 600	Class 900	Class 1500	Class 2500
−20 to 100	195	515	685	1030	1545	2575	4290
150	165	430	570	855	1285	2140	3570
200	155	400	535	800	1205	2005	3340
250	145	385	510	770	1150	1920	3200
300	140	370	495	740	1110	1850	3085
350	140	365	490	735	1100	1835	3060
400	140	365	485	725	1090	1820	3030
450	140	360	480	725	1085	1805	3010
500	140	360	480	720	1080	1800	3000
Test Pressure	300	775	1050	1550	2325	3875	6450

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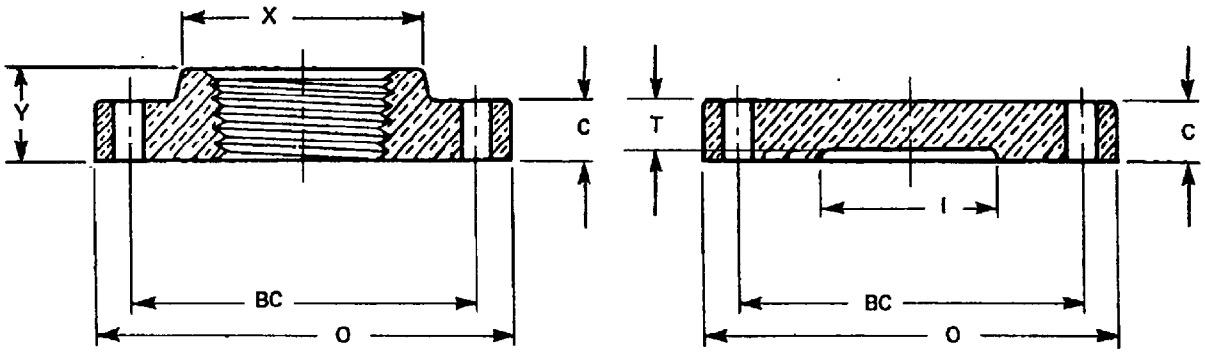

TABLE 3 DIMENSIONS OF CLASS 150 THREADED COMPANION AND BLIND FLANGES[1,4] FOR ALLOYS C83600 AND C92200

Nominal Pipe Size	Diameter of Flange O	Thickness of Flange, [Note (2)] Min. C	Bolt Circle BC	Number of Bolts [Note (3)]	Diameter of Bolts	Diameter of Bolt Hole	Diameter of Hub, Min. X	Length Overall Min. Y	Diameter of Counter-bore Max. l	Thickness at Recess, Min. T
½	3.50	0.31	2.38	4	½	0.62	1.19	0.59	0.50	0.25
¾	3.88	0.34	2.75	4	½	0.62	1.25	0.62	0.75	0.28
1	4.25	0.38	3.12	4	½	0.62	1.94	0.69	1.00	0.31
1¼	4.62	0.41	3.50	4	½	0.62	2.31	0.81	1.25	0.34
1½	5.00	0.44	3.88	4	½	0.62	2.56	0.88	1.50	0.38
2	6.00	0.50	4.75	4	⅝	0.75	3.06	1.00	2.00	0.44
2½	7.00	0.56	5.50	4	⅝	0.75	3.56	1.12	2.50	0.50
3	7.50	0.62	6.00	4	⅝	0.75	4.25	1.19	3.00	0.56
3½	8.50	0.69	7.00	8	⅝	0.75	4.81	1.25	3.50	0.62
4	9.00	0.69	7.50	8	⅝	0.75	5.31	1.31	4.00	0.62
5	10.00	0.75	8.50	8	¾	0.88	6.44	1.44	5.00	0.69
6	11.00	0.81	9.50	8	¾	0.88	7.56	1.56	6.00	0.75
8	13.50	0.94	11.75	8	¾	0.88	9.69	1.75	8.00	0.88
10	16.00	1.00	14.25	12	⅞	1.00	12.00	1.94	10.00	0.94
12	19.00	1.06	17.00	12	⅞	1.00	14.38	2.19	12.00	1.00

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) For flange facing, see para. 6.2.
(2) For flange spot facing and thickness, see para. 6.9.
(3) For flanges integral with fittings or valves, see para. 6.8.
(4) Flange diameters and drilling templates correspond to those prescribed in ASME/ANSI B16.1, B16.5, and B16.42.

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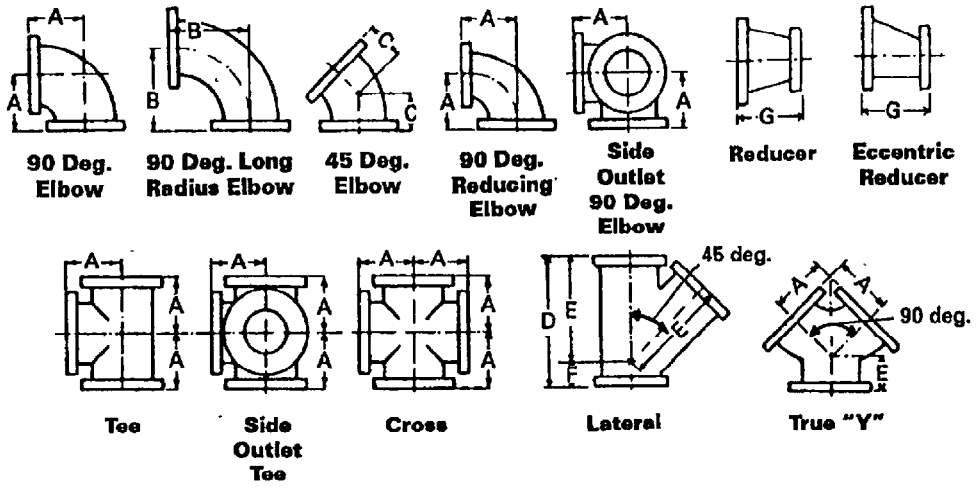

TABLE 4 DIMENSIONS OF CLASS 150 ELBOWS, TEES, CROSSES, LATERALS, TRUE Ys (STRAIGHT SIZES), AND REDUCERS[1,2]

Nominal Pipe Size	Center-to-Face [Notes (3),(4),(7),(8),(9),(10),(11)] A	Face-to-Face A+A	Center-to-Face [Note (3)] B	Center-to-Face [Note (3)] C	Face-to-Face [Notes (8),(9)] D	Center-to-Face [Notes (8),(9)] E	Center-to-Face [Notes (8),(9)] F	Face-to-Face [Notes (6)] G	Wall Thickness [Note (6)] t	Minimum Port Diameter I
½	3.00	6.00	...	1.62	...	...	...	...	0.09	0.50
¾	3.25	6.50	...	1.75	...	...	...	...	0.11	0.75
1	3.50	7.00	5.00	1.75	7.50	5.75	1.75	...	0.12	1.00
1¼	3.75	7.50	5.50	2.00	8.00	6.25	1.75	...	0.14	1.25
1½	4.00	8.00	6.00	2.25	9.00	7.00	2.00	...	0.16	1.50
2	4.50	9.00	6.50	2.50	10.50	8.00	2.50	5.00	0.19	2.00
2½	5.00	10.00	7.00	3.00	12.00	9.50	2.50	5.50	0.20	2.50
3	5.50	11.00	7.75	3.00	13.00	10.00	3.00	6.00	0.22	3.00
3½	6.00	12.00	8.50	3.50	14.50	11.50	3.00	6.50	0.25	3.50
4	6.50	13.00	9.00	4.00	15.00	12.00	3.00	7.00	0.27	4.00
5	7.50	15.00	10.25	4.50	17.00	13.50	3.50	8.00	0.30	5.00
6	8.00	16.00	11.50	5.00	18.00	14.50	3.50	9.00	0.33	6.00
8	9.00	18.00	14.00	5.50	22.00	17.50	4.50	11.00	0.41	8.00
10	11.00	22.00	16.50	6.50	25.50	20.50	5.00	12.00	0.48	10.00
12	12.00	24.00	19.00	7.50	30.00	24.50	5.50	14.00	0.56	12.00

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) For flange and bolt hole dimensions, see Table 3 and para. 6.8.
(2) For center-to-face tolerance, see para. 9.2.
(3) For intersecting center lines of side outlet fittings, see para. 7.1.1.
(4) For center-to-face dimensions of reducing elbows, see para. 7.1.2(b).
(5) For wall thickness tolerance, see para. 9.1.
(6) For face-to-face dimensions of reducers and eccentric reducers, see para. 7.1.5.
(7) For center-to-face dimensions of special degree elbows, see para. 7.1.2(c).
(8) For reinforcement of crosses and laterals, see para. 7.2.
(9) For center-to-face dimensions of reducing tees, crosses and laterals, see para 7.1.3(a).
(10) For center-to-face dimensions of tees reducing on both runs, see para. 7.1.3(b).
(11) For center-to-face dimensions of reducing side outlet tees having two different size reductions on the outlets, see para. 7.1.3(a).

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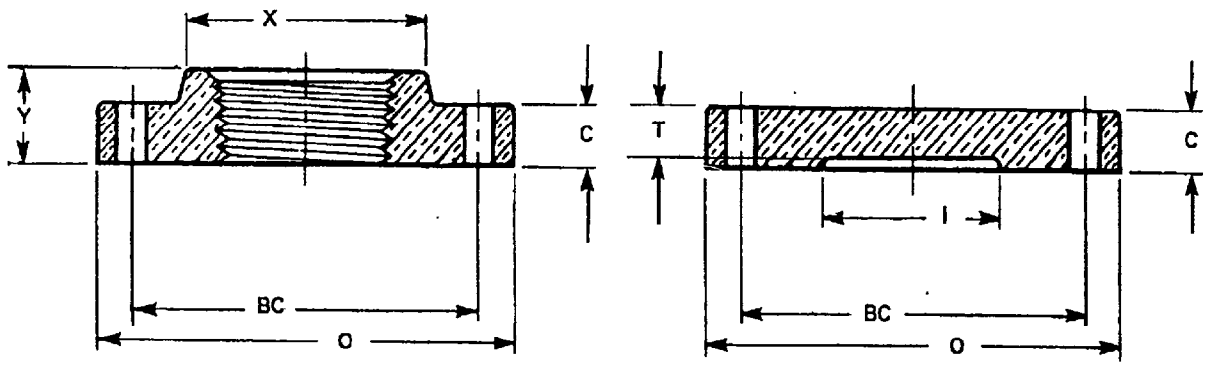

TABLE 5 DIMENSIONS OF CLASS 300 THREADED COMPANION AND BLIND FLANGES[1,4] FOR ALLOYS C83600 AND C92200

Nominal Pipe Size	Diameter of Flange O	Thickness of Flange, [Note (2)] Min. C	Bolt Circle BC	Number of Bolts [Note (3)]	Diameter of Bolts	Diameter of Bolt Hole	Diameter of Hub, Min. X	Length Overall Min. Y	Diameter of Counter-bore Max. I	Thickness at Recess, Min. T
½	3.75	0.50	2.62	4	½	0.62	1.19	0.69	0.50	0.44
¾	4.62	0.53	3.25	4	⅝	0.75	1.50	0.62	0.75	0.47
1	4.88	0.59	3.50	4	⅝	0.75	1.94	0.69	1.00	0.53
1¼	5.25	0.62	3.88	4	⅝	0.75	2.31	0.81	1.25	0.56
1½	6.12	0.69	4.50	4	¾	0.88	2.56	0.88	1.50	0.62
2	6.50	0.75	5.00	8	⅝	0.75	3.06	1.00	2.00	0.69
2½	7.50	0.81	5.88	8	¾	0.88	3.56	1.12	2.50	0.75
3	8.25	0.91	6.62	8	¾	0.88	4.25	1.19	3.00	0.84
3½	9.00	0.97	7.25	8	¾	0.88	4.81	1.25	3.50	0.91
4	10.00	1.06	7.88	8	¾	0.88	5.31	1.31	4.00	1.00
5	11.00	1.12	9.25	8	¾	0.88	6.44	1.44	5.00	1.06
6	12.50	1.19	10.62	12	¾	0.88	7.56	1.56	6.00	1.12
8	15.00	1.38	13.00	12	⅞	1.00	9.69	1.75	8.00	1.31

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) For flange facing, see para. 6.2.
(2) For flange spot facing and thickness, see para. 6.9.
(3) For flanges integral with fittings or valves, see para. 6.8.
(4) Flange diameters and drilling templates correspond to those prescribed in ASME/ANSI B16.1, B16.5, and B16.42.

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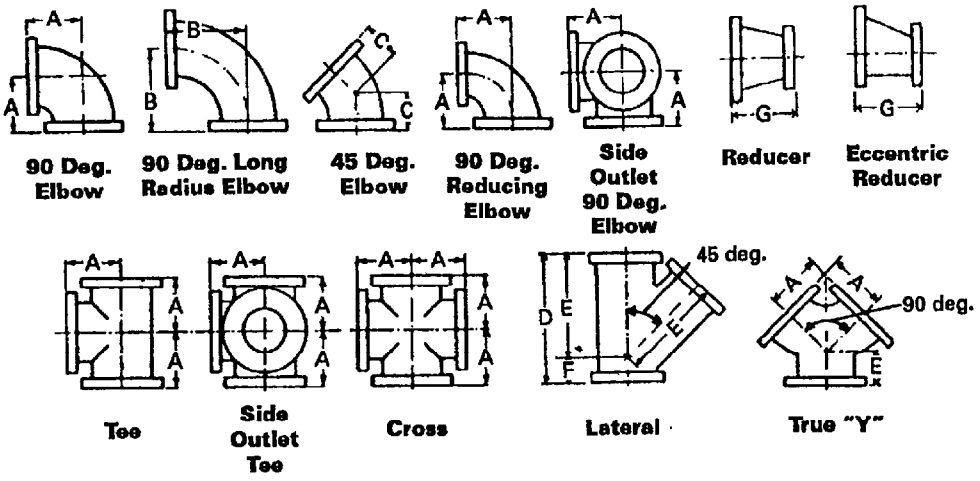

TABLE 6 DIMENSIONS OF CLASS 300 ELBOWS, TEES, CROSSES, LATERALS, TRUE Ys (STRAIGHT SIZES), AND REDUCERS[1,2]

Nominal Pipe Size	Center-to-Face [Notes (3),(4),(7),(8),(9),(10),(11)] A	Face-to-Face A+A	Center-to-Face [Note (3)] B	Center-to-Face [Note (3)] C	Face-to-Face [Notes (8),(9)] D	Center-to-Face [Notes (8),(9)] E	Center-to-Face [Notes (8),(9)] F	Face-to-Face [Note (6)] G	Wall Thickness [Note (6)] t	Minimum Port Diameter I
½	3.00	6.00	...	1.75	...	...	...	...	0.12	0.50
¾	3.50	7.00	...	2.25	...	...	...	...	0.16	0.75
1	4.00	8.00	5.00	2.25	8.50	6.50	2.00	...	0.17	1.00
1¼	4.25	8.50	5.50	2.50	9.50	7.25	2.25	...	0.19	1.25
1½	4.50	9.00	6.00	2.75	11.00	8.50	2.50	...	0.20	1.50
2	5.00	10.00	6.50	3.00	11.50	9.00	2.50	5.00	0.25	2.00
2½	5.50	11.00	7.00	3.50	13.00	10.50	2.50	5.50	0.28	2.50
3	6.00	12.00	7.75	3.50	14.00	11.00	3.00	6.00	0.33	3.00
3½	6.50	13.00	8.50	4.00	15.50	12.50	3.00	6.50	0.36	3.50
4	7.00	14.00	9.00	4.50	16.50	13.50	3.00	7.00	0.41	4.00
5	8.00	16.00	10.25	5.00	18.50	15.00	3.50	8.00	0.48	5.00
6	8.50	17.00	11.50	5.50	21.50	17.50	4.00	9.00	0.56	6.00
8	10.00	20.00	14.00	6.00	25.50	20.50	5.00	11.00	0.72	8.00

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) For flange and bolt hole dimensions, see Table 5 and para. 6.8.
(2) For center-to-face tolerance, see para. 9.2.
(3) For intersecting center lines of side outlet fittings, see para. 7.1.1.
(4) For center-to-face dimensions of reducing elbows, see para. 7.1.2(b).
(5) For wall thickness tolerance, see para. 9.1.
(6) For face-to-face dimensions of reducers and eccentric reducers, see para. 7.1.5.
(7) For center-to-face dimensions of special degree elbows, see para. 7.1.2(a).
(8) For reinforcement of crosses and laterals, see para. 7.2.
(9) For center-to-face dimensions of reducing tees, crosses and laterals, see para 7.1.3(a).
(10) For center-to-face dimensions of tees reducing on both runs, see para. 7.1.3(b).
(11) For center-to-face dimensions of reducing side outlet tees having two different size reductions on the outlets, see para. 7.1.3(a).

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ANNEX A
REFERENCES

(This Annex is an integral part of ASME B16.24-1991 and is placed after the main text for convenience.)

The following is a list of standards and specifications referenced in this Standard showing the year of approval.

ASME Publications (Approved as American National Standards)

ASME/ANSI B1.1-1989	Unified Inch Screw Threads (UN and UNR Thread Form)
ASME/ANSI B1.20.1-1983	Pipe Threads, General Purpose (Inch)
ASME/ANSI B16.1-1989	Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250 and 800
ASME/ANSI B16.5-1988	Steel Pipe Flanges and Flanges Fittings, Including Ratings for Class 150, 300, 400, 600, 900, 1500 and 2500
ANSI B16.21-1978	Nonmetallic Flat Gaskets for Pipe Flanges
ANSI B18.2.1-1981	Square and Hex Bolts and Screws
ANSI B18.2.2-1982	Square and Hex Nuts
ANSI B31.1-1989	Power Piping
ASME/ANSI B31.5-1989	Refrigeration Piping
ASME BPV-I-1989	Power Boilers

ASTM Publications

ASTM A 193-90	Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
ASTM A 307-90	Specification for Carbon Steel Externally and Internally Threaded Standard Fasteners
ASTM B 61-86	Specification for Steam or Valve Bronze Castings
ASTM B 62-86	Specification for Composition Bronze or Ounce Metal Castings
ASTM B 98-84	Specification for Copper-Silicon Alloy Rod, Bar and Shapes
ASTM B 150-86	Specification for Aluminum Bronze Rod, Bar and Shapes
ASTM B 164-84	Specification for Nickel-Copper Alloy Rod and Bar

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MSS Publications

MSS SP-6-1990	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
MSS SP-9-1987	Spot Facing for Bronze, Iron and Steel Flanges
MSS SP-25-1987(R83,88)	Standard Marking System for Valves, Fittings, Flanges and Unions

Publications of the following organizations appear on the above list:

ASME	The American Society of Mechanical Engineers 345 East 47th Street New York, NY 10017 ASME Order Department 22 Law Drive Box 2300 Fairfield, NJ 07007-2300
ASTM	American Society for Testing and Materials 1916 Race Street Philadelphia, PA 19103
MSS	Manufacturers Standardization Society of the Valve and Fittings Industry 127 Park Street, N. E. Vienna, VA 22180

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AMERICAN NATIONAL STANDARDS FOR PIPING, PIPE FLANGES, FITTINGS, AND VALVES

Scheme for the Identification of Piping Systems ..... A13.1-1981(R1985)
Pipe Threads, General Purpose (Inch) B1.20.1-1983
Dryseal Pipe Threads (Inch) ..... B1.20.3-1976(R1982)
Cast Iron Pipe Flanges and Flanged Fittings B16.1-1989
Malleable Iron Threaded Fittings, Class 150 and 300 ..... B16.3-1985
Cast Iron Threaded Fittings, Classes 125 and 250 ..... B16.4-1985
Pipe Flanges and Flanged Fittings B16.5-1988
Factory-Made Wrought Steel Buttwelding Fittings B16.9-1986
Face-to-Face and End-to-End Dimensions of Valves B16.10-1986
Forged Fittings, Socket-Welding and Threaded B16.11-1991
Cast Iron Threaded Drainage Fittings B16.12-1991
Ferrous Pipe Plugs, Bushings, and Locknuts with Pipe Threads B16.14-1991
Cast Bronze Threaded Fittings, Class 125 and 250 ..... B16.15-1985
Cast Copper Alloy Solder Joint Pressure Fittings B16.18-1984
Ring-Joint Gaskets and Grooves for Steel Pipe Flanges B16.20-1973
Nonmetallic Flat Gaskets for Pipe Flanges B16.21-1978
Wrought Copper and Copper Alloy Solder Joint Pressure Fittings B16.22-1989
Cast Copper Alloy Solder Joint Drainage Fittings — DWV B16.23-1984
Cast Copper Alloy Pipe Flanges and Flanged Fittings, Class 150, 300, 400, 600, 900, 1500, and 2500 ..... B16.24-1991
Buttwelding Ends B16.25-1986
Cast Copper Alloy Fittings for Flared Copper Tubes B16.26-1988
Wrought Steel Buttwelding Short Radius Elbows and Returns B16.28-1986
Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings — DWV B16.29-1986
Cast Copper Alloy Solder Joint Fittings for Sovent® Drainage Systems B16.32-1984
Manually Operated Metallic Gas Valves for Use in Gas Piping Systems Up to 125 psig (Sizes ½ Through 2) B16.33-1990
Valves — Flanged, Threaded, and Welding End B16.34-1988
Orifice Flanges B16.36-1988
Hydrostatic Testing of Control Valves B16.37-1980
Large Metallic Valves for Gas Distribution (Manually Operated, NPS 2½ to 12, 125 psig Maximum) B16.38-1985
Malleable Iron Threaded Pipe Unions, Classes 150, 250, and 300 ..... B16.39-1986
Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems B16.40-1985
Functional Qualification Requirements for Power Operated Active Valve Assemblies for Nuclear Power Plants ..... B16.41-1983(R1989)
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Wrought Copper and Copper Alloy Solder Joint Fittings for Sovent® Drainage Systems B16.43-1982
Cast Iron Fittings for Sovent® Drainage Systems B16.45-1987
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Power Piping B31.1-1989
Fuel Gas Piping B31.2-1968
Chemical Plant and Petroleum Refinery Piping B31.3-1990
Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols B31.4-1989
Refrigeration Piping B31.5-1987
Gas Transmission and Distribution Piping Systems B31.8-1989
Building Services Piping B31.9-1988
Slurry Transportation Piping Systems B31.11-1989
ASME Guide for Gas Transmission and Distribution Piping Systems — 1986 (not an ANSI Standard) .....
Manual for Determining the Remaining Strength of Corroded Pipelines (not an ANSI Standard) B31G-1984
Welded and Seamless Wrought Steel Pipe B36.10M-1985
Stainless Steel Pipe B36.19M-1985
Self-Operated and Power-Operated Safety-Related Valves Functional Specification Standard ..... N278.1-1975(R1984)

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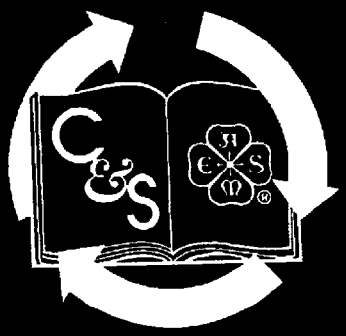

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STD.ASME B16.25-ENGL 1997 ■ 0759670 0580686 T93 ■

ASME B16.25-1997
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BUTTWELDING ENDS

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AN AMERICAN NATIONAL STANDARD

BUTTWELDING ENDS

ASME B16.25-1997
(Revision of ASME B16.25-1992)

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Date of Issuance: May 30, 1997

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FOREWORD

(This Foreword is not part of ASME B16.25–1997.)

In July 1953, the American Welding Society presented a proposal on Welding End Preparation to Sectional Committee B16 of the American Standards Association (ASA), with the recommendation that it be considered as a candidate American Standard. The proposal was expanded to include welding preparation for flanges and valves covered by ASA B16.5, Steel Pipe Flanges and Flanged Fittings, and for fittings covered by ASA B16.9, Buttwelding Fittings. Consideration was also given to Pipe Fabrication Institute Standard ES-1.

The third draft reviewed by Subcommittee 3, Subgroup 6 (now Subcommittee F) of the B16 Sectional Committee was forwarded to the Committee, to the cosponsor organizations, and then to ASA for approval. Final approval was given on September 14, 1955, with the designation ASA B16.25–1955.

Revisions were developed as need for clarification and improvement became known, and were approved as ASA B16.25–1958 and ASA B16.25–1964. After ASA reorganized as the American National Standards Institute (ANSI) and the Sectional Committee became American National Standards Committee B16, a further revision was approved as ANSI B16.25–1972.

Subcommittee F immediately began work on a major expansion and updating of the standard, adding illustrations and requirements for welding end configurations applicable to a number of specific circumstances, including cast steel and alloy valves. When a draft had been developed that overcame the many problems and conflicting demands, the Standards Committee, cosecretariat organizations, and ANSI concurred in approval of ANSI B16.25–1979 on July 18, 1979.

In 1982, American National Standards Committee B16 was reorganized as an ASME Committee operating under procedures accredited by ANSI. In the 1986 edition, inch dimensions were established as the standard and numerous changes in text and format were made. Notes for illustrations were also clarified. Following approval by the Standards Committee and ASME, approval as American National Standard was given by ANSI on October 8, 1986, with the new designation ASME/ANSI B16.25–1986.

In 1992, the subcommittee revised the requirements for the preparation of the inside diameter of welding end. The references in Annex B were also updated. After public review and approval by ASME, this edition was approved by ANSI on October 26, 1992, with the new designation ASME B16.25–1992.

In this 1997 Edition, metric dimensions were added as an independent but equal standard to the inch units. An Annex was also added to reference quality system requirements. Following approval by the Standards Committee and ASME, this revision to the 1992 edition of B16.25 was approved as an American National Standard by ANSI on April 17, 1997, with the new designation ASME B16.25–1997.

Requests for interpretation or suggestions for revision should be sent to the Secretary, B16 Committee, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017.

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Standardization of Valves, Flanges, Fittings, and Gaskets

(The following is the roster of the Committee at the time of approval of this Standard.)

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SPECIAL NOTE:

The interpretations to ASME B16.25 are included in this Edition as a separate section for the user's convenience. This section, however, is not part of the Standard.

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BUTTWELDING ENDS

1 SCOPE

1.1 General

This Standard covers the preparation of buttwelding ends of piping components to be joined into a piping system by welding. It includes requirements for welding bevels, for external and internal shaping of heavy-wall components, and for preparation of internal ends (including dimensions and tolerances). Coverage includes preparation for joints with the following:

(a) no backing rings;

(b) split or noncontinuous backing rings;

(c) solid or continuous backing rings;

(d) consumable insert rings;

(e) gas tungsten arc welding (GTAW) of the root pass.

Details of preparation for any backing ring must be specified in ordering the component.

1.2 Application

This Standard applies to any metallic materials for which a welding procedure can be satisfactorily qualified, but does not prescribe specific welding processes or procedures. Unless otherwise specified by the purchaser, it does not apply to welding ends conforming to ASME B16.5, B16.9, or B16.28.

1.3 Standard Units

The values stated in either metric or inch units are to be regarded separately as standard. Within the text, the inch units are shown in parentheses. The values stated in each system are not exact equivalents; therefore each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the Standard.

1.4 Referenced Standards

Standards and specifications adopted by reference in this Standard are shown in Annex C, which is part of this Standard. It is not considered practical to identify the specific edition of each standard and specification in the individual references; instead the specific edition is identified in Annex C. An end preparation made in conformance to this Standard in all other respects, will be considered to be in conformance to the Standard even though the edition reference may be changed in a subsequent addendum to or revision of the Standard.

1.5 Quality Systems

Nonmandatory requirements relating to the manufacturer's Quality System Program are described in Annex B.

1.6 Convention

For the purpose of determining conformance with this Standard, the convention for fixing significant digits where limits, maximum or minimum values, are specified shall be "rounding off" as defined in ASTM Practice E 29. This requires that an observed or calculated value shall be rounded off to the nearest unit in the last right-hand digit used for expressing the limit. Decimal values and tolerances do not imply a particular method of measurement.

2 TRANSITION CONTOURS

Figure 1 delineates the maximum envelope in which transitions from welding bevel to the outer surface of the component and from the root face to the inner surface of the component must lie. Except as specified in Note (5) to Fig. 1 and as otherwise specified by the purchaser, the exact contour within this envelope is the manufacturer's option, providing it maintains the specified minimum wall thickness, has no slopes steeper than those indicated for the respective regions, and includes the proper surface for backing rings if specified.

3 WELDING BEVEL DESIGN

3.1 Bevels for Other Than GTAW Root Pass

(a) Components having nominal wall thicknesses of 3 mm (0.12 in.) and less shall have ends cut square or slightly chamfered.

(b) Components having nominal wall thicknesses over 3 mm (0.12 in.) to 22 mm (0.88 in.) inclusive shall have single angle bevels as illustrated in Fig. 2.

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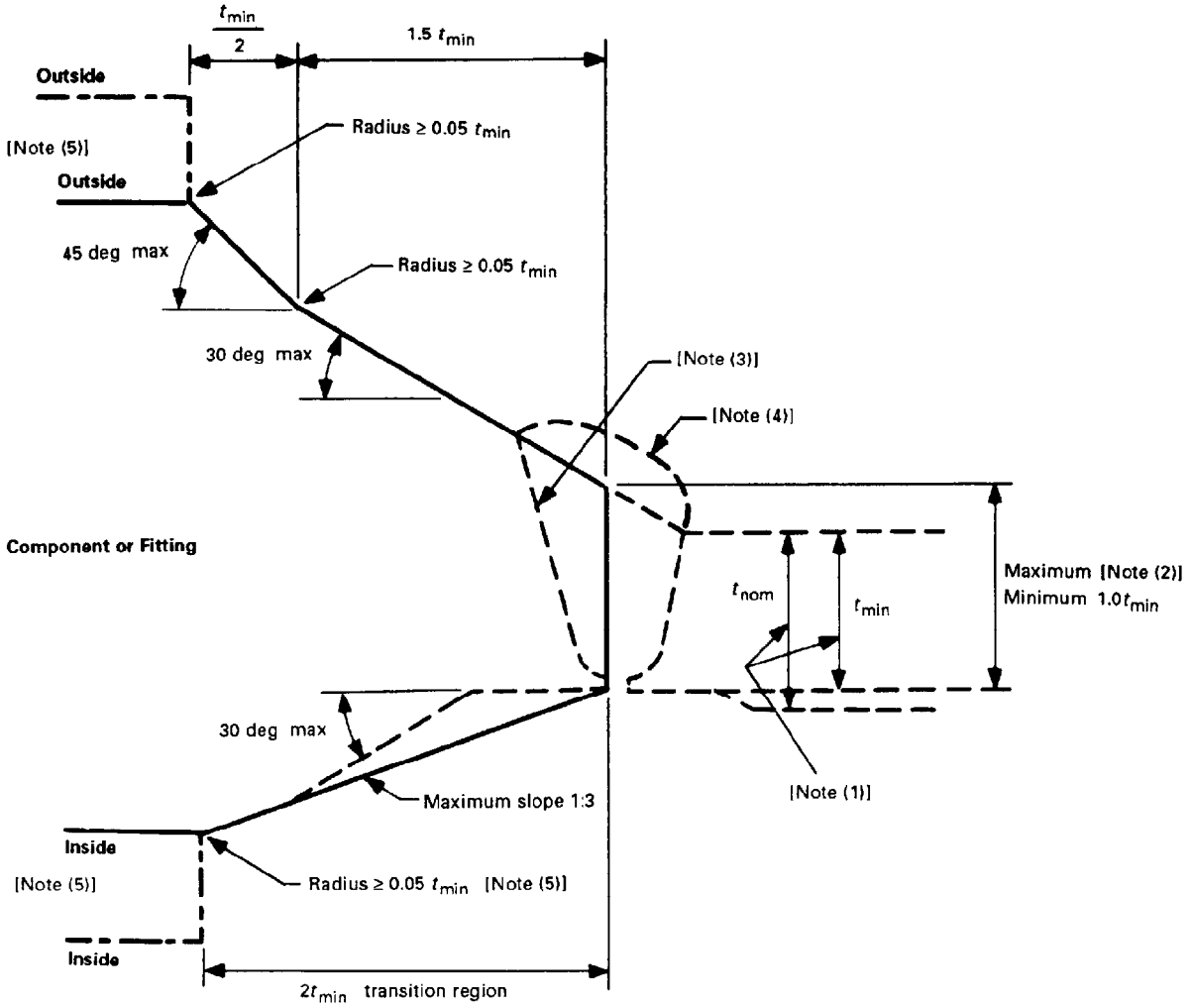

NOTES:
(1) The value of t_{min} is whichever of the following is applicable:
  (a) the minimum ordered wall thickness of the pipe;
  (b) 0.875 times the nominal wall thickness of pipe ordered to a pipe schedule wall thickness that has an under-tolerance of 12.5%;
  (c) the minimum ordered wall thickness of the cylindrical welding end of a component or fitting (or the thinner of the two) when the joint is between two components.
(2) The maximum thickness at the end of the component is:
  (a) the greater of t_{min} + 4 mm (0.16 in.) or 1.15t_{min} when ordered on a minimum wall basis;
  (b) the greater of t_{min} + 4 mm (0.16 in.) or 1.10t_{nom} when ordered on a nominal wall basis.
(3) Weld bevel shown is for illustration only.
(4) The weld reinforcement permitted by applicable code may lie outside the maximum envelope.
(5) Where transitions using maximum slope do not intersect inside or outside surface, as shown by phantom outlines, maximum slopes shown or alternate radii shall be used.

FIG. 1 MAXIMUM ENVELOPE FOR WELDING END TRANSITIONS

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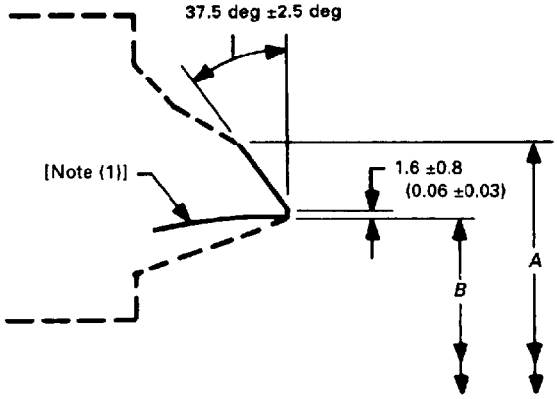
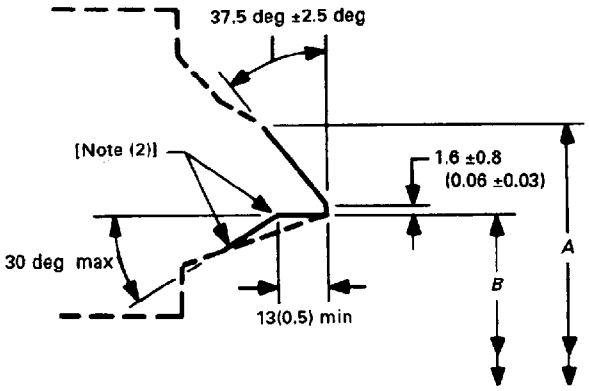
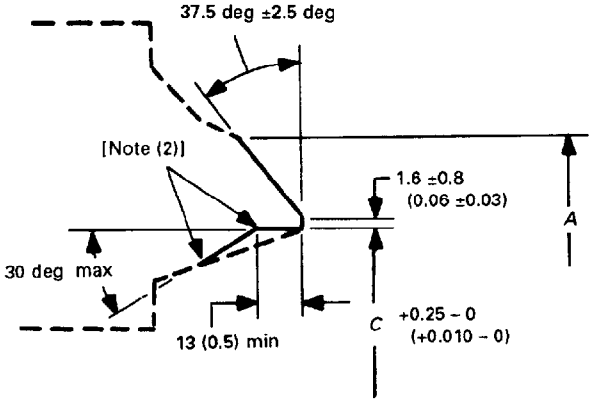


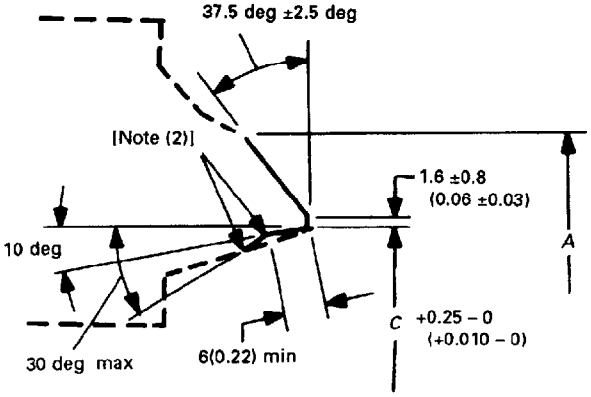
(a) Welding End Detail for Joint Without Backing Ring



(b) Welding End Detail for Joint Using Split Rectangular Backing Ring



(c) Welding End Detail for Joint Using Continuous Rectangular Backing Ring



(d) Welding End Detail for Joint Using Continuous Tapered Backing Ring

GENERAL NOTES:
(a) Broken lines denote maximum envelope for transitions from welding bevel and root face into body of component. See Fig. 1 for details.
(b) See Section 5 for tolerances other than those given in these sketches.
(c) Purchase order must specify contour of any backing ring to be used.
(d) Linear dimensions are in millimeters with inch values in parentheses.

NOTES:
(1) Internal surface may be as-formed or machined for dimension *B* at root face. Contour within the envelope shall be in accordance with Section 2.
(2) Intersections should be slightly rounded.

FIG. 2 WELD BEVELS FOR WALL THICKNESS NOT OVER 22 mm (0.88 in.)

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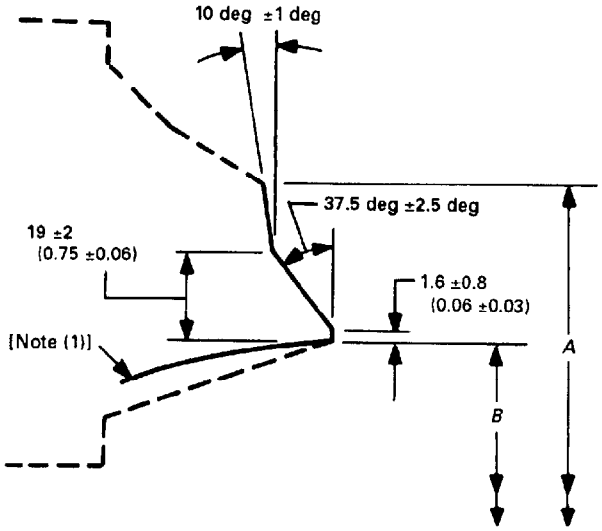
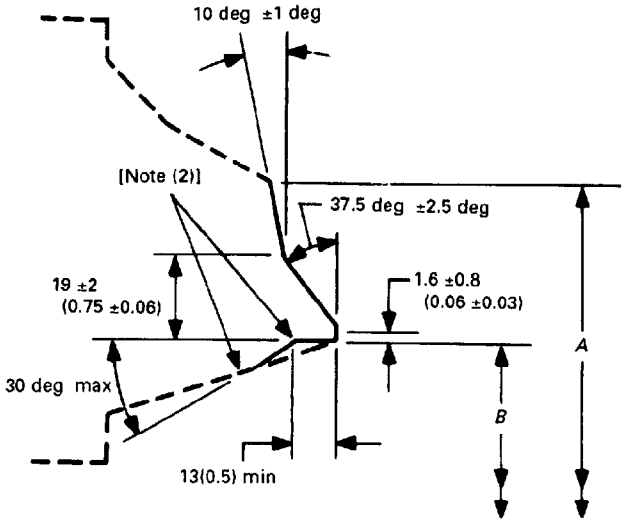
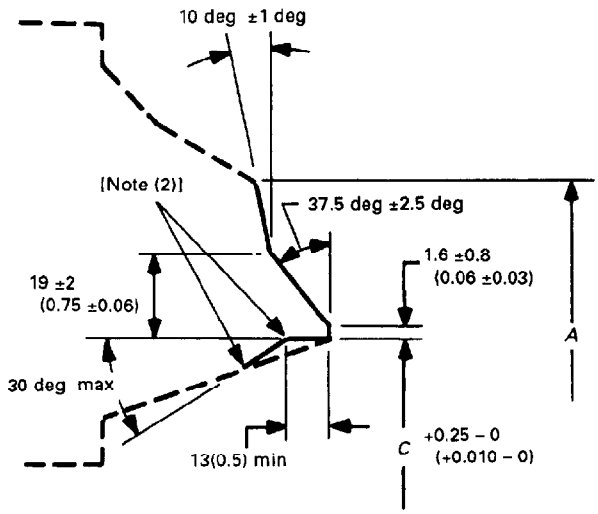


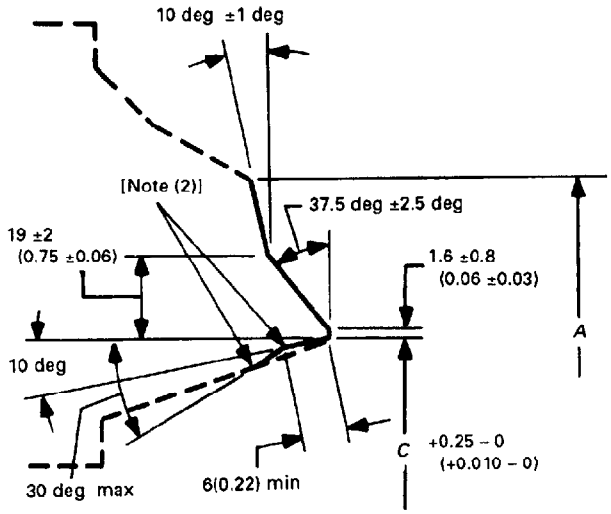
(a) Welding End Detail for Joint Without Backing Ring



(b) Welding End Detail for Joint Using Split Rectangular Backing Ring



(c) Welding End Detail for Joint Using Continuous Rectangular Backing Ring



(d) Welding End Detail for Joint Using Continuous Tapered Backing Ring

GENERAL NOTES:
(a) Broken lines denote maximum envelope for transitions from welding groove and root face into body of components. See Fig. 1 for details.
(b) See Section 5 for tolerances other than those given in these sketches.
(c) Purchase order must specify contour of any backing ring to be used.
(d) Linear dimensions are in millimeters with inch values in parentheses.

NOTES:
(1) Internal surface may be as-formed or machined for dimension *B* at root face. Contour within the envelope shall be in accordance with Section 2.
(2) Intersections should be slightly rounded.

FIG. 3 WELD BEVEL DETAILS FOR WALL THICKNESS OVER 22 mm (0.88 in.)

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(c) Components having nominal wall thicknesses greater than 22 mm (0.88 in.) shall have compound angle bevels as illustrated in Fig. 3.

3.2 Bevels for GTAW Root Pass

(a) Components having nominal wall thicknesses of 3 mm (0.12 in.) and less shall have ends cut square or slightly chamfered.

(b) Components having nominal wall thicknesses over 3 mm (0.12 in.) to 10 mm (0.38 in.) inclusive shall have 37½ deg ± 2½ deg bevels or slightly concave bevels. See Fig. 4.

(c) Components having nominal wall thicknesses over 10 mm (0.38 in.) to 25 mm (1.0 in.) inclusive shall have bevels as shown in Fig. 5.

(d) Components having nominal wall thicknesses greater than 25 mm (1.0 in.) shall have bevels as shown in Fig. 6.

4 PREPARATION OF INSIDE DIAMETER OF WELDING END

4.1 General

Preparation of the inside diameter at the end of a component shall be in accordance with one of the following, as specified by the purchaser.

(a) Components to be welded without backing rings shall meet the requirements of the standard or specification for the component.

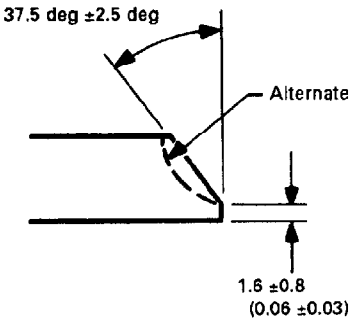
(b) Components to be welded using split or noncontinuous backing rings shall be contoured with a cylindrical surface at the end as shown in Fig. 2, sketch (b) and Fig. 3, sketch (b). If the backing ring contour is other than rectangular, details must be furnished by the purchaser.

(c) Components to be welded using solid or continuous backing rings shall be contoured with a cylindrical or tapered surface at the end as specified by the purchaser. End preparation is illustrated in Fig. 2, sketch (c) and Fig. 3, sketch (c) for rectangular ends and in Fig. 2, sketch (d) and Fig. 3, sketch (d) for tapered ends.

(d) Components to be welded using consumable insert rings or GTAW root pass shall be contoured with a cylindrical surface at the end as shown in Figs. 4, 5, and 6.

4.2 Dimension *C*

Values for dimension *C* shown in Fig. 2, sketches (c) and (d); Fig. 3, sketches (c) and (d); and Figs. 5 and 6 are tabulated in Table 1 for DN 65 through 900 (NPS 2½ through 36).



GENERAL NOTES:
(a) This detail applies for gas tungsten arc welding (GTAW) of the root pass where nominal wall thickness is over 3 mm (0.12 in.) to 10 mm (0.38 in.) inclusive.
(b) Linear dimensions are in millimeters with inch values in parentheses.

FIG. 4 WELD BEVEL DETAILS FOR GTAW ROOT PASS [Wall Thickness Over 3 mm (0.12 in.) to 10 mm (0.38 in.), Inclusive]

Dimensions for other sizes and/or wall thicknesses can be determined by the following formulas:

$$C = A - 0.79 - 1.75t - 0.25 \text{ mm}$$

$$(C = A - 0.031 - 1.75t - 0.010 \text{ in.})$$

where

A = nominal O.D. of pipe (see column 3 in Tables 1 and A1, taken from ASME B36.10M)

0.79 (0.031) = minus tolerance on O.D. of pipe, mm (in.), as covered by ASTM specifications having the more restrictive requirements such as A 106, A 335, etc.

1.75 = minimal wall of 87½% of nominal wall (permitted by ASTM specification having the more restrictive requirements such as A 106, A 335, etc.) multiplied by 2 to convert into terms of diameter

t = nominal wall thickness of pipe, mm (in.)

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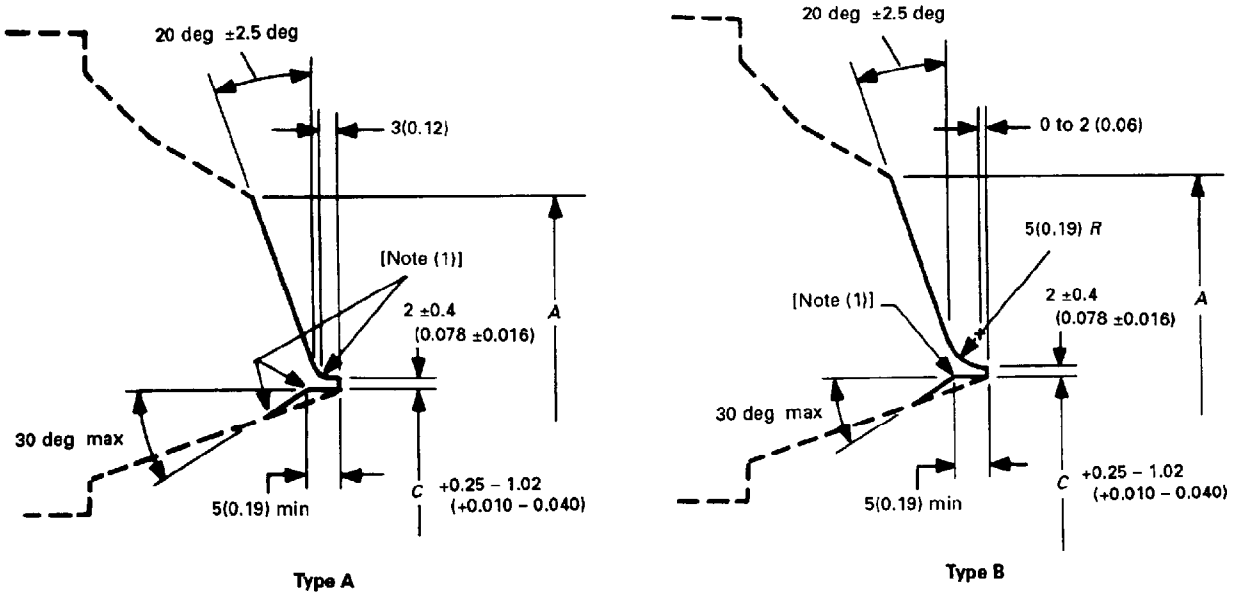

GENERAL NOTES:
(a) This detail applies for gas tungsten arc welding (GTAW) of the root pass where nominal wall thickness is over 10 mm (0.38 in.) to 25 mm (1.0 in.) inclusive.
(b) Broken lines denote maximum envelope for transitions from welding groove and land into body of component. See Fig. 1 for details.
(c) See Section 5 for tolerances other than those given in these sketches.
(d) Linear dimensions are in millimeters with inch values in parentheses.

NOTE:
(1) Inside corners should be slightly rounded.

FIG. 5 WELD BEVEL DETAILS FOR GTAW ROOT PASS [Wall Thickness Over 10 mm (0.38 in.) to 25 mm (1.0 in.), Inclusive]

0.25
(0.010) = plus machining tolerance on Bore *C*, mm (in.)

4.3 Exceptions

(a) For pipe or tubing varying from the ASTM A 106 and A 335 types, having different wall thickness and/or outside diameter tolerances (such as forged and bored pipe), the foregoing formulas may be inapplicable.

(b) For components in smaller sizes and lower schedule numbers, it may be necessary to deposit weld metal on the inside diameter or use thicker wall materials in order to machine the backing ring while maintaining required wall thickness. This condition may also arise when using material whose nominal dimensions indicate sufficient metal but whose actual inside diameter (I.D.), considering tolerances, is large enough to require additional metal.

5 TOLERANCES (See Figs. 2, 3, 5, and 6)

5.1 Dimension *B*

Values for the I.D. at the welding end [see dimension *B*, Fig. 2, sketches (a) and (b); and Fig. 3, sketches (a) and (b)] shall be as specified in the applicable standard or specification for the component.

5.2 Welding Bevels, Root Face, and Dimension *C*

Values of welding bevels, root face, and dimension *C* shall be as indicated in Figs. 2, 3, 4, 5, and 6.

Large diameter pipe and fittings with a relatively thin wall have a tendency to spring out-of-round after removal from the machining fixture. For this reason, the measured diameters may vary with orientation. A tolerance of +0.25 mm (+0.010 in.) shall apply to the average diameter.

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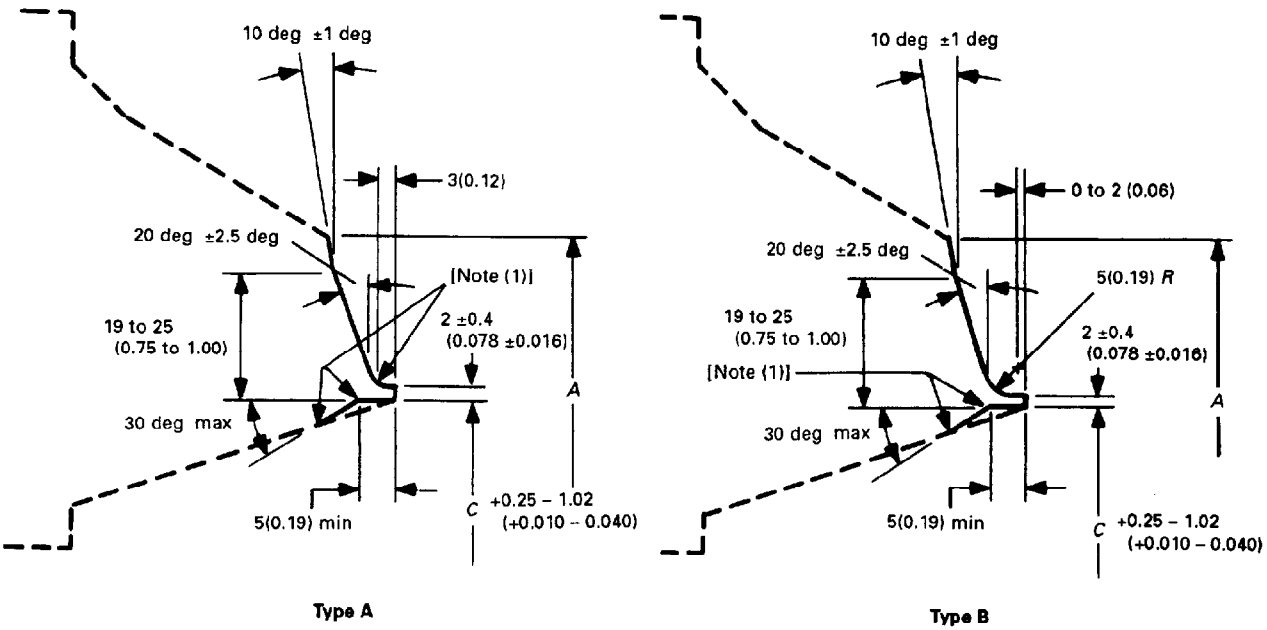

GENERAL NOTES:
(a) This detail applies for gas tungsten arc welding (GTAW) of root pass where nominal wall thickness is greater than 25 mm (1.0 in.).
(b) Broken lines denote maximum envelope for transitions from welding groove and land into body of component. See Fig. 1 for details.
(c) See Section 5 for tolerances other than those given in these sketches.
(d) Linear dimensions are in millimeters with inch values in parentheses.

NOTE:
(1) Inside corners should be slightly rounded.

FIG. 6 WELD BEVEL DETAILS FOR GTAW ROOT PASS [Wall Thickness Over 25 mm (1.0 in.)]

5.3 Dimension *A*

Dimension *A* is the nominal outside diameter of the component at the welding end.

5.3.1 Valves (Column 4 of Tables 1 and A1)

Nominal Size	Tolerance
≤ DN 125 (NPS 5)	+2.4 mm (0.09 in.) −0.8 mm (0.03 in.)
≥ DN 150 (NPS 6)	+4.0 mm (0.16 in.) −0.8 mm (0.03 in.)

5.3.2 Other Components. Dimension *A* values for other components shall be as specified in the applicable standard or specification for the component.

5.4 Wall Thickness

The maximum thickness, t_{max}, at the end of the component is:

(a) greater of t_{min} + 4 mm (0.16 in.) or $1.15t_{min}$ when ordered on a minimum wall basis;

(b) greater of t_{min} + 4 mm (0.16 in.) or $1.10t_{nom}$ when ordered on a nominal wall basis (see Fig. 1).

The minimum thickness, t_{min}, shall be as specified in the applicable standard or specification for the component (see Figs. 2, 3, 5, and 6).

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TABLE 1 DIMENSIONS OF WELDING ENDS
(See Figs. 1 to 6, Inclusive)

Nominal Pipe Size (DN)	Schedule No. [Note (1)]	O.D. at Welding Ends: Wrought or Fabricated Components, *A* [Note (1)]	O.D. at Welding Ends: Cast Steel Valves, *A* [Note (2)]	*B*	*C* [Note (3)]	*t*
65	40	73.0	75	62.5	62.93	5.16
	80	73.0	75	59	59.69	7.01
	160	73.0	75	54	55.28	9.53
	XXS	73.0	75	45	47.43	14.02
80	40	88.9	91	78	78.25	5.49
	80	88.9	91	73.5	74.53	7.62
	160	88.9	91	66.5	68.38	11.13
	XXS	88.9	91	58.5	61.19	15.24
90	40	101.6	105	90	90.52	5.74
	80	101.6	105	85.5	86.42	8.08
100	40	114.3	117	102	102.73	6.02
	80	114.3	117	97	98.28	8.56
	120	114.3	117	92	93.78	11.13
	160	114.3	117	87.5	89.65	13.49
	XXS	114.3	117	80	83.30	17.12
125	40	141.3	144	128	128.80	6.55
	80	141.3	144	122	123.58	9.53
	120	141.3	144	116	118.04	12.70
	160	141.3	144	109.5	112.47	15.88
	XXS	141.3	144	103	106.92	19.05
150	40	168.3	172	154	154.82	7.11
	80	168.3	172	146.5	148.06	10.97
	120	168.3	172	140	142.29	14.27
	160	168.3	172	132	135.31	18.26
	XXS	168.3	172	124.5	128.85	21.95
200	40	219.1	223	203	203.75	8.18
	60	219.1	223	198.5	200.02	10.31
	80	219.1	223	193.5	195.84	12.70
	100	219.1	223	189	191.65	15.09
	120	219.1	223	182.5	186.11	18.26
	140	219.1	223	178	181.98	20.62
	XXS	219.1	223	174.5	179.16	22.23
	160	219.1	223	173	177.79	23.01
250	40	273.0	278	254.5	255.74	9.27
	60	273.0	278	247.5	249.74	12.70
	80	273.0	278	243	245.55	15.09
	100	273.0	278	236.5	240.01	18.26
	120	273.0	278	230	234.44	21.44
	140	273.0	278	222	227.51	25.40
	160	273.0	278	216	221.95	28.58
300	STD	323.8	329	305	306.08	9.53
	40	323.8	329	303	304.72	10.31
	XS	323.8	329	298.5	300.54	12.70
	60	323.8	329	295	297.79	14.27

(Notes follow at end of table)

(Table 1 continues on next page)

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TABLE 1 DIMENSIONS OF WELDING ENDS (CONT'D)
(See Figs. 1 to 6, Inclusive)

Nominal Pipe Size (DN)	Schedule No. [Note (1)]	O.D. at Welding Ends: Wrought or Fabricated Components, *A* [Note (1)]	O.D. at Welding Ends: Cast Steel Valves, *A* [Note (2)]	*B*	*C* [Note (3)]	*t*
300	80	323.8	329	289	292.17	17.48
	100	323.8	329	281	285.24	21.44
	120	323.8	329	273	278.31	25.40
	140	323.8	329	266.5	272.75	28.58
	160	323.8	329	257	264.45	33.32
350	STD	355.6	362	336.5	337.88	9.53
	40	355.6	362	333.5	335.08	11.13
	XS	355.6	362	330	332.34	12.70
	60	355.6	362	325.5	328.15	15.09
	80	355.6	362	317.5	321.22	19.05
	100	355.6	362	308	312.86	23.83
	120	355.6	362	300	305.93	27.79
	140	355.6	362	292	299.00	31.75
	160	355.6	362	284	292.07	35.71
400	STD	406.4	413	387.5	388.68	9.53
	40	406.4	413	381	383.14	12.70
	60	406.4	413	373	376.21	16.66
	80	406.4	413	363.5	367.84	21.44
	100	406.4	413	354	359.53	26.19
	120	406.4	413	344.5	351.18	30.96
	140	406.4	413	333.5	341.43	36.53
	160	406.4	413	325.5	334.50	40.49
450	STD	457.2	464	438	439.48	9.53
	XS	457.2	464	432	433.94	12.70
	40	457.2	464	428.5	431.19	14.27
	60	457.2	464	419	422.82	19.05
	80	457.2	464	409.5	414.46	23.83
	100	457.2	464	398.5	404.78	29.36
	120	457.2	464	387.5	395.03	34.93
	140	457.2	464	378	386.77	39.67
	160	457.2	464	366.5	376.99	45.24
500	STD	508.0	516	489	490.28	9.53
	XS	508.0	516	482.5	484.74	12.70
	40	508.0	516	478	480.55	15.09
	60	508.0	516	467	470.88	20.62
	80	508.0	516	455.5	461.13	26.19
	100	508.0	516	443	450.02	32.54
	120	508.0	516	432	440.29	38.10
	140	508.0	516	419	429.17	44.45
	160	508.0	516	408	419.44	50.01
550	STD	558.8	567	539	541.08	9.53
	XS	558.8	567	533	535.54	12.70
	60	558.8	567	514	518.86	22.23
	80	558.8	567	501	507.75	28.58

(Notes follow at end of table)

(Table 1 continues on next page)

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TABLE 1 DIMENSIONS OF WELDING ENDS (CONT'D)
(See Figs. 1 to 6, Inclusive)

Nominal Pipe Size (DN)	Schedule No. [Note (1)]	O.D. at Welding Ends: Wrought or Fabricated Components, *A* [Note (1)]	O.D. at Welding Ends: Cast Steel Valves, *A* [Note (2)]	*B*	*C* [Note (3)]	*t*
550	100	558.8	567	488.5	496.63	34.93
	120	558.8	567	476	485.52	41.28
	140	558.8	567	463	474.41	47.63
	160	558.8	567	450.5	463.30	53.98
600	STD	609.6	619	590.5	591.88	9.53
	XS	609.6	619	584	586.34	12.70
	30	609.6	619	581	583.59	14.27
	40	609.6	619	574.5	577.97	17.48
	60	609.6	619	560.5	565.49	24.61
	80	609.6	619	547.5	554.38	30.96
	100	609.6	619	532	540.49	38.89
	120	609.6	619	517.5	528.03	46.02
	140	609.6	619	505	516.91	52.37
	160	609.6	619	490.5	504.37	59.54
650	10	660.4	670	645.5	645.50	7.92
	20	660.4	670	635	637.14	12.70
700	10	711.2	721	695.5	696.30	7.92
	20	711.2	721	686	687.94	12.70
	30	711.2	721	679.5	682.37	15.88
750	10	762.0	772	746	747.10	7.92
	20	762.0	772	736.5	738.74	12.70
	30	762.0	772	730	733.17	15.88
800	10	812.8	825	797	797.90	7.92
	20	812.8	825	787.5	789.54	12.70
	30	812.8	825	781	783.97	15.88
	40	812.8	825	778	781.17	17.48
850	10	863.6	876	848	848.70	7.92
	20	863.6	876	838	840.34	12.70
	30	863.6	876	832	834.77	15.88
	40	863.6	876	828.5	831.97	17.48
900	10	914.4	927	898.5	899.50	7.92
	20	914.4	927	889	891.14	12.70
	30	914.4	927	882.5	885.57	15.88
	40	914.4	927	876.5	880.02	19.05

GENERAL NOTES:
(a) Dimensions are in millimeters.
(b) See Section 5 for tolerances.

NOTES:
(1) Letter designations signify:
  (a) STD = standard wall thickness
  (b) XS = extra-strong wall thickness
  (c) XXS = double extra-strong wall thickness
(2) The diameters listed are not requirements. They are provided for the convenience of the user.
(3) Internal machining for continuous backing rings for sizes DN 50 and smaller is not contemplated. See para. 4.2 for *C* dimension for sizes not listed.

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ANNEX A
INCH TABLE

(This Annex is an integral part of ASME B16.25 and is placed after the main text for convenience.)

This Annex provides a table of the standard inch dimensions for fittings.

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TABLE A1 DIMENSIONS OF WELDING ENDS
(See Figs. 1 to 6, Inclusive)

Nominal Pipe Size (NPS)	Schedule No. [Note (1)]	O.D. at Welding Ends: Wrought or Fabricated Components, *A* [Note (1)]	O.D. at Welding Ends: Cast Steel Valves, *A* [Note (2)]	*B*	*C* [Note (3)]	*t*
2½	40	2.88	2.96	2.469	2.479	0.203
	80	2.88	2.96	2.323	2.351	0.276
	160	2.88	2.96	2.125	2.178	0.375
	XXS	2.88	2.96	1.771	1.868	0.552
3	40	3.50	3.59	3.068	3.081	0.216
	80	3.50	3.59	2.900	2.934	0.300
	160	3.50	3.59	2.624	2.692	0.438
	XXS	3.50	3.59	2.300	2.409	0.600
3½	40	4.00	4.12	3.548	3.564	0.226
	80	4.00	4.12	3.364	3.402	0.318
4	40	4.50	4.62	4.026	4.044	0.237
	80	4.50	4.62	3.826	3.869	0.337
	120	4.50	4.62	3.624	3.692	0.438
	160	4.50	4.62	3.438	3.530	0.531
	XXS	4.50	4.62	3.152	3.279	0.674
5	40	5.56	5.69	5.047	5.070	0.258
	80	5.56	5.69	4.813	4.866	0.375
	120	5.56	5.69	4.563	4.647	0.500
	160	5.56	5.69	4.313	4.428	0.625
	XXS	5.56	5.69	4.063	4.209	0.750
6	40	6.62	6.78	6.065	6.094	0.280
	80	6.62	6.78	5.761	5.828	0.432
	120	6.62	6.78	5.501	5.600	0.562
	160	6.62	6.78	5.187	5.326	0.719
	XXS	6.62	6.78	4.897	5.072	0.864
8	40	8.62	8.78	7.981	8.020	0.322
	60	8.62	8.78	7.813	7.873	0.406
	80	8.62	8.78	7.625	7.709	0.500
	100	8.62	8.78	7.437	7.544	0.594
	120	8.62	8.78	7.187	7.326	0.719
	140	8.62	8.78	7.001	7.163	0.812
	XXS	8.62	8.78	6.875	7.053	0.875
	160	8.62	8.78	6.813	6.998	0.906
10	40	10.75	10.94	10.020	10.070	0.365
	60	10.75	10.94	9.750	9.834	0.500
	80	10.75	10.94	9.562	9.670	0.594
	100	10.75	10.94	9.312	9.451	0.719
	120	10.75	10.94	9.062	9.232	0.844
	140	10.75	10.94	8.750	8.959	1.000
	160	10.75	10.94	8.500	8.740	1.125
12	STD	12.75	12.97	12.000	12.053	0.375
	40	12.75	12.97	11.938	11.999	0.406
	XS	12.75	12.97	11.750	11.834	0.500
	60	12.75	12.97	11.626	11.725	0.562

(Notes follow at end of table)

(Table A1 continues on next page)

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TABLE A1 DIMENSIONS OF WELDING ENDS (CONT'D)
(See Figs. 1 to 6, Inclusive)

Nominal Pipe Size (NPS)	Schedule No. [Note (1)]	O.D. at Welding Ends: Wrought or Fabricated Components, *A* [Note (1)]	O.D. at Welding Ends: Cast Steel Valves, *A* [Note (2)]	*B*	*C* [Note (3)]	*t*
12	80	12.75	12.97	11.374	11.505	0.688
	100	12.75	12.97	11.062	11.232	0.844
	120	12.75	12.97	10.750	10.959	1.000
	140	12.75	12.97	10.500	10.740	1.125
	160	12.75	12.97	10.126	10.413	1.312
14	STD	14.00	14.25	13.250	13.303	0.375
	40	14.00	14.25	13.124	13.192	0.438
	XS	14.00	14.25	13.000	13.084	0.500
	60	14.00	14.25	12.812	12.920	0.594
	80	14.00	14.25	12.500	12.646	0.750
	100	14.00	14.25	12.124	12.318	0.938
	120	14.00	14.25	11.812	12.044	1.094
	140	14.00	14.25	11.500	11.771	1.250
	160	14.00	14.25	11.188	11.498	1.406
16	STD	16.00	16.25	15.250	15.303	0.375
	40	16.00	16.25	15.000	15.084	0.500
	60	16.00	16.25	14.688	14.811	0.656
	80	16.00	16.25	14.312	14.482	0.844
	100	16.00	16.25	13.938	14.155	1.031
	120	16.00	16.25	13.562	13.826	1.219
	140	16.00	16.25	13.124	13.442	1.438
	160	16.00	16.25	12.812	13.170	1.594
18	STD	18.00	18.28	17.250	17.303	0.375
	XS	18.00	18.28	17.000	17.084	0.500
	40	18.00	18.28	16.876	16.975	0.562
	60	18.00	18.28	16.500	16.646	0.750
	80	18.00	18.28	16.124	16.318	0.938
	100	18.00	18.28	15.688	15.936	1.156
	120	18.00	18.28	15.250	15.553	1.375
	140	18.00	18.28	14.876	15.225	1.562
	160	18.00	18.28	14.438	14.842	1.781
20	STD	20.00	20.31	19.250	19.303	0.375
	XS	20.00	20.31	19.000	19.084	0.500
	40	20.00	20.31	18.812	18.920	0.594
	60	20.00	20.31	18.376	18.538	0.812
	80	20.00	20.31	17.938	18.155	1.031
	100	20.00	20.31	17.438	17.717	1.281
	120	20.00	20.31	17.000	17.334	1.500
	140	20.00	20.31	16.500	16.896	1.750
	160	20.00	20.31	16.062	16.513	1.969
22	STD	22.00	22.34	21.250	21.303	0.375
	XS	22.00	22.34	21.000	21.084	0.500
	60	22.00	22.34	20.250	20.428	0.875
	80	22.00	22.34	19.750	19.990	1.125

(Notes follow at end of table)

(Table A1 continues on next page)

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TABLE A1 DIMENSIONS OF WELDING ENDS (CONT'D)
(See Figs. 1 to 6, Inclusive)

Nominal Pipe Size (NPS)	Schedule No. [Note (1)]	O.D. at Welding Ends: Wrought or Fabricated Components, *A* [Note (1)]	O.D. at Welding Ends: Cast Steel Valves, *A* [Note (2)]	*B*	*C* [Note (3)]	*t*
22	100	22.00	22.34	19.250	19.553	1.375
	120	22.00	22.34	18.750	19.115	1.625
	140	22.00	22.34	18.250	18.678	1.875
	160	22.00	22.34	17.750	18.240	2.125
24	STD	24.00	24.38	23.250	23.303	0.375
	XS	24.00	24.38	23.000	23.084	0.500
	30	24.00	24.38	22.876	22.975	0.562
	40	24.00	24.38	22.624	22.755	0.688
	60	24.00	24.38	22.062	22.263	0.969
	80	24.00	24.38	21.562	21.826	1.219
	100	24.00	24.38	20.938	21.280	1.531
	120	24.00	24.38	20.376	20.788	1.812
	140	24.00	24.38	19.876	20.350	2.062
	160	24.00	24.38	19.312	19.857	2.344
26	10	26.00	26.38	25.376	25.413	0.312
	20	26.00	26.38	25.000	25.084	0.500
28	10	28.00	28.38	27.376	27.413	0.312
	20	28.00	28.38	27.000	27.084	0.500
	30	28.00	28.38	26.750	26.865	0.625
30	10	30.00	30.38	29.376	29.413	0.312
	20	30.00	30.38	29.000	29.084	0.500
	30	30.00	30.38	28.750	28.865	0.625
32	10	32.00	32.50	31.376	31.413	0.312
	20	32.00	32.50	31.000	31.084	0.500
	30	32.00	32.50	30.750	30.865	0.625
	40	32.00	32.50	30.624	30.755	0.688
34	10	34.00	34.50	33.376	33.413	0.312
	20	34.00	34.50	33.000	33.084	0.500
	30	34.00	34.50	32.750	32.865	0.625
	40	34.00	34.50	32.624	32.755	0.688
36	10	36.00	36.50	35.376	35.413	0.312
	20	36.00	36.50	35.000	35.084	0.500
	30	36.00	36.50	34.750	34.865	0.625
	40	36.00	36.50	34.500	34.646	0.750

GENERAL NOTES:
(a) Dimensions are in inches.
(b) See Section 5 for tolerances.

NOTES:
(1) Letter designations signify:
  (a) STD = standard wall thickness
  (b) XS = extra-strong wall thickness
  (c) XXS = double extra-strong wall thickness
(2) The diameters listed are not requirements. They are provided for the convenience of the user.
(3) Internal machining for continuous backing rings for sizes NPS 2 and smaller is not contemplated. See para. 4.2 for *C* dimension for sizes not listed.

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ANNEX B
QUALITY SYSTEM PROGRAM

(This is a nonmandatory part of ASME B16.25 and is included for information only.)

The products manufactured in accordance with ASME B16.25 shall be produced under a quality system program following the principles of an appropriate standard from the ISO 9000 series.[1] A determination of the need for registration and/or certification of the product manufacturer's quality system program by an independent organization shall be the responsibility of the manufacturer. The detailed documentation demonstrating program compliance shall be available to the purchaser at the manufacturer's facility. A written summary description of the program utilized by the product manufacturer shall be available to the purchaser upon request. The product manufacturer is defined as the entity whose name or trademark appears on the product in accordance with the marking or identification requirements of ASME B16.25.

[1] The series is also available from the American National Standards Institute (ANSI) and the American Society for Quality Control (ASQC) as American National Standards that are identified by a prefix "Q" replacing the prefix "ISO." Each standard of the series is listed under references.

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ANNEX C
REFERENCES

(This Annex is an integral part of ASME B16.25 and is placed after the main text for convenience.)

The following is a list of standards and specifications referenced in this Standard showing the year of approval.

ASME Publications (Approved as American National Standards)

ASME B16.5–1988, Pipe Flanges and Flanged Fittings

ASME B16.9–1993, Factory-Made Wrought Steel Buttwelding Fittings

ASME B16.28–1994, Wrought Steel Buttwelding Short Radius Elbows and Returns

ANSI/ASME B36.10M–1985, Welded and Seamless Wrought Steel Pipe

ASTM Publications

ASTM E 29–93, Standard Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications

ASTM A 106–94a, Specification for Seamless Carbon Steel Pipe for High-Temperature Service

ASTM A 335/A 335M–94, Specification for Seamless Ferritic Alloy Steel Pipe for High-Temperature Service

ISO Publications

ISO 9000–1: 1994: Quality Management and Quality Assurance Standards — Part 1: Guidelines for Selection and Use

ISO 9000–2: 1993: Quality Management and Quality Assurance Standards — Part 2: Generic Guidelines for the Application of ISO 9001, ISO 9002, and ISO 9003

ISO 9000–3: 1991: Quality Management and Quality Assurance Standards — Part 3: Guidelines for the Application of ISO 9001 to the Development, Supply and Maintenance of Software

ISO 9001: 1994: Quality Systems — Model for Quality Assurance in Design, Development, Production, Installation, and Servicing

ISO 9002: 1994: Quality Systems — Model for Quality Assurance in Production and Servicing

ISO 9003: 1994: Quality Systems — Model for Quality Assurance in Final Inspection and Test

Publications appearing above which have been approved as American National Standards may also be obtained from:

ANSI

American National Standards Institute, Inc.
11 West 42nd Street, New York, New York 10036

ISO

ISO Central Secretariat
Case Postale 56
CH–1211 GENEVA 20
Switzerland

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ASME B16.28 94 ■ 0759670 0550811 155 ■

ASME B16.28-1994
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Wrought Steel Buttwelding Short Radius Elbows and Returns

AN AMERICAN NATIONAL STANDARD

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AN AMERICAN NATIONAL STANDARD

Wrought Steel Buttwelding Short Radius Elbows and Returns

ASME B16.28-1994

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The 1994 edition of this Standard is being issued with an automatic addenda subscription service. The use of an addenda allows revisions made in response to public review comments or committee actions to be published as necessary; revisions published in addenda will become effective 6 months after the Date of Issuance of the addenda. The next edition of this Standard is scheduled for publication in 1999.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Standard. The interpretations will be included with the above addenda service. Interpretations are not part of the addenda to the Standard.

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FOREWORD

(This Foreword is not part of ASME B16.28-1994.)

In 1921, the American Engineering Standards Committee, later American Standards Association (ASA), organized Sectional Committee B16 to unify and further develop national standards for pipe flanges and fittings (and, later, for valves, gaskets, and valve actuators). Cosponsors of the B16 Committee were the American Society of Mechanical Engineers (ASME), the Heating and Piping Contractors National Association [now Mechanical Contractors Association of America (MCAA)], and the Manufacturers Standardization Society of the Valve and Fittings Industry (MSS). Cosponsors were later designated as cosecretariat organizations.

In 1959, recognizing the increasing use of short radius buttwelding fittings not covered by ASA B16.9-1958, MSS developed Standard Practice SP-59. In 1963, this Standard was submitted to Subcommittee 6 (now Subcommittee F), the B16 group responsible for welded fittings, for consideration as a candidate American Standard. Following approval by the Committee, cosponsors, and ASA, the standard was published as ASA B16.28-1964.

In 1969, review of the document indicated that no changes were necessary. After reorganization of ASA, first as the United States of America Standards Institute (USASI), then as the American National Standards Institute (ANSI), with the Sectional Committee being redesignated as an American National Standards Committee, the reaffirmation was approved and published as ANSI B16.28-1964 (R1972). Subcommittee F then began a major revision to bring the standard up to date with current practice and usage. Metric dimensional equivalents were also added. Following Standards Committee, cosecretariat, and ANSI approval, the revision was published as ANSI B16.28-1978.

In 1982, American National Standards Committee B16 was reorganized as an ASME Committee operating under procedures accredited by ANSI. In the 1986 edition, the text was revised and inch dimensions were established as the standard. Following approval by the Standards Committee and ASME, approval as an American National Standard was given by ANSI on November 12, 1986, with the new designation ASME/ANSI B16.28-1986.

Commencing in 1991, the subcommittee reviewed the document and made a number of revisions. The 80% factor used in the computed proof test pressure in earlier B16.28 editions was changed to 100% in this 1994 edition. After public review and approval by ASME, this edition was approved by ANSI on October 10, 1994.

Requests for interpretation or suggestions for revision should be sent to the Secretary, B16 Committee, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017.

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Standardization of Valves, Flanges, Fittings, and Gaskets

(The following is the roster of the Committee at the time of approval of this Standard.)

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WROUGHT STEEL BUTTWELDING SHORT RADIUS ELBOWS AND RETURNS

1 SCOPE

1.1 General

This Standard covers ratings, overall dimensions, testing, tolerances, and markings for wrought carbon and alloy steel buttwelding short radius elbows and returns. The term *wrought* denotes fittings made of pipe, tubing, plate, or forgings.

1.2 Fabricated Fittings

Fabricated fittings employing intersection welds are not covered by this Standard. Design of such fittings is covered in the ASME B31, Code for Pressure Piping or the ASME Boiler and Pressure Vessel Code.

1.3 References

1.3.1 Referenced Standards. Standards and specifications adopted by reference in this Standard are shown in Annex B, which is part of this Standard. It is not considered practical to identify the specific edition of each standard and specification in the individual references. Instead the specific edition reference is identified in Annex B. A product made in conformance with a prior edition of reference standards and in all other respects conforming to this Standard will be considered to be in conformance.

1.3.2 Codes and Regulations. A fitting used under the jurisdiction of the ASME Boiler and Pressure Vessel Code, the ASME Code for Pressure Piping, or a governmental regulation is subject to any limitation of that code or regulation. This includes any maximum temperature limitation or rule governing the use of a material at low temperature.

1.4 Service Conditions

Criteria for selection of fitting types and materials suitable for particular fluid service are not within the scope of this Standard.

1.5 Welding

Installation welding requirements are outside the scope of this Standard. Installation welding shall be done in accordance with the applicable piping code or regulation covering the piping system into which the fittings are installed.

2 DESIGN AND PRESSURE RATINGS

2.1 Design of Fittings

The design of the fittings shall be established by mathematical method analysis contained in nationally recognized pressure vessel or piping codes or at the manufacturer's option by proof testing in accordance with Section 9 of this Standard. In order to meet design requirements, it is expected that some portion of formed fittings may have to be thicker than the pipe wall with which the fitting is intended to be used.

2.2 Basis of Ratings

The allowable pressure ratings for fittings designed in accordance with this Standard shall be as for straight seamless pipe of equivalent size and material [nominal pipe size (NPS), wall thickness or schedule number, and including a comparison of chemical composition and mechanical properties of the respective material specification].

2.3 Record Maintenance

Records of mathematical analysis and/or successful proof test data shall be available at the manufacturer's facility for inspection by the purchaser. Certified copies of this data shall be made available to the purchaser upon agreement with the manufacturer.

3 SIZE

The sizes of fittings in Tables 1, 2, and 3 are identified by the corresponding NPS as defined in ANSI/ASME B36.10M.

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4 MARKING

4.1 Standard Marking (See Note)

Each fitting shall be permanently marked to show the following:

(a) manufacturer's name or trademark;

(b) material grade and class (ASTM or ASME grade symbol) and the heat number or manufacturer's heat identification;

(c) conformance to this Standard, designated by the prefix "WP" in the grade symbol marking;

(d) schedule number or nominal wall thickness designation;

(e) NPS.

NOTE: The pressure rating of the fitting is represented by the NPS, wall thickness (or schedule number), and material marked on the fitting. (See para. 2.2.)

4.2 Exceptions

Where the size of the fitting does not permit complete marking, the identification marks may be omitted in reverse of the order presented above.

4.3 Depth of Stamping

Where steel stamps are used, they shall be low stress and care should be taken so that the marking is not deep enough or sharp enough to cause cracks or to reduce the wall thickness of the fitting below the design minimum allowed.

5 MATERIAL

Wrought fittings covered by this Standard shall be in accordance with ASTM A 234, A 403, A 420, or the corresponding ASME Boiler and Pressure Vessel Code, Section II specification.

6 FITTINGS DIMENSIONS

This Standard provides for a fixed position for the welding ends with reference to either the center line of the fittings or the overall dimensions. Dimensional standards for these fittings are found in Tables 2, 3, A2, and A3.

The surface contour shall be essentially a segment of a torus that may be terminated in tangents.

7 END PREPARATION

Unless otherwise specified by the purchaser, welding ends shall be in accordance with ASME B16.25. For convenience, these welding ends are shown in Fig. 1 for fittings with wall thicknesses equal to that of the pipe to which they will be welded for use without a backing ring. Unless otherwise specified, fittings are furnished with welding ends for use without backing rings for the pipe wall thickness specified.

8 PRODUCTION TESTS

Hydrostatic testing of wrought fittings is not required by this Standard. All fittings shall be capable of withstanding, without leakage, a hydrostatic test pressure required by the applicable code for seamless pipe equivalent to the NPS, wall thickness, and material grade marked on the fitting.

9 DESIGN PROOF TESTS

9.1 Required Tests

Proof tests shall be made as set forth herein when the manufacturer chooses proof testing to qualify the fitting design. Unless otherwise agreed upon between manufacturer and purchaser, the only required type of proof test is a bursting strength test.

Proof tests conducted prior to the issuance of this edition of this Standard, which meet the requirements of this edition, are acceptable.

9.2 Test Assembly

9.2.1 Representative Fittings. Fittings that are representative of production and selected for test shall be identified as to material, grade, and lot, including heat treatment. They shall be inspected for dimensional compliance to this Standard.

9.2.2 Other Components. Straight seamless or welded pipe sections whose calculated bursting strength is at least as great as the proof test pressure as calculated in para. 9.3 shall be welded to each end of the fitting to be tested. Any internal misalignment greater than 0.06 in. (1.6 mm) shall be reduced by taper boring at a slope not over 1:3. The minimum length of pipe sections for closures shall be as follows:

(a) one pipe outside diameter for NPS 14 and smaller;

(b) one-half pipe outside diameter for NPS greater than 14.

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9.3 Test Procedure and Acceptance Standard

Test fluid shall be water or other liquid used for hydrostatic testing. Hydrostatic pressure shall be applied to the assembly.

The proof test requirements are met when assembly withstands, without rupture, 105% of the computed proof test pressure defined below.

$$P = \frac{2St}{D}$$

where

P = computed proof test pressure
S = actual ultimate tensile strength of the test fitting determined on a specimen taken from the fitting or representative of the test fitting. The test fitting shall meet all requirements of one of the materials listed in para. 5.
t = nominal pipe wall thickness of the pipe that the fitting marking identifies
D = specified outside diameter of pipe that the fitting marking identifies

9.4 Applicability of Results

It is not necessary to conduct an individual test of fittings with all combinations of sizes, wall thicknesses, and materials. A proof test meeting the requirements of para. 9.3 on one representative fitting may represent other fittings of the same type to the extent described below.

9.4.1 Size Range. One test fitting may be used to qualify similarly proportioned fittings with an NPS range from one-half to twice that for the tested fitting.

9.4.2 Thickness Range. One test fitting may be used to qualify similarly proportioned fittings with t/D ranges from one-half to three times that for the tested fitting.

9.4.3 Material Grades. The pressure retaining capacity of a geometrically identical fitting made of various grades of steel will be directly proportional to the tensile properties of the various grades. Therefore, it is necessary to test only a single material grade in a representative fitting to prove the design of the fitting.

10 TOLERANCES

Tolerances for all fittings are shown in Tables 1 and A1, and are based on the nominal dimensions given in Tables 2, 3, A2, and A3.

For the purpose of determining conformance with this Standard, the convention for fixing significant digits where limits, maximum or minimum values, are specified, shall be "rounded off" as defined in ASTM E 29. This requires that an observed or calculated value shall be rounded off to the nearest unit in the last right-hand digit used for expressing the limit.

The listing of decimal tolerances does not imply the method of measurement.

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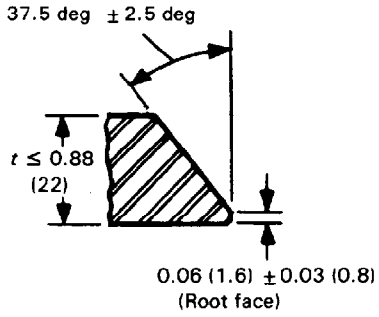
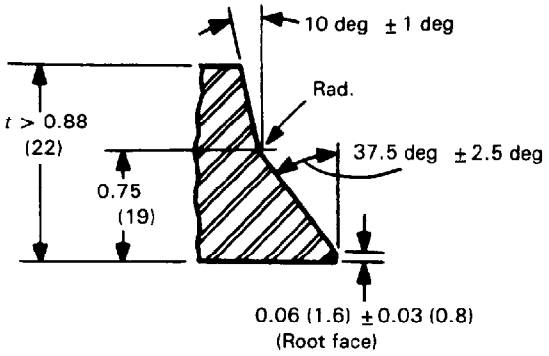


(a) Plain Bevel



(b) Compound Bevel

Nominal Wall Thickness *t*	End Preparation
Less than *x* [Note (1)]	Cut square or slightly chamfer, at manufacturer's option.
x to 0.88 incl. (22) [Note (1)]	Plain bevel as in sketch (a) above.
More than 0.88 (22)	Compound bevel as in sketch (b) above.

GENERAL NOTES:
(a) See ASME B16.25 for transitions from bevel and root face into body of fitting and backing ring preparations.
(b) Dimensions in parentheses are in millimeters.

NOTE:
(1) $x = 0.19$ (5) for carbon steel or ferritic alloy steel and 0.12 (3) for austenitic alloy steel

FIG. 1 WELDING BEVEL AND ROOT FACE FOR FITTING (Without Backing Ring, or With Split Backing Ring)

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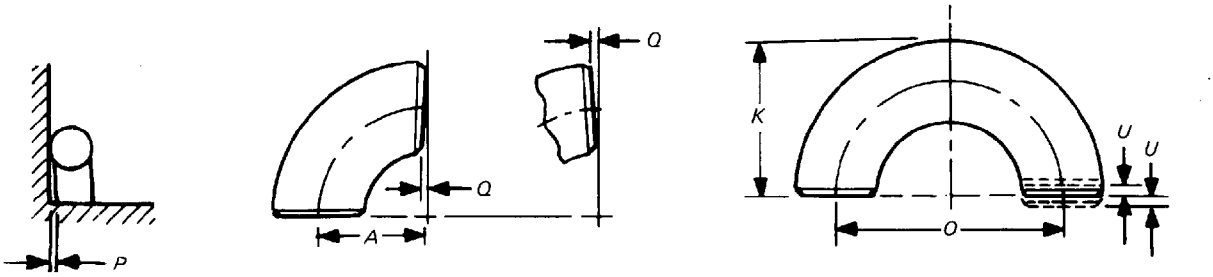

TABLE 1 TOLERANCES

Nominal Pipe Size	All Fittings					90 deg Elbows	180 deg Returns		
	Outside Diameter at Bevel [Notes (1), (2)]	Inside Diameter at End [Notes (1), (3), (4)]	Wall Thickness [Note (3)]	Angularity		Center-to-End Dimension *A*	Center-to-Center Dimension *O*	Back-to-Face Dimension *K*	Alignments of Ends *U*
				Off Angle *Q*	Off Plane *P*				
½ to 2½	+0.06 −0.03	0.03	Not less than 87.5% of nominal thickness marked on fitting	0.03	0.06	0.06	0.25	0.25	0.03
3 to 3½	0.06	0.06		0.03	0.06	0.06	0.25	0.25	0.03
4	0.06	0.06		0.03	0.06	0.06	0.25	0.25	0.03
5 to 8	+0.09 −0.06	0.06		0.06	0.12	0.06	0.25	0.25	0.03
10 to 12	+0.16 −0.12	0.12		0.09	0.19	0.09	0.38	0.25	0.06
14 to 16	+0.16 −0.12	0.12		0.09	0.25	0.09	0.38	0.25	0.06
18	+0.16 −0.12	0.12		0.12	0.38	0.09	0.38	0.25	0.06
20 to 24	+0.25 −0.19	0.19		0.12	0.38	0.09	0.38	0.25	0.06

GENERAL NOTE: Dimensions are in inches. Tolerances are equal plus and minus except as noted.

NOTES:
(1) Out-of-round is the sum of absolute values of plus and minus tolerance.
(2) This tolerance may be exceeded in localized areas of formed fittings where increased wall thickness is required to meet design requirements of para. 2.1.
(3) The inside diameter and the nominal wall thicknesses at ends are to be specified by the purchaser. Wall thickness tolerance applies throughout the fitting.
(4) Unless otherwise specified by the purchaser, these tolerances apply to the nominal inside diameter, which equals the difference between the nominal outside diameter and twice the nominal wall thickness.

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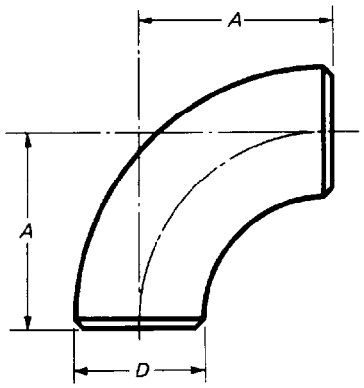

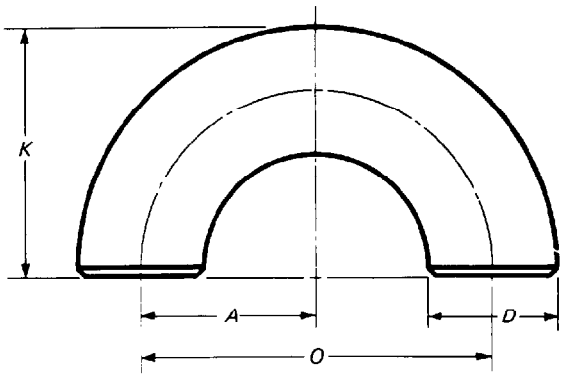

TABLE 2 DIMENSIONS OF SHORT RADIUS ELBOWS

Nominal Pipe Size	Outside Diameter at Bevel *D*	Center-to-End *A*
1	1.32	1.00
1¼	1.66	1.25
1½	1.90	1.50
2	2.38	2.00
2½	2.88	2.50
3	3.50	3.00
3½	4.00	3.50
4	4.50	4.00
5	5.56	5.00
6	6.62	6.00
8	8.62	8.00
10	10.75	10.00
12	12.75	12.00
14	14.00	14.00
16	16.00	16.00
18	18.00	18.00
20	20.00	20.00
22	22.00	22.00
24	24.00	24.00

GENERAL NOTE: Dimensions are in inches.

TABLE 3 DIMENSIONS OF SHORT RADIUS 180 deg RETURNS

Nominal Pipe Size	Outside Diameter at Bevel *D*	Center-to-Center *O*	Back-to-Face *K*
1	1.32	2.00	1.62
1¼	1.66	2.50	2.06
1½	1.90	3.00	2.44
2	2.38	4.00	3.19
2½	2.88	5.00	3.94
3	3.50	6.00	4.75
3½	4.00	7.00	5.50
4	4.50	8.00	6.25
5	5.56	10.00	7.75
6	6.62	12.00	9.31
8	8.62	16.00	12.31
10	10.75	20.00	15.38
12	12.75	24.00	18.38
14	14.00	28.00	21.00
16	16.00	32.00	24.00
18	18.00	36.00	27.00
20	20.00	40.00	30.00
22	22.00	44.00	33.00
24	24.00	48.00	36.00

GENERAL NOTES:
(a) Dimensions are in inches.
(b) Dimension *A* is equal to one-half of dimension *O*.

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ANNEX A
METRIC (SI) TABLE

(This Annex is an integral part of ASME B16.28-1994, and is placed after the main text for convenience.)

The metric tolerances and dimensions shown in Tables A1, A2, and A3 are for information and reference. They are not exact equivalents of the dimensions in Tables 1, 2, and 3. If used by agreement between manufacturer and purchaser, complete dimensional interchangeability with standard components can not be assured. Use of a combination of standard and metric values is contrary to the intent of this Standard.

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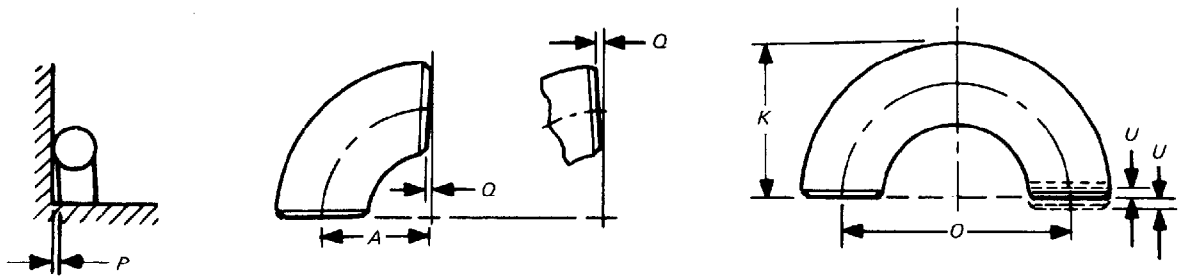

TABLE A1 TOLERANCES

Nominal Pipe Size	All Fittings					90 deg Elbows	180 deg Returns		
	Outside Diameter at Bevel [Notes (1), (2)]	Inside Diameter at End [Notes (1), (3), (4)]	Wall Thickness [Note (3)]	Angularity		Center-to-End Dimension	Center-to-Center Dimension	Back-to-Face Dimension	Alignments of Ends
				Off Angle *Q*	Off Plane *P*	*A*	*O*	*K*	*U*
½ to 2½	1	0.8	Not less than 87.5% of nominal thickness marked on fitting	1	2	2	7	7	1
3 to 3½	1	1.6		1	2	2	7	7	1
4	+2 −1	1.6		1	2	2	7	7	1
5 to 6	+3 −1	1.6		2	4	2	7	7	1
8	2	1.6		2	4	2	7	7	1
10 to 12	+4 −3	3.2		3	5	3	10	7	2
14 to 18	+4 −3	3.2		4	10	3	10	7	2
20 to 24	+6 −5	4.8		4	10	3	10	7	2

GENERAL NOTE: Dimensions are in millimeters. Tolerances are equal plus and minus except as noted.

NOTES:
(1) Out-of-round is the sum of absolute values of plus and minus tolerance.
(2) This tolerance may be exceeded in localized areas of formed fittings where increased wall thickness is required to meet design requirements of para. 2.1.
(3) The inside diameter and the nominal wall thicknesses at ends are to be specified by the purchaser. Wall thickness tolerance applies throughout the fitting.
(4) Unless otherwise specified by the purchaser, these tolerances apply to the nominal inside diameter, which equals the difference between the nominal outside diameter and twice the nominal wall thickness.

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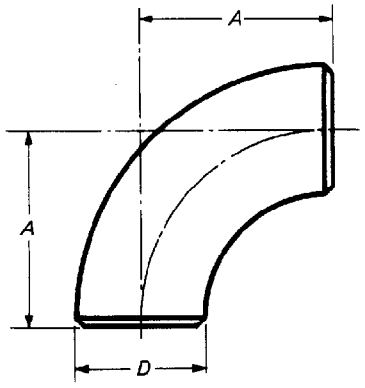

TABLE A2 DIMENSIONS OF SHORT RADIUS ELBOWS

Nominal Pipe Size	Outside Diameter at Bevel *D*			Center-to-End *A*		
				90 deg Elbows		
	Min.	Nom.	Max.	Min.	Nom.	Max.
1	32	33	34	23	25	27
1¼	41	42	43	30	32	34
1½	47	48	49	36	38	40
2	59	60	61	49	51	53
2½	72	73	74	62	64	66
3	88	89	90	74	76	78
3½	101	102	103	87	89	91
4	113	114	116	100	102	104
5	140	141	144	125	127	129
6	167	168	171	150	152	154
8	217	219	221	201	203	205
10	270	273	277	252	254	256
12	321	324	328	302	305	308
14	353	356	360	353	356	359
16	403	406	410	403	406	409
18	454	457	461	454	457	460
20	503	508	514	505	508	511
22	554	559	565	556	559	562
24	605	610	616	607	610	613

GENERAL NOTE: Dimensions are in millimeters.

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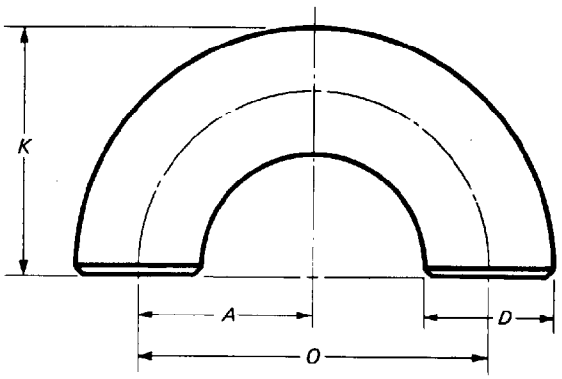

TABLE A3 DIMENSIONS OF SHORT RADIUS 180 deg RETURNS

Nominal Pipe Size	Outside Diameter at Bevel *D*			Center-to-Center *O*			Back-to-Face *K*		
	Min.	Nom.	Max.	Min.	Nom.	Max.	Min.	Nom.	Max.
1	32	33	34	44	51	58	34	41	48
1¼	41	42	43	57	64	71	45	52	59
1½	47	48	49	69	76	83	55	62	69
2	59	60	61	95	102	109	74	81	88
2½	72	73	74	120	127	134	93	100	107
3	88	89	90	145	152	159	114	121	128
3½	101	102	103	171	178	185	133	140	147
4	113	114	116	196	203	210	152	159	166
5	140	141	144	247	254	261	190	197	204
6	167	168	171	298	305	312	230	237	244
8	217	219	221	399	406	413	306	313	320
10	270	273	277	498	508	518	384	391	398
12	321	324	328	600	610	620	460	467	474
14	353	356	360	701	711	721	526	533	540
16	403	406	410	803	813	823	603	610	617
18	454	457	461	904	914	924	679	686	693
20	503	508	514	1006	1016	1026	755	762	769
22	554	559	565	1108	1118	1128	831	838	845
24	605	610	616	1209	1219	1229	907	914	921

GENERAL NOTES:
(a) Dimensions are in millimeters.
(b) Dimension *A* is equal to one-half of dimension *O*.

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ANNEX B
REFERENCES

(This Annex is an integral part of ASME B16.28-1994, and is placed after the main text for convenience.)

The following is a list of standards and specifications referenced in this Standard showing the year of approval.

ASME Publications (Approved as American National Standards)

ASME B16.25-1992	Buttwelding Ends
ASME B31	Code for Pressure Piping
ANSI/ASME B36.10M-1985	Welded and Seamless Wrought Steel Pipe
ASME Boiler and Pressure Vessel Code	Section I, Power Boilers Section II, Materials, Part A, Ferrous Material Specifications Section VIII, Pressure Vessels

ASTM Publications

ASTM A234M-92a	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures
ASTM A403M-91	Wrought Austenitic Stainless Steel Piping Fittings
ASTM A420M-92	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service
ASTM E 29-93a	Using Significant Digits in Test Data to Determine Conformance with Specifications

Publications of the following organizations appear on the above list:

ASME	The American Society of Mechanical Engineers 345 East 47th Street, New York, New York 10017 ASME Order Department 22 Law Drive, Box 2300 Fairfield, New Jersey 07007-2300
ASTM	American Society for Testing and Materials 1916 Race Street, Philadelphia, Pennsylvania 19103

Publications appearing above which have been approved as American National Standards may also be obtained from:

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AMERICAN NATIONAL STANDARDS FOR PIPING, PIPE FLANGES, FITTINGS, AND VALVES

Scheme for the Identification of Piping Systems ..... A13.1-1981(R1985)
Pipe Threads, General Purpose (Inch) ..... B1.20.1-1983(R1992)
Dryseal Pipe Threads (Inch) ..... B1.20.3-1976(R1991)
Cast Iron Pipe Flanges and Flanged Fittings B16.1-1989
Malleable Iron Threaded Fittings B16.3-1992
Gray Iron Threaded Fittings B16.4-1992
Pipe Flanges and Flanged Fittings B16.5-1988
Factory-Made Wrought Steel Buttwelding Fittings B16.9-1993
Face-to-Face and End-to-End Dimensions of Valves B16.10-1992
Forged Fittings, Socket-Welding and Threaded B16.11-1991
Cast Iron Threaded Drainage Fittings B16.12-1991
Ferrous Pipe Plugs, Bushings, and Locknuts with Pipe Threads B16.14-1991
Cast Bronze Threaded Fittings, Class 125 and 250 ..... B16.15-1985
Cast Copper Alloy Solder Joint Pressure Fittings B16.18-1984
Metallic Gaskets for Pipe Flanges — Ring-Joint, Spiral-Wound, and Jacketed B16.20-1993
Nonmetallic Flat Gaskets for Pipe Flanges B16.21-1992
Wrought Copper and Copper Alloy Solder Joint Pressure Fittings B16.22-1989
Cast Copper Alloy Solder Joint Drainage Fittings — DWV B16.23-1992
Cast Copper Alloy Pipe Flanges and Flanged Fittings, Class 150, 300, 400, 600, 900, 1500, and 2500 ..... B16.24-1991
Buttwelding Ends B16.25-1992
Cast Copper Alloy Fittings for Flared Copper Tubes B16.26-1988
Wrought Steel Buttwelding Short Radius Elbows and Returns B16.28-1994
Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings — DWV B16.29-1986
Cast Copper Alloy Solder Joint Fittings for Sovent Drainage Systems B16.32-1992
Manually Operated Metallic Gas Valves for Use in Gas Piping Systems Up to 125 psig (Sizes ½ Through 2) B16.33-1990
Valves — Flanged, Threaded, and Welding End B16.34-1988
Orifice Flanges B16.36-1988
Large Metallic Valves for Gas Distribution (Manually Operated, NPS 2½ to 12, 125 psig Maximum) ... B16.38-1985
Malleable Iron Threaded Pipe Unions, Classes 150, 250, and 300 ..... B16.39-1986
Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems B16.40-1985
Functional Qualification Requirements for Power Operated Active Valve Assemblies for Nuclear Power Plants ..... B16.41-1983(R1989)
Ductile Iron Pipe Flanges and Flanged Fittings, Class 150 and 300 ..... B16.42-1987
Wrought Copper and Copper Alloy Solder Joint Fittings for Sovent® Drainage Systems B16.43-1982
Cast Iron Fittings for Sovent® Drainage Systems B16.45-1987
Large Diameter Steel Flanges (NPS 26 Through NPS 60) B16.47-1990
Power Piping B31.1-1992
Fuel Gas Piping B31.2-1968
Chemical Plant and Petroleum Refinery Piping B31.3-1993
Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols B31.4-1992
Refrigeration Piping B31.5-1992
Gas Transmission and Distribution Piping Systems B31.8-1992
Building Services Piping B31.9-1988
Slurry Transportation Piping Systems B31.11-1989
ASME Guide for Gas Transmission and Distribution Piping Systems — 1986 (not an ANSI Standard) .....
Manual for Determining the Remaining Strength of Corroded Pipelines (not an ANSI Standard) B31G-1991
Welded and Seamless Wrought Steel Pipe B36.10M-1985
Stainless Steel Pipe B36.19M-1985
Self-Operated and Power-Operated Safety-Related Valves Functional Specification Standard .. N278.1-1975(R1984)

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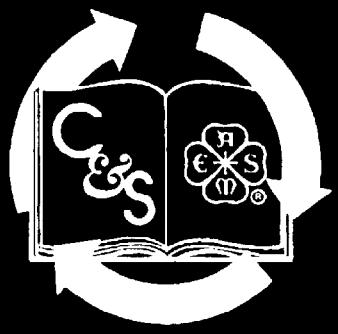

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ASME B16.42-1998
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DUCTILE IRON PIPE FLANGES AND FLANGED FITTINGS

Classes 150 and 300

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DUCTILE IRON PIPE FLANGES AND FLANGED FITTINGS

Classes 150 and 300

ASME B16.42-1998
(Revision of ASME/ANSI B16.42-1987)

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FOREWORD

(This Foreword is not part of ASME B16.42-1998.)

In 1921, the American Engineering Standards Committee, later the American Standards Association (ASA), now the American National Standards Institute (ANSI), authorized the organization of a Sectional Committee on the Standardization of Pipe Flanges and Flanged Fittings, with the following organizations as joint sponsors: Heating, Piping, and Air Conditioning Contractors National Association (later the Mechanical Contractors Association of America, MCAA), Manufacturers Standardization Society of the Valves and Fittings Industry (MSS), and The American Society of Mechanical Engineers (ASME). Cast iron flanges and flanged fittings are within the scope of Subcommittee No. 1 (now Subcommittee A), with standards approved by ASA as early as 1928.

In 1957, piping components of ductile iron (also called nodular iron and, in Europe, spheroidal graphite iron) first appeared in the market. Controversy immediately developed over proper pressure-temperature ratings, and this was further aggravated by the use of casting patterns for both gray iron and carbon steel for producing the components.

Conflicting philosophies, which emerged from that controversy, thwarted efforts by MSS to develop standard practices in the early 1960s; the conflicts persisted during a study of ratings, starting in 1966 by American National Standards Committee B16 (as the Sectional Committee was called after reorganization of ASA as ANSI). The conflict continued to delay acceptance and approval of this Standard, which ultimately originated with a draft developed by MSS (taking advantage of earlier efforts) and submitted to Subcommittee A in 1977. Combining that draft with the rating basis developed in the B16 Committee, the first edition of this Standard was found acceptable and was approved by the Standards Committee, cosecretariat organizations, and ANSI, and was published with the designation ANSI B16.42-1979.

In 1982, American National Standards Committee B16 was reorganized as an ASME Committee operating under procedures accredited by ANSI. The 1981 edition of the Standard updated the referenced standards and specifications and established U.S. customary units as the standard. Following approval by the Standards Committee and ASME, ANSI granted its approval as an American National Standard on July 13, 1987, with the new designation ASME/ANSI B16.42-1987.

In the 1998 edition of ASME B16.42, Reference Standards are updated, a Quality System Program Annex is added, and several editorial revisions are made. Following approval by ASME B16 Subcommittee B and B16 Main Committee, ANSI approved this American National Standard on November 20, 1998.

Requests for interpretation or suggestions for revision should be sent to the Secretary, B16 Committee, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

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Standardization of Valves, Flanges, Fittings, Gaskets, and Valve Actuators

(The following is the roster of the Committee at the time of approval of this Standard.)

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Secretary, B16 Main Committee
The American Society of Mechanical Engineers
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Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Interpretations. Upon request, the B16 Committee will render an interpretation of any requirement of the Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the B16 Main Committee.

The request for interpretation should be clear and unambiguous. It is further recommended that the inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. The inquirer may also include any plans or drawings, which are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in this format will be rewritten in this format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME Committee or Subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

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DUCTILE IRON PIPE FLANGES AND FLANGED FITTINGS
Classes 150 and 300

1 SCOPE

1.1 General

This Standard covers minimum requirements for Class 150 and 300 cast ductile iron pipe flanges and flanged fittings. The requirements covered are as follows:

(a) pressure-temperature ratings
(b) sizes and method of designating openings
(c) marking
(d) materials
(e) dimensions and tolerances
(f) bolts, nuts, and gaskets
(g) tests

1.2 Quality Systems

Requirements relating to the product manufacturers' Quality System Programs are described in Annex B.

1.3 References

1.3.1 Referenced Standards. Standards and specifications adopted by reference in this Standard are shown in Annex C, which is part of this Standard. It is not considered practical to identify the specific edition of each standard and specification in the individual references. Instead, the specific edition reference is identified in Annex C.

1.3.2 Codes and Regulations. A flange or flanged fitting used under the jurisdiction of the ASME Boiler and Pressure Vessel Code, the ASME Code for Pressure Piping, or a governmental regulation is subject to any limitation of that code or regulation. This includes any maximum temperature limitation, any rule governing the use of a material at low temperature, or provisions for operation at a pressure exceeding the pressure-temperature ratings in this Standard.

2 PRESSURE–TEMPERATURE RATINGS

2.1 General

Cast ductile iron pipe flanges and flanged fittings covered by this Standard shall be designated as one of the following: Class 150 or 300.

Except as provided in para. 2.5, ratings are maximum allowable nonshock working pressures, expressed as gage pressure, at the service temperature from –20°F to 650°F. Ratings in Table 1 are in U.S. customary units. For intermediate temperatures, linear interpolation is permitted. Methods for establishing pressure-temperature ratings are given in Annex A.

2.2 Ratings of Flanged Joints

Ratings in this Standard apply to flanged joints that conform to the limitations on bolting in para. 5.2 and on gaskets in para. 6.8, and which are made up in accordance with good practice for alignment and assembly. See also para. 2.4.

Use of the ratings for flanged joints not conforming to these limitations is the sole responsibility of the user. Requirements for alignment and assembly of joints are not given in this Standard.

If the two flanges in a flanged joint do not have the same pressure-temperature ratings, the rating of the joint at any temperature is the lower of the two flange ratings at that temperature.

2.3 Rating Temperature

The temperature shown for a corresponding pressure rating is the temperature of the pressure-containing shell of the flange or flanged fitting. In general, this temperature is the same as that of the contained fluid. Use of a pressure rating corresponding to a temperature other than that of the contained fluid is the responsibility of the user, subject to the requirements of the applicable code or regulation.

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TABLE 1 PRESSURE-TEMPERATURE RATINGS, U.S. CUSTOMARY UNITS

	Working Pressure, psi gage	
Temperature, °F	Class 150	Class 300
-20 to 100	250	640
200	235	600
300	215	565
400	200	525
500	170	495
600	140	465
650	125	450

2.4 Temperature Considerations

Application of the ratings in this Standard to flanged joints at both high and low temperatures shall take into consideration the risk of leakage due to forces and moments developed in the connected piping or equipment. The following provisions are intended to minimize these risks.

2.4.1 Flange Attachment. Threaded flanges are not recommended for service above 500°F if severe thermal gradients or thermal cycling is involved.

2.4.2 High Temperature Service. When used above 400°F, Class 150 flanged joints may develop leakage unless care is taken to avoid imposing severe external loads and/or severe thermal gradients.

2.5 Variances From Ratings

Except as provided herein, ratings are the maximum allowable nonshock working pressure for the corresponding temperature.

2.5.1 Safety or Relief Valve Operation. Under conditions of safety valve, relief valve, or rupture disk operation, the pressure on a flange or flanged fitting may exceed the rated pressure at the pressure relieving temperature by no more than 10%. Such conditions are necessarily of short duration. Overpressure greater than the aforementioned under pressure-relieving conditions is the responsibility of the user, subject to the requirements of the applicable code or regulation.

2.5.2 Other Variances. Operating variations (transients) that subject a flange or flanged fitting to pressure in excess of the rated pressure at the corresponding temperature are the responsibility of the user, subject to the requirements of the applicable code or regulation.

2.5.3 System Hydrostatic Test. Flanged joints and flanged fittings may be subjected to system hydrostatic tests at a pressure not to exceed the hydrostatic shell test pressure specified in para. 8.3. Testing at any higher pressure is the responsibility of the user.

3 SIZE

3.1 Nominal Size

The size of a flange or flanged fitting covered by this Standard is its nominal pipe size (NPS). The diameter of a bolt is its nominal size. Use of nominal indicates that the stated size or dimension is only for designation, not measurement. The actual dimension may or may not be the nominal size and is subject to established tolerances.

3.2 Reducing Fitting Sizes

Reducing fittings shall be designated by the size of the openings in their proper sequence as indicated in the sketches, Fig. 1.

3.3 Reducing Flange Sizes

Reducing flanges shall be designated by the two nominal pipe sizes. See examples in Note (4), Table 2.

4 MARKING

Except as modified herein, flanges and flanged fittings shall be marked as required in MSS SP-25.

(a) Name. The manufacturer's name or trademark shall be applied.

(b) Material. The word "DUCTILE" ("D.I." where space does not permit "DUCTILE").

(c) Rating Class. Numerals shall be applied giving the pressure rating class for which the product is designed.

(d) Designation. The designation "B16" shall be applied, preferably located adjacent to the Class designation, to indicate conformance to this Standard.

(e) Temperature. No temperature markings are required on flanges and flanged fittings, but if marked, the temperature shall be shown with its corresponding tabulated pressure rating.

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(f) Size. The nominal pipe size shall be given, but may be omitted from reducing flanges and reducing flanged fittings.

5 MATERIALS

5.1 Castings

Ductile iron castings covered by this Standard shall conform to ASTM A 395. The castings shall not be repaired by plugging, welding, brazing, or impregnation.

5.2 Bolting

Bolting listed in paras. 5.2.1 and 5.2.2 shall be used in flanged joints covered by this Standard. Bolting of other material may be used if permitted by the applicable code or governmental regulation.

5.2.1 High Strength Bolting. Bolting materials having allowable stresses not less than those for ASTM A 193 Grade B7 may be used with any flanged joint at all listed temperatures. The strength of the nut shall be not less than specified for ASTM A 194 Grade 2H.

5.2.2 Low Strength Bolting. Bolting materials with yield strength equivalent to ASTM A 307 Grade B are considered low strength and may be used for flanged joints at temperatures no greater than 400°F and only with gaskets described in para. 6.8.

5.2.3 Bolting to Cast Iron Flanges. When Class 150 ductile iron flanges are bolted to Class 125 cast iron flanges, or Class 300 ductile iron flanges are bolted to Class 250 cast iron flanges, it is recommended that low strength boltings be used within the limitations in para. 5.2.2. If high strength bolting is used, it is recommended that the mating flanges be flat faced and that full-faced gaskets (ASME B16.5, Fig. E1, Group Ia materials) extending to the O.D. of the flange be used.

5.3 Gaskets

Materials listed in Fig. E1 (ASME B16.5, Annex E) shall be used. The user is responsible for selection of gasket materials that will withstand the expected bolt load without injurious crushing and which are suitable for the service conditions.

For low strength bolting described in para. 5.2.2, only gaskets listed in Group Ia (ASME B16.5, Fig. E1) shall be used.

6 DIMENSIONS[1]

6.1 Center-to-Contact Surface and Center-to-End

6.1.1 Standard Fittings. Center-to-contact surface dimensions are shown in Tables 5 and 9.

6.1.2 Reducing Fittings. Center-to-contact surface or center-to-flange edge dimensions for all openings shall be the same as those of straight size fittings of the largest opening. The contact surface-to-contact surface dimensions for all combinations of reducers and eccentric reducers shall be as listed for the larger opening.

6.1.3 Side Outlet Fittings. Side outlet elbows, side outlet tees, and side outlet crosses shall have all openings on intersecting center lines, and the center-to-contact surface dimensions of the side outlet shall be the same as for the largest opening. Long radius elbows with side outlet shall have the side outlet on the radial center line of the elbow, and center-to-contact surface dimension of the side outlet shall be the same as for the regular 90 deg elbow of the largest opening.

6.1.4 Fittings With Bases. Dimensions of bases for base elbows and base tees are shown in Tables 6 and 10.

6.1.5 Special Degree Elbows. Special degree elbows ranging from 1 deg to 45 deg, inclusive, shall have the same center-to-contact surface dimensions as 45 deg elbows; those over 45 deg to 90 deg, inclusive, shall have the same center-to-contact surface dimensions as 90 deg elbows. The angle designation of an elbow is its deflection from straight line flow and is also the angle between the flange faces.

6.2 Facings

6.2.1 General. Class 150 fittings and companion flanges are regularly furnished flat or with a 0.06 in. raised face. Class 300 fittings and companion flanges are furnished with a 0.06 in. raised face. The raised face is included in the minimum flange thickness Q.

6.2.2 Facings of Blind Flanges. Blind flanges need not be faced in the center if, when this center part is raised, its diameter is at least 1 in. smaller than the inside diameter of the corresponding pressure class fittings, as given in the tables. When the center part

[1] Linear dimensions expressed in decimal fractions of an inch are actually common fractions rounded to the nearest two-place decimal.

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is depressed, its diameter shall not be greater than the inside diameter of the corresponding pressure class fittings, as given in the tables. Machining of the depressed center is not required.

6.2.3 Flange Facing Finish. Contact faces shall be finished in accordance with MSS SP-6.

6.3 Flange Bolt Holes

Bolt holes are in multiples of four so that fittings may face in any quadrant. Pairs of bolt holes shall straddle the center lines.

6.4 Spot Facing

Spot facing is required on ductile iron flanges and flanges on fittings if the flange thickness at any point exceeds the required minimum thickness Q as given in Tables 4, 5, 8, and 9 by more than the following amounts.

Nominal Pipe Size	Excess Thickness, in., Max.
2–18	0.12
20–24	0.19

Diameter of spot facing, when required, shall be in accordance with MSS SP-9.

6.5 Reducing Flanges

6.5.1 Drilling, O.D., Thickness, and Facing Dimensions. Flange drilling, O.D., thickness, and facing are the same as those of the standard flange of the size from which the reduction is being made.

6.5.2 Threaded Flanges. The hub dimensions shall be at least as large as those of the standard flange of the size from which the reduction is being made. The hub may be larger or may be omitted, as detailed in Table 2.

6.6 Threads for Threaded Flanges

Threaded flanges shall have American National Standard Pipe Threads, General Purpose (Inch) conforming to ASME B1.20.1. The thread shall be concentric with the axis of the flange, and variations in alignment shall not exceed 0.06 in./ft (0.5%).

6.6.1 Class 150 Flanges. Class 150 flanges are made without a counterbore. The threads shall be chamfered approximately to the major diameter of the thread at the back of the flange at an angle of approximately 45 deg with the axis of the thread of afford easy entrance in making a joint and to protect the thread. The chamfer shall be concentric with the thread and shall be included in the measurement of the thread length.

6.6.2 Class 300 Flanges. Class 300 flanges may be made with a counterbore. The threads shall be chamfered to the diameter of the counterbore at the back of the flange at an angle of approximately 45 deg with the axis of the threads to afford easy entrance in making a joint. The counterbore and chamfer shall be concentric with the thread.

6.6.3 Length of Threads. The minimum length of effective thread in reducing flanges shall be at least equal to dimension T of the corresponding pressure class threaded flange as shown in the tables, but does not necessarily extend to the face of the flange. See Table 2 for reducing threaded flanges.

6.6.4 Threading Tolerances. The gaging notch of the working gage shall come flush with the bottom of the chamfer in all threaded flanges, and shall be considered as the intersection of the chamfer cone and the pitch cone of the thread. This depth of chamfer is approximately equal to one-half the pitch of the thread. The maximum allowable thread variation is one turn large or small from the gaging notch.

6.7 Stud Bolts, Bolts, and Nuts

6.7.1 Alloy Bolting. Alloy steel stud bolts, threaded at both ends or full length, or heavy hex bolts may be used. Heavy hex nuts shall be used with all alloy steel bolting.

6.7.2 Carbon Steel Bolting

(a) Bolts smaller than $\frac{3}{4}$ in. shall have square heads or heavy hex heads. Nuts shall be heavy hex.

(b) Bolts $\frac{3}{4}$ in. and larger shall have square heads or hex heads. Nuts shall be hex or heavy hex.

6.7.3 Bolt Dimensions. Dimensions of all bolts shall conform to ASME B18.2.1.

6.7.4 Nut Dimensions. Dimensions of all nuts shall conform to ASME B18.2.2.

6.7.5 Threading of Bolts

(a) Carbon steel bolting shall be threaded in accordance with ASME B1.1, coarse thread series, Class 2A for bolts and stud bolts, and Class 2B for nuts.

(b) Alloy steel bolting shall be threaded in accordance with ASME B1.1. Nominal diameters 1 in. and smaller

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shall be of the coarse thread series; nominal diameters $1\frac{1}{8}$ in. and larger shall be of the 8 thread series. Bolts, studs, and stud bolts shall have Class 2A dimensions; nuts shall have Class 2B dimensions.

6.8 Gaskets

Gaskets for Class 150 flat face flanges shall conform to the dimensions shown in ASME B16.21. For flanges with raised face, gaskets shall conform to limiting dimensions of ASME B16.5, Annex E.

6.9 Drains

6.9.1 Pipe Thread Tapping. Holes may be tapped in the wall of a fitting if the metal is thick enough to allow the effective thread length specified in MSS SP-45. Where thread length is insufficient or the tapped hole needs reinforcement, a boss shall be added.

6.9.2 Bosses. Where bosses are required, the diameters shall be as specified in MSS SP-45.

6.9.3 Designating Locations. The means of designating the locations of tapped holes or sockets for drains in fittings is shown in Fig. 2.

Each possible location is designated by a letter so that the desired locations for the various types of fittings may be specified without using further sketches or descriptions.

7 TOLERANCES

7.1 Wall Thickness

The wall thickness values for fittings listed in Tables 5 and 9 are minimum. Equipment shall be designed to produce greater nominal wall thickness so that manufacturing variances will not fall below these minimum values. See para. A1.2 in Annex A for the basis used to establish these values.

7.2 Center-to-Contact Surface and Contact Surface-to-Contact Surface

7.2.1 Center-to-Contact Surface

(a) Sizes NPS 10 and smaller, ±0.03 in.
(b) Sizes NPS 12 and larger, ±0.06 in.

7.2.2 Contact Surface-to-Contact Surface

(a) Sizes NPS 10 and smaller, ±0.06 in.
(b) Sizes NPS 12 and larger, ±0.12 in.

7.3 Facings

Outside diameter, 0.06 in. raised face, ±0.03 in.

7.4 Flange Thickness

(a) Sizes NPS 18 and smaller, +0.12 in. −0
(b) Sizes NPS 20 and larger, +0.19 in. −0

7.5 Bore of Flanges

7.5.1 Lapped Flanges

(a) Sizes NPS 10 and smaller, +0.03 in. −0
(b) Sizes NPS 12 and larger, +0.06 in. −0

7.5.2 Counterbore of Threaded Flanges

(a) Sizes NPS 10 and smaller, +0.03 in. −0
(b) Sizes NPS 12 and larger, +0.06 in. −0

7.6 Drilling and Facing

(a) Bolt circle diameter, +0.06 in.
(b) Center-to-center of adjacent bolt holes, ±0.03 in.
(c) Eccentricity between bolt circle diameter and machined facing diameters:
(1) Sizes NPS $2\frac{1}{2}$ and smaller, ±0.03 in.
(2) Sizes NPS 3 and larger, ±0.06 in.

8 TESTING

8.1 General

Flanged fittings shall be hydrostatically tested in accordance with para. 8.3.

8.2 Flange Testing

Flanges are not required to be hydrostatically tested. Flanges attached to (or integral with) piping, pressure vessels, or other equipment may be subject to system hydrostatic test (see para. 2.5.3). In such cases, attention should be given to gasket selection because of possible excessive deformation of the flange.

8.3 Fitting Shell Tests

The hydrostatic shell test for flanged fittings shall be not less than 1.5 times the 100°F rating rounded off to the next higher 25 psi increment. The test pressure shall be 400 psi for Class 150 and 975 psi for Class 300.

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(a) The test shall be made with water, or with other suitable fluid provided its viscosity is no greater than that of water, at a test temperature not above 125°F.

(b) The test duration shall be a minimum of 15 sec for fittings NPS 2 and smaller, 60 sec for fittings NPS $2\frac{1}{2}$ through 8, and 3 min for fitting NPS 10 and larger.

(c) No visible leakage is permitted through the pressure boundary wall.

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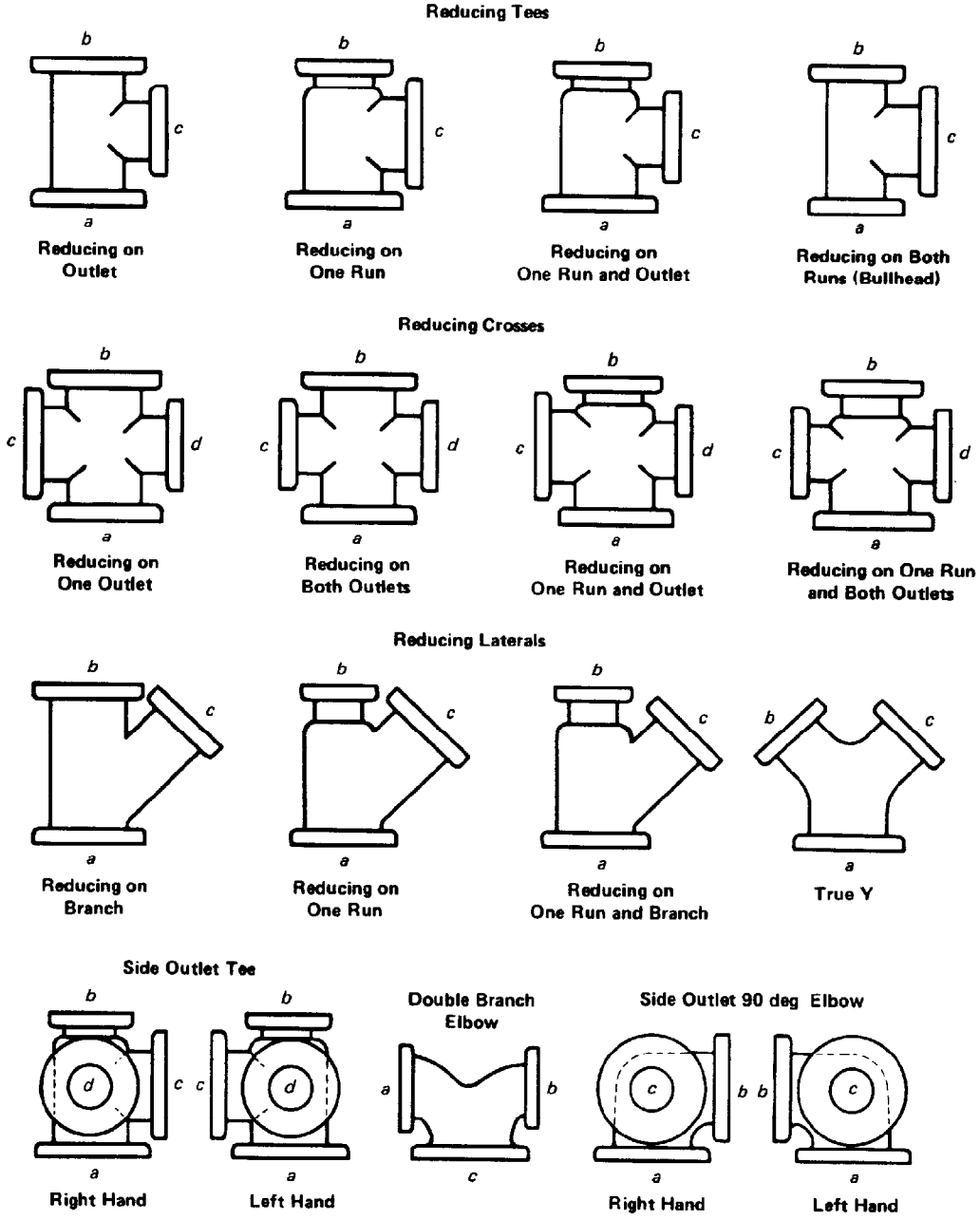

GENERAL NOTE:
In designating the outlets of reducing fittings, the openings should be read in the order indicated by the sequence of the letters *a*, *b*, *c*, and *d*. In designating the outlets of side outlet reducing fittings, the side outlet is named last, and in the case of the side outlet cross (which is not shown), the side outlet is designated by the letter *e*.

FIG. 1 METHOD OF DESIGNATING OUTLETS OF REDUCING FITTINGS

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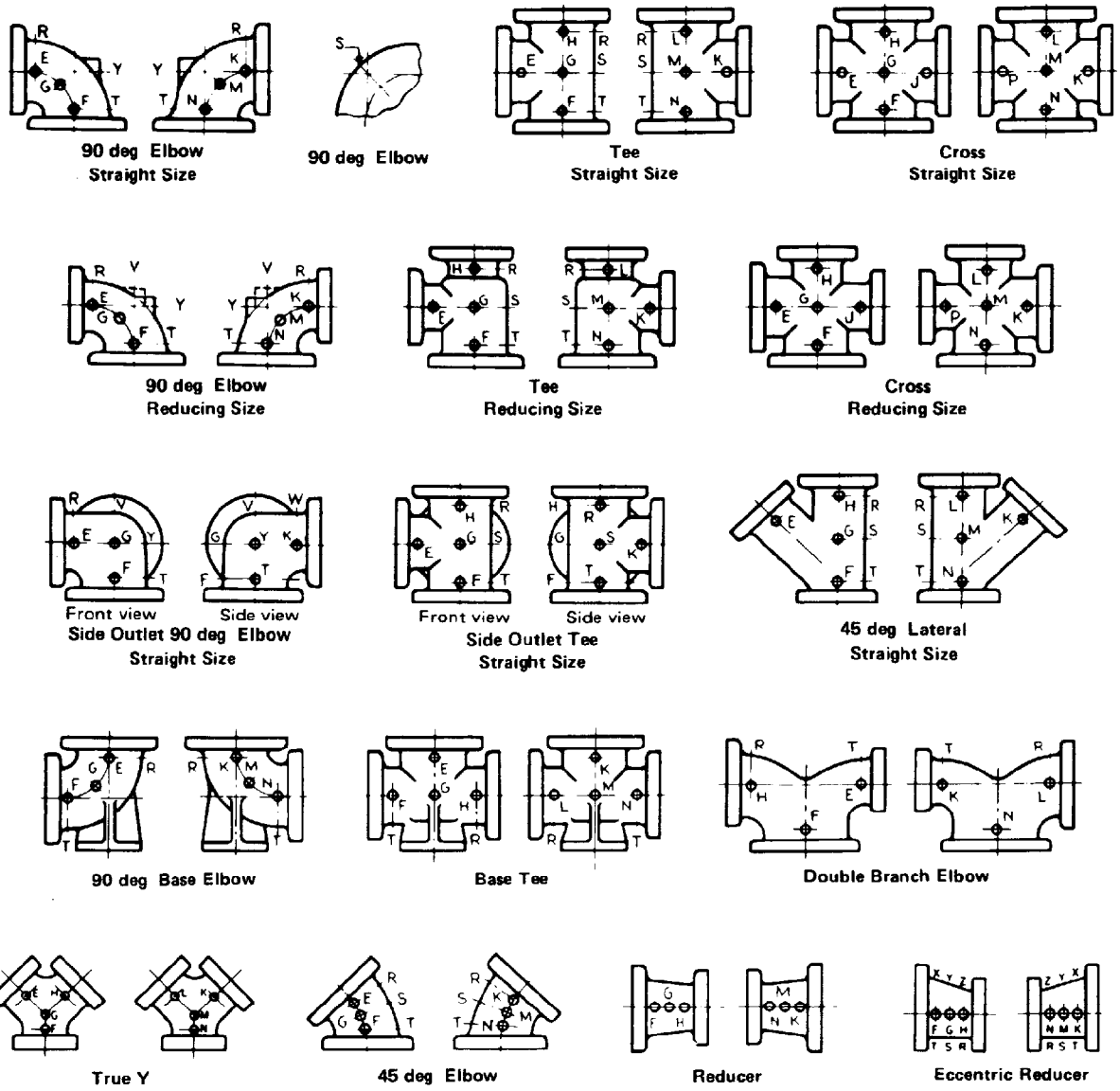

GENERAL NOTE:
The above sketches show two views of the same fitting and represent fittings with symmetrical shapes, with the exception of the side outlet elbow and the side outlet tee (straight sizes).

FIG. 2 METHOD OF DESIGNATING LOCATION OF TAPPED HOLES FOR DRAINS WHEN SPECIFIED

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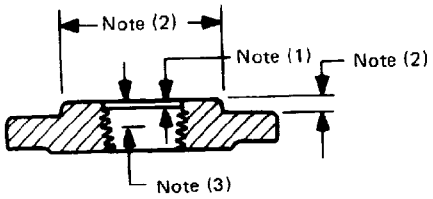

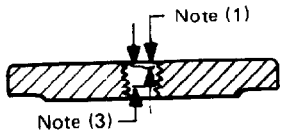

Blind Flange

TABLE 2 REDUCING THREADED FLANGES FOR CLASSES 150 AND 300

1	2	3	4	5	6
Nominal Pipe Size [Note (4)]	Smallest Size [Note (2)] of Reducing Outlet Requiring Hub Flanges	Nominal Pipe Size [Note (4)]	Smallest Size [Note (2)] of Reducing Outlet Requiring Hub Flanges	Nominal Pipe Size [Note (4)]	Smallest Size [Note (2)] of Reducing Outlet Requiring Hub Flanges
1	½	3½	1½	12	3½
1¼	½	4	1½	14	3½
1½	½	5	1½	16	4
2	1	6	2½	18	4
2½	1¼	8	3	20	4
3	1¼	10	3½	24	4

NOTES:

(1) Class 150 flanges do not have a counterbore. Class 300 flanges will have a depth of counterbore q of 0.25 in. for NPS 2 and smaller tappings and 0.38 in. for NPS 2½ and larger. The diameter of counterbore S is the same as that given in the tables of threaded flanges for the corresponding tapping.

(2) The hub dimensions shall be at least as large as those of the standard flanges of the size to which the reduction is being made, except flanges reducing to a size smaller than those of columns 2, 4, and 6 may be made from blind flanges. See example 2 below.

(3) Minimum length of effective threads shall be at least equal to dimension T of the corresponding pressure class threaded flange as shown in tables, but does not necessarily extend to the face of the flange. For thread of threaded flanges, see para. 6.6.

(4) For method of designating reducing threaded flanges, see para. 3.3 and examples 1 and 2 below.

Example 1: The size designation is NPS 6 × 2½ — Class 300 reducing threaded flange. This flange has the following dimensions:

NPS 2½ — taper pipe thread tapping (ASME B1.20.1)
12.5 in. — diameter of regular NPS 6 Class 300 threaded flange
1.44 in. — thickness of regular NPS 6 Class 300 threaded flange
7.0 in. — diameter of hub for regular NPS 5 Class 300 threaded flange
0.62 in. — height of hub for regular NPS 5 Class 300 threaded flange

Other dimensions the same as for regular NPS 6 Class 300 threaded flange, Table 8.

Example 2: The size designation is NPS 6 × 2 — Class 300 reducing threaded flange. Use regular NPS 6 Class 300 blind flange tapped with NPS 2 taper pipe thread (ASME B1.20.1).

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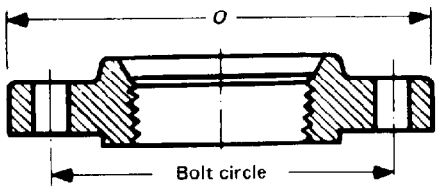
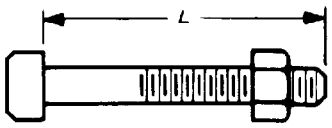
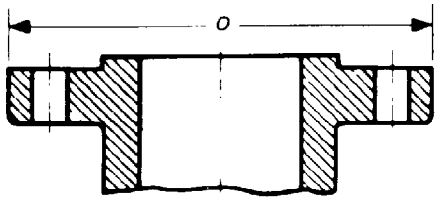


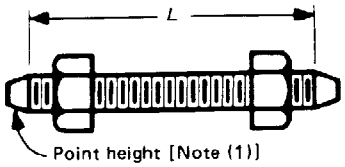
Flange



Machine Bolt With Nut



Flanged Fitting



Stud Bolt With Nuts

TABLE 3 TEMPLATES FOR DRILLING CLASS 150 DUCTILE IRON FLANGES

Nominal Pipe Size	Outside Diameter of Flange, *O*	Drilling [Notes (2), (3)]				Length of Bolts, *L*	
		Diameter of Bolt Circle	Diameter of Bolt Holes	Number of Bolts	Diameter of Bolts	Stud Bolts [Note (3)]	Machine Bolts
1	4.25	3.12	0.62	4	1/2	2.75	2.25
1 1/4	4.62	3.50	0.62	4	1/2	2.75	2.50
1 1/2	5.00	3.88	0.62	4	1/2	3.00	2.50
2	6.00	4.75	0.75	4	5/8	3.25	2.75
2 1/2	7.00	5.50	0.75	4	5/8	3.50	3.00
3	7.50	6.00	0.75	4	5/8	3.75	3.25
3 1/2	8.50	7.00	0.75	8	5/8	3.75	3.25
4	9.00	7.50	0.75	8	5/8	3.75	3.25
5	10.00	8.50	0.88	8	3/4	4.00	3.25
6	11.00	9.50	0.88	8	3/4	4.00	3.50
8	13.50	11.75	0.88	8	3/4	4.25	3.75
10	16.00	14.25	1.00	12	7/8	4.75	4.00
12	19.00	17.00	1.00	12	7/8	4.75	4.25
14	21.00	18.75	1.12	12	1	5.25	4.50
16	23.50	21.25	1.12	16	1	5.50	4.75
18	25.00	22.75	1.25	16	1 1/8	6.00	5.00
20	27.50	25.00	1.25	20	1 1/8	6.25	5.50
24	32.00	29.50	1.38	20	1 1/4	7.00	6.00

GENERAL NOTES:
(a) Dimensions are in inches.
(b) For other dimensions, see Tables 4 and 5.

NOTES:
(1) Length of stud bolts does not include the height of the points.
(2) For flange holes, see para. 6.3.
(3) For spot facing, see para. 6.4.

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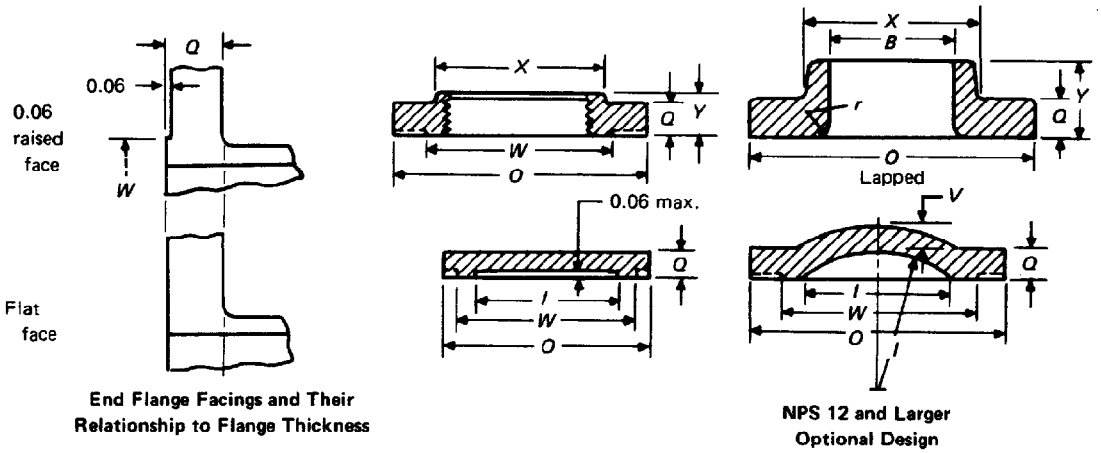

End Flange Facings and Their Relationship to Flange Thickness

NPS 12 and Larger Optional Design

TABLE 4 DIMENSIONS OF CLASS 150 DUCTILE IRON FLANGES

Nominal Pipe Size	Diameter of Port, *I*	Diameter of Flange, *O*	Thickness of Flange Min., *Q*	Diameter of Hub [Note (1)] Min., *X*	Length of Hub and Threads [Note (2)] Min., *Y*	Wall Thickness Min., *V*	Diameter of Raised Face, *W*	Bore Lapped Min., *B*	Corner Radius of Bore of Lapped Flange, *r*	Hub Length Lapped, *Y*
1	1.00	4.25	0.56	1.94	0.69	...	2.00	1.38	0.12	0.69
1¼	1.25	4.62	0.62	2.31	0.81	...	2.50	1.72	0.19	0.81
1½	1.50	5.00	0.69	2.56	0.88	...	2.88	1.97	0.25	0.88
2	2.00	6.00	0.75	3.06	1.00	...	3.62	2.46	0.31	1.00
2½	2.50	7.00	0.88	3.56	1.12	...	4.12	2.97	0.31	1.12
3	3.00	7.50	0.94	4.25	1.19	...	5.00	3.60	0.38	1.19
3½	3.50	8.50	0.94	4.81	1.25	...	5.50	4.10	0.38	1.25
4	4.00	9.00	0.94	5.31	1.31	...	6.19	4.60	0.44	1.31
5	5.00	10.00	0.94	6.44	1.44	...	7.31	5.69	0.44	1.44
6	6.00	11.00	1.00	7.56	1.56	...	8.50	6.75	0.50	1.56
8	8.00	13.50	1.12	9.69	1.75	...	10.62	8.75	0.50	1.75
10	10.00	16.00	1.19	12.00	1.94	...	12.75	10.92	0.50	1.94
12	12.00	19.00	1.25	14.38	2.19	0.81	15.00	12.92	0.50	2.19
14	14.00	21.00	1.38	15.75	2.25	0.88	16.25	14.18	0.50	3.12
16	16.00	23.50	1.44	18.00	2.50	1.00	18.50	16.19	0.50	3.44
18	18.00	25.00	1.56	19.88	2.69	1.06	21.00	18.20	0.50	3.81
20	20.00	27.50	1.69	22.00	2.88	1.12	23.00	20.25	0.50	4.06
24	24.00	32.00	1.88	26.12	3.25	1.25	27.25	24.25	0.50	4.38

GENERAL NOTES:
(a) Dimensions are in inches.
(b) For tolerances, see Section 7.
(c) For facings, see para. 6.2.
(d) For flange bolt holes, see para. 6.3 and Table 3.
(e) For spot facing, see para. 6.4.
(f) For reducing threaded flanges, see Table 2.
(g) Blind flanges may be made with or without hub at the option of the manufacturer.

NOTES:
(1) This dimension is for large end of the hub, which may be straight or tapered. Taper shall not exceed 7 deg on threaded and lapped flanges.
(2) For thread of threaded flanges, see para. 6.6.

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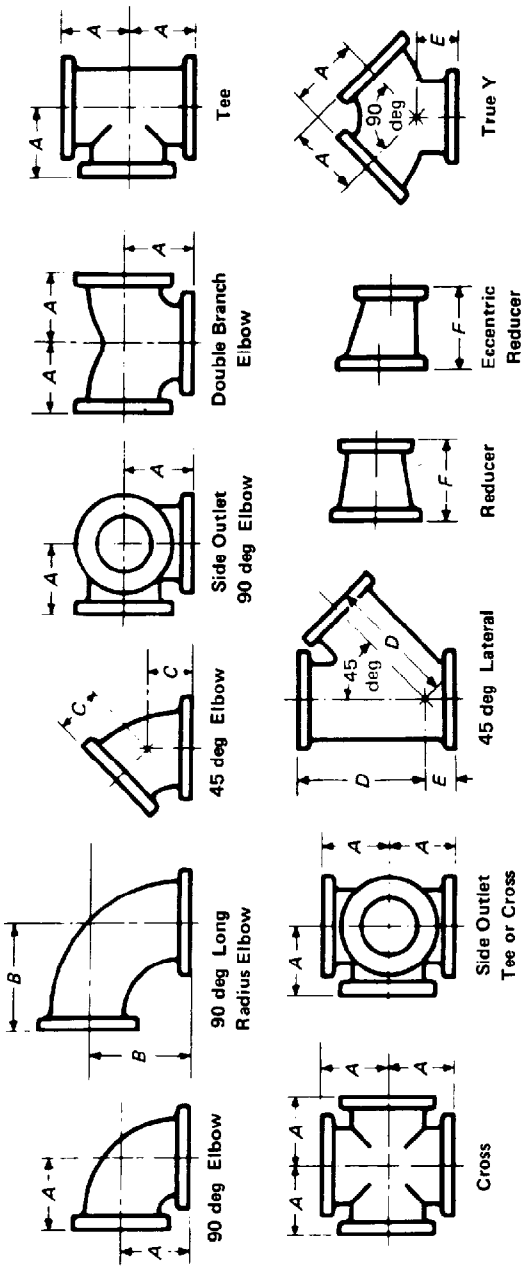

TABLE 5 ILLUSTRATION

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TABLE 5 DIMENSIONS OF CLASS 150 ELBOWS, DOUBLE BRANCH ELBOWS, TEES, CROSSES, LATERALS, TRUE Ys (STRAIGHT SIZES), AND REDUCERS

Nominal Pipe Size	Inside Diameter of Fittings	Center-to-Face 90 deg Elbow Tees, Crosses, True Y, and Double Branch Elbow, *A*	Center-to-Face 90 deg Long Radius Elbow, *B*	Center-to-Face 45 deg Elbow, *C*	Center-to-Face Lateral, *D*	Short Center-to-Face True Y and Lateral, *E*	Face-to-Face Reducer, *F*	Diameter of Flange	Thickness of Flange Min., *Q*	Wall Thickness Min.
1	1.00	3.50	5.00	1.75	5.75	1.75	4.50	4.25	0.44	0.16
1¼	1.25	3.75	5.50	2.00	6.25	1.75	4.50	4.62	0.50	0.19
1½	1.50	4.00	6.00	2.25	7.00	2.00	4.50	5.00	0.56	0.19
2	2.00	4.50	6.50	2.50	8.00	2.50	5.00	6.00	0.62	0.22
2½	2.50	5.00	7.00	3.00	9.50	2.50	5.50	7.00	0.69	0.22
3	3.00	5.50	7.75	3.00	10.00	3.00	6.00	7.50	0.75	0.22
3½	3.50	6.00	8.50	3.50	11.50	3.00	6.50	8.50	0.81	0.25
4	4.00	6.50	9.00	4.00	12.00	3.00	7.00	9.00	0.94	0.25
5	5.00	7.50	10.25	4.50	13.50	3.50	8.00	10.00	0.94	0.28
6	6.00	8.00	11.50	5.00	14.50	3.50	9.00	11.00	1.00	0.28
8	8.00	9.00	14.00	5.50	17.50	4.50	11.00	13.50	1.12	0.31
10	10.00	11.00	16.50	6.50	20.50	5.00	12.00	16.00	1.19	0.34
12	12.00	12.00	19.00	7.50	24.50	5.50	14.00	19.00	1.25	0.38
14	13.25	14.00	21.50	7.50	27.00	6.00	16.00	21.00	1.38	0.41
16	15.25	15.00	24.00	8.00	30.00	6.50	18.00	23.50	1.44	0.44
18	17.25	16.50	26.50	8.50	32.00	7.00	19.00	25.00	1.56	0.47
20	19.25	18.00	29.00	9.50	35.00	8.00	20.00	27.50	1.69	0.50
24	23.25	22.00	34.00	11.00	40.50	9.00	24.00	32.00	1.88	0.57

GENERAL NOTES:
(a) Dimensions are in inches; reference Table 5 Illustration on previous page.
(b) For tolerances, see Section 7.
(c) For facings, see para. 6.2.
(d) For flange bolt holes, see para. 6.3 and Table 3.
(e) For spot facing, see para. 6.4.
(f) For center-to-contact surface and center-to-end dimensions of reducing fittings, see para. 6.1.
(g) For contact surface-to-contact surface and end-to-end dimensions of reducers and eccentric reducers, see para. 6.1.
(h) For intersecting center lines, center-to-contact surface, and center-to-end dimensions of side outlet fittings, see para. 6.1.
(i) For center-to-contact surface and center-to-end dimensions of special degree elbows, see para. 6.1.
(j) For drains, see para. 6.9.

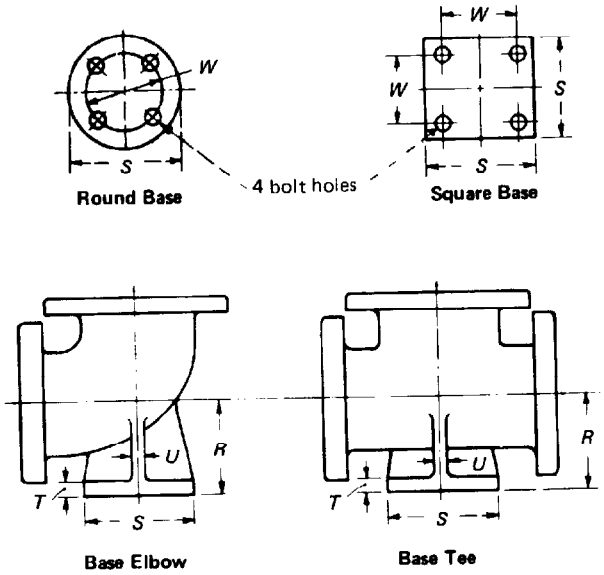

TABLE 6 DIMENSIONS OF CLASS 150 BASE ELBOWS AND BASE TEES

Nominal Pipe Size	Center-to-Base [Note (2)], *R*	Diameter of Round Base or Width of Square Base [Note (3)], *S*	Thickness of Base, *T*	Thickness of Ribs, *U*	Nominal Size of Supporting Pipe for Base	Base Drilling [Note (1)]	
						Bolt Circle or Bolt Spacing, *W*	Diameter of Drilled Holes
2	4.12	4.62	0.50	0.50	1¼	3.50	0.62
2½	4.50	4.62	0.50	0.50	1¼	3.50	0.62
3	4.88	5.00	0.56	0.50	1½	3.88	0.62
3½	5.25	5.00	0.56	0.50	1½	3.88	0.62
4	5.50	6.00	0.62	0.50	2	4.75	0.75
5	6.25	7.00	0.69	0.62	2½	5.50	0.75
6	7.00	7.00	0.69	0.62	2½	5.50	0.75
8	8.38	9.00	0.94	0.88	4	7.50	0.75
10	9.75	9.00	0.94	0.88	4	7.50	0.75
12	11.25	11.00	1.00	1.00	6	9.50	0.88
14	12.50	11.00	1.00	1.00	6	9.50	0.88
16	13.75	11.00	1.00	1.00	6	9.50	0.88
18	15.00	13.50	1.12	1.12	8	11.75	0.88
20	16.00	13.50	1.12	1.12	8	11.75	0.88
24	18.50	13.50	1.12	1.12	8	11.75	0.88

GENERAL NOTES:
(a) Dimensions are in inches.
(b) Bases are not finished unless so ordered.

NOTES:
(1) Bolt hole template shown for round base is the same as for the flange of the supporting pipe size, except using only four holes in all cases so placed as to straddle center lines. The bases of these fittings are intended for support in compression and are not to be used for anchors or supports in tension or shear.
(2) For reducing fittings, the size and center-to-face dimensions of base are determined by the size of the largest opening of fitting. In the case of reducing base elbows, orders shall specify whether the base shall be opposite the larger or smaller opening.
(3) The base dimensions apply to all straight and reducing sizes.

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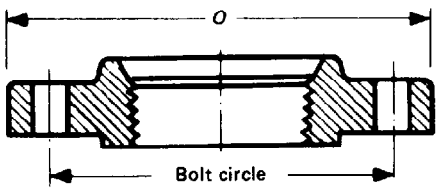
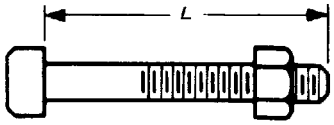
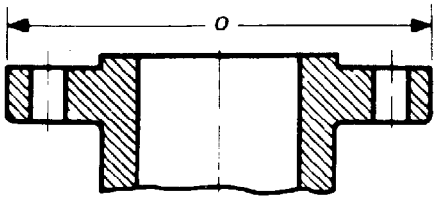


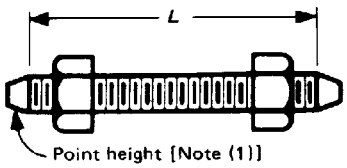
Flange



Machine Bolt With Nut



Flanged Fitting



Stud Bolt With Nuts

TABLE 7 TEMPLATES FOR DRILLING CLASS 300 DUCTILE IRON FLANGES

Nominal Pipe Size	Outside Diameter of Flange, *O*	Drilling [Notes (2), (3)]				Length of Bolts, *L*	
		Diameter of Bolt Circle	Diameter of Bolt Holes	Number of Bolts	Diameter of Bolts	Stud Bolts [Note (3)]	Machine Bolts
1	4.88	3.50	0.75	4	5/8	3.00	2.50
1 1/4	5.25	3.88	0.75	4	5/8	3.25	2.75
1 1/2	6.12	4.50	0.88	4	3/4	3.50	3.00
2	6.50	5.00	0.75	8	5/8	3.50	3.00
2 1/2	7.50	5.88	0.88	8	3/4	4.00	3.25
3	8.25	6.62	0.88	8	3/4	4.25	3.50
3 1/2	9.00	7.25	0.88	8	3/4	4.25	3.75
4	10.00	7.88	0.88	8	3/4	4.50	3.75
5	11.00	9.25	0.88	8	3/4	4.75	4.25
6	12.50	10.62	0.88	12	3/4	4.75	4.25
8	15.00	13.00	1.00	12	7/8	5.50	4.75
10	17.50	15.25	1.12	16	1	6.25	5.50
12	20.50	17.75	1.25	16	1 1/8	6.75	5.75
14	23.00	20.25	1.25	20	1 1/8	7.00	6.25
16	25.50	22.50	1.38	20	1 1/4	7.50	6.50
18	28.00	24.75	1.38	24	1 1/4	7.75	6.75
20	30.50	27.00	1.38	24	1 1/4	8.00	7.25
24	36.00	32.00	1.62	24	1 1/2	9.00	8.00

GENERAL NOTES:
(a) Dimensions are in inches.
(b) For other dimensions, see Tables 8 and 9.

NOTES:
(1) Length of stud bolts does not inlcude the height of the points.
(2) For flange bolt holes, see para. 6.3.
(3) For spot facing, see para. 6.4.

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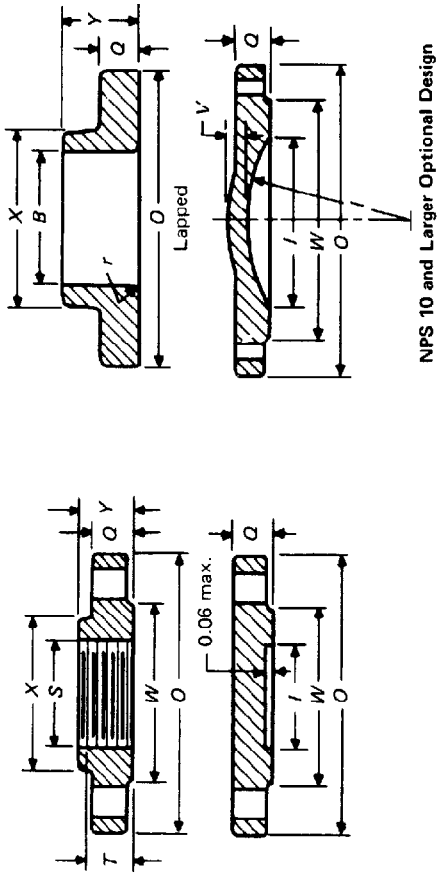

TABLE 8 ILLUSTRATION

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TABLE 8 DIMENSIONS OF CLASS 300 DUCTILE IRON FLANGES

Nominal Pipe Size	Diameter of Port, *I*	Diameter of Flange, *O*	Thickness of Flange Min., *Q*	Diameter of Hub [Note (1)] Min., *X*	Length of Hub Min., *Y*	Hub Lapped, *Y*	Wall Thickness Min., *V*	Length of Threads [Note (2)] Min., *T*	Bore Lapped Min., *B*	Corner Radius of Bore of Lapped Flange, *r*	Diameter of Raised Face, *W*	Diameter of Counterbore, *S*
1	1.00	4.88	0.69	2.06	1.06	1.06	...	0.69	1.38	0.12	2.00	1.41
1¼	1.25	5.25	0.75	2.50	1.06	1.06	...	0.81	1.72	0.19	2.50	1.75
1½	1.50	6.12	0.81	2.75	1.19	1.19	...	0.88	1.97	0.25	2.88	1.99
2	2.00	6.50	0.88	3.31	1.31	1.31	...	1.12	2.46	0.31	3.62	2.50
2½	2.50	7.50	1.00	3.94	1.50	1.50	...	1.25	2.97	0.31	4.12	3.00
3	3.00	8.25	1.12	4.62	1.69	1.69	...	1.25	3.60	0.38	5.00	3.63
3½	3.50	9.00	1.19	5.25	1.75	1.75	...	1.44	4.10	0.38	5.50	4.13
4	4.00	10.00	1.25	5.75	1.88	1.88	...	1.44	4.60	0.44	6.19	4.63
5	5.00	11.00	1.38	7.00	2.00	2.00	...	1.69	5.69	0.44	7.31	5.69
6	6.00	12.50	1.44	8.12	2.06	2.06	...	1.81	6.75	0.50	8.50	6.75
8	8.00	15.00	1.62	10.25	2.44	2.44	...	2.00	8.75	0.50	10.62	8.75
10	10.00	17.50	1.88	12.62	2.62	3.75	0.94	2.19	10.92	0.50	12.75	10.88
12	12.00	20.50	2.00	14.75	2.88	4.00	1.00	2.38	12.92	0.50	15.00	12.94
14	13.25	23.00	2.12	16.75	3.00	4.38	1.12	2.50	14.18	0.50	16.25	14.19
16	15.25	25.50	2.25	19.00	3.25	4.75	1.25	2.69	16.19	0.50	18.50	16.19
18	17.00	28.00	2.38	21.00	3.50	5.12	1.38	2.75	18.20	0.50	21.00	18.19
20	19.00	30.50	2.50	23.12	3.75	5.50	1.50	2.88	20.25	0.50	23.00	20.19
24	23.00	36.00	2.75	27.62	4.19	6.00	1.62	3.25	24.25	0.50	27.25	24.19

GENERAL NOTES:
(a) Dimensions are in inches; reference Table 8 Illustration on previous page.
(b) For tolerances, see Section 7.
(c) For facing, see para. 6.2.
(d) For flange bolt holes, see para. 6.3 and Table 7.
(e) For spot facing, see para. 6.4.
(f) For reducing threaded flanges, see Table 2.
(g) Blind flanges may be made with or without hub at the option of the manufacturer.

NOTES:
(1) This dimension is for large end of hub, which may be straight or tapered. Taper shall not exceed 7 deg on threaded and lapped flanges.
(2) For thread of threaded flanges, see para. 6.6.

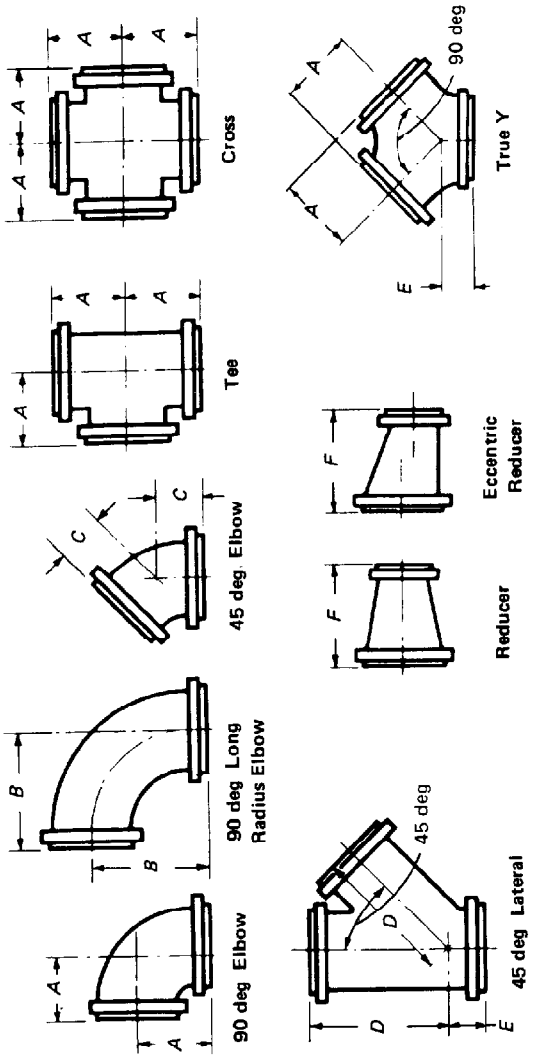

TABLE 9 ILLUSTRATION

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TABLE 9 DIMENSIONS OF CLASS 300 ELBOWS, TEES, CROSSES, LATERALS, TRUE Ys (STRAIGHT SIZES), AND REDUCERS

Nominal Pipe Size	Inside Diameter of Fittings Min.	Center-to-Face 90 deg Elbow Tees, Crosses, and True Y, *A*	Center-to-Face 90 deg Long Radius Elbow, *C*	Center-to-Face 45 deg Elbow, *C*	Center-to-Face Lateral, *D*	Short Center-to-Face True Y and Lateral, *E*	Face-to-Face Reducer, *F*	Diameter of Flange	Thickness of Flange Min., *Q*	Wall Thickness Min.
1	1.00	4.00	5.00	2.25	6.50	2.00	4.50	4.88	0.69	0.19
1¼	1.25	4.25	5.50	2.50	7.25	2.25	4.50	5.25	0.75	0.19
1½	1.50	4.50	6.00	2.75	8.50	2.50	4.50	6.12	0.81	0.19
2	2.00	5.00	6.50	3.00	9.00	2.50	5.00	6.50	0.88	0.25
2½	2.50	5.50	7.00	3.50	10.50	2.50	5.50	7.50	1.00	0.25
3	3.00	6.00	7.75	3.50	11.00	3.00	6.00	8.25	1.12	0.28
3½	3.50	6.50	8.50	4.00	12.50	3.00	6.50	9.00	1.19	0.29
4	4.00	7.00	9.00	4.50	13.50	3.00	7.00	10.00	1.25	0.31
5	5.00	8.00	10.25	5.00	15.00	3.50	8.00	11.00	1.38	0.38
6	6.00	8.50	11.50	5.50	17.50	4.00	9.00	12.50	1.44	0.38
8	8.00	10.00	14.00	6.00	20.50	5.00	11.00	15.00	1.62	0.44
10	10.00	11.50	16.50	7.00	24.00	5.50	12.00	17.50	1.88	0.50
12	12.00	13.00	19.00	8.00	27.50	6.00	14.00	20.50	2.00	0.56
14	13.25	15.00	21.50	8.50	31.00	6.50	16.00	23.00	2.12	0.62
16	15.25	16.50	24.00	9.50	34.50	7.50	18.00	25.50	2.25	0.69
18	17.00	18.00	26.50	10.00	37.50	8.00	19.00	28.00	2.38	0.75
20	19.00	19.50	29.00	10.50	40.50	8.50	20.00	30.50	2.50	0.81
24	23.00	22.50	34.00	12.00	47.50	10.00	24.00	36.00	2.75	0.94

GENERAL NOTES:
(a) Dimensions are in inches; reference Table 9 Illustration on previous page.
(b) For tolerances, see Section 7.
(c) For facings, see para. 6.2.
(d) For flange bolt holes, see para. 6.3 and Table 7.
(e) For spot facing, see para. 6.4.
(f) For center-to-contact surface and center-to-end dimensions of reducing fittings, see para. 6.1.
(g) For contact surface-to-contact surface and end-to-end dimensions of reducers and eccentric reducers, see para. 6.1.
(h) For intersecting center lines, center-to-contact surface, and center-to-end dimensions of side outlet fittings, see para. 6.1.
(i) For center-to-contact surface and center-to-end dimensions for special degree elbows, see para. 6.1.
(j) For drains, see para. 6.9.

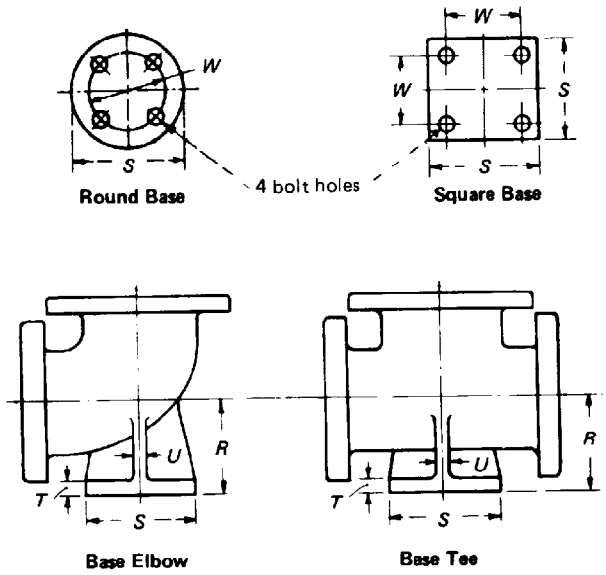

TABLE 10 DIMENSIONS OF CLASS 300 BASE ELBOWS AND BASE TEES

Nominal Pipe Size	Center-to-Base [Note (2)], *R*	Diameter of Round Base or Width of Square Base [Note (3)], *S*	Thickness of Base, *T*	Thickness of Ribs, *U*	Nominal Size of Supporting Pipe for Base	Base Drilling [Note (1)]	
						Bolt Circle or Bolt Spacing, *W*	Diameter of Drilled Holes
2	4.50	5.25	0.75	0.50	1¼	3.88	0.75
2½	4.75	5.25	0.75	0.50	1¼	3.88	0.75
3	5.25	6.12	0.81	0.62	1½	4.50	0.88
3½	5.62	6.12	0.81	0.62	1½	4.50	0.88
4	6.00	6.50	0.88	0.62	2	5.00	0.75
5	6.75	7.50	1.00	0.75	2½	5.88	0.88
6	7.50	7.50	1.00	0.75	2½	5.88	0.88
8	9.00	10.00	1.25	0.88	4	7.88	0.88
10	10.50	10.00	1.25	0.88	4	7.88	0.88
12	12.00	12.50	1.44	1.00	6	10.62	0.88
14	13.50	12.50	1.44	1.00	6	10.62	0.88
16	14.75	12.50	1.44	1.12	6	10.62	0.88
18	16.25	15.00	1.62	1.12	8	13.00	1.00
20	17.88	15.00	1.62	1.25	8	13.00	1.00
24	20.75	17.50	1.88	1.25	10	15.25	1.12

GENERAL NOTES:
(a) Dimensions are in inches.
(b) Bases are not finished unless so ordered.

NOTES:
(1) Bolt hole template shown for round base is the same as for the flange of the supporting pipe size, except using only four holes in all cases so placed as to straddle center lines. The bases of these fittings are intended for support in compression and are not to be used for anchors or supports in tension or shear.
(2) For reducing fittings, the size and center-to-face dimensions of bases are determined by the size of the largest opening of fitting. In the case of reducing base elbows, orders shall specify whether the base shall be opposite the larger or smaller opening.
(3) The base dimensions shall apply to all straight and reducing sizes.

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ANNEX A
METHODS FOR ESTABLISHING PRESSURE–TEMPERATURE RATINGS

(This Annex is an integral part of ASME B16.42-1998 and is placed after the main text for convenience.)

A1 GENERAL

A1.1 Introduction

Pressure-temperature ratings in this Standard have been determined by the procedures in this Annex. The primary consideration in establishing ratings is adequate wall thickness to sustain stresses due to pressure and other loadings. See para. A1.2. Other considerations affecting or limiting the ratings include:

(a) stresses in flanges resulting from bolt-up necessary to maintain gasket seal;

(b) distortion of flanges and flanged fittings due to loadings transmitted through the pipeline;

(c) limitations applying primarily to valves but imposed also on flanges in order to maintain compatible ratings.

A1.2 Wall Thickness

Wall thickness requirements for flanged fittings are set forth in para. 7.1, and minimum thicknesses t_m are listed in the tables designated in para. 7.1. These values are all greater than those determined by Eq. (1).

$$t = 1.5\,P_c d/(2S - 1.2P_c) \quad (1)$$

where

t = calculated thickness, in.
P_c = pressure rating class designation expressed in psi (e.g., P_c = 150 psi for Class 150)
d = inside diameter of the fitting, in.
S = stress factor of 7000 psi

Equation (1) gives thickness 50% greater than for a simple cylinder designed for a stress of 7000 psi when subjected to an internal pressure equal to the pressure rating class designation in psi. Actual values in the dimension tables listed in para. 7.1 are approximately 0.1 in. to 0.2 in. heavier than those given by the equation.

A2 RATINGS IN CUSTOMARY UNITS

A2.1 Ambient Rating Equation

Ratings for −20°F to 100°F temperatures for all pressure classes are established by Eq. (2).

$$P_T = P_r S_1/8750 \quad (2)$$

where

P_T = rated working pressure, psig, for the material at temperature T
P_r = pressure rating class index expressed in psi (P_r = 300 psi for Class 300 and P_r = 115 psi for Class 150)
S_1 = selected stress, psi

The selected stress S_1 shall be the lowest of the following values:

(a) 60% of specified minimum yield strength at 100°F.

(b) 1.25 times the allowable stress at 100°F. The allowable stress shall be determined by the rules of the ASME Boiler and Pressure Vessel Code, Section I, Appendix A-150.

$$S_1 = 31{,}300 - (T^2/49.85) \quad (3)$$

Using 100 as the value for T, Eq. (3) establishes an upper limit for bolt loads approximating 125% of allowable stress for ASTM A 193 Grade B7 bolting.

A2.2 Ratings for Class 150

Pressure-temperature ratings for Class 150 flanges and flanged fittings are determined as follows.

(a) The value for p_T at temperature T (°F) for temperatures from 400°F to 650°F shall be that given by Eq. (4).

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$$p_T = 320 - 0.3T \quad (4)$$

The limits of T are 400°F min. and 650°F max.

(b) The values for p_T between 100°F and 400°F shall be determined by linear interpolation of the values calculated for p_T at 100°F using Eqs. (2) and (4).

A2.3 Ratings for Class 300

Pressure-temperature ratings for Class 300 flanges and flanged fittings are determined as follows.

(a) The value for p_T at temperature T (°F) for temperatures from 400°F to 650°F shall be that given by Eq. (5).

$$p_T = 645 - 0.3T \quad (5)$$

The limits of T are 400°F min. and 650°F max.

(b) The values for p_T between 100°F and 400°F shall be determined by linear interpolation of the values calculated for p_T at 100°F and 400°F using Eqs. (2) and (5).

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STD.ASME B16.42-ENGL 1998 ■ 0759670 0609024 02T ■

ANNEX B
REFERENCES

(This Annex is an integral part of ASME B16.42-1998 and is placed after the main text for convenience.)

The following is a list of publications referenced in this Standard.

ASME B1.1-1989, Unified Inch Screw Threads (UN and UNR Thread Form)[1]

ASME B1.20.1-1983 (R1992), Pipe Threads, General Purpose (Inch)[1]

ASME B16.5-1996, Pipe Flanges and Flanged Fittings[1]

ASME B16.21-1992, Nonmetallic Flat Gaskets for Pipe Flanges[1]

ASME B18.2.1-1996, Square and Hex Bolts and Screws (Inch Series)[1]

ASME B18.2.2-1987, (R1993) Square and Hex Nuts (Inch Series)[1]

ASME Boiler and Pressure Vessel Code, 1995 Edition, Section I, Power Boilers[1]

Publisher: The American Society of Mechanical Engineers (ASME), Three Park Avenue, New York, NY 10016-5990

ASTM A 193/A 193M-97a, Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service

ASTM A 194/A 194M-97, Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service

ASTM A 307-94, Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength

ASTM A 395-88 (R1993), Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures

Publisher: American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

ISO 9000-1: 1994, Quality management and quality assurance standards — Part 1: Guidelines for selection and use

ISO 9000-2: 1997, Quality management and quality assurance standards — Part 2: Generic guidelines for the application of ISO 9001, ISO 9002, and ISO 9003

ISO 9000-3: 1991, Quality management and quality assurance standards — Part 3: Guidelines for the application of ISO 9001 to the development, supply, and maintenance of software

ISO 9001: 1994, Quality systems — Model for quality assurance in design, development, production, installation, and servicing

ISO 9002: 1994, Quality systems — Model for quality assurance in production and servicing

ISO 9003: 1994, Quality systems — Model for quality assurance in final inspection and test

Publisher: International Organization for Standardization (ISO), 1 rue de Varembè, Case postale 56 CH-1121 Genève 20, Switzerland/Suisse

MSS SP-6-1996, Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings

MSS SP-9-1997, Spot Facing for Bronze, Iron and Steel Flanges

MSS SP-25-1998, Standard Marking System for Valves, Fittings, Flanges and Unions

MSS SP-45-1992, Bypass and Drain Connections

Publisher: Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park Street, NE, Vienna, VA 22180

[1] May also be obtained from American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036.

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ANNEX C
QUALITY SYSTEM PROGRAM

(This is a nonmandatory part of ASME B16.42-1998 and is provided for informational purposes only.)

The products manufactured in accordance with this Standard shall be produced under a quality system program following the principles of an appropriate standard from the ISO 9000 series.[1] A determination of the need for registration and/or certification of the product manufacturer's quality system program by an independent organization shall be the responsibility of the manufacturer. The detailed documentation demonstrating program compliance shall be available to the purchaser at the manufacturer's facility. A written summary description of the program utilized by the product manufacturer shall be available to the purchaser upon request. The product manufacturer is defined as the entity whose name or trademark appears on the product in accordance with the marking or identification requirements of this Standard.

[1] The series is also available from the American National Standards Institute (ANSI) and the American Society for Quality Control (ASQC) as American National Standards that are identified by a prefix "Q" replacing the prefix "ISO." Each standard of the series is listed under Annex C.

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AMERICAN NATIONAL STANDARDS FOR PIPING, PIPE FLANGES, FITTINGS, AND VALVES

Scheme for the Identification of Piping Systems A13.1-1996
Pipe Threads, General Purpose (Inch) ..... B1.20.1-1983(R1992)
Dryseal Pipe Threads (Inch) ..... B1.20.3-1976(R1991)
Cast Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250 ..... B16.1-1998
Malleable Iron Threaded Fittings: Classes 150 and 300 ..... B16.3-1998
Gray Iron Threaded Fittings: Classes 125 and 250 ..... B16.4-1998
Pipe Flanges and Flanged Fittings (NPS ½ Through NPS 24) B16.5-1996
Factory-Made Wrought Steel Buttwelding Fittings B16.9-1993
Face-to-Face and End-to-End Dimensions of Valves B16.10-1992
Forged Fittings, Socket-Welding and Threaded B16.11-1996
Cast Iron Threaded Drainage Fittings B16.12-1998
Ferrous Pipe Plugs, Bushings, and Locknuts with Pipe Threads B16.14-1991
Cast Bronze Threaded Fittings: Classes 125 and 250 ..... B16.15-1985(R1994)
Cast Copper Alloy Solder Joint Pressure Fittings ..... B16.18-1984(R1994)
Metallic Gaskets for Pipe Flanges: Ring-Joint, Spiral-Wound, and Jacketed B16.20-1998
Nonmetallic Flat Gaskets for Pipe Flanges B16.21-1992
Wrought Copper and Copper Alloy Solder Joint Pressure Fittings B16.22-1995
Cast Copper Alloy Solder Joint Drainage Fittings — DWV B16.23-1992
Cast Copper Alloy Pipe Flanges and Flanged Fittings: Classes 150, 300, 400, 600, 900, 1500, and 2500 ..... B16.24-1991
Buttwelding Ends B16.25-1992
Cast Copper Alloy Fittings for Flared Copper Tubes B16.26-1988
Wrought Steel Buttwelding Short Radius Elbows and Returns B16.28-1994
Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings — DWV B16.29-1994
Cast Copper Alloy Solder Joint Fittings for Sovent Drainage Systems B16.32-1992
Manually Operated Metallic Gas Valves for Use in Gas Piping Systems up to 125 psig (Sizes ½ Through 2) B16.33-1990
Valves — Flanged, Threaded, and Welding End B16.34-1996
Orifice Flanges B16.36-1996
Large Metallic Valves for Gas Distribution (Manually Operated, NPS 2½ to 12, 125 psig Maximum) ..... B16.38-1985(R1994)
Malleable Iron Threaded Pipe Unions B16.39-1998
Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems ..... B16.40-1985(R1994)
Functional Qualification Requirements for Power Operated Active Valve Assemblies for Nuclear Power Plants ..... B16.41-1983(R1989)
Ductile Iron Pipe Flanges and Flanged Fittings, Classes 150 and 300 ..... B16.42-1998
Manually Operated Metallic Gas Valves for Use in House Piping Systems B16.44-1995
Cast Iron Fittings for Sovent® Drainage Systems B16.45-1998
Large Diameter Steel Flanges (NPS 26 Through NPS 60) B16.47-1996
Steel Line Blanks B16.48-1997
Power Piping B31.1-1995
Fuel Gas Piping (not an ANSI standard) B31.2-1968
Process Piping B31.3-1996
Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids B31.4-1992
Refrigeration Piping B31.5-1992
Gas Transmission and Distribution Piping Systems B31.8-1995
Building Services Piping B31.9-1988
Slurry Transportation Piping Systems B31.11-1989
Manual for Determining the Remaining Strength of Corroded Pipelines B31G-1991
Welded and Seamless Wrought Steel Pipe B36.10M-1995
Stainless Steel Pipe ..... B36.19M-1985(R1994)
Self-Operated and Power-Operated Safety-Related Valves Functional Specification Standard ..... N278.1-1975(R1992)

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AN AMERICAN NATIONAL STANDARD

ASME B16.47a-1998

ADDENDA

to

ASME B16.47-1996
LARGE DIAMETER STEEL FLANGES
NPS 26 Through NPS 60

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
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ASME B16.47a–1998

Following approval by the ASME B16 Committee and ASME, and after public review, ASME B16.47a-1998 was approved by the American National Standards Institute on February 20, 1998.

Addenda to the 1996 Edition of ASME B16.47 are issued in the form of replacement pages. Revisions, additions, and deletions are incorporated directly into the affected pages. It is advisable, however, that this page, the Addenda title and copyright pages, and all replaced pages be retained for reference.

SUMMARY OF CHANGES

This is the first Addenda to be published to ASME B16.47-1996.

Replace or insert the pages listed. Changes given below are identified on the pages by a margin note, **(a)**, placed next to the affected area. The pages not listed are the reverse sides of the listed pages and contain no changes.

Page	*Location*	*Change*
iii	Foreword	In the last paragraph, ASME address updated
vii	Committee Roster	Updated
2	2.4	First sentence corrected by Errata
8, 9	Table 1A	(1) A 350 Gr. LF6 Cl. 1 added to material group 1.1 (2) A 350 Gr. LF6 Cl. 2 added to material group 1.2 (3) New material group 1.15 added (4) A 351 Gr. CE8MN, A 351 Gr. CD4MCu, A 351 Gr. CD3MWCuN, A 182 Gr. F55, and A 240 Gr. S32760 added to material group 2.8
11	Table 2-1.1	(1) A 350 Gr. LF6 Cl. 1 added (2) Note (4) added (3) Entries for last four class temperatures corrected by Errata
12	Table 2-1.2	(1) A 350 Gr. LF6 Cl. 2 added (2) Note (3) added (3) Working pressure for Class 75 at 500°F corrected by Errata to read *85*

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Page	*Location*	*Change*
20.1	Table 2-1.15	Added
27	Table 2-2.7	Working pressure for Class 400 at 850°F corrected by Errata to read *570*
28	Table 2-2.8	A 351 Gr. CE8MN, A 351 Gr. CD4MCu, A 351 Gr. CD3MWCuN, A 182 Gr. F55, and A 240 Gr. S32760 added
42	Table 13	Depth of *C* in sketch corrected by Errata
43	Table 14	Depth of *C* in sketch corrected by Errata
44	Table 15	Depth of *C* in sketch corrected by Errata
59	Annex D	Addresses of ASME and ASTM updated
61	Interpretations	ASME address updated

SPECIAL NOTE:

The Interpretations to ASME B16.47 are included in this Addenda as a separate section for the user's convenience. This section, however, is not part of the Addenda or the edition.

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FOREWORD (a)

(This Foreword is not part of ASME B16.47-1996.)

In November, 1980, a task force was appointed within Subcommittee C of the American National Standards (ANSI) B16 Committee to develop a standard for pipe flanges in size NPS 26 through NPS 48. Every attempt was made to standardize those dimensions that existed within the industry for the materials covered by ANSI B16.5.

Prompted by suggestions received from committee members, the task force was authorized to increase the size range to NPS 60. The first draft was developed in December 1982 to include Class 75 through Class 1500 for the size range NPS 26 through NPS 60. Flange dimensions were based on the Manufacturers Standardization Society Standard Practice (MSS SP) 44 flanges except for Class 75 flanges which are ANSI/API 605 flanges.

At the request of the American Petroleum Institute (API), flange dimensions in accordance with the API Standard 605 were included in the subsequent drafts. Class 1500 flanges were deleted due to lack of interest in using large size flanges in that pressure–temperature rating.

The API-605 flanges for Classes 150 and 300 and for sizes NPS 36 and smaller for classes higher than Class 300 are not compatible with the MSS SP-44 flanges. Thus, the MSS SP-44 flanges are designated as Series A flanges and the API-605 flanges are designated as Series B flanges in this Standard. Materials covered in this Standard are as in ANSI B16.5 except nickel base alloys are excluded. Pressure–temperature ratings are in accordance with ANSI B16.5.

In 1982, American National Standards Committee B16 was reorganized as the American Society of Mechanical Engineers (ASME) B16 Committee operating under procedures accredited by ANSI. Following approval by the Standards Committee and ASME, approval as an American National Standard was given by ANSI on June 12, 1990.

This 1996 Edition allows flanges marked with more than one material grade or specification, revises flange facing finish requirements, has revised pressure–temperature ratings for several material groups, adds permissible flange facing imperfections, adds blind flanges for Series B flanges, and includes several other revisions. Following approval by the Standards Committee and ASME, approval as an American National Standard was given by ANSI on October 3, 1996 with the new designation ASME B16.47-1996.

All requests for interpretations or suggestions for revisions should be sent to the Administrative Secretary B16, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

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ASME B16 COMMITTEE
Standardization of Valves, Flanges, Fittings, Gaskets, and Valve Actuators

(a)

(The following is a roster of the Committee at the time of approval of this Standard.)

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LARGE DIAMETER STEEL FLANGES

1 SCOPE

1.1 General

This Standard covers pressure–temperature ratings, materials, dimensions, tolerances, marking, and testing for pipe flanges in sizes NPS 26 through NPS 60 and in ratings Classes 75, 150, 300, 400, 600, and 900. Flanges may be cast, forged, or plate (for blind flanges only) materials, as listed in Table 1A.

Requirements and recommendations regarding bolting and gaskets are also included.

1.2 Flange Series

This Standard provides two series of flange dimensions. Series A specifies flange dimensions for general use flanges. Series B specifies flange dimensions for compact flanges which, in general, have smaller bolt circle diameters than Series A flanges. These two series of flanges are not interchangeable. The user should recognize that some flanged valves, equipment bolted between flanges, and flanged equipment may only be compatible with bolt circle diameter of one series of flanges.

1.3 References

1.3.1 Referenced Standards. Standards and specifications adopted by reference in this Standard are shown in Annex E, which is part of this Standard. It is not considered practical to identify the specific edition of each standard and specification in the individual references. Instead, the specific edition reference is identified in Annex E. A flange manufactured in accordance with earlier editions of the referenced standards, and in all other respects conforming to this Standard, will be considered to be in conformance with this Standard.

1.3.2 Codes and Regulations. A flange used under the jurisdiction of the ASME Boiler and Pressure Vessel Code (ASME BPV Code), the ASME Code for Pressure Piping, or a governmental regulation is subject to any limitation of that code or regulation. This includes any maximum temperature limitation, rule governing the use of a material at low temperature, or provisions for operation at a pressure exceeding the pressure–temperature ratings in this Standard.

1.4 Applicable Ratings

The pressure–temperature ratings in this Standard are applicable upon its publication to all flanges within its scope which otherwise meet its requirements. For unused flanges maintained in inventory, the manufacturer of the flange may certify conformance to this Edition, provided he can demonstrate that all requirements of this Edition have been met. Where such components were installed in accordance with the pressure–temperature ratings of an earlier edition of this Standard, those ratings are applicable, except as may be governed by the applicable code or regulation (see para. 1.3.2).

1.5 User Accountability

This Standard cites duties and responsibilities that are to be assumed by the user in the areas of application, installation, hydrostatic testing, operation, and material selection.

1.6 Quality Systems

Nonmandatory requirements relating to the product manufacturer's Quality System Program are described in Annex D.

2 PRESSURE–TEMPERATURE RATINGS

2.1 Rating Basis

Ratings are maximum allowable working gage pressures, at the temperatures shown in Table 2 for the applicable material and rating. For intermediate temperatures, linear interpolation is permitted. See Annex A for methods of establishing pressure–temperature ratings.

2.2 Ratings of Flanged Joints

A flanged joint is composed of three separate and independent, although interrelated, components: the flanges, the gasket, and the bolting, which are assembled by yet another influence, the assembler. Proper controls must be exercised in the selection and application for all these elements in order to attain a joint which has

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acceptable leak tightness. Special techniques such as controlled bolt tightening may be necessary to achieve a tight joint in service.

Ratings in this Standard apply to flanged joints which conform to the limitations on bolting in para. 5.3 and on gaskets in para. 5.4, and which are made up in accordance with good practice for alignment and assembly. See also para. 2.4. Use of the ratings for flanged joints not conforming to these limitations is the sole responsibility of the user. Requirements for alignment and assembly of joints are not given in this Standard.

If the two flanges in a flanged joint do not have the same pressure–temperature ratings, the rating of the joint at any temperature is the lower of the two flange ratings at that temperature.

2.3 Rating Temperature

The temperature shown for a corresponding pressure rating is the temperature of the pressure containing shell of the flange. In general, this temperature is the same as that of the contained fluid. Use of a pressure rating corresponding to a temperature other than that of the contained fluid is the responsibility of the user, subject to the requirements of the applicable code or regulation. For any temperature below −20°F the rating shall be no greater than the rating shown for −20°F.

(a) 2.4 Temperature Considerations

Application of the ratings in this Standard to flanged joints at both high and low temperatures shall take into consideration the risk of leakage due to forces and moments developed in the connected piping or equipment. The following provisions are intended to minimize these risks.

2.4.1 High Temperature Service. At temperatures in the creep range, gradual relaxation of flanges, bolts, and gaskets may progressively reduce bolt loads. It may be necessary to arrange for periodic tightening of bolts to prevent leakage. Joints subject to substantial thermal gradients may require the same attention.

When used above 400°F, Classes 75 and 150 flanged joints may develop leakage unless care is taken to avoid imposing severe external loads and/or severe thermal gradients. For other classes, similar consideration should be given above 750°F.

2.4.2 Low Temperature Service. Some of the materials listed in the rating tables undergo sufficient decrease in toughness at low temperatures that they cannot safely sustain shock loadings, sudden changes of stress or temperature, or high stress concentrations.

2.5 System Hydrostatic Test

Flanged joints may be subjected to system hydrostatic tests at a pressure not to exceed 1.5 times the 100°F rating rounded off to the next higher 25 psi.

Testing at any higher pressure is the responsibility of the user, subject to the requirements of the applicable code or regulation.

2.6 Welding Neck Flanges

Ratings for carbon steel cylindrically bored welding neck flanges covered by this Standard are based upon their hubs at the welding end having a thickness at least equal to that calculated for pipe having 40.0 ksi specified minimum yield strength. The ratings also apply to such flanges used with components of unequal strength and unequal wall thickness when the attachment welds is made in accordance with the applicable code or regulation. See Figs. 5, 6, and 7.

2.7 Multiple Material Grades

Materials for flanges may meet the requirements for more than one specification or grade of a specification listed in Table 1A. In that event, the pressure–temperature ratings for any of these specifications or grades may be used provided that the marking is in accordance with para. 4.1.2(d).

3 SIZE

3.1 Nominal Size

The size of a flange covered by this Standard is its nominal pipe size (NPS). The diameter of a bolt is its nominal size. Use of nominal indicates that the stated size or dimension is only for designation, not measurement. The actual dimension may or may not be the nominal size and is subject to established tolerances.

4 MARKING

4.1 General

Except as modified herein, flanges shall be marked as required in MSS SP-25.

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7.6.2 Center-to-center of adjacent bolt holes, 0.03 in.

7.6.3 Eccentricity between bolt circle diameter and machined facing diameters, 0.06 in.

8 TEST

8.1 Flange Testing

Flanges are not required to be hydrostatically tested.

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TABLE 1A LIST OF MATERIAL SPECIFICATIONS

Material Group	Nominal Designation	Pressure–Temperature Rating Table	Applicable ASTM Specifications[1]		
			Forgings	Castings	Plates
1.1	C–Si C–Mn–Si C–Mn–Si–V	2-1.1	A 105 A 350 Gr. LF2 A 350 Gr. LF6 Cl.1	A 216 Gr. WCB	A 515 Gr.70 A 516 Gr. 70 A 537 Cl. 1
1.2	C–Mn–Si C–Mn–Si–V 2½Ni 3½Ni	2-1.2	 A 350 Gr. LF6 Cl.2 A 350 Gr. LF3	A 216 Gr. WCC A 352 Gr. LCC A 352 Gr. LC2 A 352 Gr. LC3	 A 203 Gr. B A 203 Gr. E
1.3	C–Si C–Mn–Si 2½Ni 3½Ni	2-1.3		A 352 Gr. LCB	A 515 Gr. 65 A 516 Gr. 65 A 203 Gr. A A 203 Gr. D
1.4	C–Si C–Mn–Si	2-1.4	 A 350 Gr. LF1 Cl. 1		A 515 Gr. 60 A 516 Gr. 60
1.5	C–½Mo	2-1.5	A 182 Gr. F1	A 217 Gr. WC1 A 352 Gr. LC1	A 204 Gr. A A 204 Gr. B
1.7	C–½Mo ½Cr–½Mo Ni–½Cr–½Mo ¾Ni–¾Cr–1Mo	2-1.7	 A 182 Gr. F2	 A 217 Gr. WC4 A 217 Gr. WC5	A 204 Gr. C
1.9	1Cr–½Mo 1¼Cr–½Mo 1¼Cr–½Mo–Si	2-1.9	A 182 Gr. F12 Cl. 2 A 182 Gr. F11 Cl. 2	 A 217 Gr. WC6	 A 387 Gr. 11 Cl. 2
1.10	2¼Cr–1Mo	2-1.10	A 182 Gr. F22 Cl. 3	A 217 Gr. WC9	A 387 Gr. 22 Cl.2
1.13	5Cr–½Mo ¾Ni–1Mo–¾Cr	2-1.13	A 182 Gr. F5 A 182 Gr. F5a	 A 217 Gr. C5	
1.14	9Cr–1Mo	2-1.14	A 182 Gr. F9	A 217 Gr. C12	
1.15	9Cr–1Mo–V	2-1.15	A 182 Gr. F91	A 217 Gr. C12A	A 387 Gr. 91 Cl.2
2.1	18Cr–8Ni	2-2.1	A 182 Gr. F304 A 182 Gr. F304H	A 351 Gr. CF3 A 351 Gr. CF8	A 240 Gr. 304 A 240 Gr. 304H
2.2	16Cr–12Ni–2Mo 18Cr–13Ni–3Mo 19Cr–10Ni–3Mo	2-2.2	A 182 Gr. F316 A 182 Gr. F316H	A 351 Gr. CF3M A 351 Gr. CF8M A 351 Gr. CG8M	A 240 Gr. 316 A 240 Gr. 316H A 240 Gr. 317
2.3	18Cr–8Ni 16Cr–12Ni–2Mo	2-2.3	A 182 Gr. F304L A 182 Gr. F316L		A 240 Gr. 304L A 240 Gr. 316L
2.4	18Cr–10Ni–Ti	2-2.4	A 182 Gr. F321 A 182 Gr. F321H		A 240 Gr. 321 A 240 Gr. 321H

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TABLE 1A LIST OF MATERIAL SPECIFICATIONS (CONT'D)

Material Group	Nominal Designation	Pressure–Temperature Rating Table	Applicable ASTM Specifications[1]		
			Forgings	Castings	Plates
2.5	18Cr–10Ni–Cb	2-2.5	A 182 Gr. F347 A 182 Gr. F347H A 182 Gr. F348 A 182 Gr. F348H	A 351 Gr. CF8C	A 240 Gr. 347 A 240 Gr. 347H A 240 Gr. 348 A 240 Gr. 348H
2.6	25Cr–12Ni 23Cr–12Ni	2-2.6		A 351 Gr. CH8 A 351 Gr. CH20	 A 240 Gr. 309S A 240 Gr. 309H
2.7	25Cr–20Ni	2-2.7	A 182 Gr. F310	A 351 Gr. CK20	A 240 Gr. 310S A 240 Gr. 310H
2.8	20Cr–18Ni–6Mo 22Cr–5Ni–3Mo–N 25Cr–7Ni–4Mo–N 24Cr–10Ni–4Mo–V 25Cr–5Ni–2Mo–3Cu 25Cr–7Ni–3.5Mo–W–Cb 25Cr–7Ni–3.5Mo–N–Cu–W	2-2.8	A 182 Gr. F44 A 182 Gr. F51 A 182 Gr. F53 A 182 Gr. F55	A 351 Gr. CK3MCuN A 351 Gr. CE8MN A 351 Gr. CD4MCu A 351 Gr. CD3MWCuN	A 240 Gr. S31254 A 240 Gr. S31803 A 240 Gr. S32750 A 240 Gr. S32760

NOTE:
(1) ASME Boiler and Pressure Vessel Code, Section II materials, which also meet the requirements of the listed ASTM specifications, may also be used.

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TABLE 1B LIST OF BOLTING SPECIFICATIONS

Applicable ASTM Specifications[11]

Bolting Materials[1]					
High Strength (2)		Intermediate Strength (3)		Low Strength (4)	
Spec.-Gr.	Notes	Spec.-Gr.	Notes	Spec.-Gr.	Notes
A 193-B7	...	A 193-B5	...	A 193-B8 Cl. 1	(5)
A 193-B16	...	A 193-B6	...	A 193-B8C Cl. 1	(5)
		A 193-B6X	...	A 193-B8M Cl. 1	(5)
A 320-L7	(6)	A 193-B7M	...	A 193-B8T Cl. 1	(5)
A 320-L7A	(6)				
A 320-L7B	(6)	A 193-B8 Cl. 2	(7)	A 193-B8A	(5)
A 320-L7C	(6)	A 193-B8C Cl. 2	(7)	A 193-B8CA	...
A 320-L43	(6)	A 193-B8M Cl. 2	(7)	A 193-B8MA	...
		A 193-B8T Cl. 2	(7)	A 193-B8TA	(5)
A 354-BC	...				
A 354-BD	...	A 320-B8 Cl. 2	(7)	A 307-B	(8)
		A 320-B8C Cl. 2	(7)		
A 540-B21	...	A 320-B8F Cl. 2	(7)	A 320-B8 Cl. 1	(5)
A 540-B22	...	A 320-B8M Cl. 2	(7)	A 320-B8C Cl. 1	(5)
A 540-B23	...	A 320-B8T Cl. 2	(7)	A 320-B8M Cl. 1	(5)
A 540-B24	...			A 320-B8T Cl. 1	(5)
		A 449	(9)		
		A 453-651	(10)		
		A 453-660	(10)		

GENERAL NOTE:
Bolting material shall not be used beyond temperature limits specified in the governing code.

NOTES:
(1) Repair welding of bolting material is prohibited.
(2) These bolting materials may be used with all listed materials and gaskets.
(3) These bolting materials may be used with all listed materials and gaskets, provided it has been verified that a sealed joint can be maintained under rated working pressure and temperature.
(4) These bolting materials may be used with all listed materials but are limited to Class 150 and Class 300 joints. See para. 5.4.1 for recommended gasket practices.
(5) This austenitic stainless material has been carbide solution treated but not strain hardened. Use A 194 nuts of corresponding material.
(6) This ferritic material is intended for low temperature service. Use A 194 Gr. 4 or Gr. 7 nuts.
(7) This austenitic stainless material has been carbide solution treated and strain hardened. Use A 194 nuts of corresponding material.
(8) This carbon steel fastener shall not be used above 400°F or below −20°F. See also Note (4). Bolts with drilled or undersized heads shall not be used.
(9) Acceptable nuts for use with quenched and tempered bolts are A 194 Gr. 2 and Gr. 2H. Mechanical property requirements for studs shall be the same as those for bolts.
(10) This special alloy is intended for high temperature service with austenitic stainless steel.
(11) ASME Boiler and Pressure Vessel Code, Section II materials, which also meet the requirements of the listed ASTM specifications, may also be used.

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TABLES 2 PRESSURE–TEMPERATURE RATINGS FOR GROUPS 1.1 THROUGH 2.8 MATERIALS

TABLE 2-1.1 RATINGS FOR GROUP 1.1 MATERIALS (a)

Nominal Designation	Forgings	Castings	Plates
C–Si	A 105 (1)	A 216 Gr. WCB (1)	A 515 Gr. 70 (1)
C–Mn–Si	A 350 Gr. LF2 (1)		A 516 Gr. 70 (1)(2)
C–Mn–Si–V	A 350 Gr. LF6 Cl. 1 (4)		A 537 Cl. 1 (3)

NOTES:
(1) Upon prolonged exposure to temperatures above 800°F, the carbide phase of steel may be converted to graphite. Permissible, but not recommended for prolonged use above 800°F.
(2) Not to be used over 850°F.
(3) Not to be used over 700°F.
(4) Not to be used over 500°F.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
-20 to 100	140	285	740	990	1480	2220
200	130	260	675	900	1350	2025
300	115	230	655	875	1315	1970
400	100	200	635	845	1270	1900
500	85	170	600	800	1200	1795
600	70	140	550	730	1095	1640
650	60	125	535	715	1075	1610
700	...	110	535	710	1065	1600
750	...	95	505	670	1010	1510
800	...	80	410	550	825	1235
850	...	65	270	355	535	805
900	...	50	170	230	345	515
950	...	35	105	140	205	310
1000	...	20	50	70	105	155

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(a)

TABLE 2-1.2 RATINGS FOR GROUP 1.2 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C–Mn–Si		A 216 Gr. WCC (1) A 352 Gr. LCC (2)	
C–Mn–Si–V	A 350 Gr. LF6 Cl. 2 (3)		
2½Ni		A 352 Gr. LC2	A 203 Gr. B (1)
3½Ni	A 350 Gr. LF3	A 352 Gr. LC3	A 203 Gr. E (1)

NOTES:
(1) Upon prolonged exposure to temperatures above 800°F, the carbide phase of steel may be converted to graphite. Permissible, but not recommended for prolonged use above 800°F.
(2) Not to be used over 650°F.
(3) Not to be used over 500°F.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
–20 to 100	145	290	750	1000	1500	2250
200	130	260	750	1000	1500	2250
300	115	230	730	970	1455	2185
400	100	200	705	940	1410	2115
500	85	170	665	885	1330	1995
600	70	140	605	805	1210	1815
650	60	125	590	785	1175	1765
700	...	110	570	755	1135	1705
750	...	95	505	670	1010	1510
800	...	80	410	550	825	1235
850	...	65	270	355	535	805
900	...	50	170	230	345	515
950	...	35	105	140	205	310
1000	...	20	50	70	105	155

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TABLE 2-1.15 RATINGS FOR GROUP 1.15 MATERIALS (a)

Nominal Designation	Forgings	Castings	Plates
9Cr–1Mo–V	A 182 Gr. F91	A 217 Gr. C12A	A 387 Gr. 91 Cl. 2

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
–20 to 100	145	290	750	1000	1500	2250
200	130	260	750	1000	1500	2250
300	115	230	730	970	1455	2185
400	100	200	705	940	1410	2115
500	85	170	665	885	1330	1995
600	70	140	605	805	1210	1815
650	60	125	590	785	1175	1765
700	...	110	570	755	1135	1705
750	...	95	530	710	1065	1595
800	...	80	510	675	1015	1525
850	...	65	485	650	975	1460
900	...	50	450	600	900	1350
950	...	35	385	515	775	1160
1000	...	20	365	485	725	1090
1050	...	...	360	480	720	1080
1100	...	...	300	400	605	905
1150	...	...	225	295	445	670
1200	...	...	145	190	290	430

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TABLE 2-2.7 RATINGS FOR GROUP 2.7 MATERIALS (a)

Nominal Designation	Forgings	Castings	Plates
25Cr–20Ni	A 182 Gr. F310 (1)(3)	A 351 Gr. CK20 (1)	A 240 Gr. 310S (1)(2)(3) A 240 Gr. 310H

NOTES:
(1) At temperatures over 1000°F, use only when the carbon content is 0.04% or higher.
(2) For temperatures above 1000°F, use only if the material is heat treated by heating it to a temperature of at least 1900°F and quenching in water or rapidly cooling by other means.
(3) Service temperatures of 1050°F and above should be used only when assurance is provided that grain size is not finer than ASTM 6.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
–20 to 100	130	260	670	895	1345	2015
200	115	235	605	810	1215	1820
300	110	220	570	760	1140	1705
400	100	200	535	715	1070	1605
500	85	170	505	675	1015	1520
600	70	140	480	640	960	1440
650	60	125	470	625	935	1405
700	...	110	455	610	910	1370
750	...	95	450	600	900	1345
800	...	80	435	580	875	1310
850	...	65	425	570	855	1280
900	...	50	420	555	835	1255
950	...	35	385	515	775	1160
1000	...	20	345	460	685	1030
1050	...	...	335	450	670	1010
1100	...	...	260	345	520	780
1150	...	...	190	250	375	565
1200	...	...	135	185	275	410
1250	...	...	105	135	205	310
1300	...	...	75	100	150	225
1350	...	...	60	80	115	175
1400	...	...	45	60	90	135
1450	...	...	35	45	65	100
1500	...	...	25	35	50	75

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(a)

TABLE 2-2.8 RATINGS FOR GROUP 2.8 MATERIALS

Nominal Designation	Forgings	Castings	Plates
20Cr–18Ni–6Mo	A 182 Gr. F44	A 351 Gr. CK3MCuN	A 240 Gr. S31254
22Cr–5Ni–3Mo–N	A 182 Gr. F51 (1)		A 240 Gr. S31803 (1)
25Cr–7Ni–4Mo–N	A 182 Gr. F53 (1)		A 240 Gr. S32750 (1)
24Cr–10Ni–4Mo–V		A 351 Gr. CE8MN (1)	
25Cr–5Ni–2Mo–3Cu		A 351 Gr. CD4MCu (1)	
25Cr–7Ni–3.5Mo–W–Cb		A 351 Gr. CD3MWCuN (1)	
25Cr–7Ni–3.5Mo–N–Cu–W	A 182 Gr. F55		A 240 Gr. S32760 (1)

NOTE:
(1) This steel may become brittle after service at moderately elevated temperatures. Not to be used over 600°F.

WORKING PRESSURES BY CLASSES, psig

Class Temp., °F	75	150	300	400	600	900
–20 to 100	145	290	750	1000	1500	2250
200	130	260	720	960	1440	2160
300	115	230	665	885	1330	1995
400	100	200	615	820	1230	1845
500	85	170	575	770	1150	1730
600	70	140	555	740	1115	1670
650	60	125	550	735	1100	1650
700	...	110	540	725	1085	1625
750	...	95	530	710	1065	1595

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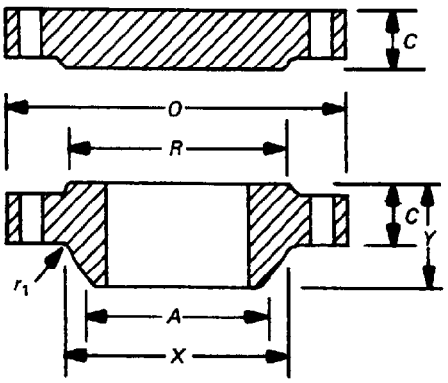

TABLE 12 DIMENSIONS OF CLASS 300 SERIES B FLANGES[1-6]

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	34.12	3.50	3.50	5.69	27.62	26.19	29.00	31.62	32	1.38	1¼	0.56
28	36.25	3.50	3.50	5.88	29.75	28.19	31.00	33.75	36	1.38	1¼	0.56
30	39.00	3.69	3.69	6.22	32.00	30.25	33.25	36.25	36	1.50	1⅜	0.56
32	41.50	4.06	4.06	6.62	34.00	32.25	35.50	38.50	32	1.62	1½	0.62
34	43.62	4.06	4.06	6.81	36.12	34.25	37.50	40.62	36	1.62	1½	0.62
36	46.12	4.06	4.06	7.12	38.00	36.25	39.75	42.88	32	1.75	1⅝	0.62
38	48.12	4.38	4.38	7.56	40.00	38.25	41.75	44.88	36	1.75	1⅝	0.62
40	50.12	4.56	4.56	7.81	42.00	40.25	43.88	46.88	40	1.75	1⅝	0.62
42	52.50	4.69	4.69	8.06	44.00	42.31	46.00	49.00	36	1.88	1¾	0.62
44	54.50	5.00	5.00	8.44	46.19	44.31	48.00	51.00	40	1.88	1¾	0.62
46	57.50	5.06	5.12	8.75	48.38	46.31	50.00	53.75	36	2.00	1⅞	0.62
48	59.50	5.06	5.31	8.81	50.31	48.31	52.25	55.75	40	2.00	1⅞	0.62
50	61.50	5.44	5.50	9.25	52.38	50.31	54.25	57.75	44	2.00	1⅞	0.62
52	63.50	5.62	5.68	9.56	54.44	52.31	56.25	59.75	48	2.00	1⅞	0.62
54	65.88	5.38	5.88	9.44	56.50	54.31	58.25	62.12	48	2.00	1⅞	0.62
56	69.50	6.06	6.18	10.56	58.81	56.31	60.50	65.00	36	2.38	2¼	0.69
58	71.94	6.06	6.38	10.81	60.94	58.31	62.75	67.44	40	2.38	2¼	0.69
60	73.94	5.94	6.56	10.69	62.94	60.31	65.00	69.44	40	2.38	2¼	0.69

(Notes follow Table 15)

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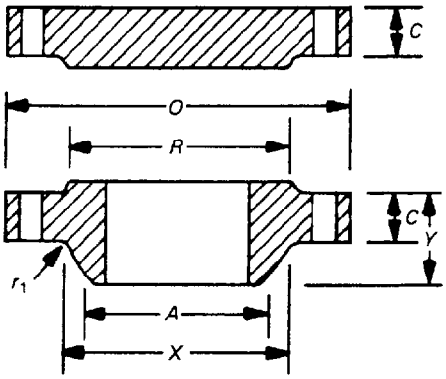

(a) **TABLE 13 DIMENSIONS OF CLASS 400 SERIES B FLANGES[1-6,10]**

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	33.50	3.50	3.50	5.88	27.12	26.00	28.00	30.75	28	1.50	1 3/8	0.44
28	36.00	3.75	3.75	6.25	29.12	28.00	30.00	33.00	24	1.62	1 1/2	0.50
30	38.25	4.00	4.00	6.69	31.25	30.00	32.25	35.25	28	1.62	1 1/2	0.50
32	40.75	4.25	4.25	7.06	33.25	32.00	34.38	37.50	28	1.75	1 5/8	0.50
34	42.75	4.38	4.38	7.38	35.38	34.00	36.50	39.50	32	1.75	1 5/8	0.56
36	45.50	4.69	4.69	7.88	37.50	36.00	38.62	42.00	28	1.88	1 3/4	0.56
38	...	...	...	...	...	...	...	...	...	...	...	...
40	...	...	...	...	...	...	...	...	...	...	...	...
42	...	...	...	...	...	...	...	...	...	...	...	...
44	...	...	...	...	...	...	...	...	...	...	...	...
46	...	...	...	...	...	...	...	...	...	...	...	...
48	...	...	...	...	...	...	...	...	...	...	...	...
50	...	...	...	...	...	...	...	...	...	...	...	...
52	...	...	...	...	...	...	...	...	...	...	...	...
54	...	...	...	...	...	...	...	...	...	...	...	...
56	...	...	...	...	...	...	...	...	...	...	...	...
58	...	...	...	...	...	...	...	...	...	...	...	...
60	...	...	...	...	...	...	...	...	...	...	...	...

(Notes follow Table 15)

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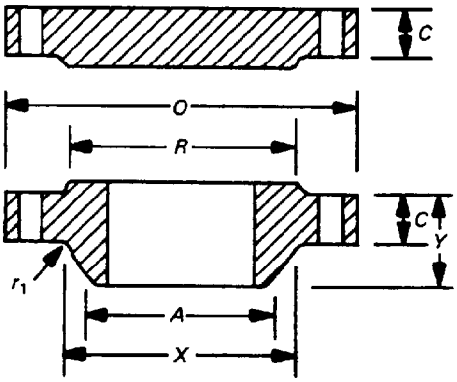

(a)

TABLE 14 DIMENSIONS OF CLASS 600 SERIES B FLANGES[1-6,10]

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	35.00	4.38	4.38	7.12	27.50	26.00	28.62	31.75	28	1.75	1 5/8	0.50
28	37.50	4.56	4.56	7.50	29.62	28.00	30.88	34.00	28	1.88	1 3/4	0.50
30	40.25	4.94	5.00	8.06	31.75	30.00	33.12	36.50	28	2.00	1 7/8	0.50
32	42.75	5.12	5.31	8.50	33.88	32.00	35.25	38.75	28	2.12	2	0.50
34	45.75	5.56	5.68	9.19	36.00	34.00	37.50	41.50	24	2.38	2 1/4	0.56
36	47.75	5.75	5.94	9.56	38.12	36.00	39.75	43.50	28	2.38	2 1/4	0.56
38	...	...	...	...	...	...	...	...	...	...	...	...
40	...	...	...	...	...	...	...	...	...	...	...	...
42	...	...	...	...	...	...	...	...	...	...	...	...
44	...	...	...	...	...	...	...	...	...	...	...	...
46	...	...	...	...	...	...	...	...	...	...	...	...
48	...	...	...	...	...	...	...	...	...	...	...	...
50	...	...	...	...	...	...	...	...	...	...	...	...
52	...	...	...	...	...	...	...	...	...	...	...	...
54	...	...	...	...	...	...	...	...	...	...	...	...
56	...	...	...	...	...	...	...	...	...	...	...	...
58	...	...	...	...	...	...	...	...	...	...	...	...
60	...	...	...	...	...	...	...	...	...	...	...	...

(Notes follow Table 15)

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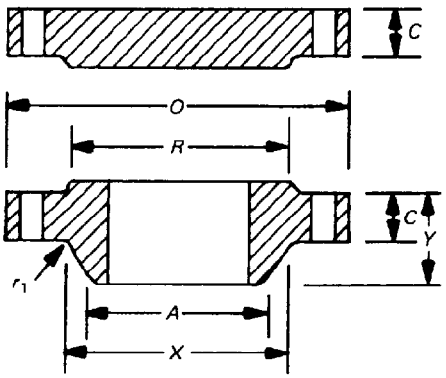

(a) **TABLE 15 DIMENSIONS OF CLASS 900 SERIES B FLANGES[1–6, 10]**

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	40.25	5.31	6.06	10.19	29.25	26.00	30.00	35.50	20	2.62	2½	0.44
28	43.50	5.81	6.56	10.88	31.38	28.00	32.25	38.25	20	2.88	2¾	0.50
30	46.50	6.12	6.93	11.38	33.50	30.00	34.50	40.75	20	3.12	3	0.50
32	48.75	6.31	7.31	11.94	35.75	32.00	36.50	43.00	20	3.12	3	0.50
34	51.75	6.75	7.68	12.56	37.88	34.00	39.00	45.50	20	3.38	3¼	0.56
36	53.00	6.81	7.94	12.81	40.00	36.00	40.50	47.25	24	3.12	3	0.56
38	...	...	...	...	...	...	...	...	...	...	...	...
40	...	...	...	...	...	...	...	...	...	...	...	...
42	...	...	...	...	...	...	...	...	...	...	...	...
44	...	...	...	...	...	...	...	...	...	...	...	...
46	...	...	...	...	...	...	...	...	...	...	...	...
48	...	...	...	...	...	...	...	...	...	...	...	...
50	...	...	...	...	...	...	...	...	...	...	...	...
52	...	...	...	...	...	...	...	...	...	...	...	...
54	...	...	...	...	...	...	...	...	...	...	...	...
56	...	...	...	...	...	...	...	...	...	...	...	...
58	...	...	...	...	...	...	...	...	...	...	...	...
60	...	...	...	...	...	...	...	...	...	...	...	...

(Notes follow on next page)

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	MSS	Manufacturers Standardization Society of the Valve & Fittings Industry 127 Park Street, N.E., Vienna, Virginia 22180

ISO documents are available from ANSI. Publications appearing above which have been approved as American National Standards may also be obtained from ANSI.

ANSI	American National Standards Institute, Inc. 11 West 42nd St., New York, New York 10036

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INTERPRETATIONS TO ASME B16.47 (a)

(These interpretations are not part of ASME B16.47-1996 and are included for information only. These interpretations apply to the 1988 and earlier editions and the requirements cited may be different in this Edition. Therefore, some replies may not be valid in regard to this Edition.)

INTRODUCTION

As a service to persons who use the B16 standards, the B16 Committee renders interpretations of the requirements upon request. The procedure for requesting an interpretation is described in the following paragraphs.

The interpretations include all replies which have been approved by the B16 Main Committee in response to inquiries concerning interpretation of this Standard.

An interpretation applies either to the Edition and Addenda in effect on the date of issuance of the interpretation or the Edition and Addenda stated in the interpretation. Subsequent revisions to this Standard may supersede the interpretation.

PROCEDURE FOR REQUESTING INTERPRETATIONS

On request, the B16 Committee will render an interpretation of any requirement of this Standard. Interpretations can only be rendered in response to a written request, which should be addressed to:

Secretary, B16 Main Committee
The American Society of Mechanical Engineers
Three Park Avenue
New York, NY 10016-5990

The request for interpretation should be clear and unambiguous. It is further recommended that the inquirer submit his request using the following format:

(a) Subject. Cite the applicable paragraph number(s) and/or give a concise description of the subject.

(b) Question. Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. The inquirer may also include any plans or drawings which are necessary to explain the question; however, they should not contain proprietary names or information.

Requests which are not in this format may be rewritten in this format prior to being answered, which may inadvertently change the original intent of the request.

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INTERPRETATIONS NO. 2

Replies to Technical Inquiries Issued from January 1, 1996 Through December 31, 1997

Interpretation: 2-1

Subject: Series A Flanges

Date Issued: April 30, 1997

File: B16-96-013

Question: According to ASME B16.47-1990, may Series A flanges be manufactured and used for all materials listed in Table 1A?

Reply: Yes, within the restriction of General Note (b) of Table 1A.

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STD.ASME B16.47-ENGL 1996 ■ 0759670 0579158 831 ■

ASME B16.47-1996
(Revision of ASME B16.47-1990)

LARGE DIAMETER STEEL FLANGES

NPS 26 Through NPS 60

AN AMERICAN NATIONAL STANDARD

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AN AMERICAN NATIONAL STANDARD

LARGE DIAMETER STEEL FLANGES

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ASME B16.47-1996
(Revision of ASME B16.47-1990)

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Date of Issuance: January 31, 1997

The 1996 edition of this Standard is being issued with an automatic addenda subscription service. The use of an addenda allows revisions made in response to public review comments or committee actions to be published as necessary; revisions published in addenda will become effective 6 months after the Date of Issuance of the addenda. The next edition of this Standard is scheduled for publication in 2001.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Standard. The interpretations will be included with the above addenda service. Interpretations are not part of the addenda to the Standard.

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FOREWORD

(This Foreword is not part of ASME B16.47-1996.)

In November, 1980, a task force was appointed within Subcommittee C of the American National Standards (ANSI) B16 Committee to develop a standard for pipe flanges in size NPS 26 through NPS 48. Every attempt was made to standardize those dimensions that existed within the industry for the materials covered by ANSI B16.5.

Prompted by suggestions received from committee members, the task force was authorized to increase the size range to NPS 60. The first draft was developed in December 1982 to include Class 75 through Class 1500 for the size range NPS 26 through NPS 60. Flange dimensions were based on the Manufacturers Standardization Society Standard Practice (MSS SP) 44 flanges except for Class 75 flanges which are ANSI/API 605 flanges.

At the request of the American Petroleum Institute (API), flange dimensions in accordance with the API Standard 605 were included in the subsequent drafts. Class 1500 flanges were deleted due to lack of interest in using large size flanges in that pressure–temperature rating.

The API-605 flanges for Classes 150 and 300 and for sizes NPS 36 and smaller for classes higher than Class 300 are not compatible with the MSS SP-44 flanges. Thus, the MSS SP-44 flanges are designated as Series A flanges and the API-605 flanges are designated as Series B flanges in this Standard. Materials covered in this Standard are as in ANSI B16.5 except nickel base alloys are excluded. Pressure–temperature ratings are in accordance with ANSI B16.5.

In 1982, American National Standards Committee B16 was reorganized as the American Society of Mechanical Engineers (ASME) B16 Committee operating under procedures accredited by ANSI. Following approval by the Standards Committee and ASME, approval as an American National Standard was given by ANSI on June 12, 1990.

This 1996 Edition allows flanges marked with more than one material grade or specification, revises flange facing finish requirements, has revised pressure–temperature ratings for several material groups, adds permissible flange facing imperfections, adds blind flanges for Series B flanges, and includes several other revisions. Following approval by the Standards Committee and ASME, approval as an American National Standard was given by ANSI on October 3, 1996 with the new designation ASME B16.47-1996.

All requests for interpretations or suggestions for revisions should be sent to the Administrative Secretary B16, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017.

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Standardization of Valves, Flanges, Fittings, Gaskets, and Valve Actuators

(The following is a roster of the Committee at the time of approval of this Standard.)

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LARGE DIAMETER STEEL FLANGES

1 SCOPE

1.1 General

This Standard covers pressure–temperature ratings, materials, dimensions, tolerances, marking, and testing for pipe flanges in sizes NPS 26 through NPS 60 and in ratings Classes 75, 150, 300, 400, 600, and 900. Flanges may be cast, forged, or plate (for blind flanges only) materials, as listed in Table 1A.

Requirements and recommendations regarding bolting and gaskets are also included.

1.2 Flange Series

This Standard provides two series of flange dimensions. Series A specifies flange dimensions for general use flanges. Series B specifies flange dimensions for compact flanges which, in general, have smaller bolt circle diameters than Series A flanges. These two series of flanges are not interchangeable. The user should recognize that some flanged valves, equipment bolted between flanges, and flanged equipment may only be compatible with bolt circle diameter of one series of flanges.

1.3 References

1.3.1 Referenced Standards. Standards and specifications adopted by reference in this Standard are shown in Annex E, which is part of this Standard. It is not considered practical to identify the specific edition of each standard and specification in the individual references. Instead, the specific edition reference is identified in Annex E. A flange manufactured in accordance with earlier editions of the referenced standards, and in all other respects conforming to this Standard, will be considered to be in conformance with this Standard.

1.3.2 Codes and Regulations. A flange used under the jurisdiction of the ASME Boiler and Pressure Vessel Code (ASME BPV Code), the ASME Code for Pressure Piping, or a governmental regulation is subject to any limitation of that code or regulation. This includes any maximum temperature limitation, rule governing the use of a material at low temperature, or provisions for operation at a pressure exceeding the pressure–temperature ratings in this Standard.

1.4 Applicable Ratings

The pressure–temperature ratings in this Standard are applicable upon its publication to all flanges within its scope which otherwise meet its requirements. For unused flanges maintained in inventory, the manufacturer of the flange may certify conformance to this Edition, provided he can demonstrate that all requirements of this Edition have been met. Where such components were installed in accordance with the pressure–temperature ratings of an earlier edition of this Standard, those ratings are applicable, except as may be governed by the applicable code or regulation (see para. 1.3.2).

1.5 User Accountability

This Standard cites duties and responsibilities that are to be assumed by the user in the areas of application, installation, hydrostatic testing, operation, and material selection.

1.6 Quality Systems

Nonmandatory requirements relating to the product manufacturer's Quality System Program are described in Annex D.

2 PRESSURE–TEMPERATURE RATINGS

2.1 Rating Basis

Ratings are maximum allowable working gage pressures, at the temperatures shown in Table 2 for the applicable material and rating. For intermediate temperatures, linear interpolation is permitted. See Annex A, which is part of this Standard, for methods of establishing pressure–temperature ratings.

2.2 Ratings of Flanged Joints

A flanged joint is composed of three separate and independent, although interrelated, components: the flanges, the gasket, and the bolting, which are assembled by yet another influence, the assembler. Proper controls must be exercised in the selection and application for

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all these elements in order to attain a joint which has acceptable leak tightness. Special techniques such as controlled bolt tightening may be necessary to achieve a tight joint in service.

Ratings in this Standard apply to flanged joints which conform to the limitations on bolting in para. 5.3 and on gaskets in para. 5.4, and which are made up in accordance with good practice for alignment and assembly. See also para. 2.4. Use of the ratings for flanged joints not conforming to these limitations is the sole responsibility of the user. Requirements for alignment and assembly of joints are not given in this Standard.

If the two flanges in a flanged joint do not have the same pressure–temperature ratings, the rating of the joint at any temperature is the lower of the two flange ratings at that temperature.

2.3 Rating Temperature

The temperature shown for a corresponding pressure rating is the temperature of the pressure containing shell of the flange. In general, this temperature is the same as that of the contained fluid. Use of a pressure rating corresponding to a temperature other than that of the contained fluid is the responsibility of the user, subject to the requirements of the applicable code or regulation. For any temperature below –20°F the rating shall be no greater than the rating shown for –20°F.

2.4 Temperature Considerations

Application of the ratings in this Standard to flanged joints both high and low temperatures shall take into consideration the risk of leakage due to forces and moments developed in the connected piping or equipment. The following provisions are intended to minimize these risks.

2.4.1 High Temperature Service. At temperatures in the creep range, gradual relaxation of flanges, bolts, and gaskets may progressively reduce bolt loads. It may be necessary to arrange for periodic tightening of bolts to prevent leakage. Joints subject to substantial thermal gradients may require the same attention.

When used above 400°F, Classes 75 and 150 flanged joints may develop leakage unless care is taken to avoid imposing severe external loads and/or severe thermal gradients. For other classes, similar consideration should be given above 750 F.

2.4.2 Low Temperature Service. Some of the materials listed in the rating tables undergo sufficient decrease in toughness at low temperatures that they cannot safely sustain shock loadings, sudden changes of stress or temperature, or high stress concentrations.

2.5 System Hydrostatic Test

Flanged joints may be subjected to system hydrostatic tests at a pressure not to exceed 1.5 times the 100°F rating rounded off to the next higher 25 psi.

Testing at any higher pressure is the responsibility of the user, subject to the requirements of the applicable code or regulation.

2.6 Welding Neck Flanges

Ratings for carbon steel cylindrically bored welding neck flanges covered by this Standard are based upon their hubs at the welding end having a thickness at least equal to that calculated for pipe having 40.0 ksi specified minimum yield strength. The ratings also apply to such flanges used with components of unequal strength and unequal wall thickness when the attachment welds is made in accordance with the applicable code or regulation. See Figs. 5, 6, and 7.

2.7 Multiple Material Grades

Materials for flanges may meet the requirements for more than one specification or grade of a specification listed in Table 1A. In that event, the pressure–temperature ratings for any of these specifications or grades may be used provided that the marking is in accordance with para. 4.1.2(d).

3 SIZE

3.1 Nominal Size

The size of a flange covered by this Standard is its nominal pipe size (NPS). The diameter of a bolt is its nominal size. Use of nominal indicates that the stated size or dimension is only for designation, not measurement. The actual dimension may or may not be the nominal size and is subject to established tolerances.

4 MARKING

4.1 General

Except as modified herein, flanges shall be marked as required in MSS SP-25.

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4.1.1 Name. The manufacturer's name or trademark shall be applied.

4.1.2 Materials

(a) Cast flanges shall be marked with the ASTM specification[1], grade identification symbol, and the melt number identification or melt identification.

(b) Plate flanges and forged flanges shall be marked with the ASTM specification number and grade identification symbol.

(c) A manufacturer may supplement these mandatory material indications with his trade designation for the material grade, but confusion of symbols shall be avoided.

(d) Flanges manufactured from material which meets the requirements for more than one specification or grade of a specification listed in Table 1A may be marked with more than one of the applicable specification or grade symbols. The symbols shall be placed to avoid confusion in identification.

4.1.3 Rating Class. The marking shall be the applicable pressure rating class: 75 (Series B only), 150, 300, 400, 600, or 900.

4.1.4 Designation. The designation of Series A B16/A for flange dimensions in accordance with Tables 5 through 9 and Series B B16/B for flange dimensions in accordance with Tables 10 through 15 shall be applied, preferably located adjacent to the class designation, to indicate conformance to this Standard.

4.1.5 Temperature. No temperature markings are required on flanges, but if marked, the temperature shall be shown with its corresponding tabulated pressure rating for the material.

4.1.6 Size. The nominal pipe size shall be given.

4.1.7 Ring-Joint Flange. The edge (periphery) of each ring-joint flange shall be marked with the letter "R" and the corresponding ring-groove number.

5 MATERIALS

5.1 General

Flanges covered by this Standard shall be castings, forgings, and (for blind flanges only) plate, as listed in Table 1A. Recommended bolting materials are listed in Table 1B. (See also para. 5.3.) The ASME Boiler and Pressure Vessel Code, Section II materials, which also meet the requirements of the specifications listed in Table 1, may also be used.

5.1.1 Application. Criteria for the selection of materials are not within the scope of this Standard. The possibility of material deterioration in service should be considered by the user. Carbide phase conversion to graphite and excessive oxidation of ferritic materials or susceptibility to intergranular corrosion of austenitic materials are among those items requiring attention. A detailed discussion of precautionary considerations can be found in Appendix F of ASME B31.3.

5.1.2 Toughness. Some of the materials listed in Table 1A undergo a decrease in toughness when used at low temperatures, to the extent that codes referencing this Standard may require impact tests for applications even at temperatures higher than +20°F. It is the responsibility of the user to assure that such testing is performed.

5.1.3 Responsibility. When service conditions dictate the implementation of special material requirements, e.g., using a Group 2 material above 1000°F, it is the user's responsibility to so specify to the manufacturer in order to ensure compliance with metallurgical requirements listed in the notes in Table 2.

5.2 Mechanical Properties

Mechanical properties shall be obtained from test specimens that represent the final heat-treated condition of the material.

5.3 Bolting

Bolting listed in Table 1B is recommended for use in flange joints covered by this Standard. Bolting of other material may be used if permitted by the applicable code or governmental regulation. All bolting materials are subject to the following limitations.

5.3.1 High Strength Bolting. Bolting materials having allowable stresses not less than those for ASTM A 193 Gr. B7 are listed as high strength in Table 1B. These and other materials of comparable strength may be used in any flanged joint.

5.3.2 Intermediate Strength Bolting. Bolting materials listed as intermediate strength in Table 1B, and other bolting of comparable strength, may be used in any flanged joint, provided the user verifies their

[1] The ASME Boiler and Pressure Vessel Code, Section II specification number may be substituted provided the material is covered by Section II.

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ability to seat the selected gasket and to maintain a sealed joint under expected operating conditions.

5.3.3 Low Strength Bolting. Bolting materials having not more than 30 ksi specified minimum yield strength are listed as low strength in Table 1B. These materials and others of comparable strength shall be used only in Classes 75, 150, and 300 joints, and only with gaskets described in para. 5.4.1. Flanged joints using low strength carbon steel bolts shall not be used above 400°F or below −20°F.

5.3.4 Bolting to Gray Cast Iron Flanges. The following recommendations are made in recognition of the low ductility of gray cast iron.

(a) Where Class 150 steel flanges are bolted to Class 125 cast iron flanges, the gaskets should be made of Group Ia materials, the steel flanges should have flat faces, and:

(1) low strength bolting within the limitations of para. 5.3.3 should be used with ring gaskets extending to the bolt holes; or

(2) bolting of low (para. 5.3.3), intermediate (para. 5.3.2), or high (para. 5.3.1) strength may be used with full face gaskets extending to the outside diameters of the flanges.

(b) Where Class 300 steel flanges are bolted to Class 250 cast iron flanges, the gaskets should be made of Group Ia materials and:

(1) low strength bolting within the limitations of para. 5.3.3 should be used with gaskets extending to the bolt holes and with flanges having either raised or flat faces; or

(2) bolting of low (para. 5.3.3), intermediate (para. 5.3.2), or high (para. 5.3.1) strength may be used with full face gaskets extending to the outside diameters of the flanges and with both the Class 300 steel and Class 250 cast iron flanges having flat faces.

(c) Alignment of flange faces is essential along with control of assembly bolt torque so as not to over-stress the cast iron flanges. Care must also be exercised to ensure that piping loads transmitted to cast iron flanges are controlled taking into account its lack of ductility and recognizing that cast iron flanges should not be used where suddenly applied loads such as rapid pressure fluctuations may occur.

5.4 Gaskets

Ring-joint gasket materials shall conform to ASME B16.20. Materials for other gaskets are described in Annex B, which is part of this Standard. The user is responsible for selection of gasket materials which will withstand the expected bolt loading without injurious crushing, and which are suitable for the service conditions. Particular attention should be given to gasket selection if a system hydrostatic test approaches the test pressure specified in para. 2.5.

5.4.1 Gaskets for Low Strength Bolting. If bolting listed as low strength in Table 1B is used, gaskets shown in Annex B, Fig. B1, Group Ia, shall be used.

5.4.2 Gaskets for Class 150 Flanged Joints. It is recommended that only Fig. B1, Group Ia or Ib gaskets be used for Class 150 flanged joints.

5.4.3 Gaskets for Class 75 Flanged Joints. It is recommended that only Group Ia gaskets with a gasket factor $m = 2$ or less, and minimum design seating stress $y = 1600$ psi or less, be used. The m and y factors are those given in Table 2-5.1, Appendix 2 of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

6 DIMENSIONS

6.1 Facings

6.1.1 General. Classes 75, 150, and 300 flanges are regularly furnished with a 0.06 in. raised face, which is included in the minimum flange thickness *C*. Classes 400, 600, and 900 flanges are regularly furnished with 0.25 in. raised face, which is additional to the minimum flange thickness *C*. It is recommended that the Class 75 flanges be used only with a 0.06 in. raised face or flat face.

Dimensions for ring-joint facing are given in Table 3 for Series A flanges. Any other facing than the above, when required for any class, shall be furnished as follows.

6.1.1.1 In the case of the 0.25 in. raised face for Classes 150 and 300, the minimum flange thickness *C* shall first be provided and then the raised face shall be added thereto.

6.1.1.2 With ring-joint, the minimum flange thickness shall first be provided and then sufficient metal added thereto so that the bottom of the ring-joint groove is in the same plane as the flange edge of a full thickness flange.

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6.1.2 Blind Flanges. Blind flanges need not be faced in the center if, when this center part is raised, its diameter is at least 1 in. smaller than the inside diameter of the mating flange. When the center part is depressed, its diameter shall not be greater than the inside diameter of the mating flange. Machining of the depressed center is not required.

6.1.3 Flat Face Flanges. This Standard permits flat face flanges in all classes, either by providing flanges having the full thickness or the thickness with the raised face removed, without reduction of the pressure-temperature ratings subject to the following provisions.

6.1.3.1 The thickness of a Class 75, 150, or 300 flange from which the raised face has been removed shall be no less than the applicable *C* dimension of Tables 5, 6, 10, 11, and 12, minus 0.06 in.

6.1.3.2 The thickness of a flange of Class 400 or higher from which the raised face has been removed shall be no less than the applicable *C* dimension of Tables 7 to 9 and 13 to 15.

6.1.3.3 A gasket of Group Ia material in Annex B, Fig. B1, is recommended for all joints having two flat faced flanges using a gasket which has a larger diameter than those of the raised face.

6.1.3.4 The flange facing shall conform with para. 6.1.4 for the full width of seating of the gasket.

6.1.4 Flange Facing Finish. The finish of contact faces of pipe flanges shall be judged by visual comparison with Ra Standards (see ANSI/ASME B46.1) and not by instruments having stylus tracers and electronic amplification. The finishes required are given below. Other finishes may be furnished by agreement between user and manufacturer.

6.1.4.1 Ring-Joint. The side wall surface to gasket groove shall not exceed 63 μin. roughness.

6.1.4.2 Other Flange Facings. Either a serrated concentric or serrated spiral finish having a resultant surface finish from 125 μin. to 250 μin. average roughness shall be furnished. The cutting tool employed should have an approximate 0.06 in. or larger radius, and there should be from 45 grooves/in. through 55 grooves/in.

6.1.5 Flange Facing Finish Imperfections. Imperfections in the flange facing finish shall not exceed the dimensions shown in Table 16. Adjacent imperfections shall be separated by a distance of at least four times the maximum radial projection. A radial projection shall be measured by the difference between an outer radius and an inner radius encompassing the imperfection where the radii are struck from the centerline of the bore. Imperfections less than half the depth of the serrations shall not be considered cause for rejection. Protrusions above the serrations are not permitted.

6.2 Flange Bolt Holes

Bolt holes are in multiples of four. Bolt holes shall be equally spaced.

6.3 Spot Facing

All cast and forged steel flanges shall have bearing surfaces for bolting which shall be parallel to the flange face within 1 deg. Any back facing or spot facing required to accomplish parallelism shall not reduce the flange thickness *C* below the dimensions given in Tables 5 through 15. Any spot facing or back facing shall be in accordance with MSS SP-9.

6.4 Welding End Preparation for Welding Neck Flanges

6.4.1 Welding ends are shown in Figs. 1 through 7.

6.4.2 The contours of the outside of the welding neck beyond the welding groove are shown in Figs. 1, 2, 5, and 7.

6.4.3 Straight through bores shown in Figs. 1 and 2 are standard unless otherwise specifically ordered to suit the special conditions illustrated in Figs. 3, 4, 6, and 7.

6.4.4 Other welding end preparations furnished by agreement between purchaser and manufacturer do not invalidate compliance with this Standard.

6.5 Flange Bolting Dimensions

6.5.1 Stud-bolts threaded at both ends or full length, or bolts with hexagonal heads may be used. Dimensional recommendations for bolts, stud-bolts, and nuts are shown in Table 4. See para. 5.3 for bolting material.

6.5.2 For the method of calculating bolt lengths, see Annex C. The method of calculating bolt length is established for the convenience of industry to simplify the assembly of these parts on construction work, but

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users may select combinations of these bolt lengths to suit their needs. Hence, Annex C is not considered part of this Standard.

6.6 Gaskets for Line Flanges

6.6.1 Ring-joint gasket dimensions shall conform to ASME B16.20.

6.6.2 Nonmetallic gasket dimensions for Series A flanges with raised face shall conform to ASME B16.21.

6.6.3 Solid flat metal gaskets shall have contact width not greater than for Group III gaskets.

6.6.4 Spiral wound and double-jacketed corrugated metal gasket shall conform to ASME B16.20.

6.6.5 Nonmetallic gasket dimensions for Series B flanges with raised face shall have outside diameter equal to the raised face diameter and inside diameter equal to the nominal pipe size. If self-centering ring gaskets are used, the outside diameter shall equal the bolt circle diameter less one bolt hole diameter.

7 TOLERANCES[2]

7.1 General

For the purposes of determining conformance with this Standard, the convention for fixing significant digits where limits, maximum or minimum values are specified, shall be the rounding-off method defined in ASTM Practice E29. This requires that an observed or calculated value shall be rounded to the nearest unit in the last right-hand digit used for expressing the limit.

The listing of decimal tolerances does not imply a particular method of measurement.

7.2 Facings

7.2.1 Outside diameter, 0.06 in. raised face, 0.08 in.

7.2.2 Outside diameter, 0.25 in. raised face, 0.04 in.

7.2.3 Ring-joint groove tolerances are shown in Table 3.

[2] Unless otherwise stated, tolerances are equal, plus and minus.

7.3 Flange Thickness

Thickness, in.	
To 1.0	+0.12 in. −0
1.0–2.0	+0.19 in. −0
2.0–3.0	+0.31 in. −0
Over 3.0	+0.38 in. −0

7.4 Hub Dimensions Including Welding Ends

7.4.1 Nominal outside diameter of welding end of welding neck flanges (dimension *A* of Figs. 1 and 2).

+0.21 in.
−0.06 in.

7.4.2 Nominal inside diameter of welding ends of welding neck flanges (dimension *B* in the referenced Figures).

Figs. 1 and 2	+0.12 in. −0.06 in.
Fig. 3	+0 −0.06 in.

7.4.3 Bore of backing ring of welding neck flanges (dimension *C* of Figs. 3 and 4).

+0.010 in.
−0

7.4.4 Thickness of Hub. Regardless of tolerances specified for dimensions *A* and *B*, the thickness of hub at the welding end shall never be less than $87\frac{1}{2}\%$ of the nominal thickness of the pipe to which the flange is to be attached.

7.5 Overall Length Through Hub on Welding Neck Flanges

0.19 in.

7.6 Drilling and Facing

7.6.1 Bolt circle diameter, 0.06 in.

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7.6.2 Center-to-center of adjacent bolt holes, 0.03 in.

7.6.3 Eccentricity between bolt circle diameter and machined facing diameters, 0.06 in.

8 TEST

8.1 Flange Testing

Flanges are not required to be hydrostatically tested.

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TABLE 1A LIST OF MATERIAL SPECIFICATIONS

Material Group	Nominal Designation	Pressure–Temperature Rating Table	Applicable ASTM Specifications[1]		
			Forgings	Castings	Plates
1.1	C–Si C–Mn–Si	2-1.1	A 105 A 350 Gr. LF2	A 216 Gr. WCB	A 515 Gr.70 A 516 Gr. 70 A 537 Cl. 1
1.2	C–Mn–Si 2½Ni 3½Ni	2-1.2	 A 350 Gr. LF3	A 216 Gr. WCC A 352 Gr. LCC A 352 Gr. LC2 A 352 Gr. LC3	 A 203 Gr. B A 203 Gr. E
1.3	C–Si C–Mn–Si 2½Ni 3½Ni	2-1.3		A 352 Gr. LCB	A 515 Gr. 65 A 516 Gr. 65 A 203 Gr. A A 203 Gr. D
1.4	C–Si C–Mn–Si	2-1.4	 A 350 Gr. LF1 Cl. 1		A 515 Gr. 60 A 516 Gr. 60
1.5	C–½Mo	2-1.5	A 182 Gr. F1	A 217 Gr. WC1 A 352 Gr. LC1	A 204 Gr. A A 204 Gr. B
1.7	C–½Mo ½Cr–½Mo Ni–½Cr–½Mo ¾Ni–¾Cr–1Mo	2-1.7	 A 182 Gr. F2	 A 217 Gr. WC4 A 217 Gr. WC5	A 204 Gr. C
1.9	1Cr–½Mo 1¼Cr–½Mo 1¼Cr–½Mo–Si	2-1.9	A 182 Gr. F12 Cl. 2 A 182 Gr. F11 Cl. 2	 A 217 Gr. WC6	 A 387 Gr. 11 Cl. 2
1.10	2¼Cr–1Mo	2-1.10	A 182 Gr. F22 Cl. 3	A 217 Gr. WC9	A 387 Gr. 22 Cl.2
1.13	5Cr–½Mo ¾Ni–1Mo–¾Cr	2-1.13	A 182 Gr. F5 A 182 Gr. F5a	 A 217 Gr. C5	
1.14	9Cr–1Mo	2-1.14	A 182 Gr. F9	A 217 Gr. C12	
2.1	18Cr–8Ni	2-2.1	A 182 Gr. F304 A 182 Gr. F304H	A 351 Gr. CF3 A 351 Gr. CF8	A 240 Gr. 304 A 240 Gr. 304H
2.2	16Cr–12Ni–2Mo 18Cr–13Ni–3Mo 19Cr–10Ni–3Mo	2-2.2	A 182 Gr. F316 A 182 Gr. F316H	A 351 Gr. CF3M A 351 Gr. CF8M A 351 Gr. CG8M	A 240 Gr. 316 A 240 Gr. 316H A 240 Gr. 317
2.3	18Cr–8Ni 16Cr–12Ni–2Mo	2-2.3	A 182 Gr. F304L A 182 Gr. F316L		A 240 Gr. 304L A 240 Gr. 316L
2.4	18Cr–10Ni–Ti	2-2.4	A 182 Gr. F321 A 182 Gr. F321H		A 240 Gr. 321 A 240 Gr. 321H

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TABLE 1A LIST OF MATERIAL SPECIFICATIONS (CONT'D)

Material Group	Nominal Designation	Pressure–Temperature Rating Table	Applicable ASTM Specifications[1]		
			Forgings	Castings	Plates
2.5	18Cr–10Ni–Cb	2-2.5	A 182 Gr. F347 A 182 Gr. F347H A 182 Gr. F348 A 182 Gr. F348H	A 351 Gr. CF8C	A 240 Gr. 347 A 240 Gr. 347H A 240 Gr. 348 A 240 Gr. 348H
2.6	25Cr–12Ni 23Cr–12Ni	2-2.6		A 351 Gr. CH8 A 351 Gr. CH20	 A 240 Gr. 309S A 240 Gr. 309H
2.7	25Cr–20Ni	2-2.7	A 182 Gr. F310	A 351 Gr. CK20	A 240 Gr. 310S A 240 Gr. 310H
2.8	20Cr–18Ni–6Mo 22Cr–5Ni–3Mo–N 25Cr–7Ni–4Mo–N	2-2.8	A 182 Gr. F44 A 182 Gr. F51 A 182 Gr. F53	A 351 Gr. CK3MCuN	A 240 Gr. S31254 A 240 Gr. S31803 A 240 Gr. S32750

NOTE:

(1) ASME Boiler and Pressure Vessel Code, Section II materials, which also meet the requirements of the listed ASTM specifications, may also be used.

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TABLE 1B LIST OF BOLTING SPECIFICATIONS

Applicable ASTM Specifications[11]

Bolting Materials[1]					
High Strength (2)		Intermediate Strength (3)		Low Strength (4)	
Spec.-Gr.	Notes	Spec.-Gr.	Notes	Spec.-Gr.	Notes
A 193-B7	...	A 193-B5	...	A 193-B8 Cl. 1	(5)
A 193-B16	...	A 193-B6	...	A 193-B8C Cl. 1	(5)
		A 193-B6X	...	A 193-B8M Cl. 1	(5)
A 320-L7	(6)	A 193-B7M	...	A 193-B8T Cl. 1	(5)
A 320-L7A	(6)				
A 320-L7B	(6)	A 193-B8 Cl. 2	(7)	A 193-B8A	(5)
A 320-L7C	(6)	A 193-B8C Cl. 2	(7)	A 193-B8CA	...
A 320-L43	(6)	A 193-B8M Cl. 2	(7)	A 193-B8MA	...
		A 193-B8T Cl. 2	(7)	A 193-B8TA	(5)
A 354-BC	...				
A 354-BD	...	A 320-B8 Cl. 2	(7)	A 307-B	(8)
		A 320-B8C Cl. 2	(7)		
A 540-B21	...	A 320-B8F Cl. 2	(7)	A 320-B8 Cl. 1	(5)
A 540-B22	...	A 320-B8M Cl. 2	(7)	A 320-B8C Cl. 1	(5)
A 540-B23	...	A 320-B8T Cl. 2	(7)	A 320-B8M Cl. 1	(5)
A 540-B24	...			A 320-B8T Cl. 1	(5)
		A 449	(9)		
		A 453-651	(10)		
		A 453-660	(10)		

GENERAL NOTE:
Bolting material shall not be used beyond temperature limits specified in the governing code.

NOTES:
(1) Repair welding of bolting material is prohibited.
(2) These bolting materials may be used with all listed materials and gaskets.
(3) These bolting materials may be used with all listed materials and gaskets, provided it has been verified that a sealed joint can be maintained under rated working pressure and temperature.
(4) These bolting materials may be used with all listed materials but are limited to Class 150 and Class 300 joints. See para. 5.4.1 for recommended gasket practices.
(5) This austenitic stainless material has been carbide solution treated but not strain hardened. Use A 194 nuts of corresponding material.
(6) This ferritic material is intended for low temperature service. Use A 194 Gr. 4 or Gr. 7 nuts.
(7) This austenitic stainless material has been carbide solution treated and strain hardened. Use A 194 nuts of corresponding material.
(8) This carbon steel fastener shall not be used above 400°F or below −20°F. See also Note (4). Bolts with drilled or undersized heads shall not be used.
(9) Acceptable nuts for use with quenched and tempered bolts are A 194 Gr. 2 and Gr. 2H. Mechanical property requirements for studs shall be the same as those for bolts.
(10) This special alloy is intended for high temperature service with austenitic stainless steel.
(11) ASME Boiler and Pressure Vessel Code, Section II materials, which also meet the requirements of the listed ASTM specifications, may also be used.

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TABLES 2 PRESSURE–TEMPERATURE RATINGS FOR GROUPS 1.1 THROUGH 2.8 MATERIALS

TABLE 2-1.1 RATINGS FOR GROUP 1.1 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C–Si	A 105 (1)	A 216 Gr. WCB (1)	A 515 Gr. 70 (1)
C–Mn–Si	A 350 Gr. LF2 (1)		A 516 Gr. 70 (1)(2) A 537 Cl. 1 (3)

NOTES:
(1) Upon prolonged exposure to temperatures above 800°F, the carbide phase of steel may be converted to graphite. Permissible, but not recommended for prolonged use above 800°F.
(2) Not to be used over 850°F.
(3) Not to be used over 700°F.

	WORKING PRESSURES BY CLASSES, psig					
Class Temp., °F	75	150	300	400	600	900
−20 to 100	140	285	740	990	1480	2220
200	130	260	675	900	1350	2025
300	115	230	655	875	1315	1970
400	100	200	635	845	1270	1900
500	85	170	600	800	1200	1795
600	70	140	550	730	1095	1640
650	60	125	535	715	1075	1610
700	...	110	535	710	1065	1600
750	...	95	505	670	1010	1510
800	...	80	410	550	825	1235
850	65	270	355	535	805	805
900	50	170	230	345	515	515
950	35	105	140	205	310	310
1000	20	50	70	105	155	155

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TABLE 2-1.2 RATINGS FOR GROUP 1.2 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C–Mn–Si		A 216 Gr. WCC (1) A 352 Gr. LCC (2)	
2½Ni		A 352 Gr. LC2	A 203 Gr. B (1)
3½Ni	A 350 Gr. LF3	A 352 Gr. LC3	A 203 Gr. E (1)

NOTES:
(1) Upon prolonged exposure to temperatures above 800°F, the carbide phase of steel may be converted to graphite. Permissible, but not recommended for prolonged use above 800°F.
(2) Not to be used over 650°F.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
–20 to 100	145	290	750	1000	1500	2250
200	130	260	750	1000	1500	2250
300	115	230	730	970	1455	2185
400	100	200	705	940	1410	2115
500	80	170	665	885	1330	1995
600	70	140	605	805	1210	1815
650	60	125	590	785	1175	1765
700	...	110	570	755	1135	1705
750	...	95	505	670	1010	1510
800	...	80	410	550	825	1235
850	...	65	270	355	535	805
900	...	50	170	230	345	515
950	...	35	105	140	205	310
1000	...	20	50	70	105	155

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TABLE 2-1.3 RATINGS FOR GROUP 1.3 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C–Si		A 352 Gr. LCB (3)	A 515 Gr. 65 (1)
C–Mn–Si			A 516 Gr. 65 (1)(2)
2½Ni			A 203 Gr. A (1)
3½Ni			A 203 Gr. D (1)

NOTES:
(1) Upon prolonged exposure to temperatures above 800°F, the carbide phase of steel may be converted to graphite. Permissible, but not recommended for prolonged use above 800°F.
(2) Not to be used over 850°F.
(3) Not to be used over 650°F.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
−20 to 100	130	265	695	925	1390	2085
200	125	250	655	875	1315	1970
300	115	230	640	850	1275	1915
400	100	200	620	825	1235	1850
500	85	170	585	775	1165	1745
600	70	140	535	710	1065	1600
650	60	125	525	695	1045	1570
700	...	110	520	690	1035	1555
750	...	95	475	630	945	1420
800	...	80	390	520	780	1175
850	...	65	270	355	535	805
900	...	50	170	230	345	515
950	...	35	105	140	205	310
1000	...	20	50	70	105	155

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TABLE 2-1.4 RATINGS FOR GROUP 1.4 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C–Si			A 515 Gr. 60 (1)
C–Mn–Si	A 350 Gr. LF1, Cl. 1 (1)		A 516 Gr. 60 (1)(2)

NOTES:
(1) Upon prolonged exposure to temperatures above 800°F, the carbide phase of steel may be converted to graphite. Permissible, but not recommended for prolonged use above 800°F.
(2) Not to be used over 850°F.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
−20 to 100	115	235	620	825	1235	1850
200	105	215	560	750	1125	1685
300	105	210	550	730	1095	1640
400	100	200	530	705	1060	1585
500	85	170	500	665	995	1495
600	70	140	455	610	915	1370
650	60	125	450	600	895	1345
700	...	110	450	600	895	1345
750	...	95	445	590	885	1325
800	...	80	370	495	740	1110
850	...	65	270	355	535	805
900	...	50	170	230	345	515
950	...	35	105	140	205	310
1000	...	20	50	70	105	155

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TABLE 2-1.5 RATINGS FOR GROUP 1.5 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C-½Mo	A 182 Gr. F1 (1)	A 217 Gr. WC1 (1)(2) A 352 Gr. LC1 (3)	A 204 Gr. A (1) A 204 Gr. B (1)

NOTES:
(1) Upon prolonged exposure to temperatures above 875°F, the carbide phase of Carbon-molybdenum steel may be converted to graphite. Permissible, but not recommended for prolonged use above 875°F.
(2) Use normalized and tempered material only.
(3) Not to be used over 650°F.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
−20 to 100	130	265	695	925	1390	2085
200	130	260	680	905	1360	2035
300	115	230	655	870	1305	1955
400	100	200	640	855	1280	1920
500	85	170	620	830	1245	1865
600	70	140	605	805	1210	1815
650	60	125	590	785	1175	1765
700	...	110	570	755	1135	1705
750	...	95	530	710	1065	1595
800	...	80	510	675	1015	1525
850	...	65	485	650	975	1460
900	...	50	450	600	900	1350
950	...	35	280	375	560	845
1000	...	20	165	220	330	495

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TABLE 2-1.7 RATINGS FOR GROUP 1.7 MATERIALS

Nominal Designation	Forgings	Castings	Plates
C–½Mo			A 204 Gr. C (2)
½Cr–½Mo	A 182 Gr. F2 (3)		
Ni–½Cr–½Mo		A 217 Gr. WC4 (1)(3)	
¾Ni–¾Cr–1Mo		A 217 Gr. WC5 (1)	

NOTES:
(1) Use normalized and tempered material only.
(2) Not to be used over 850°F.
(3) Not to be used over 1000°F.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
−20 to 100	145	290	750	1000	1500	2250
200	130	260	750	1000	1500	2250
300	115	230	720	965	1445	2165
400	100	200	695	925	1385	2080
500	85	170	665	885	1330	1995
600	70	140	605	805	1210	1815
650	60	125	590	785	1175	1765
700	...	110	570	755	1135	1705
750	...	95	530	710	1065	1595
800	...	80	510	675	1015	1525
850	...	65	485	650	975	1460
900	...	50	450	600	900	1350
950	...	35	315	420	630	945
1000	...	20	200	270	405	605
1050	...	...	160	210	315	475

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TABLE 2-1.9 RATINGS FOR GROUP 1.9 MATERIALS

Nominal Designation	Forgings	Castings	Plates
1Cr–½Mo	A 182 Gr. F12 Cl. 2 (1)(2)		
1¼Cr–½Mo		A 217 Gr. WC6 (1)(3)	
1¼Cr–½Mo	A 182 Gr. F11 Cl. 2 (1)(2)		A 387 Gr. 11 Cl. 2 (2)

NOTES:
(1) Use normalized and tempered material only.
(2) Permissible, but not recommended for prolonged use above 1100°F.
(3) Not to be used over 1100°F.

	WORKING PRESSURES BY CLASSES, psig					
Class Temp., °F	75	150	300	400	600	900
−20 to 100	145	290	750	1000	1500	2250
200	130	260	750	1000	1500	2250
300	115	230	720	965	1445	2165
400	100	200	695	925	1385	2080
500	85	170	665	885	1330	1995
600	70	140	605	805	1210	1815
650	60	125	590	785	1175	1765
700	...	110	570	755	1135	1705
750	...	95	530	710	1065	1595
800	...	80	510	675	1015	1525
850	...	65	485	650	975	1460
900	...	50	450	600	900	1350
950	...	35	320	425	640	955
1000	...	20	215	290	430	650
1050	...	...	145	190	290	430
1100	...	...	95	130	190	290
1150	...	...	60	80	125	185
1200	...	...	40	50	75	115

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TABLE 2-1.10 RATINGS FOR GROUP 1.10 MATERIALS

Nominal Designation	Forgings	Castings	Plates
2¼Cr–1Mo	A 182 Gr. F22 Cl. 3 (2)	A 217 Gr. WC9 (1)(3)	A 387 Gr. 22 Cl. 2 (2)

NOTES:
(1) Use normalized and tempered material only.
(2) Permissible, but not recommended for prolonged use above 1100°F.
(3) Not to be used over 1100°F.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
−20 to 100	145	290	750	1000	1500	2250
200	130	260	750	1000	1500	2250
300	115	230	730	970	1455	2185
400	100	200	705	940	1410	2115
500	85	170	665	885	1330	1995
600	70	140	605	805	1210	1815
650	60	125	590	785	1175	1765
700	...	110	570	755	1135	1705
750	...	95	530	710	1065	1595
800	...	80	510	675	1015	1525
850	...	65	485	650	975	1460
900	...	50	450	600	900	1350
950	...	35	375	505	755	1130
1000	...	20	260	345	520	780
1050	...	...	175	235	350	525
1100	...	...	110	145	220	330
1150	...	...	70	90	135	205
1200	...	...	40	55	80	125

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TABLE 2-1.13 RATINGS FOR GROUP 1.13 MATERIALS

Nominal Designation	Forgings	Castings	Plates
5Cr–½Mo	A 182 Gr. F5 A 182 Gr. F5a	A 217 Gr. C5 (1)	

NOTE:
(1) Use normalized and tempered material only.

	WORKING PRESSURES BY CLASSES, psig					
Class Temp., °F	75	150	300	400	600	900
−20 to 100	145	290	750	1000	1500	2250
200	130	260	745	995	1490	2235
300	115	230	715	955	1430	2150
400	100	200	705	940	1410	2115
500	85	170	665	885	1330	1995
600	70	140	605	805	1210	1815
650	60	125	590	785	1175	1765
700	...	110	570	755	1135	1705
750	...	95	530	705	1055	1585
800	...	80	510	675	1015	1525
850	...	65	485	645	965	1450
900	...	50	370	495	740	1110
950	...	35	275	365	550	825
1000	...	20	200	265	400	595
1050	...	...	145	190	290	430
1100	...	...	100	135	200	300
1150	...	...	60	80	125	185
1200	...	...	35	45	70	105

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TABLE 2-1.14 RATINGS FOR GROUP 1.14 MATERIALS

Nominal Designation	Forgings	Castings	Plates
9Cr–1Mo	A 182 Gr. F9	A 217 Gr. C12 (1)	

NOTE:
(1) Use normalized and tempered material only.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
−20 to 100	145	290	750	1000	1500	2250
200	130	260	750	1000	1500	2250
300	115	230	730	970	1455	2185
400	100	200	705	940	1410	2115
500	85	170	665	885	1330	1995
600	70	140	605	805	1210	1815
650	60	125	590	785	1175	1765
700	...	110	570	755	1135	1705
750	...	95	530	710	1065	1595
800	...	80	510	675	1015	1525
850	...	65	485	650	975	1460
900	...	50	450	600	900	1350
950	...	35	375	505	755	1130
1000	...	20	255	340	505	760
1050	...	...	170	230	345	515
1100	...	...	115	150	225	340
1150	...	...	75	100	150	225
1200	...	...	50	70	105	155

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TABLE 2-2.1 RATINGS FOR GROUP 2.1 MATERIALS

Nominal Designation	Forgings	Castings	Plates
18Cr–8Ni	A 182 Gr. F304 (1) A 182 Gr. F304H	A 351 Gr. CF3 (2) A 351 Gr. CF8 (1)	A 240 Gr. 304 (1) A 240 Gr. 304H

NOTES:
(1) At temperatures over 1000°F, use only when the carbon content is 0.04% or higher.
(2) Not to be used over 800°F.

	WORKING PRESSURES BY CLASSES, psig					
Class Temp., °F	75	150	300	400	600	900
−20 to 100	135	275	720	960	1440	2160
200	115	230	600	800	1200	1800
300	100	205	540	720	1080	1620
400	95	190	495	660	995	1490
500	85	170	465	620	930	1395
600	70	140	435	580	875	1310
650	60	125	430	575	860	1290
700	...	110	425	565	850	1275
750	...	95	415	555	830	1245
800	...	80	405	540	805	1210
850	...	65	395	530	790	1190
900	...	50	390	520	780	1165
950	...	35	380	510	765	1145
1000	...	20	320	430	640	965
1050	...	...	310	410	615	925
1100	...	...	255	345	515	770
1150	...	...	200	265	400	595
1200	...	...	155	205	310	465
1250	...	...	115	150	225	340
1300	...	...	85	115	170	255
1350	...	...	60	80	125	185
1400	...	...	50	65	95	145
1450	...	...	35	45	70	105
1500	...	...	25	35	55	80

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TABLE 2-2.2 RATINGS FOR GROUP 2.2 MATERIALS

Nominal Designation	Forgings	Castings	Plates
16Cr–12Ni–2Mo	A 182 Gr. F316 (1) A 182 Gr. F316H	A 351 Gr.CF3M (2) A 351 Gr. CF8M (1)	A 240 Gr. 316 (1) A 240 Gr. 316H
18Cr–13Ni–3Mo			A 240 Gr. 317 (1)
19Cr–10Ni–3Mo		A 351 Gr. CG8M (3)	

NOTES:
(1) At temperatures over 1000°F, use only when the carbon content is 0.04% or higher.
(2) Not to be used over 850°F.
(3) Not to be used over 1000°F.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
−20 to 100	135	275	720	960	1440	2160
200	115	235	620	825	1240	1860
300	105	215	560	745	1120	1680
400	95	195	515	685	1025	1540
500	85	170	480	635	955	1435
600	70	140	450	600	900	1355
650	60	125	445	590	890	1330
700	...	110	430	580	870	1305
750	...	95	425	570	855	1280
800	...	80	420	565	845	1265
850	...	65	420	555	835	1255
900	...	50	415	555	830	1245
950	...	35	385	515	775	1160
1000	...	20	350	465	700	1050
1050	...	...	345	460	685	1030
1100	...	...	305	405	610	915
1150	...	...	235	315	475	710
1200	...	...	185	245	370	555
1250	...	...	145	195	295	440
1300	...	...	115	155	235	350
1350	...	...	95	130	190	290
1400	...	...	75	100	150	225
1450	...	...	60	80	115	175
1500	...	...	40	55	85	125

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TABLE 2-2.3 RATINGS FOR GROUP 2.3 MATERIALS

Nominal Designation	Forgings	Castings	Plates
18Cr–8Ni	A 182 Gr. F304L (1)		A 240 Gr. 304L (1)
16Cr–12Ni–2Mo	A 182 Gr. F316L		A 240 Gr. 316L

NOTE:
(1) Not to be used over 800°F.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
−20 to 100	115	230	600	800	1200	1800
200	95	195	505	675	1015	1520
300	85	175	455	605	910	1360
400	80	160	415	550	825	1240
500	70	145	380	510	765	1145
600	70	140	360	480	720	1080
650	60	125	350	470	700	1050
700	...	110	345	460	685	1030
750	...	95	335	450	670	1010
800	...	80	330	440	660	985
850	...	65	320	430	645	965

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TABLE 2-2.4 RATINGS FOR GROUP 2.4 MATERIALS

Nominal Designation	Forgings	Castings	Plates
18Cr–10Ni–Ti	A 182 Gr. F321 (2) A 182 Gr. F321H (1)		A 240 Gr. 321 (2) A 240 Gr. 321H (1)

NOTES:
(1) At temperatures over 1000°F, use only if the material is heat treated by heating to a minimum temperature of 2000°F.
(2) Not to be used over 1000°F.

	WORKING PRESSURES BY CLASSES, psig					
Class Temp., °F	75	150	300	400	600	900
−20 to 100	135	275	720	960	1440	2160
200	120	245	645	860	1290	1935
300	115	230	595	795	1190	1785
400	100	200	550	735	1105	1655
500	85	170	515	685	1030	1545
600	70	140	485	650	975	1460
650	60	125	480	635	955	1435
700	...	110	465	620	930	1395
750	...	95	460	610	915	1375
800	...	80	450	600	900	1355
850	...	65	445	595	895	1340
900	...	50	440	590	885	1325
950	...	35	385	515	775	1160
1000	...	20	355	475	715	1070
1050	...	...	315	415	625	940
1100	...	...	270	360	545	815
1150	...	...	235	315	475	710
1200	...	...	185	245	370	555
1250	...	...	140	185	280	420
1300	...	...	110	145	220	330
1350		...	85	115	170	255
1400	...	...	65	85	130	195
1450	...	...	50	70	105	155
1500	...	...	40	50	75	115

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TABLE 2-2.5 RATINGS FOR GROUP 2.5 MATERIALS

Nominal Designation	Forgings	Castings	Plates
18Cr–10Ni–Cb	A 182 Gr. F347 (2) A 182 Gr. F347H (1) A 182 Gr. F348 (2) A 182 Gr. F348H (1)	A 351 Gr. CF8C (3)	A 240 Gr. 347 (2) A 240 Gr. 347H (1) A 240 Gr. 348 (2) A 240 Gr. 348H (1)

NOTES:
(1) For temperatures over 1000°F, use only if the material is heat treated by heating to a minimum temperature of 2000°F.
(2) Not to be used over 1000°F.
(3) At temperatures over 1000°F, use the material only when the carbon content is 0.04% or higher.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
−20 to 100	135	275	720	960	1440	2160
200	125	255	660	880	1320	1980
300	115	230	615	820	1230	1845
400	100	200	575	765	1145	1720
500	85	170	540	720	1080	1620
600	70	140	515	685	1025	1540
650	60	125	505	670	1010	1510
700	...	110	495	660	990	1485
750	...	95	490	655	985	1475
800	...	80	485	650	975	1460
850	...	65	485	645	970	1455
900	...	50	450	600	900	1350
950	...	35	385	515	775	1160
1000	...	20	365	485	725	1090
1050	...	...	360	480	720	1080
1100	...	...	325	430	645	965
1150	...	...	275	365	550	825
1200	...	...	170	230	345	515
1250	...	...	125	165	245	370
1300	...	...	95	125	185	280
1350	...	...	70	90	135	205
1400	...	...	55	75	110	165
1450	...	...	40	55	80	125
1500	...	...	35	45	70	105

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TABLE 2-2.6 RATINGS FOR GROUP 2.6 MATERIALS

Nominal Designation	Forgings	Castings	Plates
25Cr–12Ni		A 351 Gr. CH8 (1) A 351 Gr. CH20 (1)(4)	
23Cr–12Ni			A 240 Gr. 309S (1)(2)(3) A 240 Gr. 309H

NOTES:
(1) At temperatures over 1000°F, use only when the carbon content is 0.04% or higher.
(2) For temperatures above 1000°F, use only if the material is heat treated by heating it to a temperature of at least 1900°F and quenching in water or rapidly cooling by other means.
(3) This material should be used for service temperatures 1050°F and above only when assurance is provided that grain size is not finer than ASTM 6.
(4) For service temperatures above 850°F, it is recommended that killed steel containing not less than 0.10% residual silicon be used.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
−20 to 100	130	260	670	895	1345	2015
200	115	230	605	805	1210	1815
300	110	220	570	760	1140	1705
400	100	200	535	710	1065	1600
500	85	170	505	670	1010	1510
600	70	140	480	635	955	1435
650	60	125	465	620	930	1395
700	...	110	455	610	910	1370
750	...	95	445	595	895	1340
800	...	80	435	580	870	1305
850	...	65	425	565	850	1275
900	...	50	415	555	830	1245
950	...	35	385	515	775	1160
1000	...	20	335	450	670	1010
1050	...	...	290	390	585	875
1100	...	...	225	300	445	670
1150	...	...	170	230	345	515
1200	...	...	130	175	260	390
1250	...	...	100	135	200	300
1300	...	...	80	105	160	235
1350		...	60	80	115	175
1400	...	...	45	60	90	135
1450	...	...	30	40	60	95
1500	...	...	25	30	50	70

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TABLE 2-2.7 RATINGS FOR GROUP 2.7 MATERIALS

Nominal Designation	Forgings	Castings	Plates
25Cr–20Ni	A 182 Gr. F310 (1)(3)	A 351 Gr. CK20 (1)	A 240 Gr. 310S (1)(2)(3) A 240 Gr. 310H

NOTES:
(1) At temperatures over 1000°F, use only when the carbon content is 0.04% or higher.
(2) For temperatures above 1000°F, use only if the material is heat treated by heating it to a temperature of at least 1900°F and quenching in water or rapidly cooling by other means.
(3) Service temperatures of 1050°F and above should be used only when assurance is provided that grain size is not finer than ASTM 6.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
−20 to 100	130	260	670	895	1345	2015
200	115	235	605	810	1215	1820
300	110	220	570	760	1140	1705
400	100	200	535	715	1070	1605
500	85	170	505	675	1015	1520
600	70	140	480	640	960	1440
650	60	125	470	625	935	1405
700	...	110	455	610	910	1370
750	...	95	450	600	900	1345
800	...	80	435	580	875	1310
850	...	65	425	575	855	1280
900	...	50	420	555	835	1255
950	...	35	385	515	775	1160
1000	...	20	345	460	685	1030
1050	...	...	335	450	670	1010
1100	...	...	260	345	520	780
1150	...	...	190	250	375	565
1200	...	...	135	185	275	410
1250	...	...	105	135	205	310
1300	...	...	75	100	150	225
1350	...	...	60	80	115	175
1400	...	...	45	60	90	135
1450	...	...	35	45	65	100
1500	...	...	25	35	50	75

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TABLE 2-2.8 RATINGS FOR GROUP 2.8 MATERIALS

Nominal Designation	Forgings	Castings	Plates
20Cr–18Ni–6Mo	A 182 Gr. F44	A 351 Gr. CK3MCuN	A 240 Gr. S31254
22Cr–5Ni–3Mo–N	A 182 Gr. F51 (1)		A 240 Gr. S31803 (1)
25Cr–7Ni–4Mo–N	A 182 Gr. F53 (1)		A 240 Gr. S32750 (1)

NOTE:
(1) This steel may become brittle after service at moderately elevated temperatures. Not to be used over 600°F.

WORKING PRESSURES BY CLASSES, psig						
Class Temp., °F	75	150	300	400	600	900
−20 to 100	145	290	750	1000	1500	2250
200	130	260	720	960	1440	2160
300	115	230	665	885	1330	1995
400	100	200	615	820	1230	1845
500	85	170	575	770	1150	1730
600	70	140	555	740	1115	1670
650	60	125	550	735	1100	1650
700	...	110	540	725	1085	1625
750	...	95	530	710	1065	1595

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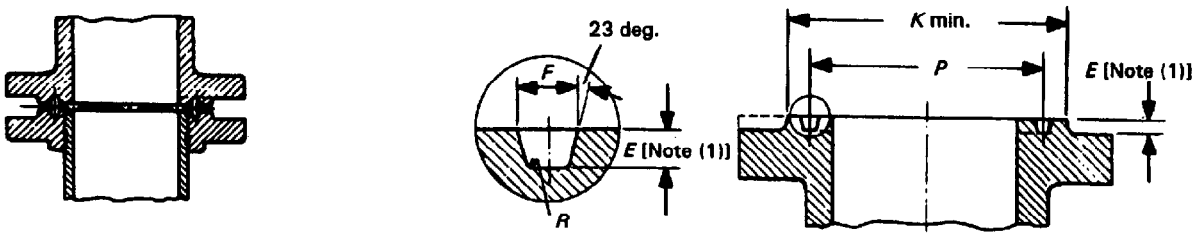

TABLE 3 DIMENSIONS OF RING-JOINT FACINGS[2,3]

Nominal Pipe Size				Groove Number	Groove Dimensions				Diameter of Raised Portion
					Pitch Diam.	Depth	Width	Radius at Bottom	
300	400	600	900		*P*	*E*	*F*	*R*	*K*
26	26	26	...	R93	29.500	0.500	0.781	0.06	31.88
28	28	28	...	R94	31.500	0.500	0.781	0.06	33.88
30	30	30	...	R95	33.750	0.500	0.781	0.06	36.12
32	32	32	...	R96	36.000	0.562	0.906	0.06	38.75
34	34	34	...	R97	38.000	0.562	0.906	0.06	40.75
36	36	36	...	R98	40.250	0.562	0.906	0.06	43.00
...	...	...	26	R100	29.500	0.688	1.188	0.09	32.75
...	...	...	28	R101	31.500	0.688	1.312	0.09	35.00
...	...	...	30	R102	33.750	0.688	1.312	0.09	37.25
...	...	...	32	R103	36.000	0.688	1.312	0.09	39.50
...	...	...	34	R104	38.000	0.812	1.438	0.09	42.00
...	...	...	36	R105	40.250	0.812	1.438	0.09	44.25

Tolerances	
E (depth)	+0.016 −0
F (width)	±0.008
P (pitch diameter)	±0.005
R (radius at bottom)	Max.
23 deg. (angle)	±½ deg.

GENERAL NOTES:

(a) Dimensions are in inches.

(b) Ring-joint gaskets are not contemplated for NPS 38 and larger flanges.

NOTES:

(1) Height of raised portion is equal to the depth of groove dimension *E*, but is not subjected to the tolerances for *E*. Full face contour may be used.

(2) For facing requirements for flanges, see para. 6.1.1.

(3) See para. 4.1.7 for marking requirements.

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TABLE 4 FLANGE BOLTING DIMENSIONAL RECOMMENDATIONS

Stud-bolts	Carbon Steel	Other Materials
	ANSI B18.2.1	
Bolts smaller than 3/4 in.	ANSI B18.2.1, square or heavy hex head	ANSI B18.2.1, heavy hex head
Bolts equal to or larger than 3/4 in.	ANSI B18.2.1, square or hex head	ANSI B18.2.1, heavy hex head
Nuts smaller than 3/4 in.	ASME/ANSI B18.2.2, heavy hex	
Nuts equal to or larger than 3/4 in.	ASME/ANSI B18.2.2, hex or heavy hex	ASME/ANSI B18.2.2, heavy hex
Male threads	ANSI B1.1, Cl. 2A, coarse series	ANSI B1.1., Cl. 2A; coarse series up through 1 in. bolts; 8 thread series for larger bolts
Female threads	ANSI B1.1, Cl. 2B, coarse series	ANSI B1.1, Cl. 2B; coarse series up through 1 in. bolts, 8 thread series for larger bolts

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WELDING ENDS
(Welding Neck Flanges, No Backing Rings)

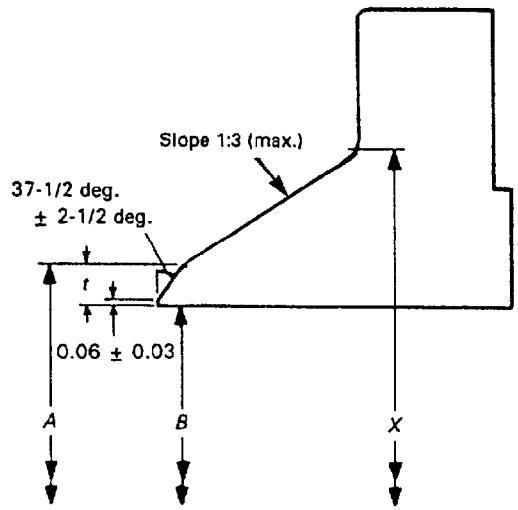

FIG. 1 BEVEL FOR WALL THICKNESSES *t* FROM 0.19 in. TO 0.88 in., INCLUSIVE[1-3]

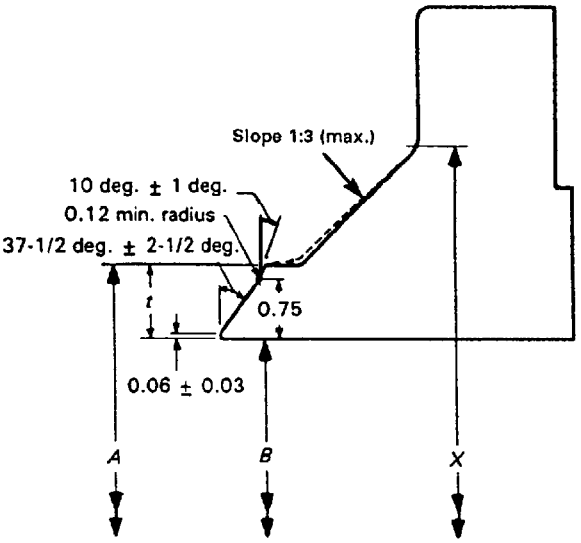

FIG. 2 BEVEL FOR WALL THICKNESSES *t* GREATER THAN 0.88 in.[1-3]

A = nominal outside diameter of pipe, in.
B = nominal inside diameter of pipe, in.
t = nominal wall thickness of pipe, in.

NOTES:

(1) See paras. 6.4 and 7.4 for details and tolerances.

(2) See Figs. 3 and 4 for additional details of welding ends.

(3) When the thickness of the hub at the bevel is greater than that of the pipe to which the flange is joined, and the additional thickness is provided on the outside diameter, a taper weld having a slope not exceeding 1 to 3 may be employed or, alternatively, the greater outside diameter may be tapered, at the same maximum slope or less, from a point on the welding bevel equal to the O.D. of the mating pipe. Similarly, when the greater thickness is provided on the inside of the flange, it shall be taper bored from the welding end at a slope not exceeding 1 to 3.

When flanges covered by this Standard are intended for services with light wall and higher strength pipe, the thickness of the hub at the bevel may be greater than that of the pipe to which the flange is joined. Under these conditions a single taper hub may be provided and the outside diameter of the hub at the base (dimension *X*) may also be modified.

The additional thickness may be provided on either inside or outside or partially on each side, but the total additional thickness shall not exceed one-half times the nominal wall thickness of intended mating pipe. See Figs. 5, 6, and 7.

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WELDING ENDS
(Welding Neck Flanges With Backing Rings)

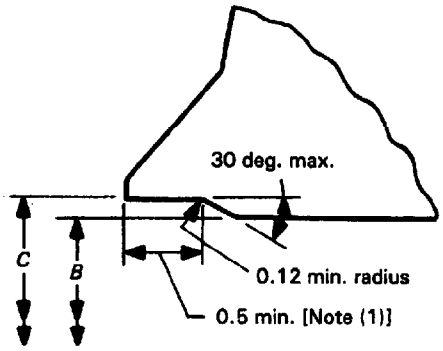

FIG. 3 INSIDE CONTOUR FOR USE WITH RECTANGULAR BACKING RING[1-3]

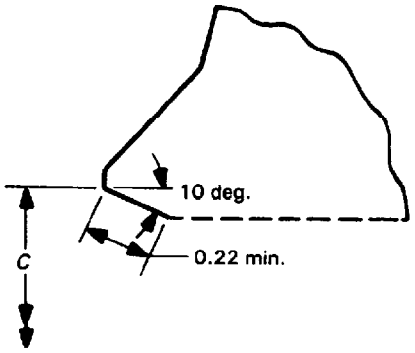

FIG. 4 INSIDE CONTOUR FOR USE WITH TAPER BACKING RING[1-3]

A = nominal outside diameter of welding end, in.
B = nominal inside diameter of pipe
= $A - 2t$, in.
C = $A - 0.031 - 1.75t - 0.010$ in.
t = nominal wall thickness of pipe, in.
0.031 = minus tolerance on O.D. of pipe, in.
$1.75t$ = 87½% of nominal wall multiplied by two to convert into terms of diameter
0.010 = plus tolerance on diameter C, in. (see para. 7.4.3.)

NOTES:
(1) 0.5 in. depth based on use of 0.75 in. wide backing ring.
(2) See paras. 6.4 and 7.4 for details and tolerances.
(3) See Figs. 1 and 2 for welding end details of welding neck flanges.

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WELDING ENDS
(Welding Neck Flanges)

ADDITIONAL THICKNESS FOR WELDING TO HIGHER STRENGTH PIPE

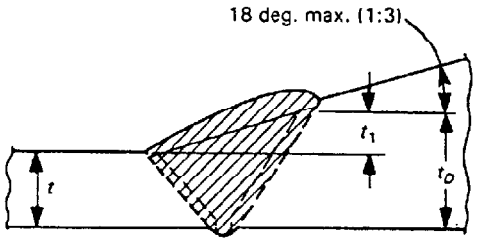

FIG. 5 BEVEL FOR OUTSIDE THICKNESS[1-3]

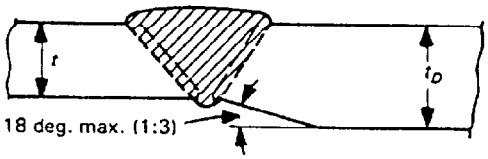

FIG. 6 BEVEL FOR INSIDE THICKNESS[1-3]

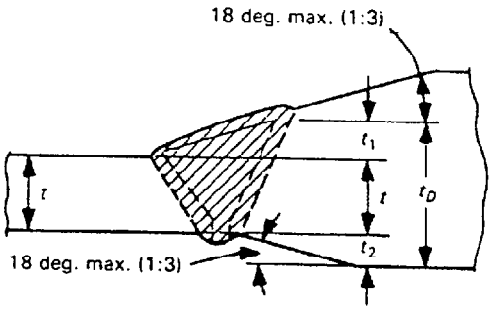

FIG. 7 BEVEL FOR COMBINED THICKNESS[1-3]

NOTES:

(1) Neither t_1, t_2, nor their sum ($t_1 + t_2$) shall exceed $0.5t$.

(2) When the minimum specified yield strengths of the sections to be joined are unequal, the value of t_D shall at least equal t times the ratio of minimum specified yield strength of the pipe to yield strength of the flange.

(3) Welding shall be in accordance with the applicable code.

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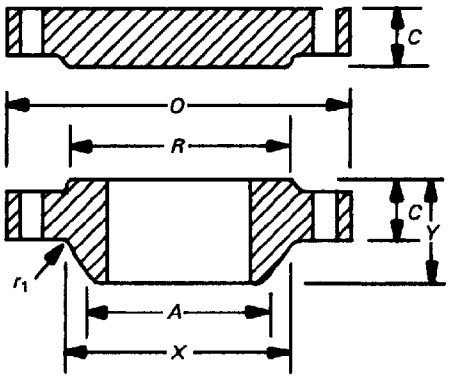

TABLE 5 DIMENSIONS OF CLASS 150 SERIES A FLANGES[1–6]

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	34.25	2.69	2.69	4.75	26.62	26.00	29.50	31.75	24	1.38	1¼	0.38
28	36.50	2.81	2.81	4.94	28.62	28.00	31.50	34.00	28	1.38	1¼	0.44
30	38.75	2.94	2.94	5.38	30.75	30.00	33.75	36.00	28	1.38	1¼	0.44
32	41.75	3.19	3.19	5.69	32.75	32.00	36.00	38.50	28	1.62	1½	0.44
34	43.75	3.25	3.25	5.88	34.75	34.00	38.00	40.50	32	1.62	1½	0.50
36	46.00	3.56	3.56	6.19	36.75	36.00	40.25	42.75	32	1.62	1½	0.50
38	48.75	3.44	3.44	6.19	39.00	38.00	42.25	45.25	32	1.62	1½	0.50
40	50.75	3.56	3.56	6.44	41.00	40.00	44.25	47.25	36	1.62	1½	0.50
42	53.00	3.81	3.81	6.75	43.00	42.00	47.00	49.50	36	1.62	1½	0.50
44	55.25	4.00	4.00	7.00	45.00	44.00	49.00	51.75	40	1.62	1½	0.50
46	57.25	4.06	4.06	7.31	47.12	46.00	51.00	53.75	40	1.62	1½	0.50
48	59.50	4.25	4.25	7.56	49.12	48.00	53.50	56.00	44	1.62	1½	0.50
50	61.75	4.38	4.38	8.00	51.25	50.00	55.50	58.25	44	1.88	1¾	0.50
52	64.00	4.56	4.56	8.25	53.25	52.00	57.50	60.50	44	1.88	1¾	0.50
54	66.25	4.75	4.75	8.50	55.25	54.00	59.50	62.75	44	1.88	1¾	0.50
56	68.75	4.88	4.88	9.00	57.38	56.00	62.00	65.00	48	1.88	1¾	0.50
58	71.00	5.06	5.06	9.25	59.38	58.00	64.00	67.25	48	1.88	1¾	0.50
60	73.00	5.19	5.19	9.44	61.38	60.00	66.00	69.25	52	1.88	1¾	0.50

(Notes follow Table 15)

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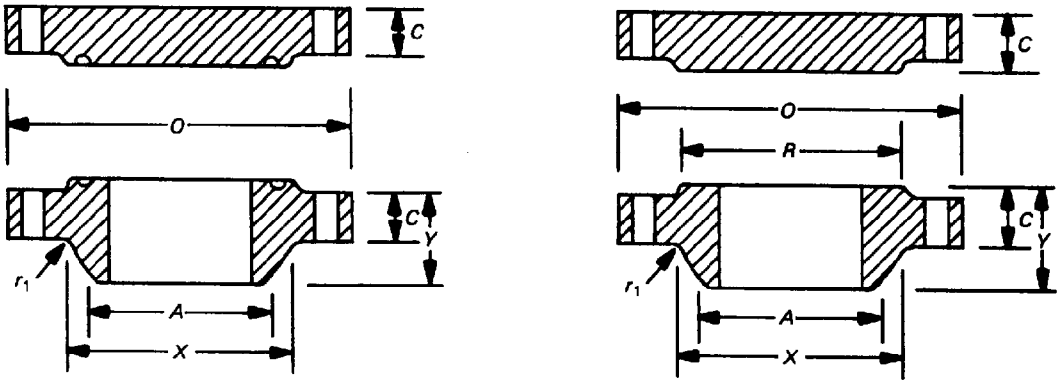

TABLE 6 DIMENSIONS OF CLASS 300 SERIES A FLANGES[1-6]

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	38.25	3.12	3.31	7.25	28.38	26.00	29.50	34.50	28	1.75	1⅝	0.38
28	40.75	3.38	3.56	7.75	30.50	28.00	31.50	37.00	28	1.75	1⅝	0.44
30	43.00	3.62	3.75	8.25	32.56	30.00	33.75	39.25	28	1.88	1¾	0.44
32	45.25	3.88	3.94	8.75	34.69	32.00	36.00	41.50	28	2.00	1⅞	0.44
34	47.50	4.00	4.12	9.12	36.88	34.00	38.00	43.50	28	2.00	1⅞	0.50
36	50.00	4.12	4.38	9.50	39.00	36.00	40.25	46.00	32	2.12	2	0.50
38	46.00	4.25	4.25	7.12	39.12	38.00	40.50	43.00	32	1.62	1½	0.50
40	48.75	4.50	4.50	7.62	41.25	40.00	42.75	45.50	32	1.75	1⅝	0.50
42	50.75	4.69	4.69	7.88	43.25	42.00	44.75	47.50	32	1.75	1⅝	0.50
44	53.25	4.88	4.88	8.12	45.25	44.00	47.00	49.75	32	1.88	1¾	0.50
46	55.75	5.06	5.06	8.50	47.38	46.00	49.00	52.00	28	2.00	1⅞	0.50
48	57.75	5.25	5.25	8.81	49.38	48.00	51.25	54.00	32	2.00	1⅞	0.50
50	60.25	5.50	5.50	9.12	51.38	50.00	53.50	56.25	32	2.12	2	0.50
52	62.25	5.69	5.69	9.38	53.38	52.00	55.50	58.25	32	2.12	2	0.50
54	65.25	6.00	6.00	9.94	55.50	54.00	57.75	61.00	28	2.38	2¼	0.50
56	67.25	6.06	6.06	10.25	57.62	56.00	59.75	63.00	28	2.38	2¼	0.50
58	69.25	6.25	6.25	10.50	59.62	58.00	62.00	65.00	32	2.38	2¼	0.50
60	71.25	6.44	6.44	10.75	61.62	60.00	64.00	67.00	32	2.38	2¼	0.50

(Notes follow Table 15)

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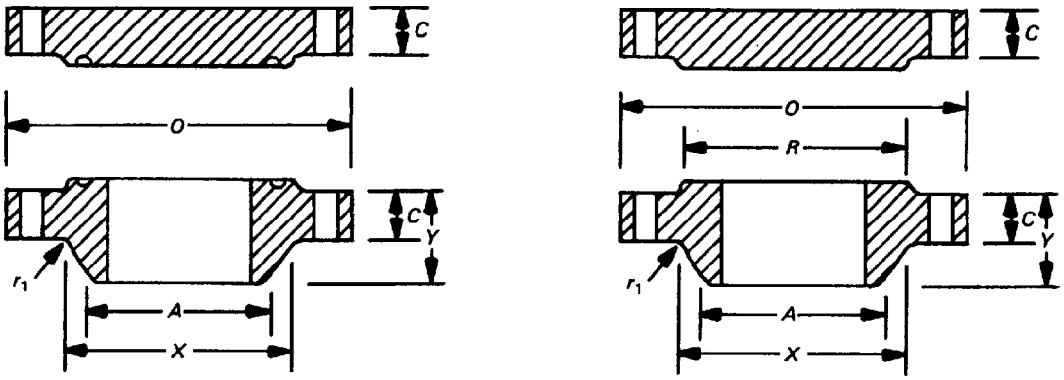

TABLE 7 DIMENSIONS OF CLASS 400 SERIES A FLANGES[1–6]

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	38.25	3.50	3.88	7.62	28.62	26.00	29.50	34.50	28	1.88	1¾	0.44
28	40.75	3.75	4.12	8.12	30.81	28.00	31.50	37.00	28	2.00	1⅞	0.50
30	43.00	4.00	4.38	8.62	32.94	30.00	33.75	39.25	28	2.12	2	0.50
32	45.25	4.25	4.56	9.12	35.00	32.00	36.00	41.50	28	2.12	2	0.50
34	47.50	4.38	4.81	9.50	37.19	34.00	38.00	43.50	28	2.12	2	0.56
36	50.00	4.50	5.06	9.88	39.38	36.00	40.25	46.00	32	2.12	2	0.56
38	47.50	4.88	4.88	8.12	39.50	38.00	40.75	44.00	32	1.88	1¾	0.56
40	50.00	5.12	5.12	8.50	41.50	40.00	43.00	46.25	32	2.00	1⅞	0.56
42	52.00	5.25	5.25	8.81	43.62	42.00	45.00	48.25	32	2.00	1⅞	0.56
44	54.50	5.50	5.50	9.18	45.62	44.00	47.25	50.50	32	2.12	2	0.56
46	56.75	5.75	5.75	9.62	47.75	46.00	49.50	52.75	36	2.12	2	0.56
48	59.50	6.00	6.00	10.12	49.88	48.00	51.50	55.25	28	2.38	2¼	0.56
50	61.75	6.19	6.25	10.56	52.00	50.00	53.62	57.50	32	2.38	2¼	0.56
52	63.75	6.38	6.44	10.88	54.00	52.00	55.62	59.50	32	2.38	2¼	0.56
54	67.00	6.69	6.75	11.38	56.12	54.00	57.88	62.25	28	2.62	2½	0.56
56	69.00	6.88	6.94	11.75	58.25	56.00	60.12	64.25	32	2.62	2½	0.56
58	71.00	7.00	7.12	12.06	60.25	58.00	62.12	66.25	32	2.62	2½	0.56
60	74.25	7.31	7.44	12.56	62.38	60.00	64.38	69.00	32	2.88	2¾	0.56

(Notes follow Table 15)

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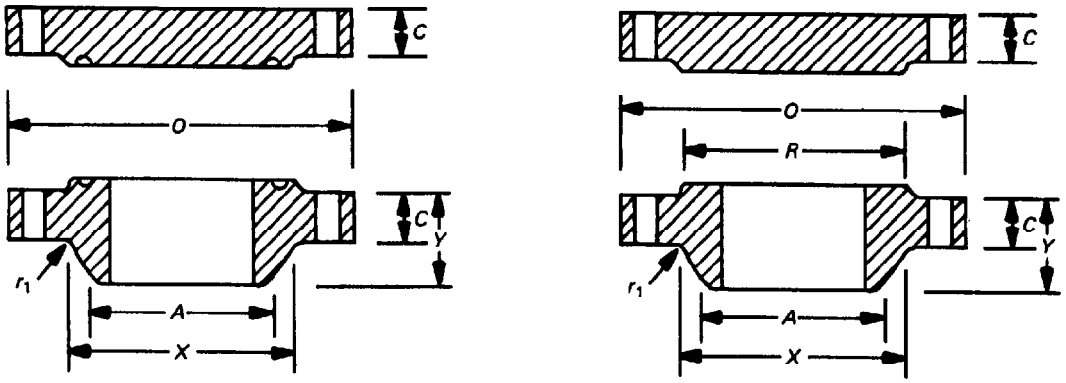

TABLE 8 DIMENSIONS OF CLASS 600 SERIES A FLANGES[1-6]

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	40.00	4.25	4.94	8.75	29.44	26.00	29.50	36.00	28	2.00	1⅞	0.50
28	42.25	4.38	5.19	9.25	31.62	28.00	31.50	38.00	28	2.12	2	0.50
30	44.50	4.50	5.50	9.75	33.94	30.00	33.75	40.25	28	2.12	2	0.50
32	47.00	4.62	5.81	10.25	36.12	32.00	36.00	42.50	28	2.38	2¼	0.50
34	49.00	4.75	6.06	10.62	38.31	34.00	38.00	44.50	28	2.38	2¼	0.56
36	51.75	4.88	6.38	11.12	40.62	36.00	40.25	47.00	28	2.62	2½	0.56
38	50.00	6.00	6.12	10.00	40.25	38.00	41.50	45.75	28	2.38	2¼	0.56
40	52.00	6.25	6.38	10.38	42.25	40.00	43.75	47.75	32	2.38	2¼	0.56
42	55.25	6.62	6.75	11.00	44.38	42.00	46.00	50.50	28	2.62	2½	0.56
44	57.25	6.81	7.00	11.38	46.50	44.00	48.25	52.50	32	2.62	2½	0.56
46	59.50	7.06	7.31	11.81	48.62	46.00	50.25	54.75	32	2.62	2½	0.56
48	62.75	7.44	7.69	12.44	50.75	48.00	52.50	57.50	32	2.88	2¾	0.56
50	65.75	7.75	8.00	12.94	52.88	50.00	54.50	60.00	28	3.12	3	0.56
52	67.75	8.00	8.25	13.25	54.88	52.00	56.50	62.00	32	3.12	3	0.56
54	70.00	8.25	8.56	13.75	57.00	54.00	58.75	64.25	32	3.12	3	0.56
56	73.00	8.56	8.88	14.25	59.12	56.00	60.75	66.75	32	3.38	3¼	0.62
58	75.00	8.75	9.12	14.56	61.12	58.00	63.00	68.75	32	3.38	3¼	0.62
60	78.50	9.19	9.56	15.31	63.38	60.00	65.25	71.75	28	3.62	3½	0.69

(Notes follow Table 15)

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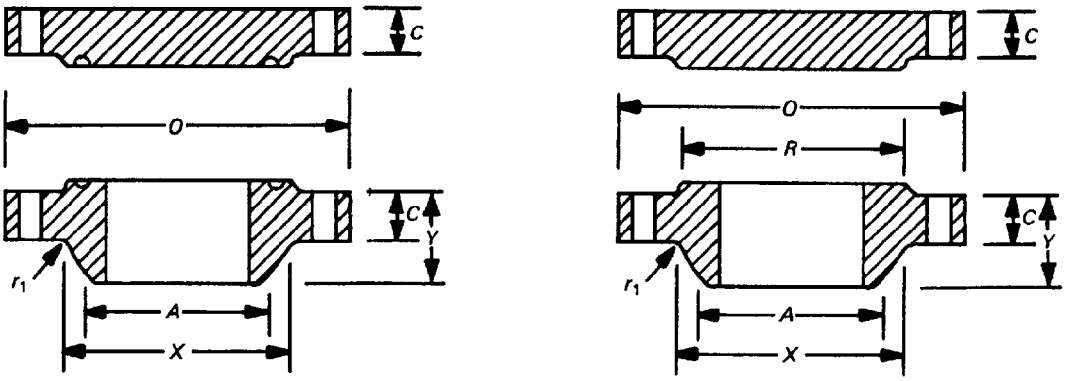

TABLE 9 DIMENSIONS OF CLASS 900 SERIES A FLANGES[1–6]

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	42.75	5.50	6.31	11.25	30.50	26.00	29.50	37.50	20	2.88	2¾	0.44
28	46.00	5.62	6.75	11.75	32.75	28.00	31.50	40.25	20	3.12	3	0.50
30	48.50	5.88	7.18	12.25	35.00	30.00	33.75	42.75	20	3.12	3	0.50
32	51.75	6.25	7.62	13.00	37.25	32.00	36.00	45.50	20	3.38	3¼	0.50
34	55.00	6.50	8.06	13.75	39.62	34.00	38.00	48.25	20	3.62	3½	0.56
36	57.50	6.75	8.44	14.25	41.88	36.00	40.25	50.75	20	3.62	3½	0.56
38	57.50	7.50	8.50	13.88	42.25	38.00	43.25	50.75	20	3.62	3½	0.75
40	59.50	7.75	8.81	14.31	44.38	40.00	45.75	52.75	24	3.62	3½	0.81
42	61.50	8.12	9.12	14.62	46.31	42.00	47.75	54.75	24	3.62	3½	0.81
44	64.88	8.44	9.56	15.38	48.62	44.00	50.00	57.62	24	3.88	3¾	0.88
46	68.25	8.88	10.06	16.18	50.88	46.00	52.50	60.50	24	4.12	4	0.88
48	70.25	9.19	10.38	16.50	52.88	48.00	54.50	62.50	24	4.12	4	0.94
50	...	...	...	...	...	...	...	...	...	...	...	...
52	...	...	...	...	...	...	...	...	...	...	...	...
54	...	...	...	...	...	...	...	...	...	...	...	...
56	...	...	...	...	...	...	...	...	...	...	...	...
58	...	...	...	...	...	...	...	...	...	...	...	...
60	...	...	...	...	...	...	...	...	...	...	...	...

(Notes follow Table 15)

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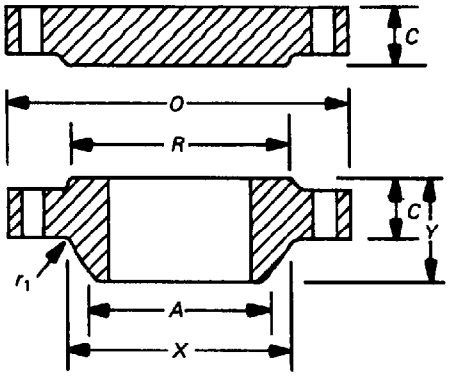

TABLE 10 DIMENSIONS OF CLASS 75 SERIES B FLANGES[1–6]

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	30.00	1.31	1.31	2.31	26.62	26.06	27.75	28.50	36	0.75	5/8	0.31
28	32.00	1.31	1.31	2.44	28.62	28.06	29.75	30.50	40	0.75	5/8	0.31
30	34.00	1.31	1.31	2.56	30.62	30.06	31.75	32.50	44	0.75	5/8	0.31
32	36.00	1.38	1.44	2.75	32.62	32.06	33.75	34.50	48	0.75	5/8	0.31
34	38.00	1.38	1.50	2.88	34.62	34.06	35.75	36.50	52	0.75	5/8	0.31
36	40.69	1.44	1.67	3.38	36.81	36.06	38.00	39.06	40	0.88	3/4	0.38
38	42.69	1.50	1.75	3.50	38.81	38.06	40.00	41.06	40	0.88	3/4	0.38
40	44.69	1.50	1.75	3.62	40.81	40.06	42.00	43.06	44	0.88	3/4	0.38
42	46.69	1.56	1.88	3.75	42.81	42.06	44.00	45.06	48	0.88	3/4	0.38
44	49.25	1.69	1.94	4.12	44.88	44.06	46.25	47.38	36	1.00	7/8	0.38
46	51.25	1.75	2.00	4.25	46.88	46.06	48.25	49.38	40	1.00	7/8	0.38
48	53.25	1.81	2.12	4.38	48.88	48.06	50.25	51.38	44	1.00	7/8	0.38
50	55.25	1.88	2.18	4.56	50.94	50.06	52.25	53.38	44	1.00	7/8	0.38
52	57.38	1.88	2.25	4.75	52.94	52.06	54.25	55.50	48	1.00	7/8	0.38
54	59.38	1.94	2.38	4.94	55.00	54.06	56.25	57.50	48	1.00	7/8	0.38
56	62.00	2.00	2.44	5.31	57.12	56.06	58.50	59.88	40	1.12	1	0.44
58	64.00	2.06	2.50	5.44	59.12	58.06	60.50	61.88	44	1.12	1	0.44
60	66.00	2.19	2.62	5.69	61.12	60.06	62.50	63.88	44	1.12	1	0.44

(Notes follow Table 15)

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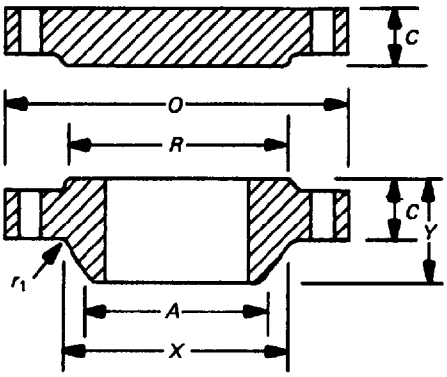

TABLE 11 DIMENSIONS OF CLASS 150 SERIES B FLANGES[1–6]

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	30.94	1.62	1.75	3.50	26.94	26.06	28.00	29.31	36	0.88	3/4	0.38
28	32.94	1.75	1.88	3.75	28.94	28.06	30.00	31.31	40	0.88	3/4	0.38
30	34.94	1.75	2.00	3.94	31.00	30.06	32.00	33.31	44	0.88	3/4	0.38
32	37.06	1.81	2.12	4.25	33.06	32.06	34.00	35.44	48	0.88	3/4	0.38
34	39.56	1.94	2.25	4.34	35.12	34.06	36.25	37.69	40	1.00	7/8	0.38
36	41.62	2.06	2.31	4.62	37.19	36.06	38.25	39.75	44	1.00	7/8	0.38
38	44.25	2.12	2.50	4.88	39.25	38.12	40.25	42.12	40	1.12	1	0.38
40	46.25	2.19	2.62	5.06	41.31	40.12	42.50	44.12	44	1.12	1	0.38
42	48.25	2.31	2.69	5.25	43.38	42.12	44.50	46.12	48	1.12	1	0.44
44	50.25	2.38	2.81	5.38	45.38	44.12	46.50	48.12	52	1.12	1	0.44
46	52.81	2.44	2.94	5.69	47.44	46.12	48.62	50.56	40	1.25	1 1/8	0.44
48	54.81	2.56	3.06	5.88	49.50	48.12	50.75	52.56	44	1.25	1 1/8	0.44
50	56.81	2.69	3.18	6.06	51.50	50.12	52.75	54.56	48	1.25	1 1/8	0.44
52	58.81	2.75	3.31	6.19	53.56	52.12	54.75	56.56	52	1.25	1 1/8	0.44
54	61.00	2.81	3.44	6.38	55.62	54.12	56.75	58.75	56	1.25	1 1/8	0.44
56	63.00	2.88	3.56	6.56	57.69	56.12	58.75	60.75	60	1.25	1 1/8	0.56
58	65.94	2.94	3.68	6.88	59.69	58.12	60.75	63.44	48	1.38	1 1/4	0.56
60	67.94	3.00	3.81	7.06	61.81	60.12	63.00	65.44	52	1.38	1 1/4	0.56

(Notes follow Table 15)

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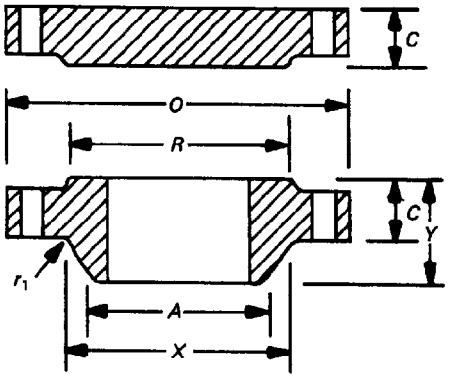

TABLE 12 DIMENSIONS OF CLASS 300 SERIES B FLANGES[1–6]

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	34.12	3.50	3.50	5.69	27.62	26.19	29.00	31.62	32	1.38	1¼	0.56
28	36.25	3.50	3.50	5.88	29.75	28.19	31.00	33.75	36	1.38	1¼	0.56
30	39.00	3.69	3.69	6.22	32.00	30.25	33.25	36.25	36	1.50	1⅜	0.56
32	41.50	4.06	4.06	6.62	34.00	32.25	35.50	38.50	32	1.62	1½	0.62
34	43.62	4.06	4.06	6.81	36.12	34.25	37.50	40.62	36	1.62	1½	0.62
36	46.12	4.06	4.06	7.12	38.00	36.25	39.75	42.88	32	1.75	1⅝	0.62
38	48.12	4.38	4.38	7.56	40.00	38.25	41.75	44.88	36	1.75	1⅝	0.62
40	50.12	4.56	4.56	7.81	42.00	40.25	43.88	46.88	40	1.75	1⅝	0.62
42	52.50	4.69	4.69	8.06	44.00	42.31	46.00	49.00	36	1.88	1¾	0.62
44	54.50	5.00	5.00	8.44	46.19	44.31	48.00	51.00	40	1.88	1¾	0.62
46	57.50	5.06	5.12	8.75	48.38	46.31	50.00	53.75	36	2.00	1⅞	0.62
48	59.50	5.06	5.31	8.81	50.31	48.31	52.25	55.75	40	2.00	1⅞	0.62
50	61.50	5.44	5.50	9.25	52.38	50.31	54.25	57.75	44	2.00	1⅞	0.62
52	63.50	5.62	5.68	9.56	54.44	52.31	56.25	59.75	48	2.00	1⅞	0.62
54	65.88	5.38	5.88	9.44	56.50	54.31	58.25	62.12	48	2.00	1⅞	0.62
56	69.50	6.06	6.18	10.56	58.81	56.31	60.50	65.00	36	2.38	2¼	0.69
58	71.94	6.06	6.38	10.81	60.94	58.31	62.75	67.44	40	2.38	2¼	0.69
60	73.94	5.94	6.56	10.69	62.94	60.31	65.00	69.44	40	2.38	2¼	0.69

(Notes follow Table 15)

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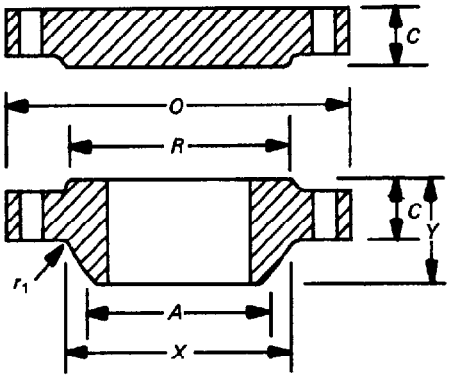

TABLE 13 DIMENSIONS OF CLASS 400 SERIES B FLANGES[1–6,10]

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	33.50	3.50	3.50	5.88	27.12	26.00	28.00	30.75	28	1.50	1⅜	0.44
28	36.00	3.75	3.75	6.25	29.12	28.00	30.00	33.00	24	1.62	1½	0.50
30	38.25	4.00	4.00	6.69	31.25	30.00	32.25	35.25	28	1.62	1½	0.50
32	40.75	4.25	4.25	7.06	33.25	32.00	34.38	37.50	28	1.75	1⅝	0.50
34	42.75	4.38	4.38	7.38	35.38	34.00	36.50	39.50	32	1.75	1⅝	0.56
36	45.50	4.69	4.69	7.88	37.50	36.00	38.62	42.00	28	1.88	1¾	0.56
38	...	...	...	...	...	...	...	...	...	...	...	...
40	...	...	...	...	...	...	...	...	...	...	...	...
42	...	...	...	...	...	...	...	...	...	...	...	...
44	...	...	...	...	...	...	...	...	...	...	...	...
46	...	...	...	...	...	...	...	...	...	...	...	...
48	...	...	...	...	...	...	...	...	...	...	...	...
50	...	...	...	...	...	...	...	...	...	...	...	...
52	...	...	...	...	...	...	...	...	...	...	...	...
54	...	...	...	...	...	...	...	...	...	...	...	...
56	...	...	...	...	...	...	...	...	...	...	...	...
58	...	...	...	...	...	...	...	...	...	...	...	...
60	...	...	...	...	...	...	...	...	...	...	...	...

(Notes follow Table 15)

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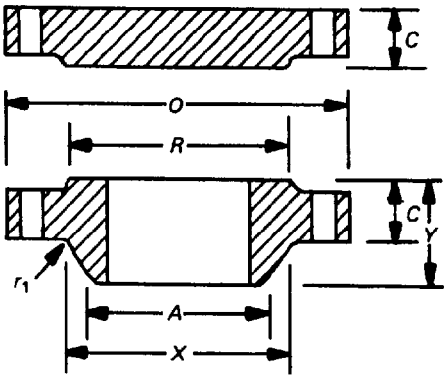

TABLE 14 DIMENSIONS OF CLASS 600 SERIES B FLANGES[1–6,10]

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	35.00	4.38	4.38	7.12	27.50	26.00	28.62	31.75	28	1.75	$1\frac{5}{8}$	0.50
28	37.50	4.56	4.56	7.50	29.62	28.00	30.88	34.00	28	1.88	$1\frac{3}{4}$	0.50
30	40.25	4.94	5.00	8.06	31.75	30.00	33.12	36.50	28	2.00	$1\frac{7}{8}$	0.50
32	42.75	5.12	5.31	8.50	33.88	32.00	35.25	38.75	28	2.12	2	0.50
34	45.75	5.56	5.68	9.19	36.00	34.00	37.50	41.50	24	2.38	$2\frac{1}{4}$	0.56
36	47.75	5.75	5.94	9.56	38.12	36.00	39.75	43.50	28	2.38	$2\frac{1}{4}$	0.56
38	...	...	...	...	...	...	...	...	...	...	...	...
40	...	...	...	...	...	...	...	...	...	...	...	...
42	...	...	...	...	...	...	...	...	...	...	...	...
44	...	...	...	...	...	...	...	...	...	...	...	...
46	...	...	...	...	...	...	...	...	...	...	...	...
48	...	...	...	...	...	...	...	...	...	...	...	...
50	...	...	...	...	...	...	...	...	...	...	...	...
52	...	...	...	...	...	...	...	...	...	...	...	...
54	...	...	...	...	...	...	...	...	...	...	...	...
56	...	...	...	...	...	...	...	...	...	...	...	...
58	...	...	...	...	...	...	...	...	...	...	...	...
60	...	...	...	...	...	...	...	...	...	...	...	...

(Notes follow Table 15)

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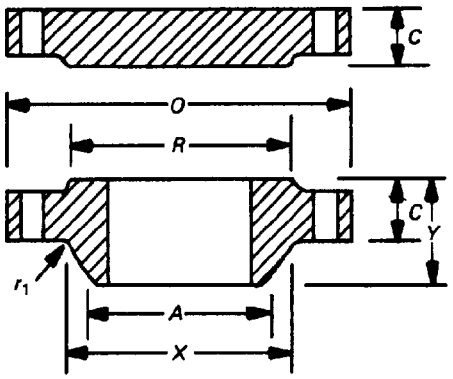

TABLE 15 DIMENSIONS OF CLASS 900 SERIES B FLANGES[1-6, 10]

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal Pipe Size	O. D. of Flange	Thickness of Flange, Min.[7]		Length Through Hub	Diam. of Hub[8]	Hub Diam.[9] Top	Raised Face Diam.	Drilling			Diam. of Bolt	Fillet Radius Min.
		WNF	Blind					Diam. of Bolt Circle	No. of Bolt Holes	Diam. of Bolt Hole		
	O	*C*	*C*	*Y*	*X*	*A*	*R*					r_1
26	40.25	5.31	6.06	10.19	29.25	26.00	30.00	35.50	20	2.62	2½	0.44
28	43.50	5.81	6.56	10.88	31.38	28.00	32.25	38.25	20	2.88	2¾	0.50
30	46.50	6.12	6.93	11.38	33.50	30.00	34.50	40.75	20	3.12	3	0.50
32	48.75	6.31	7.31	11.94	35.75	32.00	36.50	43.00	20	3.12	3	0.50
34	51.75	6.75	7.68	12.56	37.88	34.00	39.00	45.50	20	3.38	3¼	0.56
36	53.00	6.81	7.94	12.81	40.00	36.00	40.50	47.25	24	3.12	3	0.56
38	...	...	...	...	...	...	...	...	...	...	...	...
40	...	...	...	...	...	...	...	...	...	...	...	...
42	...	...	...	...	...	...	...	...	...	...	...	...
44	...	...	...	...	...	...	...	...	...	...	...	...
46	...	...	...	...	...	...	...	...	...	...	...	...
48	...	...	...	...	...	...	...	...	...	...	...	...
50	...	...	...	...	...	...	...	...	...	...	...	...
52	...	...	...	...	...	...	...	...	...	...	...	...
54	...	...	...	...	...	...	...	...	...	...	...	...
56	...	...	...	...	...	...	...	...	...	...	...	...
58	...	...	...	...	...	...	...	...	...	...	...	...
60	...	...	...	...	...	...	...	...	...	...	...	...

(Notes follow on next page)

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Notes to Tables 5–15

GENERAL NOTE: Dimensions are in inches.

NOTES:
(1) For tolerances, see Section 7.
(2) For facings, see para. 6.1.
(3) For flange bolt holes, see para. 6.2.
(4) For spot facing, see para. 6.3.
(5) The bore is to be specified by the purchaser. Tolerances in para. 7.4.2 apply.
(6) Blind flanges may be made with or without hubs at the manufacturer's option.
(7) When these flanges are required with flat face, either the full thickness or thickness with raised face removed may be furnished. Users are reminded that removing the raised face will make the length through hub nonstandard.
(8) This dimension is for the large end of hub, which may be straight or tapered.
(9) For welding and bevel, see para. 6.4.
(10) Dimensions for Classes 400, 600, and 900 NPS 38 and larger for Series B flanges are the same as for the Series A flanges.

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TABLE 16 PERMISSIBLE IMPERFECTIONS IN FLANGE FACING FINISH
(See Para. 6.1.5)

Nominal Pipe Size	Maximum Radial Projection of Imperfections Which Are No Deeper Than the Bottom of the Serration, in.	Maximum Depth and Radial Projection of Imperfections Which Are Deeper Than the Bottom of the Serration, in.
26–36	0.50	0.25
38–48	0.56	0.28
50–60	0.62	0.31

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ANNEX A
METHODS FOR ESTABLISHING PRESSURE-TEMPERATURE RATINGS

(This Annex is not part of ASME B16.47-1996 and is included for information only.)

A1 GENERAL

A1.1 Introduction

Pressure–temperature ratings in this Standard have been determined by the procedures in this Annex.

The primary consideration in establishing ratings is adequate wall thickness to sustain stresses due to pressure and other loadings. Other considerations affecting or limiting the ratings include:

(a) stresses in flanges resulting from bolt-up necessary to maintain gasket seal;

(b) distortion of flanges due to loadings transmitted through the pipeline; and

(c) limitations applying primarily to valves but imposed also on flanges in order to maintain compatible ratings.

A1.2 Material Groups

Material groups in Table 1 are based on identical or closely matched allowable stress and yield strength values. Where they are not identical, the lower value has been applied.

Note that material groups are not numbered consecutively. Some groups are intended for use only in valves. See ASME B16.34.

A1.3 Material Properties

The allowable stress and yield strength values used to calculate the pressure–temperature ratings were taken from the ASME Boiler and Pressure Vessel Code, Section II, Part D. In addition, data has been provided directly by the ASME Boiler and Pressure Vessel Subcommittee on Materials.

A2 RATINGS

A2.1 Rating Equation

Ratings given in Tables 2, psig at temperatures expressed in degrees Fahrenheit, for all materials and pressure classes, are established by Eq. (1):

$$P_T = P_r S_1/8750 \le P_c \qquad (1)$$

where

P_t = rated working pressure, psig, for the specified material at temperature T

P_r = pressure rating class index expressed in psi[1] (e.g. P_r = 300 psi for Class 300)

S_1 = selected stress, psi, for the specified material at temperature T (see paras. A2.2, A2.3, and A2.4)

P_c = ceiling pressure, psig, as specified in A3 at temperature T

A2.2 Ratings for Group 1 Materials, Class 300 and Higher

The selected stress S_1 fore each material group among Group 1 materials in Table 1A is determined as follows.

(a) At temperatures below the creep range, S_1 shall be lowest of the following values:

(1) 60% of specified minimum yield strength at 100°F;

(2) 60% of the yield strength at temperature T;

(3) 1.25 times the alowable stress at temperature T as listed for ASME BPV Code, Section I, or, if not listed for Section I, as listed for Section VIII Division 1.

(b) At temperatures in the creep range (defined as those above 700°F for Group 1 materials), S_1 shall be the lowest of the following values:

(1) 60% of the yield strength at temperature T;

(2) the allowable stress at temperature T as listed

[1]This definition of P_r does not apply to Class 75 and Class 150. See para. A2.4.

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for ASME BPV Code, Section I, or, if not listed for Section I, as listed for Section VIII, Division 1.

(c) In no case shall the value of S_1 increase with increasing temperature.

(d) Yield strength values for determination of values of S_1 shall be obtained from ASME BPV Code, Section II, Part D.

(e) Where more than one allowable stress value is listed for a material at any temperature, the lower value shall be used. If lower allowable stress values do not appear, and it is noted in the allowable stress table that the allowable stress values exceed two-thirds of the yield strength at temperature, then the allowable stress values shall be determined as two-thirds of the tabulated yield strength at temperature.

(f) Allowable stress values listed for the ASME BPV Code, Section III, Class 2 and Class 3 may be used only if the material is not listed for either Section I or Section VIII, Division 1.

A2.3 Ratings for Group 2 Materials, Class 300 and Higher

The selected stress S_1, for each material group among Group 2 materials in Table 1A is determined as follows.

(a) At temperatures below the creep range, S_1 is determined in accordance with para. A2.2(a), except that 70% of yield strength shall be used, instead of 60%, in paras. A2.2(a)(1) and (a)(2).

(b) At temperatures in the creep range (defined as those above 950°F for Group 2 materials), S_1 is determined in accordance with para. A2.2(b).

(c) The limitations in paras. A2.2(c), (d), (e), and (f) apply.

A2.4 Ratings for Classes 75 and 150, All Material Groups

Pressure–temperature ratings for Classes 75 and 150 flanges are determined for each material group as set forth in paras. A2.1, A2.2, and A2.3 with the following exceptions.

(a) The value of P_r in Eq. (1) (para A2.1) shall be 57.5 psi for Class 75 and 115 psi for Class 150.

(b) The value for S_1 shall be in accordance with the requirements of paras. A2.1, A2.2, and A2.3.

(c) The value for P_T in Eq. (1) at temperature T (degrees Fahrenheit) shall not exceed that given by Eqs. (2) and (3).

For Class 75

$$P_T = 160 - 0.15T \quad (2)$$

For Class 150

$$P_T = 320 - 0.3T \quad (3)$$

The limits of T in equation (2) and (3) are 100°F min. and 1000°F max. For values of T less than 100°F, T equal to 100°F is used.

A3 MAXIMUM RATINGS

A3.1 Maximum Ratings

A set of maximum or ceiling pressure–temperature ratings, P_c, are shown in Table A1. They are imposed to limit deflections.

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TABLE A1 RATING CEILING VALUES

Temperature, °F	Working Pressure, psig, by Classes					
	75	150	300	400	600	900
−20 to 100	145	290	750	1000	1500	2250
200	130	260	750	1000	1500	2250
300	115	230	730	970	1455	2185
400	100	200	705	940	1410	2115
500	85	170	665	885	1330	1995
600	70	140	605	805	1210	1815
650	60	125	590	785	1175	1765
700	...	110	570	755	1135	1705
750	...	95	530	710	1065	1595
800	...	80	510	675	1015	1525
850	...	65	485	650	975	1460
900	...	50	450	600	900	1350
950	...	35	385	515	775	1160
1000	...	20	365	485	725	1090
1050	...	...	360	480	720	1080
1100	...	...	325	430	645	965
1150	...	...	275	365	550	825
1200	...	...	205	275	410	620
1250	...	...	180	245	365	545
1300	...	...	140	185	275	410
1350	...	...	105	140	205	310
1400	...	...	75	100	150	225
1450	...	...	60	80	115	175
1500	...	...	40	55	85	125

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ANNEX B

GASKETS
(Other Than Ring-Joint)

(This Annex is an integral part of ASME B16.47-1996 and is placed after the main text for convenience.)

B1 SCOPE

This Annex covers gasket characteristics.

B2 GASKET MATERIALS AND CONSTRUCTION

Classification of gasket materials and types is shown in Fig. B1. Other gaskets, which result in no increase in bolt loads or flange moment over those resulting from the gaskets included in the respective groups in this Appendix, may be used and warrant the ratings of this Standard with the limiting dimensions of the applicable group. See also para. 5.4 for application of gaskets.

B3 GASKET DIMENSIONS

(a) The actual dimensions of a gasket must be established by the user. Reference to a dimensional standard for gaskets, such as ASME B16.21 and ASME B16.20 is recommended. In any case, selected dimensions should be based on the type of gasket and its characteristics. These characteristics include its density, flexibility, resistance to the fluid and its temperature, and the necessity for satisfactorily compressing the gasket on its I.D., its O.D., or both. Also to be considered is the question of allowing a "pocket" at the gasket I.D. (between the flange facings) or of allowing any intrusion of the gasket into the flange bore. Consideration should be given to the service fluid as well as to the possibility of damage which might result from partially disintegrated gaskets.

(b) Gaskets are divided into three groups based on their gasket loading factors as shown in the ASME BPV Code, Section VIII, Division 1, Pressure Vessels.

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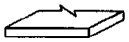
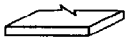
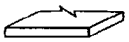
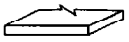
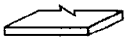
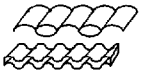
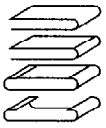
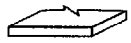
Gasket Group Number	Gasket Material	Sketches
Ia	Self-Energizing Types O-rings, metallic, elastomer, other gasket types considered as self-sealing	. . .
	Elastomer Without Fabric	
	Compressed Sheet Suitable for the Operating Conditions	
	Elastomer With Cotton Fabric Insertion	
	Elastomer With or Without Wire Reinforcement	
	Vegetable Fiber	
Ib	Spiral-Wound Metal, With Nonmetallic Fiber	
	Corrugated Aluminum, Copper or Copper Alloy or Corrugated Aluminum, Copper or Copper Alloy Double Jacketed With Nonmetallic Filler	
	Corrugated Aluminum, Copper, or Brass	
IIa and IIb	Corrugated Metal or Corrugated Metal Double Jacketed With Nonmetallic Fiber	
	Corrugated Metal	
	Flat Metal Jacketed With Nonmetallic Fiber	
	Grooved Metal	
	Solid Flat Soft Aluminum	
IIIa and IIIb	Solid Flat Metal	
. . .	Ring-Joint	. . .

FIG. B1 GASKET GROUPS AND TYPICAL MATERIALS

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ANNEX C
METHOD FOR CALCULATING BOLT LENGTHS

(This Annex is not part of ASME B16.47-1996 and is included for information only. See para. 6.5.2.)

The following formulas [see Note (1)] may be used to establish bolt lengths.

$$L_{CSB} = A + n$$

where

A = $2(C + t + d) + G + F$ (i.e., stud-bolt length exclusive of negative length tolerance n)
C = minimum flange thickness [see Tables 5 through 15 and Note (2) below]
F = total height of facings of depth of ring-joint groove for both flanges (see Table C1)
G = 0.12 in. gasket thickness for raised face
L_{CSB} = calculated stud-bolt length (effective thread length, excluding end points)
L_{SSB} = specified stud-bolt length (effective thread length, excluding end points), which is L_{CSB} rounded off to the nearest practical increment (see Fig. C1)
d = heavy nut thickness (equals nominal bolt diameter, see ASME/ANSI B18.2.2)
n = negative tolerance on bolt length (see Table C2)
t = plus tolerance for flange thickness (see para. 7.2)

NOTES:

(1) The equations used in this Annex are for calculated bolt lengths established to assure full thread engagement of heavy hexagon nuts when worst case tolerances occur on all relevant dimensions of the flanged joint. The use of shorter bolt lengths is acceptable provided that full thread engagement is obtained at assembly (see para. 6.5.2)

(2) 0.06 in. raised face is included in minimum flange thickness for Classes 75, 150, and 300 flanges.

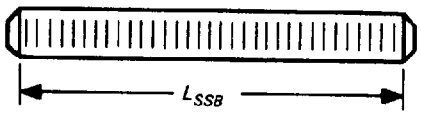

FIG. C1 SPECIFIED STUD-BOLT LENGTH

Data for Length Calculations
TABLE C1 *F* VALUES

Flanged Joint Class	Total Height of Facings or Depth of Ring-Joint Groove for Both Flanges, *F*		
	Type of Flange Facing		
	0.06 in. Raised	0.25 in. Raised	Ring-Joint
150 and 300	Zero [Note (1)]	0.50 in.	2 × groove depth
400 to 2500	0.12 in.	0.50 in.	2 × groove depth

NOTE:
(1) Raised face (0.06 in.) is included in minimum flange thickness for Classes 75, 150, and 300 flanges.

TABLE C2 *n* VALUES

Length		Negative Tolerance on Bolt Lengths, *n*
Stud-bolt	A	0.06 in. for lengths up to 12 in., incl. 0.12 in. for lengths over 12 in. to 18 in., incl. 0.25 in. for lengths over 18 in.

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ANNEX D
QUALITY SYSTEM PROGRAM

(This Annex is an integral part of ASME B16.47.1996 and is placed after the main text for convenience.)

The products manufactured in accordance with this Standard shall be produced under a quality system program following the principles of an appropriate standard from the ISO 9000 series.[1] A determination of the need for registration and/or certification of the product manufacturer's quality system program by an independent organization shall be the responsibility of the manufacturer. The detailed documentation demonstrating program compliance shall be available to the purchaser at the manufacturer's facility. A written summary description of the program utilized by the product manufacturer shall be available to the purchaser upon request. The product manufacturer is defined as the entity whose name or trademark appears on the product in accordance with the marking or identification requirements of this Standard.

[1]The series is also available from the American National Standards Institute (ANSI) and the American Society for Quality Control (ASQC) as American National Standards that are identified by a prefix "Q" replacing the prefix "ISO". Each standard of the series is listed under Annex E.

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ANNEX E
REFERENCES

(This Annex is an integral part of ASME B16.47.1996 and is placed after the main text for convenience.)

The following is a list of standards and specifications referenced in this Standard, showing the year of approval. Products covered by each ASTM specification are listed for convenience. (See specifications for exact titles and detailed contents.)

API Publications

API Standard 605-1988	Large-Diameter Carbon Steel Flanges

ASME Publications

ASME B1.1-1989	Unified Inch Screw Threads (UN and UNR Thread Form)
ASME B1.20.1-1983(R1992)	Pipe Threads, General Purpose (Inch)
ASME B16.20-1993	Metallic Gaskets for Pipe Flanges — Ring-Joint, Spiral-Wound, and Jacketed
ASME B16.21-1992	Nonmetallic Flat Gaskets for Pipe Flanges
ASME B16.34-1996	Valves — Flanged, Threaded, and Welding End
ASME B18.2.1-1981(R1992)	Square and Hex Bolts and Screws, Inch Series
ASME B18.2.2-1987(R1993)	Square and Hex Nuts (Inch Series)
ASME B31.3-1992	Chemical Plant and Petroleum Refinery Piping
ASME B36.10M-1985	Welded and Seamless Wrought Steel Pipe
ANSI/ASME B46.1-1985	Surface Texture (Surface Roughness, Waviness, and Lay)

ASME Boiler and Pressure Vessel Code, 1995 Edition (Including Addenda Through 1995)

Section I	Power Boilers
Section II	Materials
Section III	Nuclear Power Plant Components
Section VIII, Div. 1 & 2	Pressure Vessels

International Standards Organization (ISO)

ISO 9000-1: 1994	Quality management and quality assurance standards — Part 1: Guidelines for selection and use
ISO 9000-2: 1993	Quality management and quality assurance standard — Part 2: Generic guidelines for the application of ISO 9001, ISO 9002, and ISO 9003
ISO 9000-3: 1991	Quality management and quality assurance standards — Part 3: Guidelines for the application of ISO 9001 to the development, supply and maintenance of software
ISO 9001: 1994	Quality systems — Model for quality assurance in design, development, production, installation, and servicing
ISO 9002: 1994	Quality systems — Model for quality assurance in production and servicing
ISO 9003: 1994	Quality systems — Model for quality assurance in final inspection and test

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ASTM Publications

A 105-93b	Forgings, Carbon Steel, for Piping Components
A 182-93b	Forged or Rolled Alloy Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service
A 193-93a	Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
A 194-93a	Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service
A 203-93	Pressure Vessel Plates, Alloy Steel, Nickel
A 204-93	Pressure Vessel Plates, Alloy Steel, Molybdenum
A 216-89	Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
A 217-91	Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service
A 240-93b	Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
A 307-93a	Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength
A 320-93	Alloy-Steel Bolting Materials for Low-Temperature Service
A 350-93	Forgings, Carbon and Low-Alloy Steel, Requiring Notch Toughness Testing for Piping Components
A 351-93	Steel Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts
A 352-92	Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service
A 354-93	Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
A 387-92$^{\epsilon 1}$	Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum
A 449-93	Quenched and Tempered Steel Bolts and Studs
A 453-92	Bolting Materials, High-Temperature, 50 to 120 ksi [345 to 827 MPa] Yield Strength, With Expansion Coefficients Comparable to Austenitic Steels
A 515-92	Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
A 516-90	Pressure Vessel Plates, Carbon Steel, For Moderate- and Lower-Temperature Service
A 537-91	Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel
A 540-92	Alloy-Steel Bolting Materials for Special Applications
E 29-93	Using Significant Digits in Test Data to Determine Conformance with Specifications

MSS Publications

MSS SP-9-1992	Spot-Facing for Bronze, Iron, and Steel Flanges
MSS SP-25-1978(R1983,R1988)	Standard Marking System for Valves, Fittings, Flanges, and Unions
MSS SP-44-1991	Steel Pipe Line Flanges
MSS SP-45-1992	Bypass and Drain Connection
MSS SP-61-1992	Pressure Testing of Steel Valves

Publications of the following organizations appear in the above list:

ASQC	American Society for Quality Control P.O. Box 3005 Milwaukee, WI 53201-3005
API	American Petroleum Institute 1220 L Street, N.W., Washington, D.C. 20005

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STD.ASME B16.47-ENGL 1996 ■ 0759670 0579221 620 ■

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	ASME Order Department 22 Law Drive, Box 2300, Fairfield, New Jersey 07007-2300
ASTM	American Society for Testing and Materials 1916 Race Street, Philadelphia, Pennsylvania 19103
MSS	Manufacturers Standardization Society of the Valve & Fittings Industry 127 Park Street, N.E., Vienna, Virginia 22180

ISO documents are available from ANSI. Publications appearing above which have been approved as American National Standards may also be obtained from ANSI.

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ASME B31.1-2001

(Revision of ASME B31.1-1998)

POWER PIPING

ASME CODE FOR PRESSURE PIPING, B31

AN AMERICAN NATIONAL STANDARD

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POWER PIPING

ASME CODE FOR PRESSURE PIPING, B31

ASME B31.1-2001

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The 2001 Edition of this Code is being issued with an automatic update service that includes Addenda, Interpretations, and Cases. The next Edition is scheduled for publication in 2004.

The use of Addenda allows revisions made in response to public review comments or committee actions to be published on a regular basis; revisions published in Addenda will become effective 6 months after the Date of Issuance of the Addenda.

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FOREWORD

The general *philosophy* underlying this Power Piping Code is to parallel those provisions of Section I, Power Boilers, of the ASME Boiler and Pressure Vessel Code, as they can be applied to power piping systems. The Allowable Stress Values for power piping are generally consistent with those assigned for power boilers. This Code is more conservative than some other piping codes, reflecting the need for long service life and maximum reliability in power plant installations.

The Power Piping Code as currently written does not differentiate between the design, fabrication, and erection requirements for *critical and noncritical piping systems,* except for certain stress calculations and mandatory nondestructive tests of welds for heavy wall, high temperature applications. The *problem involved* is to try to reach agreement on how to evaluate criticality, and to avoid the inference that noncritical systems do not require competence in design, fabrication, and erection. Some day such levels of quality may be definable, so that the need for the many different piping codes will be overcome.

There are many instances where the Code serves to *warn a designer,* fabricator, or erector against possible pitfalls; but the Code is *not a handbook,* and cannot substitute for education, experience, and sound engineering judgment.

Nonmandatory Appendices are included in the Code. Each contains information on a specific subject, and is maintained current with the Code. Although written in mandatory language, these Appendices are offered for application at the user's discretion.

The Code *never intentionally puts a ceiling limit on conservatism.* A designer is free to specify more rigid requirements as he feels they may be justified. *Conversely, a designer who is capable* of a more rigorous analysis than is specified in the Code may justify a less conservative design, and still satisfy the basic intent of the Code.

The Power Piping Committee strives to keep abreast of the current technological improvements in new materials, fabrication practices, and testing techniques; and endeavors to keep the Code updated to permit the use of acceptable new developments.

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ASME CODE FOR PRESSURE PIPING, B31

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INTRODUCTION

The ASME B31 Code for Pressure Piping consists of a number of individually published Sections, each an American National Standard, under the direction of ASME Committee B31, Code for Pressure Piping.

Rules for each Section have been developed considering the need for application of specific requirements for various types of pressure piping. Applications considered for each Code Section include:

B31.1 Power Piping: piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems;

B31.3 Process Piping: piping typically found in petroleum refineries, chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants, and related processing plants and terminals;

B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids: piping transporting products which are predominately liquid between plants and terminals and within terminals, pumping, regulating, and metering stations;

B31.5 Refrigeration Piping: piping for refrigerants and secondary coolants;

B31.8 Gas Transportation and Distribution Piping Systems: piping transporting products which are predominately gas between sources and terminals, including compressor, regulating, and metering stations; and gas gathering pipelines;

B31.9 Building Services Piping: piping typically found in industrial, institutional, commercial, and public buildings, and in multi-unit residences, which does not require the range of sizes, pressures, and temperatures covered in B31.1;

B31.11 Slurry Transportation Piping Systems: piping transporting aqueous slurries between plants and terminals and within terminals, pumping, and regulating stations.

This is the B31.1 Power Piping Code Section. Hereafter, in this Introduction and in the text of this Code Section B31.1, where the word *Code* is used without specific identification, it means this Code Section.

It is the owner's responsibility to select the Code Section which most nearly applies to a proposed piping installation. Factors to be considered by the owner include: limitations of the Code Section; jurisdictional requirements; and the applicability of other codes and standards. All applicable requirements of the selected Code Section shall be met. For some installations, more than one Code Section may apply to different parts of the installation. The owner is also responsible for imposing requirements supplementary to those of the selected Code Section, if necessary, to assure safe piping for the proposed installation.

Certain piping within a facility may be subject to other codes and standards, including but not limited to:

ASME Boiler and Pressure Vessel Code, Section III: nuclear power piping;

ANSI Z223.1 National Fuel Gas Code: piping for fuel gas from the point of delivery to the connection of each fuel utilization device;

NFPA Fire Protection Standards: fire protection systems using water, carbon dioxide, halon, foam, dry chemical, and wet chemicals;

NFPA 99 Health Care Facilities: medical and laboratory gas systems;

NFPA 8503 Standard for Pulverized Fuel Systems: piping for pulverized coal from the coal mills to the burners;

Building and plumbing codes, as applicable, for potable hot and cold water, and for sewer and drain systems.

The Code sets forth engineering requirements deemed necessary for safe design and construction of pressure piping. While safety is the basic consideration, this factor alone will not necessarily govern the final specifications for any piping system. The designer is cautioned that the Code is not a design handbook; it does not do away with the need for the designer or for competent engineering judgment.

To the greatest possible extent, Code requirements for design are stated in terms of basic design principles and formulas. These are supplemented as necessary with specific requirements to assure uniform application of principles and to guide selection and application of piping elements. The Code prohibits designs and practices known to be unsafe and contains warnings where caution, but not prohibition, is warranted.

The specific design requirements of the Code usually revolve around a simplified engineering approach to a subject. It is intended that a designer capable of applying

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more complete and rigorous analysis to special or unusual problems shall have latitude in the development of such designs and the evaluation of complex or combined stresses. In such cases the designer is responsible for demonstrating the validity of his approach.

This Code Section includes:

(1) references to acceptable material specifications and component standards, including dimensional requirements and pressure-temperature ratings;

(2) requirements for design of components and assemblies, including pipe supports;

(3) requirements and data for evaluation and limitation of stresses, reactions, and movements associated with pressure, temperature changes, and other forces;

(4) guidance and limitations on the selection and application of materials, components, and joining methods;

(5) requirements for the fabrication, assembly, and erection of piping; and

(6) requirements for examination, inspection, and testing of piping.

It is intended that this Edition of Code Section B31.1 and any subsequent Addenda not be retroactive. Unless agreement is specifically made between contracting parties to use another issue, or the regulatory body having jurisdiction imposes the use of another issue, the latest Edition and Addenda issued at least 6 months prior to the original contract date for the first phase of activity covering a piping system or systems shall be the governing document for all design, materials, fabrication, erection, examination, and testing for the piping until the completion of the work and initial operation.

Users of this Code are cautioned against making use of revisions without assurance that they are acceptable to the proper authorities in the jurisdiction where the piping is to be installed.

Code users will note that clauses in the Code are not necessarily numbered consecutively. Such discontinuities result from following a common outline, insofar as practicable, for all Code Sections. In this way, corresponding material is correspondingly numbered in most Code Sections, thus facilitating reference by those who have occasion to use more than one Section.

The Code is under the direction of ASME Committee B31, Code for Pressure Piping, which is organized and operates under procedures of The American Society of Mechanical Engineers which have been accredited by the American National Standards Institute. The Committee is a continuing one, and keeps all Code Sections current with new developments in materials, construction, and industrial practice. Addenda are issued periodically. New editions are published at intervals of three to five years.

When no Section of the ASME Code for Pressure Piping, specifically covers a piping system, at his discretion the user may select any Section determined to be generally applicable. However, it is cautioned that supplementary requirements to the Section chosen may be necessary to provide for a safe piping system for the intended application. Technical limitations of the various Sections, legal requirements, and possible applicability of other codes or standards are some of the factors to be considered by the user in determining the applicability of any Section of this Code.

The Committee has established an orderly procedure to consider requests for interpretation and revision of Code requirements. To receive consideration, inquiries must be in writing and must give full particulars (see Mandatory Appendix H covering preparation of technical inquiries). The Committee will not respond to inquiries requesting assignment of a Code Section to a piping installation.

The approved reply to an inquiry will be sent directly to the inquirer. In addition, the question and reply will be published as part of an Interpretation Supplement issued to the applicable Code Section.

A Case is the prescribed form of reply to an inquiry when study indicates that the Code wording needs clarification or when the reply modifies existing requirements of the Code or grants permission to use new materials or alternative constructions. Proposed Cases are published in *Mechanical Engineering* for public review. In addition, the Case will be published as part of a Case Supplement issued to the applicable Code Section.

A case is normally issued for a limited period after which it may be renewed, incorporated in the Code, or allowed to expire if there is no indication of further need for the requirements covered by the Case. However, the provisions of a Case may be used after its expiration or withdrawal, provided the Case was effective on the original contract date or was adopted before completion of the work; and the contracting parties agree to its use.

Materials are listed in the Stress Tables only when sufficient usage in piping within the scope of the Code has been shown. Materials may be covered by a Case. Requests for listing shall include evidence of satisfactory usage and specific data to permit establishment of allowable stresses, maximum and minimum temperature limits, and other restrictions. Additional criteria can be found in the guidelines for addition of new materials

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in the ASME Boiler and Pressure Vessel Code, Section II and Section VIII, Division 1, Appendix B. (To develop usage and gain experience, unlisted materials may be used in accordance with Para. 123.1.)

Requests for interpretation and suggestions for revision should be addressed to the Secretary, ASME B31 Committee, Three Park Avenue, New York, NY 10016-5990.

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SUMMARY OF CHANGES

Changes given below are identified on the pages by a margin note, **01**, placed next to the affected area.

Page	*Location*	*Change*
vi, viii	Contents	Updated to reflect 01
1, 4	100.1.2	Subparagraph (B) deleted
4	100.1.3	Subparagraph (B) revised
18	104.1.2	Subparagraph (C.1) revised
22	104.3.1	First equation in subparagraph (D.2.2) revised
29, 30	104.8.1	First paragraph revised
	104.8.2	Nomenclature for M_B revised
	104.8.3	First sentence revised
31, 32	105.3	Subparagraph (E) revised
34	108.6.1	Subparagraph (E) added
	108.6.2	Subparagraph (C) revised
37	Table 112	Under Gaskets, Item (f)(2) revised
40	Table 114.2.1	Note (1) redesignated as General Note
44	119.10.1	Nomenclature for E_c corrected by Errata
45	121.2	Subparagraph (A) revised
52	122.1.7	First paragraph of subparagraph (A.3) revised
56, 57	122.4	(1) Subparagraph (A.8) revised (2) Subparagraph (A.10) added
58	Fig. 122.4	Art revised and General Note added
61, 62	122.8.2	Subparagraph (C.3) revised
65, 66	123	Revised through 123.1.2
	123.1.6	Added
72, 73	Table 126.1	(1) MSS Standard Practices revised (2) Under ASME Codes and Standards, B16.48 added
84	127.5.4	Added
88–92	Table 132	General Notes renumbered from (I)(A), (I)(B), etc., (II)(A), (II)(B), etc., to (A)(1), (A)(2), etc., (B)(1), (B)(2), etc.

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Page	*Location*	*Change*
97	Table 136.4	(1) In column headings, *Piping Service Conditions etc.* revised to read *Piping Design Condtions etc.* (2) Under General Notes, (D) deleted; (E) and (F) redesignated as new (D) and (E)
104	Table A-1	Under Seamless Pipe and Tube, reference to Note (1) added to A 333 6
106–114, 118	Table A-1	On even-numbered pages, references to Notes (16) to (24) renumbered as (15) to (23), respectively
107	Table A-1	Under Electric Resistance Welded Pipe and Tube, second Grade of A 178 corrected by Errata
115	Table A-1	Under Plate, both stress values at 800°F for A 299 corrected by Errata
119	Table A-1	Notes (16) to (24) renumbered as (15) to (23), respectively
120–130	Table A-2	On even-numbered pages, references to Notes (12) to (21) renumbered as (11) to (20), respectively
128	Table A-2	Under Forgings, Nominal Composition for A 182 F1 corrected by Errata
133, 134	Table A-2	Notes (12) to (21) renumbered as (11) to (20), respectively
140	Table A-3	Under Seamless Pipe and Tube, Austenitic, reference to Note (32) added to last two A 312 entries
142	Table A-3	Under Seamless Pipe and Tube, Ferritic/Martensitic, reference to Note (32) added to A 268 TPXM27, TP446-1, and TPXM33 and A 731 TPXM27 and TPXM33
144, 154, 156 166–172	Table A-3	On even-numbered pages, references to Notes (18) to (27) renumbered as (17) to (26), respectively, and (29) to (33) as (27) to (31), respectively
146	Table A-3	Under Welded Pipe and Tube — Without Filler Metal, Austenitic, reference to Note (32) added to last two A 249 entries
150	Table A-3	Under Welded Pipe and Tube — Without Filler Metal: (1) Under Austenitic, reference to Note (32) added to last two A 312 entries

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Page	*Location*	*Change*
150	Table A-3	(2) Under Ferritic/Martensitic, reference to Note (32) added to A 268 TP446-1, TPXM27, and TPXM33 and A 731 TPXM27 and TPXM33
154	Table A-3	Under Welded Pipe — Filler Metal Added, Austenitic, reference to Note (32) added to last four A 358 entries
158	Table A-3	(1) Under Plate, Sheet, and Strip: (a) Under Austenitic, reference to Note (32) added to last two A 240 entries (b) Under Ferritic/Martensitic, reference to Note (32) added to A 240 XM27 and XM33 (2) Under Forgings, Austenitic, reference to Note (32) added to A 182 F44 in two places
175	Table A-3	(1) Notes (18) through (27) renumbered as (17) through (26), respectively (2) Notes (29) through (33) rennumbered as (27) through (31), respectively (3) Note (32) added
176	Table A-4	Under Seamless Pipe and Tube, reference to Note (13) added to B 622 N06022 in two places and B 690 N08367 in two places
178	Table A-4	Under Welded Pipe and Tube, reference to Note (13) added to B 675 N08367 in two places, B 676 N08367 in two places, and B 804 N08367 in two places
180, 182	Table A-4	(1) Under Plate, Sheet, and Strip, reference to Note (13) added to B 688 N08367 in six places (2) Under Bars, Rods, Shapes, Forgings, reference to Note (13) added to both B 564 N08367 entries and both B 691 N08367 entries (3) Under Seamless Fittings, reference to Note (13) added to B 366 N06022 in two places and N08367 in two places and B 462 N08367 in two places (4) Under Welded Fittings, reference to Note (13) added to B 366 N06022 in two places
183	Table A-4	Note (13) added
188, 189	Table A-6	Under Seamless Pipe and Tube, B 280 added
213–215	Table B-1	Thermal Expansion Data designated as Table B-1 and revised

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Page	*Location*	*Change*
216–219	Table B-1 (SI)	Thermal Expansion Data (SI) designated as Table B-1 (SI) and revised
222	Table C-1 (SI)	Revised
223, 224	Table C-2	(1) Note (1) reference moved from main title to column head for *E* (2) First column head revised (3) Under High Nickel Alloys: (a) Stress value at 1100°F revised for N06002(X) (b) Note (2) reference added to N08800 (800) and N08810 (800H) (4) Under Aluminum and Aluminum Alloys, stress value at 500°F revised for third bracketed group (5) Unalloyed Titanium heading revised (6) Note (2) added
225, 226	Table C-2 (SI)	Revised
236	Appendix F	(1) MSS Standard Practices revised (2) Under ASME Codes and Standards, B16.48 added
238	Apppendix G	Under Paragraph References for *A*, 104.3.1 added
287	III-5.1.3	Second line of subparagraph (B.4.B) corrected by Errata
323	Index	Updated to reflect 01

NOTES:

(1) The interpretations to ASME B31.1 issued between January 1, 2000, and June 30, 2000, follow the last page of this Addenda as a separate supplement, Interpretations No. 35. The interpretations to ASME B31.1 issued between July 1, 2000, and December 31, 2000, follow the last page of Interpretations No. 35 as a separate supplement, Interpretations No. 36.

(2) After the Interpretations, a separate supplement, Cases No. 27, follows.

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CHAPTER I
SCOPE AND DEFINITIONS

100 GENERAL

This Power Piping Code is one of several Sections of the American Society of Mechanical Engineers Code for Pressure Piping, B31. This Section is published as a separate document for convenience.

Standards and specifications specifically incorporated by reference into this Code are shown in Table 126.1. It is not considered practical to refer to a dated edition of each of the standards and specifications in this Code. Instead, the dated edition references are included in an Addenda which will be revised yearly.

100.1 Scope

Rules for this Code Section have been developed considering the needs for applications which include piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems.

100.1.1 This Code prescribes requirements for the design, materials, fabrication, erection, test, and inspection of piping systems.

Piping as used in this Code includes pipe, flanges, bolting, gaskets, valves, relief devices, fittings, and the pressure containing portions of other piping components, whether manufactured in accordance with Standards listed in Table 126.1 or specially designed. It also includes hangers and supports and other equipment items necessary to prevent overstressing the pressure containing components.

Rules governing piping for miscellaneous appurtenances, such as water columns, remote water level indicators, pressure gages, gage glasses etc., are included within the scope of this Code, but the requirements for boiler appurtenances shall be in accordance with Section I of the ASME Boiler and Pressure Vessel Code, PG-60.

The users of this Code are advised that in some areas legislation may establish governmental jurisdiction over the subject matter covered by this Code. However, any such legal requirement shall not relieve the owner of his inspection responsibilities specified in para. 136.1.

100.1.2 Power piping systems as covered by this Code apply to all piping and their component parts except as excluded in para. 100.1.3. They include but are not limited to steam, water, oil, gas, and air services. 01

(A) This Code covers boiler external piping as defined below for power boilers and high temperature, high pressure water boilers in which: steam or vapor is generated at a pressure of more than 15 psig [100 kPa (gage)]; and high temperature water is generated at pressures exceeding 160 psig [1103 kPa (gage)] and/or temperatures exceeding 250°F (120°C).

Boiler external piping shall be considered as that piping which begins where the boiler proper terminates at:

(1) the first circumferential joint for welding end connections; or

(2) the face of the first flange in bolted flanged connections; or

(3) the first threaded joint in that type of connection; and which extends up to and including the valve or valves required by para. 122.1.

The terminal points themselves are considered part of the boiler external piping. The terminal points and piping external to power boilers are illustrated by Figs. 100.1.2(A), 100.1.2(B), and 100.1.2(C).

Piping between the terminal points and the valve or valves required by para. 122.1 shall be provided with Data Reports, inspection, and stamping as required by Section I of the ASME Boiler and Pressure Vessel Code. All welding and brazing of this piping shall be performed by manufacturers or contractors authorized to use the appropriate symbol shown in Figs. PG-105.1 through PG-105.3 of Section I of the ASME Boiler and Pressure Vessel Code. The installation of boiler external piping by mechanical means may be performed by an organization not holding a Code symbol stamp. However, the holder of a valid S, A, or PP Certificate of Authorization shall be responsible for the documentation and hydrostatic test, regardless of the method of assembly. The quality control system requirements of

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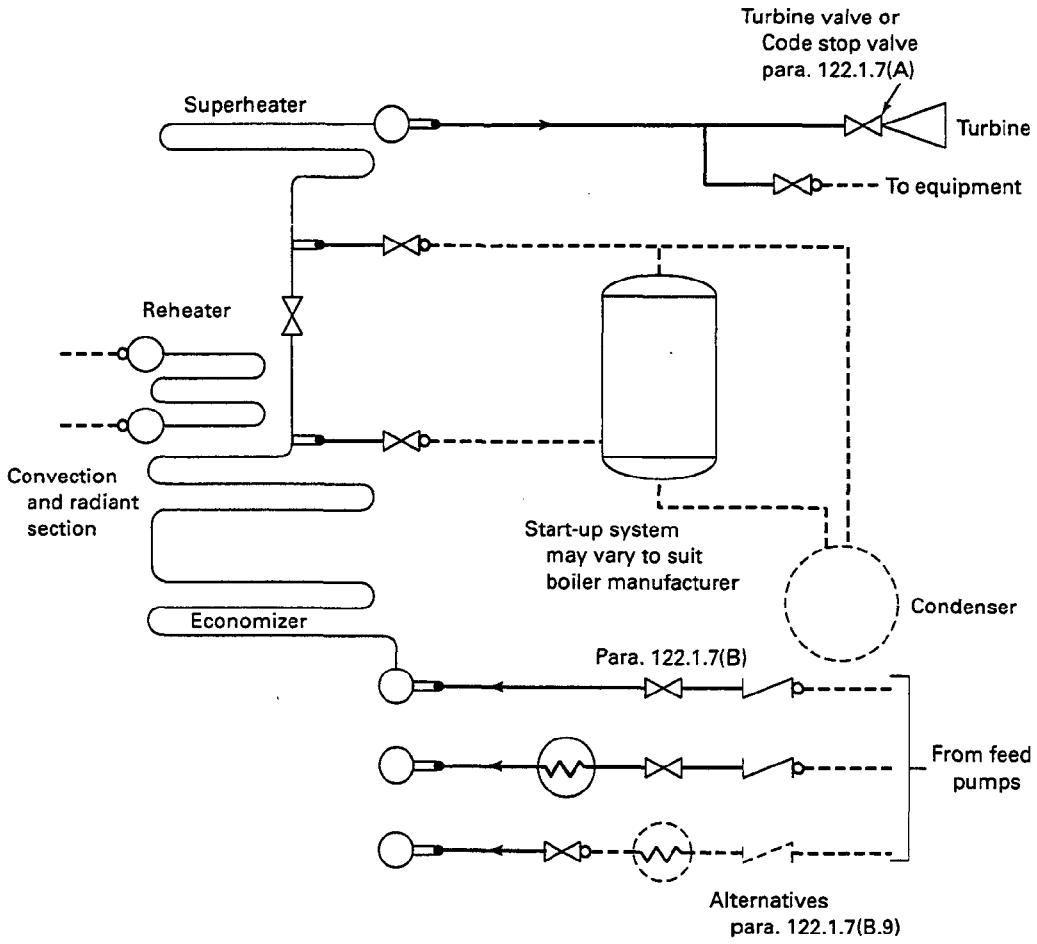

Administrative Jurisdiction and Technical Responsibility

——— Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility. Refer to ASME BPVC Section I Preamble.

•——— Boiler External Piping and Joint (BEP) — The ASME BPVC has total administrative jurisdiction (mandatory certification by Code Symbol stamping, ASME Data Forms, and Authorized Inspection) of BEP. The ASME Section Committee B31.1 has been assigned technical responsibility. Refer to ASME BPVC Section I Preamble, fifth, sixth, and seventh paragraphs and ASME B31.1 Scope, para. 100.1.2(A). Applicable ASME B31.1 Editions and Addenda are referenced in ASME BPVC Section I, PG-58.3.

o----- Nonboiler External Piping and Joint (NBEP) — The ASME Code Committee for Pressure Piping, B31, has total administrative and technical responsibility.

FIG. 100.1.2(A) CODE JURISDICTIONAL LIMITS FOR PIPING — FORCED FLOW STEAM GENERATOR WITH NO FIXED STEAM AND WATER LINE

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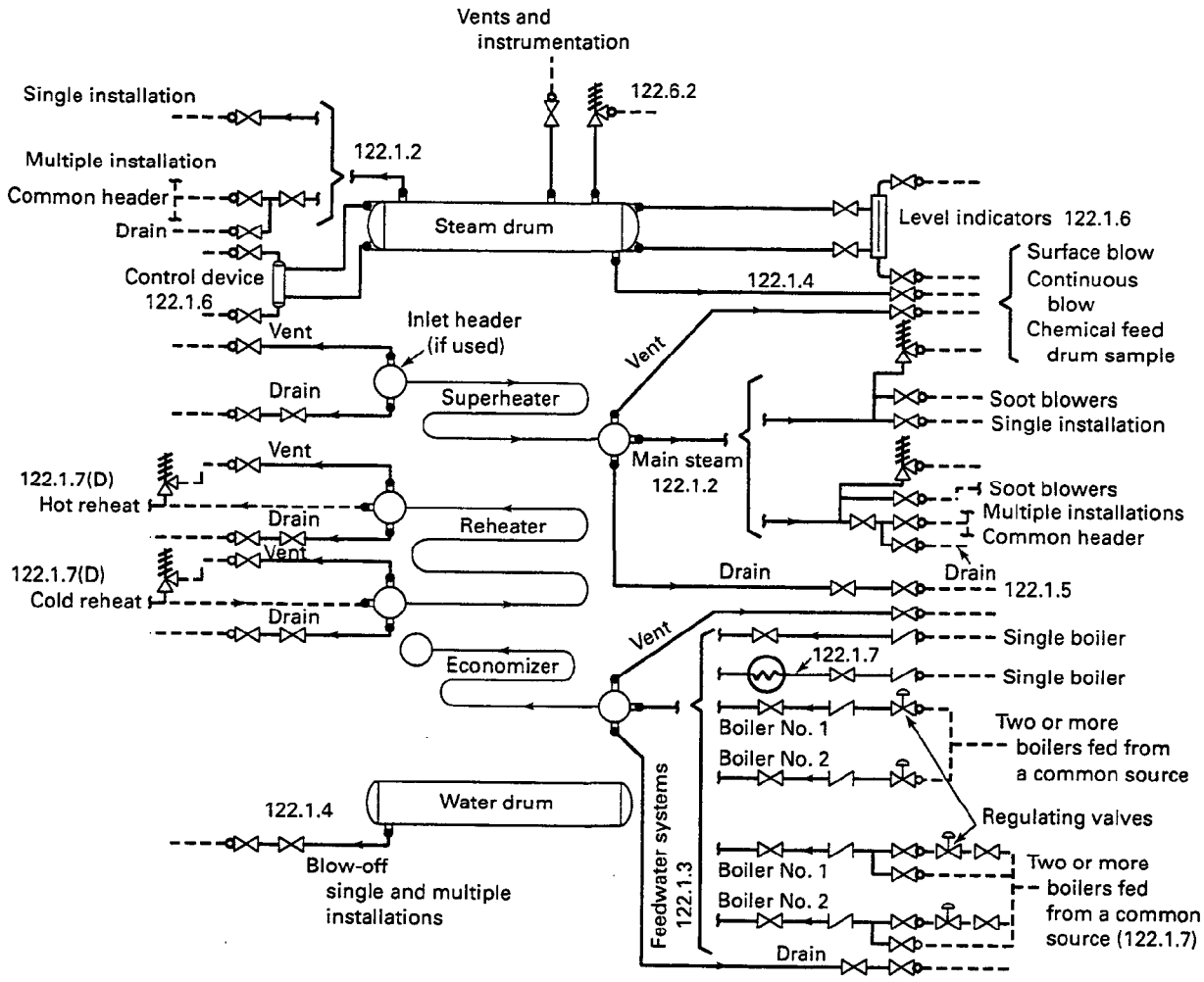

Administrative Jurisdiction and Technical Responsibility

——— Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility. Refer to ASME BPVC Section I Preamble.

•——— Boiler External Piping and Joint (BEP) — The ASME BPVC has total administrative jurisdiction (mandatory certification by Code Symbol stamping, ASME Data Forms, and Authorized Inspection) of BEP. The ASME Section Committee B31.1 has been assigned technical responsibility. Refer to ASME BPVC Section I Preamble and ASME B31.1 Scope, para. 100.1.2(A). Applicable ASME B31.1 Editions and Addenda are referenced in ASME BPVC Section I, PG-58.3.

o----- Nonboiler External Piping and Joint (NBEP) — The ASME Code Committee for Pressure Piping, B31, has total administrative and technical responsibility.

FIG. 100.1.2(B) CODE JURISDICTIONAL LIMITS FOR PIPING — DRUM TYPE BOILERS

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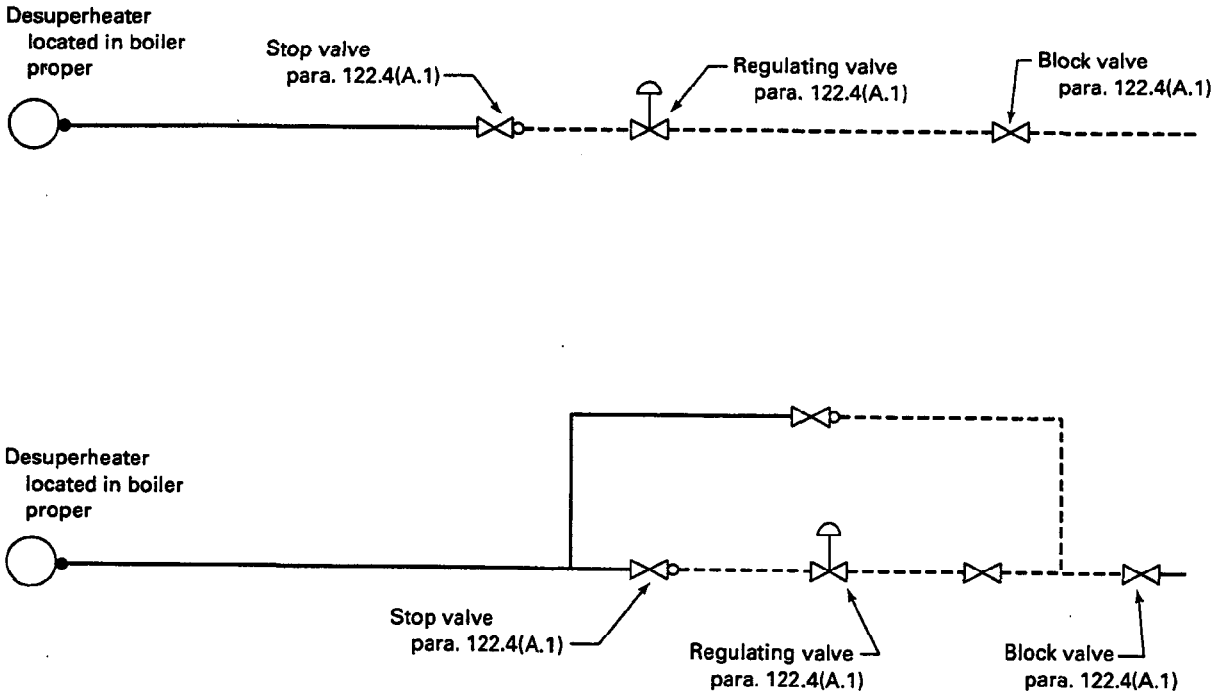

Administrative Jurisdiction and Technical Responsibility

——— Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility. Refer to ASME BPVC Section 1 Preamble.

●——— Boiler External Piping and Joint (BEP) — The ASME BPVC has total administrative jurisdiction (mandatory certification by Code Symbol stamping, ASME Data Forms, and Authorized Inspection) of BEP. The ASME Section Committee B31.1 has been assigned technical responsibility. Refer to ASME BPVC Section I Preamble and ASME B31.1 Scope, para. 100.1.2(A). Applicable ASME B31.1 Editions and Addenda are referenced in ASME BPVC Section I, PG-58.3.

o– – – – Nonboiler External Piping and Joint (NBEP) — The ASME Code Committee for Pressure Piping, B31, has total administrative and technical responsibility.

FIG. 100.1.2(C) CODE JURISDICTIONAL LIMITS FOR PIPING — SPRAY TYPE DESUPERHEATER

Section I of the ASME Boiler and Pressure Vessel Code shall apply. These requirements are shown in Appendix J of this Code.

The valve or valves required by para. 122.1 are part of the boiler external piping, but do not require ASME Boiler and Pressure Vessel Code, Section I inspection and stamping except for safety, safety relief, and relief valves, see para. 107.8.2. Refer to PG-11.

Pipe connections meeting all other requirements of this Code but not exceeding NPS ½ may be welded to pipe or boiler headers without inspection and stamping required by Section I of the ASME Boiler and Pressure Vessel Code.

Nonboiler external piping includes all the piping covered by this Code except for that portion defined above as boiler external piping.

100.1.3 This Code does not apply to the following:

(A) economizers, heaters, pressure vessels, and components covered by Sections of the ASME Boiler and Pressure Vessel Code;

(B) building heating and distribution steam and condensate piping designed for 15 psig [100 kPa(gage)] or less, or hot water heating systems designed for 30 psig [200 kPa (gage)] or less; 01

(C) piping for hydraulic or pneumatic tools and their

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components downstream of the first block or stop valve off the system distribution header;

(D) piping for marine or other installations under Federal control;

(E) towers, building frames, tanks, mechanical equipment, instruments, and foundations;

100.2 Definitions

Some commonly used terms relating to piping are defined below. Terms related to welding generally agree with AWS A3.0. Some welding terms are defined with specified reference to piping. For welding terms used in this Code, but not shown here, definitions of AWS A3.0 apply.

anchor: a rigid restraint providing substantially full fixation, permitting neither translatory nor rotational displacement of the pipe.

annealing: see *heat treatments.*

arc welding: a group of welding processes wherein coalescence is produced by heating with an electric arc or arcs, with or without the application of pressure and with or without the use of filler metal.

assembly: the joining together of two or more piping components by bolting, welding, caulking, brazing, soldering, cementing, or threading into their installed location as specified by the engineering design.

automatic welding: welding with equipment which performs the entire welding operation without constant observation and adjustment of the controls by an operator. The equipment may or may not perform the loading and unloading of the work.

backing ring: backing in the form of a ring that can be used in the welding of piping.

ball joint: a component which permits universal rotational movement in a piping system.

base metal: the metal to be welded, brazed, soldered, or cut.

branch connection: the attachment of a branch pipe to the run of a main pipe with or without the use of fittings.

braze welding: a method of welding whereby a groove, fillet, plug, or slot weld is made using a nonferrous filler metal having a melting point below that of the base metals, but above 800°F (425°C). The filler metal is not distributed in the joint by capillary action. (Bronze welding, formerly used, is a misnomer for this term.)

brazing: a metal joining process wherein coalescence is produced by use of a nonferrous filler metal having a melting point above 800°F (425°C) but lower than that of the base metals joined. The filler metal is distributed between the closely fitted surfaces of the joint by capillary action.

butt joint: a joint between two members lying approximately in the same plane.

component: component as used in this Code is defined as consisting of but not limited to items such as pipe, piping subassemblies, parts, valves, strainers, relief devices, fittings, etc.

standard component: a component manufactured in accordance with one or more of the standards listed in Table 126.1.

specially designed component: a component designed in accordance with para. 104.7.2.

defect: a flaw (imperfection or unintentional discontinuity) of such size, shape, orientation, location, or properties as to be rejectable.

discontinuity: a lack of continuity or cohesion; an interruption in the normal physical structure of material or a product.

employer: the owner, manufacturer, fabricator, contractor, assembler, or installer responsible for the welding, brazing, and NDE performed by his organization including procedure and performance qualifications.

engineering design: the detailed design developed from process requirements and conforming to Code requirements, including all necessary drawings and specifications, governing a piping installation.

equipment connection: an integral part of such equipment as pressure vessels, heat exchangers, pumps, etc., designed for attachment of pipe or piping components.

erection: the complete installation of a piping system, including any field assembly, fabrication, testing, and inspection of the system.

examination: denotes the procedures for all nondestructive examination. Refer to para. 136.1 and the definition for visual examination.

expansion joint: a flexible piping component which absorbs thermal and/or terminal movement.

fabrication: primarily, the joining of piping components into integral pieces ready for assembly. It includes bending, forming, threading, welding, or other opera-

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tions upon these components, if not part of assembly. It may be done in a shop or in the field.

face of weld: the exposed surface of a weld on the side from which the welding was done.

filler metal: metal to be added in welding, soldering, brazing, or braze welding.

fillet weld: a weld of approximately triangular cross section joining two surfaces approximately at right angles to each other in a lap joint, tee joint, corner joint, or socket weld.

fire hazard: situation in which a material of more than average combustibility or explosibility exists in the presence of a potential ignition source.

flaw: an imperfection or unintentional discontinuity which is detectable by a nondestructive examination.

full fillet weld: a fillet weld whose size is equal to the thickness of the thinner member joined.

fusion: the melting together of filler metal and base metal, or of base metal only, which results in coalescence.

gas welding: a group of welding processes wherein coalescence is produced by heating with a gas flame or flames, with or without the application of pressure, and with or without the use of filler metal.

groove weld: a weld made in the groove between two members to be joined.

heat affected zone: that portion of the base metal which has not been melted, but whose mechanical properties or microstructure have been altered by the heat of welding or cutting.

heat treatments

annealing, full: heating a metal or alloy to a temperature above the critical temperature range and holding above the range for a proper period of time, followed by cooling to below that range. (A softening treatment is often carried out just below the critical range which is referred to as a subcritical anneal.)

normalizing: a process in which a ferrous metal is heated to a suitable temperature above the transformation range and is subsequently cooled in still air at room temperature.

postweld heat treatment: any heat treatment subsequent to welding.

preheating: the application of heat to a base metal immediately prior to a welding or cutting operation.

stress-relieving: uniform heating of a structure or portion thereof to a sufficient temperature to relieve the major portion of the residual stresses, followed by uniform cooling.

imperfection: a condition of being imperfect; a departure of a quality characteristic from its intended condition.

indication: the response or evidence from the application of a nondestructive examination.

inert gas metal arc welding: an arc welding process wherein coalescence is produced by heating with an electric arc between a metal electrode and the work. Shielding is obtained from an inert gas, such as helium or argon. Pressure may or may not be used and filler metal may or may not be used.

inspection: denotes verifying the performance of examination and tests by an Inspector.

joint design: the joint geometry together with the required dimensions of the welded joint.

joint penetration: the minimum depth of a groove weld extends from its face into a joint, exclusive of reinforcement.

low energy capacitor discharge welding: a resistance welding process wherein coalescence is produced by the rapid discharge of stored electric energy from a low voltage electrostatic storage system.

manual welding: welding wherein the entire welding operation is performed and controlled by hand.

maximum allowable stress: the maximum stress value that may be used in the design formulas for a given material and design temperature.

maximum allowable working pressure (MAWP): the pressure at the coincident temperature to which a boiler or pressure vessel can be subjected without exceeding the maximum allowable stress of the material or pressure-temperature rating of the equipment. For the purposes of this Code, the term MAWP is as defined in the ASME Boiler and Pressure Vessel Code, Sections I and VIII.

may: may is used to denote permission, neither a requirement nor a recommendation.

mechanical joint: a joint for the purpose of mechanical strength or leak resistance, or both, where the mechanical strength is developed by threaded, grooved, rolled, flared, or flanged pipe ends, or by bolts, pins, and compounds, gaskets, rolled ends, caulking, or machined

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and mated surfaces. These joints have particular application where ease of disassembly is desired.

miter: two or more straight sections of pipe matched and joined on a line bisecting the angle of junction so as to produce a change in direction.

nominal thickness: the thickness given in the product material specification or standard to which manufacturing tolerances are applied.

normalizing: see *heat treatments.*

oxygen cutting: a group of cutting processes wherein the severing of metals is effected by means of the chemical reaction of oxygen with the base metal at elevated temperatures. In the case of oxidation-resistant metals, the reaction is facilitated by use of a flux.

oxygen gouging: an application of oxygen cutting wherein a chamfer or groove is formed.

peening: the mechanical working of metals by means of hammer blows.

pipe and tube: the fundamental difference between pipe and tube is the dimensional standard to which each is manufactured.

A pipe is a tube with a round cross section conforming to the dimensional requirements for nominal pipe size as tabulated in ANSI B36.10, Tables 2 and 4, and ANSI B36.19, Table 1. For special pipe having a diameter not listed in these Tables, and also for round tube, the nominal diameter corresponds with the outside diameter.

A tube is a hollow product of round or any other cross section having a continuous periphery. Round tube size may be specified with respect to any two, but not all three, of the following: outside diameter, inside diameter, wall thickness; types K, L, and M copper tube may also be specified by nominal size and type only. Dimensions and permissible variations (tolerances) are specified in the appropriate ASTM or ASME standard specifications.

Types of pipe, according to the method of manufacture, are defined as follows:

(A) electric resistance welded pipe: pipe produced in individual lengths or in continuous lengths from coiled skelp and subsequently cut into individual lengths, having a longitudinal butt joint wherein coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which the pipe is a part, and by the application of pressure.

(B) furnace butt welded pipe

(B.1) furnace butt welded pipe, bell welded: pipe produced in individual lengths from cut length skelp, having its longitudinal butt joint forge welded by the mechanical pressure developed in drawing the furnace heated skelp through a cone shaped die (commonly known as a "welding bell") which serves as a combined forming and welding die.

(B.2) furnace butt welded pipe, continuous welded: pipe produced in continuous lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt joint forge welded by the mechanical pressure developed in rolling the hot formed skelp through a set of round pass welding rolls.

(C) electric fusion welded pipe: pipe having a longitudinal butt joint wherein coalescence is produced in the performed tube by manual or automatic electric arc welding. The weld may be single (welded from one side), or double (welded from inside and outside) and may be made with or without the use of filler metal. Spiral welded pipe is also made by the electric fusion welded process with either a butt joint, a lap joint, or a lock seam joint.

(D) electric flash welded pipe: pipe having a longitudinal butt joint wherein coalescence is produced, simultaneously over the entire area of abutting surfaces, by the heat obtained from resistance to the flow of electric current between the two surfaces, and by the application of pressure after heating is substantially completed. Flashing and upsetting are accompanied by expulsion of metal from the joint.

(E) double submerged arc welded pipe: pipe having a longitudinal butt joint produced by the submerged arc process, with at least two passes, one of which is on the inside of the pipe.

(F) seamless pipe: pipe produced by one or more of the following processes:

(F.1) rolled pipe: pipe produced from a forged billet which is pierced by a conical mandrel between two diametrically opposed rolls. The pierced shell is subsequently rolled and expanded over mandrels of increasingly larger diameter. Where closer dimensional tolerances are desired, the rolled pipe is cold or hot drawn through dies, and machined.

One variation of this process produces the hollow shell by extrusion of the forged billet over a mandrel in a vertical, hydraulic piercing press.

(F.2) forged and bored pipe: pipe produced by boring or trepanning of a forged billet.

(F.3) extruded pipe: pipe produced from hollow or solid round forgings, usually in a hydraulic extrusion press. In this process the forging is contained in a cylindrical die. Initially a punch at the end of the

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extrusion plunger pierces the forging. The extrusion plunger then forces the contained billet between the cylindrical die and the punch to form the pipe, the latter acting as a mandrel.

(F.4) centrifugally cast pipe: pipe formed from the solidification of molten metal in a rotating mold. Both metal and sand molds are used. After casting, the pipe is machined, to sound metal, on the internal and external diameters to the surface roughness and dimensional requirements of the applicable material specification.

One variation of this process utilizes autofrettage (hydraulic expansion) and heat treatment, above the recrystallization temperature of the material, to produce a wrought structure.

(F.5) statistically cast pipe: pipe formed by the solidification of molten metal in a sand mold.

pipe supporting elements: pipe supporting elements consist of hangers, supports, and structural attachments.

hangers and supports: hangers and supports include elements which transfer the load from the pipe or structural attachment to the supporting structure or equipment. They include hanging type fixtures, such as hanger rods, spring hangers, sway braces, counterweights, turnbuckles, struts, chains, guides, and anchors, and bearing type fixtures, such as saddles, bases, rollers, brackets, and sliding supports.

structural attachments: structural attachments include elements which are welded, bolted, or clamped to the pipe, such as clips, lugs, rings, clamps, clevises, straps, and skirts.

porosity: cavity-type discontinuities formed by gas entrapment during metal solidification.

postweld heat treatment: see *heat treatments.*

preheating: see *heat treatments.*

pressure: an application of force per unit area; fluid pressure (an application of internal or external fluid force per unit area on the pressure boundary of piping components).

Procedure Qualification Record (PQR): a record of the welding data used to weld a test coupon. The PQR is a record of variables recorded during the welding of the test coupons. It also contains the test results of the tested specimens. Recorded variables normally fall within a small range of the actual variables that will be used in production welding.

readily accessible: for visual examination, readily accessible inside surfaces are defined as those inside surfaces which can be examined without the aid of optical devices. (This definition does not prohibit the use of optical devices for a visual examination; however, the selection of the device should be a matter of mutual agreement between the owner and the fabricator or erector.)

Reid vapor pressure: the vapor pressure of a flammable or combustible liquid as determined by ASTM Standard Test Method D 323 Vapor Pressure of Petroleum Products (Reid Method).

reinforcement of weld: weld metal on the face of a groove weld in excess of the metal necessary for the specified weld size.

restraint: any device which prevents, resists, or limits movement of a piping system.

root opening: the separation between the members to be joined, at the root of the joint.

root penetration: the depth a groove weld extends into the root opening of a joint measured on the center line of the root cross section.

seal weld: a weld used on a pipe joint primarily to obtain fluid tightness as opposed to mechanical strength.

semiautomatic arc welding: arc welding with equipment which controls only the filler metal feed. The advance of the welding is manually controlled.

shall: "shall" or "shall not" is used to indicate that a provision or prohibition is mandatory.

shielded metal arc welding: an arc welding process wherein coalescence is produced by heating with an electric arc between a covered metal electrode and the work. Shielding is obtained from decomposition of the electrode covering. Pressure is not used and filler metal is obtained from the electrode.

should: "should" or "it is recommended" is used to indicate that a provision is not mandatory but recommended as good practice.

size of weld

groove weld: the joint penetration (depth of chamfering plus the root penetration when specified).

fillet weld: for equal leg fillet welds, the leg lengths of the largest isosceles right triangle which can be inscribed within the fillet weld cross section. For unequal leg fillet welds, the leg lengths of the largest right triangle which can be inscribed within the fillet weld cross section.

slag inclusion: nonmetallic solid material entrapped in weld metal or between weld metal and base metal.

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soldering: a metal joining process wherein coalescence is produced by heating to suitable temperature and by using a nonferrous alloy fusible at temperatures below 800°F (425°C) and having a melting point below that of the base metals being joined. The filler metal is distributed between closely fitted surfaces of the joint by capillary action. In general, solders are lead-tin alloys and may contain antimony, bismuth, silver, and other elements.

steel: an alloy of iron and carbon with no more than 2% carbon by weight. Other alloying elements may include manganese, sulfur, phosphorus, silicon, aluminum, chromium, copper, nickel, molybdenum, vanadium, and others depending upon the type of steel. For acceptable material specifications for steel refer to Chapter III, Materials.

stress-relieving: see *heat treatments.*

submerged arc welding: an arc welding process wherein coalescence is produced by heating with an electric arc or arcs between a bare metal electrode or electrodes and the work. The welding is shielded by a blanket of granular, fusible material on the work. Pressure is not used and filler metal is obtained from the electrode and sometimes from a supplementary welding rod.

supplementary steel: steel members which are installed between existing members for the purpose of installing supports for piping or piping equipment.

swivel joint: a component which permits single-plane rotational movement in a piping system.

tack weld: a weld made to hold parts of a weldment in proper alignment until the final welds are made.

throat of a fillet weld

theoretical: the distance from the beginning of the root of the joint perpendicular to the hypotenuse of the largest right triangle that can be inscribed within the fillet weld cross section.

actual: the shortest distance from the root of a fillet weld to its face.

toe of weld: the junction between the face of the weld and the base metal.

tube: refer to *pipe and tube.*

tungsten electrode: a nonfiller metal electrode used in arc welding, consisting of a tungsten wire.

undercut: a groove melted into the base metal adjacent to the toe of a weld and not filled with weld metal.

visual examination: the observation of whatever portions of components, joints, and other piping elements that are exposed to such observation either before, during, or after manufacture, fabrication, assembly, erection, inspection, or testing. This examination may include verification of the applicable requirements for materials, components, dimensions, joint preparation, alignment, welding or joining, supports, assembly, and erection.

weld: a localized coalescence of metal which is produced by heating to suitable temperatures, with or without the application of pressure, and with or without the use of filler metal. The filler metal shall have a melting point approximately the same as the base metal.

welder: one who is capable of performing a manual or semiautomatic welding operation.

Welder/Welding Operator Performance Qualification (WPQ): demonstration of a welder's ability to produce welds in a manner described in a welding procedure specification that meets prescribed standards.

welding operator: one who operates machine or automatic welding equipment.

Welding Procedure Specification (WPS): a written qualified welding procedure prepared to provide direction for making production welds to Code requirements. The WPS or other documents may be used to provide direction to the welder or welding operator to assure compliance with the Code requirements.

weldment: an assembly whose component parts are joined by welding.

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CHAPTER II
DESIGN

PART 1
CONDITIONS AND CRITERIA

101 DESIGN CONDITIONS

101.1 General

These design conditions define the pressures, temperatures and various forces applicable to the design of power piping systems. Power piping systems shall be designed for the most severe condition of coincident pressure, temperature and loading, except as herein stated. The most severe condition shall be that which results in the greatest required pipe wall thickness and the highest flange rating.

101.2 Pressure

All pressures referred to in this Code are expressed in pounds per square inch and kilopascals above atmospheric pressure, i.e., psig [kPa (gage)], unless otherwise stated.

101.2.2 Internal Design Pressure. The internal design pressure shall be not less than the maximum sustained operating pressure (MSOP) within the piping system including the effects of static head.

101.2.4 External Design Pressure. Piping subject to external pressure shall be designed for the maximum differential pressure anticipated during operating, shutdown, or test conditions.

101.3 Temperature

101.3.1 All temperatures referred to in this Code, unless otherwise stated, are the average metal temperatures of the respective materials expressed in degrees Fahrenheit, i.e., °F (Celsius, i.e., °C).

101.3.2 Design Temperature

(A) The piping shall be designed for a metal temperature representing the maximum sustained condition expected. The design temperature shall be assumed to be the same as the fluid temperature unless calculations or tests support the use of other data, in which case the design temperature shall not be less than the average of the fluid temperature and the outside wall temperature.

(B) Where a fluid passes through heat exchangers in series, the design temperature of the piping in each section of the system shall conform to the most severe temperature condition expected to be produced by the heat exchangers in that section of the system.

(C) For steam, feedwater, and hot water piping leading from fired equipment (such as boiler, reheater, superheater, economizer, etc.), the design temperature shall be based on the expected continuous operating condition plus the equipment manufacturers guaranteed maximum temperature tolerance. For operation at temperatures in excess of this condition, the limitations described in para. 102.2.4 shall apply.

(D) Accelerated creep damage, leading to excessive creep strains and potential pipe rupture, caused by extended operation above the design temperature shall be considered in selecting the design temperature for piping to be operated above 800°F.

101.4 Ambient Influences

101.4.1 Cooling Effects on Pressure. Where the cooling of a fluid may reduce the pressure in the piping to below atmospheric, the piping shall be designed to withstand the external pressure or provision shall be made to break the vaccum.

101.4.2 Fluid Expansion Effects. Where the expansion of a fluid may increase the pressure, the piping system shall be designed to withstand the increased pressure or provision shall be made to relieve the excess pressure.

101.5 Dynamic Effects

101.5.1 Impact. Impact forces caused by all external and internal conditions shall be considered in the piping design. One form of internal impact force is due to the propagation of pressure waves produced by sudden changes in fluid momentum. This phenomena is often called water or steam "hammer." It may be caused by the rapid opening or closing of a valve in the system.

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The designer should be aware that this is only one example of this phenomena and that other causes of impact loading exist.

101.5.2 Wind. Exposed piping shall be designed to withstand wind loadings, using meteorological data to determine wind forces. Where state or municipal ordinances covering the design of building structures are in effect and specify wind loadings, these values shall be considered the minimum design values.

101.5.3 Earthquake. The effect of earthquakes, where applicable, shall be considered in the design of piping, piping supports, and restraints, using data for the site as a guide in assessing the forces involved. However, earthquakes need not be considered as acting concurrently with wind.

101.5.4 Vibration. Piping shall be arranged and supported with consideration of vibration (see paras. 120.1(c) and 121.7.5).

101.6 Weight Effects

The following weight effects combined with loads and forces from other causes shall be taken into account in the design of piping. Piping shall be carried on adjustable hangers or properly leveled rigid hangers or supports, and suitable springs, sway bracing, vibration dampeners, etc., shall be provided where necessary.

101.6.1 Live Load. The live load consists of the weight of the fluid transported. Snow and ice loads shall be considered in localities where such conditions exist.

101.6.2 Dead Load. The dead load consists of the weight of the piping components, insulation, protective lining and coating, and other superimposed permanent loads.

101.6.3 Test or Cleaning Fluid Load. The test or cleaning fluid load consists of the weight of the test or cleaning fluid.

101.7 Thermal Expansion and Contraction Loads

101.7.1 General. The design of piping systems shall take account of the forces and moments resulting from thermal expansion and contraction, and from the effects of expansion joints.

Thermal expansion and contraction shall be provided for preferably by pipe bends, elbows, offsets or changes in direction of the pipeline.

Hangers and supports shall permit expansion and contraction of the piping between anchors.

101.7.2 Expansion, Swivel, or Ball Joints, and Flexible Metal Hose Assemblies. Joints of the corrugated bellows, slip, sleeve, ball, or swivel types and flexible metal hose assemblies may be used if their materials conform to this Code, their structural and working parts are of ample proportions, and their design prevents the complete disengagement of working parts while in service. However, flexible metal hose assemblies, and expansion joints of the corrugated bellows, slip, or sleeve type shall not be used in any piping system connecting the boiler and the first stop valve in that system.

102 DESIGN CRITERIA

102.1 General

These criteria cover pressure-temperature ratings for standard and specially designed components, allowable stresses, stress limits, and various allowances to be used in the design of piping and piping components.

102.2 Pressure-Temperature Ratings for Piping Components

102.2.1 Components Having Specific Ratings. Pressure-temperature ratings for certain piping components have been established and are contained in some of the standards listed in Table 126.1.

Where piping components have established pressure-temperature ratings which do not extend to the upper material temperature limits permitted by this Code, the pressure-temperature ratings between those established and the upper material temperature limit may be determined in accordance with the rules of this Code, but such extensions are subject to restrictions, if any, imposed by the standards.

Standard components may not be used at conditions of pressure and temperature which exceed the limits imposed by this Code.

102.2.2 Components Not Having Specific Ratings. Some of the Standards listed in Table 126.1, such as those for buttwelding fittings, specify that components shall be furnished in nominal thicknesses. Unless limited elsewhere in this Code, such components shall be rated

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for the same allowable pressures as seamless pipe of the same nominal thickness, as determined in paras. 103 and 104 for material having the same allowable stress.

Piping components, such as pipe, for which allowable stresses have been developed in accordance with para. 102.3, but which do not have established pressure ratings, shall be rated by rules for pressure design in para. 104, modified as applicable by other provisions of this Code.

Should it be desired to use methods of manufacture or design of components not covered by this Code or not listed in referenced standards, it is intended that the manufacturer shall comply with the requirements of paras. 103 and 104 and other applicable requirements of this Code for design conditions involved. Where components other than those discussed above, such as pipe or fittings not assigned pressure-temperature ratings in an American National Standard, are used, the manufacturer's recommended pressure-temperature rating shall not be exceeded.

102.2.3 Ratings: Normal Operating Condition. A piping system shall be considered safe for operation if the maximum sustained operating pressure and temperature which may act on any part or component of the system does not exceed the maximum pressure and temperature allowed by this Code for that particular part or component. The design pressure and temperature shall not exceed the pressure-temperature rating for the particular component and material as defined in the applicable specification or standard listed in Table 126.1.

102.2.4 Ratings: Allowance for Variation From Normal Operation. The maximum internal pressure and temperature allowed shall include considerations for occasional loads and transients of pressure and temperature.

It is recognized that variations in pressure and temperature inevitably occur, and therefore the piping system, except as limited by component standards referred to in para. 102.2.1 or by manufacturers of components referred to in para. 102.2.2, shall be considered safe for occasional short operating periods at higher than design pressure or temperature. For such variations, either pressure or temperature, or both, may exceed the design values if the computed circumferential pressure stress does not exceed the maximum allowable stress from Appendix A for the coincident temperature by:

(A) 15% if the event duration occurs for no more than 8 hr at any one time and no more than 800 hr/year; or

(B) 20% if the event duration occurs for no more than 1 hr at any one time and no more than 80 hr/year.

102.2.5 Ratings at Transitions. Where piping systems operating at different design conditions are connected, a division valve shall be provided having a pressure-temperature rating equal to or exceeding the more severe conditions. See para. 122 for design requirements pertaining to specific piping systems.

102.3 Allowable Stress Values and Other Stress Limits for Piping Components

102.3.1 Allowable Stress Values

(A) Allowable stress values to be used for the design of power piping systems are given in the Tables in Appendix A, also referred to in this Code Section as the Allowable Stress Tables. These Tables list allowable stress values for commonly used materials at temperatures appropriate to power piping installations. In every case the temperature is understood to be the metal temperature. Where applicable, weld joint efficiency factors and casting quality factors are included in the tabulated values. Thus, the tabulated values are values of *S*, *SE*, or *SF*, as applicable.

(B) Allowable stress values in shear shall not exceed 80% of the values determined in accordance with the rules of para. 102.3.1(A). Allowable stress values in bearing shall not exceed 160% of the determined values.

(C) The basis for establishing the allowable stress values in this Code Section are the same as those in the ASME Boiler and Pressure Vessel Code, Section II, Part D, Appendix 1; except that allowable stresses for cast iron and ductile iron are in accordance with Section VIII, Division 1, Appendix P for Tables UCI-23 and UCD-23, respectively.

102.3.2 Limits of Calculated Stresses Due to Sustained Loads and Thermal Expansion

(A) Internal Pressure Stress. The calculated stress due to internal pressure shall not exceed the allowable stress values given in the Allowable Stress Tables in Appendix A. This criterion is satisfied when the wall thickness of the piping component, including any reinforcement, meets the requirements of para. 104.1 through 104.7, excluding para. 104.1.3 but including the consideration of allowances permitted by paras. 102.2.4, 102.3.3(B), and 102.4.

(B) External Pressure Stress. Piping subject to external pressure shall be considered safe when the wall thickness and means of stiffening meet the requirements of para. 104.1.3.

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TABLE 102.3.2(C)
STRESS RANGE REDUCTION FACTORS

Number of Equivalent Full Temperature Cycles N	f
7,000 and less	1.0
7,000–14,000	0.9
14,000–22,000	0.8
22,000–45,000	0.7
45,000–100,000	0.6
100,000 and over	0.5

(C) Allowable Stress Range for Expansion Stresses. Except as permitted in para. 102.3.2(D), the thermal expansion stress range S_E (see paras. 104.8.3 and 119.6.4) shall not exceed the allowable stress range S_A given by the following formula:

$$S_A = f(1.25S_c + 0.25S_h) \quad (1)$$

where

S_c = basic material allowable stress at minimum (cold) temperature from the Allowable Stress Tables

S_h = basic material allowable stress at maximum (hot) temperature from the Allowable Stress Tables

f = stress range reduction factor for cyclic conditions for total number N of full temperature cycles over total number of years during which system is expected to be in operation, from Table 102.3.2(C)

In determining the basic material allowable stresses, S_c and S_h, joint efficiencies need not be applied. The values of allowable stress in the Allowable Stress Tables for welded pipe may be divided by the weld joint factors listed in para. 102.4.3.

Stress reduction factors apply essentially to noncorrosive service and to corrosion resistant materials where employed to minimize the reduction in cyclic life caused by corrosive action.

If the range of temperature change varies, equivalent full temperature cycles may be computed as follows:

$$N = N_E + r_1^5 N_1 + r_2^5 N_2 + \ldots + r_n^5 N_n \quad (2)$$

where

N_E = number of cycles at full temperature change ΔT_E for which expansion stress S_E has been calculated

$N_1, N_2, \ldots, N_n$ = number of cycles at lesser temperature changes $\Delta T_1, \Delta T_2, \ldots, \Delta T_n$

$r_1, r_2, \ldots, r_n$ = ratio of lesser temperature cycles to that for any which the expansion stress S_E has been calculated = $\Delta T_1/\Delta T_E, \Delta T_2/\Delta T_E, \ldots, \Delta T_n/\Delta T_E$

(D) Longitudinal Stresses. The sum of the longitudinal stresses S_L due to pressure, weight, and other sustained loads shall not exceed the allowable stress in the hot condition S_h. Where the sum of these stresses is less than S_h, the difference may be used as an additional thermal expansion allowance, which is the second term on the right side of Eq. (13) of para. 104.8.3.

The longitudinal pressure stress S_{lp} shall be determined by either of the following equations:

$$S_{lp} = \frac{PD_o}{4t_n}$$

or

$$S_{lp} = \frac{Pd_n^2}{D_n^2 - d_n^2}$$

102.3.3 Limits of Calculated Stresses due to Occasional Loads

(A) During Operation. The sum of the longitudinal stresses produced by internal pressure, live and dead loads and those produced by occasional loads, such as the temporary supporting of extra weight, may exceed the allowable stress values given in the Allowable Stress Tables by the amounts and durations of time given in para. 104.8.2.

(B) During Test. During pressure tests performed in accordance with para. 137, the circumferential (hoop) stress shall not exceed 90% of the yield strength (0.2% offset) at test temperature. In addition, the sum of longitudinal stresses due to test pressure and live and dead loads at the time of test, excluding occasional loads, shall not exceed 90% of the yield strength at test temperature.

102.4 Allowances

102.4.1 Corrosion or Erosion. When corrosion or erosion is expected, an increase in wall thickness of the piping shall be provided over that required by other

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design requirements. This allowance in the judgment of the designer shall be consistent with the expected life of the piping.

102.4.2 Threading and Grooving. The calculated minimum thickness of piping (or tubing) which is to be threaded shall be increased by an allowance equal to thread depth; dimension h of ASME B1.20.1 or equivalent shall apply. For machined surfaces or grooves, where the tolerance is not specified, the tolerance shall be assumed to be $\frac{1}{64}$ in. (0.40 mm) in addition to the specified depth of cut. The requirements of para. 104.1.2(C) shall also apply.

102.4.3 Weld Joint Efficiency Factors. The use of joint efficiency factors for welded pipe is required by this Code. The factors in Table 102.4.3 are based on full penetration welds. These factors are included in the allowable stress values given in Appendix A. The factors in Table 102.4.3 apply to both straight seam and spiral seam welded pipe.

102.4.4 Mechanical Strength. Where necessary for mechanical strength to prevent damage, collapse, excessive sag, or buckling of pipe due to superimposed loads from supports or other causes, the wall thickness of the pipe should be increased; or, if this is impractical or would cause excessive local stresses, the superimposed loads or other causes shall be reduced or eliminated by other design methods. The requirements of para. 104.1.2(C) shall also apply.

102.4.5 Bending. The minimum wall thickness at any point in a completed bend shall not be less than required by Formulas (3) or (3A) of para. 104.1.2(A).

(A) Table 102.4.5 is a guide to the designer who must specify wall thickness for ordering pipe. In general it has been the experience that when good shop practices are employed, the minimum thicknesses of straight pipe shown in Table 102.4.5 should be sufficient for bending, and still meet the minimum thickness requirements of para. 104.1.2(A).

(B) The bend thinning allowance in Table 102.4.5 may be provided in all parts of the cross section of the pipe circumference without any detrimental effects being produced.

102.4.6 Casting Quality Factors

(A) General. The use of a casting quality factor is required for all cast components which use the allowable stress values of Appendix A as the design basis. A factor of 0.80 is included in the allowable stress values for all castings given in Appendix A.

This required factor does not apply to component standards listed in Table 126.1, if such standards define allowable pressure-temperature ratings or provide the allowable stresses to be used as the design basis for the component.

(B) For steel materials, a casting quality factor not exceeding 1.0 may be applied when the following requirements are met.

(B.1) All steel castings having a nominal body thickness of $4\frac{1}{2}$ in. (114 mm) or less (other than pipe flanges, flanged valves and fittings, and butt welding end valves, all complying with ASME B16.5 or B16.34) shall be inspected as follows.

(B.1.1) All critical areas, including the junctions of all gates, risers, and abrupt changes in section or direction and area of weld end preparation shall be radiographed in accordance with Article 2 of Section V of the ASME Boiler and Pressure Vessel Code, and the radiographs shall conform to the requirements of ASTM E 446 Reference Radiographs for Steel Castings up to 2 in. (50 mm) in Thickness or E 186 Reference Radiographs for Heavy Walled [2 to $4\frac{1}{2}$ in. (50 to 114 mm)] Steel Castings, depending upon the section thickness. The maximum acceptable severity level for a 1.0 quality factor shall be as listed in Table 102.4.6(B.1.1).

(B.1.2) All surfaces of each casting, including machined gasket seating surfaces, shall be examined by the magnetic particle or dye penetrant method after heat treatment. The examination techniques shall be in accordance with Article 6 or 7, as applicable, and Article 9 of Section V of the ASME Boiler and Pressure Vessel Code. Magnetic particle or dye penetrant indications exceeding degree 1 of Type I, degree 2 of Type II, and degree 3 of Type III, and exceeding degree 1 of Types IV and V of ASTM E 125, Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings, are not acceptable and shall be removed.

(B.1.3) Where more than one casting of a particular design is produced, each of the first five castings shall be inspected as above. Where more than five castings are being produced, the examination shall be performed on the first five plus one additional casting to represent each five additional castings. If this additional casting proves to be unacceptable, each of the remaining castings in the group shall be inspected.

(B.1.4) Any discontinuities in excess of the maximum permitted in (B.1.1) and (B.1.2) above shall be removed, and the casting may be repaired by welding after the base metal has been inspected to assure complete removal of discontinuities. [Refer to para. 127.4.11(A).] The completed repair shall be subject to

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TABLE 102.4.3
LONGITUDINAL WELD JOINT EFFICIENCY FACTORS

No.	Type of Joint	Type of Seam	Examination	Factor *E*
1	Furnace butt weld, continuous weld	Straight	As required by listed specification	0.60 [Note (1)]
2	Electric resistance weld	Straight or spiral	As required by listed specification	0.85 [Note (1)]
3	Electric fusion weld			
	(a) Single butt weld (without filler metal)	Straight or spiral	As required by listed specification	0.85
			Additionally 100% radiographed	1.00 [Note (2)]
	(b) Single butt weld (with filler metal)	Straight or spiral	As required by listed specification	0.80
			Additionally 100% radiographed	1.00 [Note (2)]
	(c) Double butt weld (without filler metal)	Straight or spiral	As required by listed specification	0.90
			Additionally 100% radiographed	1.00 [Note (2)]
	(d) Double butt weld (with filler metal)	Straight or spiral	As required by listed specification	0.90
			Additionally 100% radiographed	1.00 [Note (2)]
4	API 5L Submerged arc weld (SAW) Gas metal arc weld (GMAW) Combined GMAW, SAW	Straight with one or two seams Spiral	As required by specification	0.90
			Additionally 100% radiographed	1.00 [Note (2)]

NOTES:
(1) It is not permitted to increase the longitudinal weld joint efficiency factor by additional examination for joint 1 or 2.
(2) Radiography shall be in accordance with the requirements of para. 136.4.5 or the material specification as applicable.

reinspection by the same method as was used in the original inspection and shall be reinspected after any required postweld heat treatment.

(B.2) All steel castings having a nominal body thickness greater than 4½ in. (114 mm) (other than pipe flanges, flanged valves and fittings, and butt welding end valves, all complying with ASME B16.5 or B16.34) shall be inspected as follows.

(B.2.1) All surfaces of each casting including machined gasket seating surfaces, shall be examined by the magnetic particle or dye penetrant method after heat treatment. The examination techniques shall be in accordance with Article 6 or 7, as applicable, and with Article 9 of Section V of the ASME Boiler and Pressure Vessel Code. Magnetic particle or dye penetrant indications exceeding degree 1 of Type I, degree 2 of Type II, and degree 3 of Type III and exceeding degree 1 of Types IV and V of ASTM E 125, Standard Reference

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TABLE 102.4.5

Radius of Bends	Min. Thickness Recommended Prior to Bending
6 pipe diameters or greater	$1.06t_m$
5 pipe diameters	$1.08t_m$
4 pipe diameters	$1.14t_m$
3 pipe diameters	$1.25t_m$

GENERAL NOTES:
(a) Interpolation is permissible for bending to intermediate radii.
(b) t_m is determined by Formula (3) or (3A) of para. 104.1.2(A).
(c) Pipe diameter is the nominal diameter as tabulated in ASME B36.10M, Tables 2 and 4, and ASME B36.19M, Table 1. For piping with a diameter not listed in these Tables, and also for tubing, the nominal diameter corresponds with the outside diameter.

Photographs for Magnetic Particle Indications on Ferrous Castings, shall be removed.

(B.2.2) All parts of castings shall be subjected to complete radiographic inspection in accordance with Article 2 of Section V of the ASME Boiler and Pressure Vessel Code, and the radiographs shall conform to the requirements of ASTM E 280, Reference Radiographs for Heavy Walled [4½ to 12 in. (114 to 305 mm)] Steel Castings.

The maximum acceptable severity level for a 1.0 quality factor shall be as listed in Table 102.4.6 (B.2.2).

(B.2.3) Any discontinuities in excess of the maximum permitted in (B.2.1) and (B.2.2) above shall be removed and may be repaired by welding after the base metal has been magnetic particle or dye penetrant inspected to assure complete removal of discontinuities. [Refer to para. 127.4.11(A).]

(B.2.4) All weld repairs of depth exceeding 1 in. (25 mm) or 20% of the section thickness, whichever is the lesser, shall be inspected by radiography in accordance with (B.2.2) above and by magnetic particle or dye penetrant inspection of the finished weld surface. All weld repairs of depth less than 20% of the section thickness, or 1 in. (25 mm), whichever is the lesser, and all weld repairs of section which cannot be effectively radiographed shall be examined by magnetic particle or dye penetrant inspection of the first layer, of each ¼ in. (6 mm) thickness of deposited weld metal, and of the finished weld surface. Magnetic particle or dye penetrant testing of the finished weld surface shall be done after postweld heat treatment.

(C) For cast iron and nonferrous materials, no increase of the casting quality factor is allowed except when special methods of examination, prescribed by the material specification, are followed. If such increase is specifically permitted by the material specification, a factor not exceeding 1.0 may be applied.

PART 2
PRESSURE DESIGN OF PIPING COMPONENTS

103 CRITERIA FOR PRESSURE DESIGN OF PIPING COMPONENTS

The design of piping components shall consider the effects of pressure and temperature, in accordance with paras. 104.1 through 104.7, including the consideration of allowances permitted by paras. 102.2.4 and 102.4. In addition, the mechanical strength of the piping system shall be determined adequate in accordance with para. 104.8 under other applicable loadings, including but not limited to those loadings defined in para. 101.

104 PRESSURE DESIGN OF COMPONENTS

104.1 Straight Pipe

104.1.2 Straight Pipe Under Internal Pressure

(A) Minimum Wall Thickness. The minimum thickness of pipe wall required for design pressures and for temperatures not exceeding those for the various materials listed in the Allowable Stress Tables, including allowances for mechanical strength, shall not be less than that determined by Formula (3) or (3A), as follows:

$$t_m = \frac{PD_o}{2(SE + Py)} + A \qquad (3)^1$$

$$t_m = \frac{Pd + 2SEA + 2yPA}{2(SE + Py - P)} \qquad (3A)^1$$

Design pressure shall not exceed

$$P = \frac{2SE(t_m - A)}{D_o - 2y(t_m - A)} \qquad (4)^1$$

$$P = \frac{2SE(t_m - A)}{d - 2y(t_m - A) + 2t_m} \qquad (4A)^1$$

[1] *SF* shall be used in place of *SE* where casting quality factors are intended. See definition of *SE*. Units of *P* and *SE* must be identical. Appendix A values must be converted to kPa when the design pressure is in kPa.

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TABLE 102.4.6(B.1.1)

Discontinuity Category Designation	Severity Level ≤1 in. (25 mm) Thick	Severity Level >1 in. (25 mm) Thick
For E 446 [Castings up to 2 in. (50 mm) Thickness]		
A	1	2
B	2	3
C Types 1, 2, 3, and 4	1	3
D, E, F, and G	None acceptable	None acceptable

Discontinuity Category Designation	Severity Level
For E 186 [Castings 2 to 4½ in. (50 to 114 mm) Thickness]	
A, B, and Types 1 and 2 of C	2
Type 3 of C	3
D, E, and F	None acceptable

TABLE 102.4.6(B.2.2)

Discontinuity Category Designation	Severity Level
A, B, and Types 1,2, and 3 of C	2
D, E, and F	None acceptable

where the nomenclature used above are:

(A.1) t_m = minimum required wall thickness, in. (mm)

(A.1.1) If pipe is ordered by its nominal wall thickness, the manufacturing tolerance on wall thickness must be taken into account. After the minimum pipe wall thickness t_m is determined by Formula (3) or (3A), this minimum thickness shall be increased by an amount sufficient to provide the manufacturing tolerance allowed in the applicable pipe specification or required by the process. The next heavier commercial wall thickness shall then be selected from thickness schedules such as contained in ASME B36.10M or from manufacturers' schedules for other than standard thickness.

(A.1.2) To compensate for thinning in bends, refer to para. 102.4.5.

(A.1.3) For cast piping components, refer to para. 102.4.6.

(A.1.4) Where ends are subject to forming or machining for jointing, the wall thickness of the pipe, tube, or component after such forming or machining shall not be less than t_m minus the amount provided for removal by para. 104.1.2 (A.6.1).

(A.2) P = internal design pressure, psig [kPa (gage)]

NOTE: When computing the design pressure for a pipe of a definite minimum wall thickness by Formula (4) or (4A), the value of P obtained by these Formulas may be rounded out to the next higher unit of 10. For cast iron pipe, see para. 104.1.2(B).

(A.3) D_o = outside diameter of pipe, in. (mm). For design calculations, the outside diameter of pipe as given in tables of standards and specifications shall be used in obtaining the value of t_m. When calculating the allowable working pressure of pipe on hand or in stock, the actual measured outside diameter and actual measured minimum wall thickness at the thinner end of the pipe may be used to calculate this pressure.

(A.4) d = inside diameter of pipe, in. (mm). For design calculations, the inside diameter of pipe is the maximum possible value allowable under the purchase specification. When calculating the allowable working pressure of pipe on hand or in stock, the actual measured inside diameter and actual measured minimum wall thickness at the thinner end of the pipe may be used to calculate this pressure.

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TABLE 104.1.2(A)
VALUES OF y

Temperature, °F	900 and Below	950	1000	1050	1100	1150	1200	1250 and Above
Temperature, °C	482 and Below	510	538	566	593	621	649	677 and Above
Ferritic steels	0.4	0.5	0.7	0.7	0.7	0.7	0.7	0.7
Austenitic steels	0.4	0.4	0.4	0.4	0.5	0.7	0.7	0.7
Nickel Alloys UNS Nos. N08800, N08810, N08825	0.4	0.4	0.4	0.4	04	0.4	0.5	0.7

GENERAL NOTES:

(a) The value of y may be interpolated between the 50°F (27.8°C) values shown in the Table. For cast iron and nonferrous materials, y equals 0.4.

(b) For pipe with a D_o/t_m ratio less than 6, the value of y for ferritic and austenitic steels designed for temperatures of 900°F (480°C) and below shall be taken as:

$$y = \frac{d}{d + D_o} \quad (5)$$

(A.5) SE or *SF* = maximum allowable stress in material due to internal pressure and joint efficiency (or casting quality factor) at the design temperature, psi (kPa). The value of *SE* or *SF* shall not exceed that given in Appendix A, for the respective material and design temperature. These values include the weld joint efficiency *E*, or the casting factor *F*.

(A.6) A = additional thickness, in. (mm):

(A.6.1) to compensate for material removed in threading, grooving, etc., required to make a mechanical joint, refer to para. 102.4.2;

(A.6.2) to provide for mechanical strength of the pipe, refer to para. 102.-4.4 (not intended to provide for extreme conditions of misapplied external loads or for mechanical abuse);

(A.6.3) to provide for corrosion and/or erosion, refer to para. 102.4.1;

(A.6.4) for cast iron pipe the following values of *A* shall apply:

Centrifugally cast . . . . . 0.14 in. (3.56 mm)
Statically cast . . . . . 0.18 in. (4.57 mm)

(A.7) y = coefficient having values as given in Table 104.1.2(A)

(B) The thickness of gray and ductile iron pipe and fittings conveying liquids may be determined from ANSI/AWWA C110/A21.10, ANSI/AWWA C115/A21.15, ANSI/AWWA C150/A21.50, ANSI/AWWA C151/A21.51, or Federal Specification WW-P-421, using the class of pipe for the pressure next higher than the desired internal design pressure in psi (kPa). These thickness include allowances for foundry tolerances and water hammer. Where the thickness of ductile iron pipe for liquid service is calculated, the methods of ANSI/AWWA C115/A21.15, or ANSI/AWWA C150/A21.50 may be used.

Where cast gray and ductile iron pipe is used for steam service, the thickness shall be calculated in accordance with Formula (3) or (3A) using the allowable stress value from the Allowable Stress Tables.

(C) While the thickness determined from Formula (3) or (3A) are theoretically ample for both bursting pressure and material removed in threading, the following minimum requirements are mandatory to furnish added mechanical strength.

(C.1) Where steel pipe is threaded and used for steam service at pressure above 250 psi (1750 kPa) or for water service above 100 psi (700 kPa) with water temperature above 220°F (105°C), the pipe shall be seamless having the minimum ultimate tensile strength of 48,000 psi (330 MPa) and a weight at least equal to Schedule 80 of ASME B36.10M. 01

(C.2) Where threaded brass or copper pipe is used for the services described in (C.1) above, it shall comply with pressure and temperature classifications permitted for these materials by other paragraphs of this Code and shall have a wall thickness at least equal to that specified above for steel pipe of corresponding size.

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(C.3) Plain end nonferrous pipe or tube shall have minimum wall thicknesses as follows.

For nominal sizes smaller than NPS $^3/_4$, the thickness shall not be less than that specified for Type K of ASTM B 88.

For nominal sizes NPS $^3/_4$ and larger, the wall thickness shall not be less than 0.049 in. (1.25 mm). The wall thickness shall be further increased, as required, in accordance with para. 102.4.

104.1.3 Straight Pipe Under External Pressure. For determining wall thickness and stiffening requirements for straight pipe under external pressure, the procedures outlined in UG-28, UG-29, and UG-30 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code shall be followed.

104.2 Curved Segments of Pipe

104.2.1 Pipe Bends. Pipe bends shall be subject to the following limitations.

(A) The minimum wall thickness shall meet the requirements of para. 102.4.5 and the fabrication requirements of para. 129.

(B) For ferrous material, when the radius of a bend is 5 nominal pipe diameters or greater, and the nominal wall thickness of the pipe is schedule 40 or thicker, the difference between maximum and minimum diameters shall not exceed 8% of average measured outside diameter of the pipe before bending.

(C) Greater flattening may be permitted or less flattening may be required by the design, depending upon the service, the material, and the stress level involved.

104.2.2 Elbows. Elbows manufactured in accordance with the standards listed in Table 126.1 are suitable for use at the pressure-temperature ratings specified by such standards, subject to the requirements of para. 106.

104.3 Intersections

104.3.1 Branch Connections

(A) This paragraph gives rules governing the design of branch connections to sustain internal and external pressure in cases where the axes of the branch and the run intersect, and the angle between the axes of the branch and of the run is between 45 deg and 90 deg, inclusive.

Branch connections in which the smaller angle between the axes of the branch and the run is less than 45 deg or branch connections where the axes of the branch and the run do not intersect impose special design and fabrication problems. The rules given herein may be used as a guide, but sufficient additional strength must be provided to assure safe service. Such branch connections shall be designed to meet the requirement of para. 104.7.

(B) Branch connections in piping may be made from materials listed in Appendix A by the use of the following:

(B.1) fittings, such as tees, laterals, and crosses made in accordance with the applicable standards listed in Table 126.1 where the attachment of the branch pipe to the fitting is by butt welding, socket welding, brazing, soldering, threading, or by a flanged connection;

(B.2) weld outlet fittings, such as cast or forged nozzles, couplings and adaptors, or similar items where the attachment of the branch pipe to the fitting is by butt welding, socket welding, threading, or by a flanged connection. Such weld outlet fittings are attached to the run by welding similar to that shown in Fig. 127.4.8(E). Couplings are restricted to a maximum of NPS 3.

(B.3) extruded outlets at right angles to the run pipe, in accordance with (G) below, where the attachment of the branch pipe is by butt welding;

(B.4) piping directly attached to the run pipe by welding in accordance with para. 127.4.8 or by socket welding or threading as stipulated below:

(B.4.1) socket welded right angle branch connections may be made by attaching the branch pipe directly to the run pipe provided:

(B.4.1.1) the nominal size of the branch does not exceed NPS 2 or one-fourth of the nominal size of the run, whichever is smaller;

(B.4.1.2) the depth of the socket measured at its minimum depth in the run pipe is at least equal to that shown in ASME B16.11. If the run pipe wall does not have sufficient thickness to provide the proper depth of socket, an alternate type of construction shall be used.

(B.4.1.3) the clearance between the bottom of the socket and the end of the inserted branch pipe is in accordance with Fig. 127.4.4(C);

(B.4.1.4) the size of the fillet weld is not less than 1.09 times the nominal wall thickness of the branch pipe.

(B.4.2) threaded right angle branch connections may be made by attaching the branch pipe directly to the run provided:

(B.4.2.1) the nominal size of the branch does not exceed NPS 2 or one-fourth of the nominal size of the run whichever is smaller;

(B.4.2.2) the minimum thread engagement is: 6 full threads for NPS $^1/_2$ and NPS $^3/_4$ branches; 7 for NPS 1, NPS $1^1/_4$, and NPS $1^1/_2$ branches; and 8 for NPS 2

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branches. If the run pipe wall does not have sufficient thickness to provide the proper depth for thread engagement, an alternative type of construction shall be used.

(C) Branch Connections Not Requiring Reinforcement. A pipe having a branch connection is weakened by the opening that must be made in it. Unless the wall thickness of the branch and/or run pipe is sufficiently in excess of that required to sustain the pressure, it is necessary to provide additional material in order to meet the reinforcement requirements of (D) and (E) below. However, there are certain branch connections for which supporting calculations are not required. These are as follows:

(C.1) branch connections made by the use of a fitting (tee, lateral, cross, or branch weld-on fitting), manufactured in accordance with a standard listed in Table 126.1, and used within the limits of pressure-temperature ratings specified in that standard;

(C.2) branch connections made by welding a coupling or half coupling directly to the run pipe in accordance with Fig. 127.4.8(E) provided the nominal diameter of the branch does not exceed NPS 2 or one-fourth the nominal diameter of the run, whichever is less. The minimum wall thickness of the coupling anywhere in the reinforcement zone (if threads are in the zone, wall thickness is measured from the root of the thread to the minimum O.D.) shall not be less than that of the unthreaded branch pipe. In no case shall the thickness of the coupling be less than extra heavy or Class 3000 rating.

Small branch connections NPS 2 or smaller as shown in Fig. 127.4.8(F) may be used provided t_w is not less than the thickness of schedule 160 pipe of the branch size.

(C.3) integrally reinforced fittings welded directly to the run pipe when the reinforcements provided by the fitting and the deposited weld metal meets the requirements of (D) below.

(C.4) integrally reinforced extruded outlets in the run pipe. The reinforcement requirements shall be in accordance with (G) below.

(D) Branch Connections Subject to Internal Pressure Requiring Reinforcement

(D.1) Reinforcement is required when it is not provided inherently in the components of the branch connection. This paragraph gives rules covering the design of branch connections to sustain internal pressure in cases where the angle between the axes of the branch and of the run is between 45 deg and 90 deg Subparagraph (E) below gives rules governing the design of connections to sustain external pressure.

(D.2) Figure 104.3.1(D) illustrates the notations used in the pressure-temperature design conditions of branch connections but does not illustrate the allowances for mill tolerance or any other wall thickness allowance. The designer shall make proper allowances for the effects of corrosion or erosion, threading and grooving, and mechanical strength as specified in paras. 102.4.1, 102.4.2, and 102.4.4 in order that the required minimum reinforcement is assured over the design life of the piping system. These notations are as follows:

α = angle between axes of branch and run, deg

b = subscript referring to branch

D_o = outside diameter of pipe, in. (mm)

d_1 = inside center line longitudinal dimension of the finished branch opening in the run of the pipe, in. (mm)
= $[D_{ob} - 2(T_b - A)]/\sin\alpha$

d_2 = "half width" of reinforcing zone, in. (mm)
= the greater of d_1 or $(T_b - A) + (T_h - A) + d_1/2$ but in no case more than D_{oh}, in. (mm)

h = subscript referring to run or header

L_4 = altitude of reinforcement zone outside of run, in. (mm)
= $2.5(T_b - A) + t_r$ or $2.5(T_h - A)$, whichever is smaller

t_r = thickness of attached reinforcing pad, in Example B, in. (mm); or height of the largest 60 deg right triangle supported by the run and branch outside diameter projected surfaces and lying completely within the area of integral reinforcement, in Example C, in. (mm)

T_b, T_h = actual (by measurement), or minimum wall thickness of the branch or header pipe, in. (mm), permissible under purchase specification

t_{mb}, t_{mh} = required minimum wall thickness, in. (mm), of the branch or header pipe as determined by use of Formula (3) or (3A) in para. 104.1.2(A)

(D.2.1) If the run pipe contains a longitudinal seam which is not intersected by the branch, the stress value of seamless pipe of comparable grade may be used to determine the value of t_{mh} for the purpose of reinforcement calculations only. If the branch intersects a longitudinal weld in the run, or if the branch contains a weld, the weld joint efficiency for either or both shall enter the calculations. If the branch and run both contain longitudinal welds, care shall be taken to ensure that the two welds do not intersect each other.

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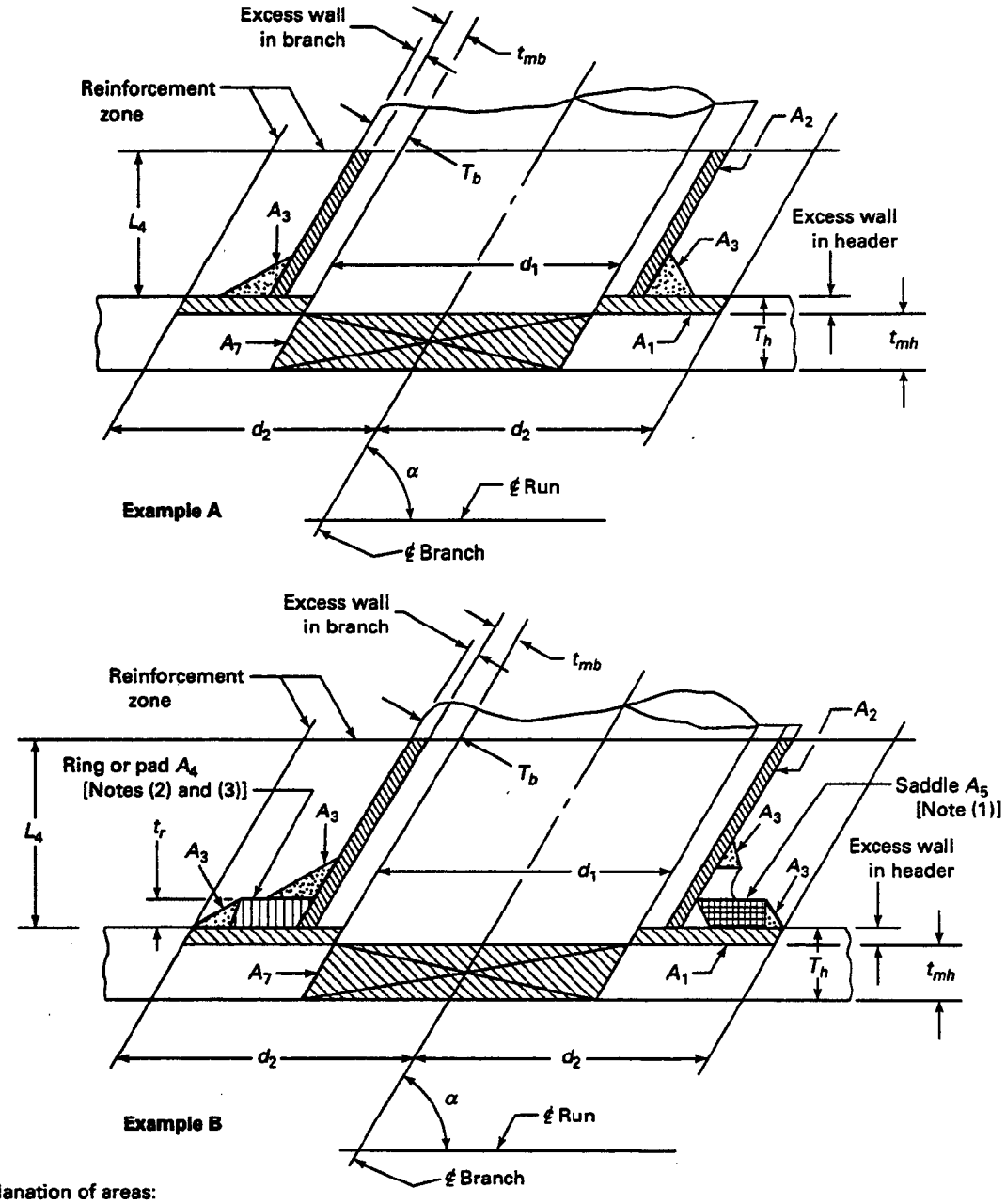
required reinforcement = $(t_{mh})\ (d_1)\ (2 - \sin \alpha) = A_7$

reinforcement areas = A_1, A_2, A_3, A_4, and A_5



Explanation of areas:

Area A_7 — required reinforcement area

Area A_1 — excess wall in header

Area A_2 — excess wall in branch

Area A_3 — fillet weld metal

Area A_4 — metal in ring, pad, or integral reinforcement

Area A_5 — metal in saddle along run

FIG. 104.3.1(D) REINFORCEMENT OF BRANCH CONNECTIONS

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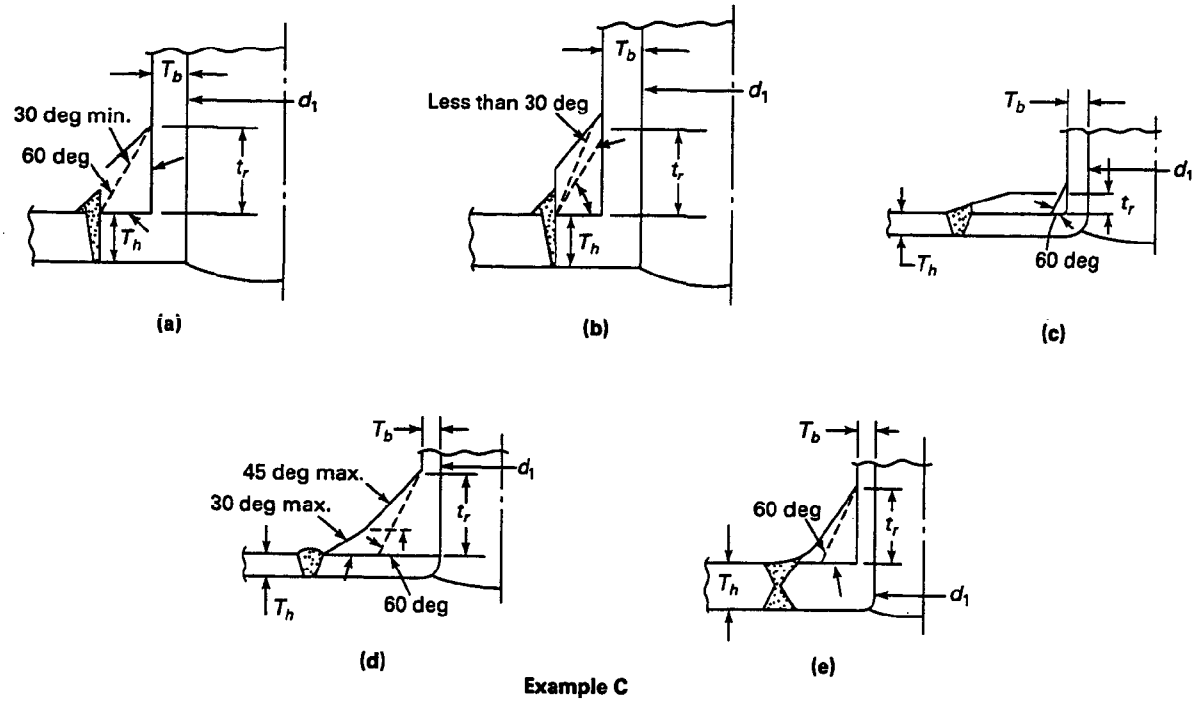

Example C

NOTES:

(1) Reinforcing saddles are limited to use on 90 deg branches.

(2) When a ring or pad is added as reinforcement (Example B), the value of reinforcing area may be taken in the same manner in which excess header metal is considered, provided the weld completely fuses the branch pipe, header pipe, and ring or pad. Typical acceptable methods of welding that meet the above requirement are shown in Fig. 127.4.8(D), examples (c) and (d).

(3) Width to height of rings and pads shall be reasonably proportioned, preferably on a ratio as close to 4:1 as the available horizontal space within the limits of the reinforcing zone along the run and the O.D. of the branch will permit, but in no case may the ratio be less than 1:1.

FIG. 104.3.1(D) REINFORCEMENT OF BRANCH CONNECTIONS (CONT'D)

01 *(D.2.2)* The required reinforcement area in square inches (square millimeters) for branch connections shall be the quantity

$$A_7 = (t_{mh} - A)d_1\,(2 - \sin\alpha)$$

For right angle connections the required reinforcement becomes

$$A_7 = t_{mh}d_1$$

The required reinforcement must be within the limits of the reinforcement zone as defined in (D.2.4) below.

(D.2.3) The reinforcement required by (D.2) shall be that provided by any combination of areas A_1, A_2, A_3, A_4, and A_5, as defined below and illustrated in Fig. 104.3.1 (D) where

A_1 = area provided by excess pipe wall in the run
= $(2d_2 - d_1)(T_h - t_{mh})$

A_2 = area, in.^{2} (mm^2), provided by excess pipe wall in the branch for a distance L_4 above the run
= $2L_4\,(T_b - t_{mb})/\sin\alpha$

A_3 = area provided by deposited weld metal beyond the outside diameter of the run and branch, and for fillet weld attachments of rings, pads, and saddles

A_4 = are provided by a reinforcing ring, pad, or integral reinforcement. The value of A_4 may be taken in the same manner in which excess header metal is considered, provided the weld completely fuses the branch pipe, run pipe, and ring or pad, or integral reinforcement. For welding branch connections refer to para. 127.4.8.

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A_5 = area provided by a saddle on right angle connections
= (O.D. of saddle − D_{ob})t_r

Portions of the reinforcement area may be composed of materials other than those of the run pipe, but if the allowable stress of these materials is less than that for the run pipe, the corresponding calculated reinforcement area provided by this material shall be reduced in the ratio of the allowable stress being applied to the reinforcement area. No additional credit shall be taken for materials having higher allowable stress values than the run pipe.

(D.2.4) Reinforcement Zone. The reinforcement zone is a parallelogram whose width shall extend a distance d_2 on each side of the center line of the branch pipe, and whose altitude shall start at the inside surface of the run pipe and extend to a distance L_4 from the outside surface of the run pipe.

(D.2.5) Reinforcement of Multiple Openings. It is preferred that multiple branch openings be spaced so that their reinforcement zones do not overlap. If closer spacing is necessary, the following requirement shall be met. The two or more openings shall be reinforced in accordance with (D.2), with a combined reinforcement that has a strength equal to the combined strength of the reinforcement that would be required for the separate openings. No portion of the cross section shall be considered as applying to more than one opening, or be evaluated more than once in a combined area.

When more than two adjacent openings are to be provided with a combined reinforcement, the minimum distance between centers of any two of these openings should preferably be at least $1\frac{1}{2}$ times their average diameter, and the area of reinforcement between them shall be at least equal to 50% of the total required for these two openings.

(D.2.6) Rings, Pads, and Saddles. Reinforcement provided in the form of rings, pads, or saddles shall not be appreciably narrower at the side than at the crotch.

A vent hole shall be provided at the ring, pad, or saddle to provide venting during welding and heat treatment. Refer to para. 127.4.8(E).

Rings, pads, or saddles may be made in more than one piece, provided the joints between pieces have full thickness welds, and each piece is provided with a vent hole.

(D.2.7) Other Designs. The adequacy of designs to which the reinforcement requirements of para. 104.3 cannot be applied shall be proven by burst or proof tests on scale models or on full size structures, or by calculations previously substantiated by successful service of similar design.

(E) Branch Connections Subject to External Pressure Requiring Reinforcement. The reinforcement area in square inches (square millimeters) required for branch connections subject to external pressure shall be

$$0.5t_{mh}d_1\ (2 - \sin\alpha)$$

Procedures established heretofore for connections subject to internal pressure shall apply for connections subject to external pressure provided that D_{oh}, D_{ob}, and t_r are reduced to compensate for external corrosion, if required by design conditions.

(F) Branch Connections Subject to External Forces and Moments. The requirements of the preceding paragraphs are intended to assure safe performance of a branch connection subjected only to pressure. However, when external forces and moments are applied to a branch connection by thermal expansion and contraction, by dead weight of piping, valves, and fittings, covering and contents, or by earth settlement, the branch connection shall be analyzed considering the stress intensification factors as specified in Appendix D. Use of ribs, gussets, and clamps designed in accordance with para. 104.3.4 is permissible to stiffen the branch connection, but their areas cannot be counted as contributing to the required reinforcement area of the branch connection.

(G) Extruded Outlets Integrally Reinforced

(G.1) The following definitions, modifications, notations, and requirements are specifically applicable to extruded outlets. The designer shall make proper wall thickness allowances in order that the required minimum reinforcement is assured over the design life of the system.

(G.2) Definition. An extruded outlet header is defined as a header in which the extruded lip at the outlet has an altitude above the surface of the run which is equal to or greater than the radius of curvature of the external contoured portion of the outlet; i.e., $h_o \geq r_o$. See nomenclature and Fig. 104.3.1(G).

(G.3) These rules apply only to cases where the axis of the outlet intersects and is perpendicular to the axis of the run. These rules do not apply to any nozzle in which additional nonintegral material is applied in the form of rings, pads, or saddles.

(G.4) The notation used herein is illustrated in Fig. 104.3.1(G). All dimensions are in inches (millimeters).

d = outside diameter of branch pipe
d_b = corroded internal diameter of branch pipe
D = outside diameter of run

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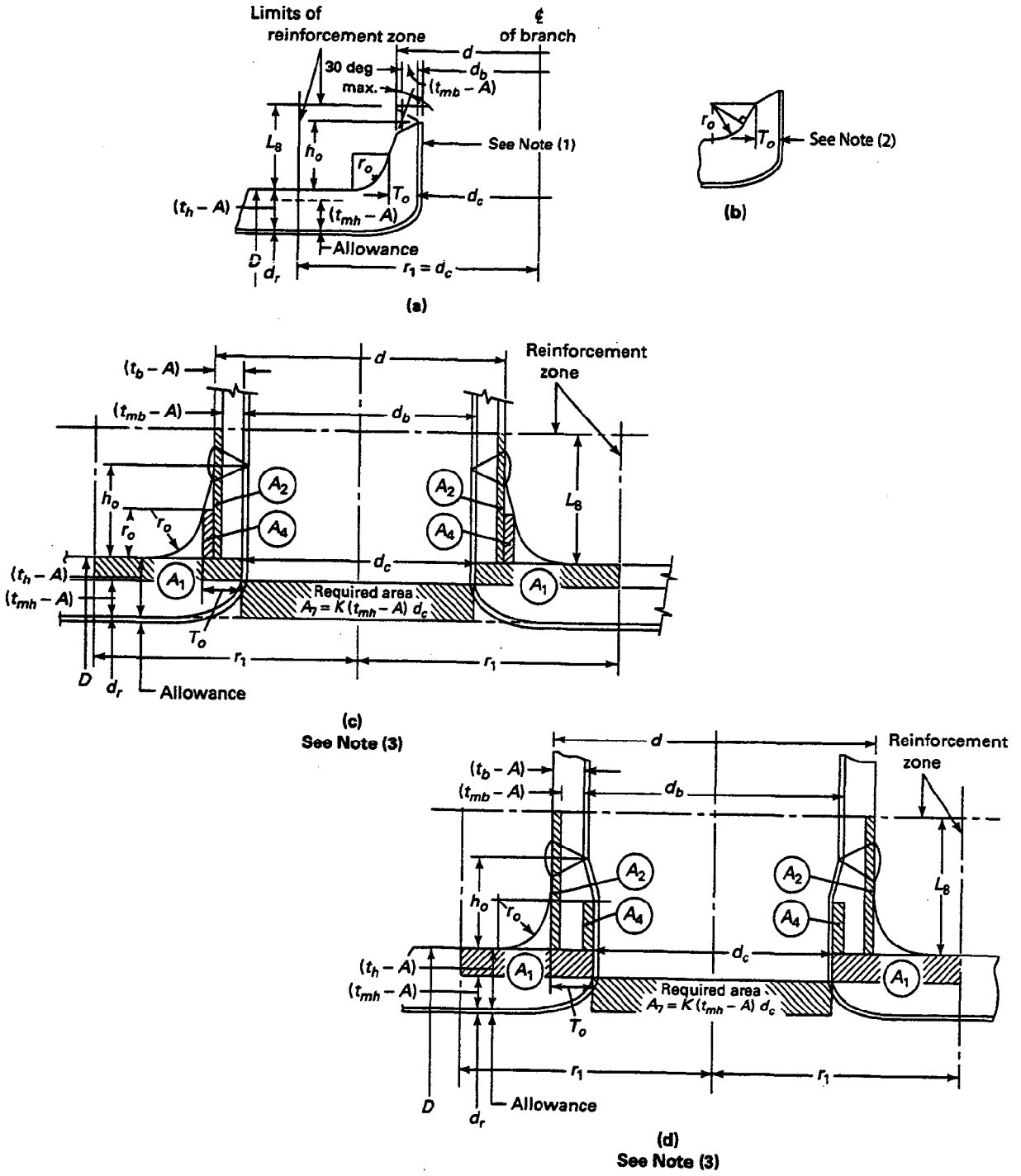

NOTES:
(1) Taper bore inside diameter (if required) to match branch pipe 1:3 maximum taper.
(2) Sketch to show method of establishing T_o when the taper encroaches on the crotch radius.
(3) Sketch is drawn for condition where $k = 1.00$.

FIG. 104.3.1(G) REINFORCED EXTRUDED OUTLETS

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d_r = corroded internal diameter of run

d_c = corroded internal diameter of extruded outlet measured at the level of the outside surface of the run

h_o = height of the extruded lip. This must be equal to or greater than r_o except as shown in (G.4.2) below.

L_8 = altitude of reinforcement zone
= $0.7\sqrt{dT_o}$

$t_{mb} - A$ = required thickness of branch pipe according to wall thickness Formula (3) or (3A) in para. 104.1.2(A), but not including any thickness for corrosion

$t_b - A$ = actual thickness of branch wall not including corrosion allowance

$t_{mh} - A$ = required thickness of the run according to the Formula (3) or (3A) in para. 104.1.2(A), but not including any allowance for corrosion

$t_h - A$ = actual thickness of run wall, not including the corrosion allowance

T_o = corroded finished thickness of extruded outlet measured at a height equal to r_o above the outside surface of the run

r_1 = half width of reinforcement zone (equal to d_c)

r_o = radius of curvature of external contoured portion of outlet measured in the plane containing the axes of the run and branch. This is subject to the following limitations.

(G.4.1) Minimum Radius. This dimension shall not be less than $0.05d$ except that on branch diameters larger than NPS 30, it need not exceed 1.50 in. (38 mm).

(G.4.2) Maximum Radius. For outlet pipe sizes 6 in. nominal and larger, this dimension shall not exceed $0.10d + 0.50$ in. ($0.10d + 12.7$ mm). For outlet pipe sizes less than NPS 6, this dimension shall not be greater than 1.25 in. (32 mm).

(G.4.3) When the external contour contains more than one radius, the radius of any arc sector of approximately 45 deg shall meet the requirements of (G.4.1) and (G.4.2) above. When the external contour has a continuously varying radius, the radius of curvature at every point on the contour shall meet the requirements of (G.4.1) and (G.4.2) above.

(G.4.4) Machining other than grinding for weld cleanup shall not be employed in order to meet the above requirements.

(G.5) Required Area. The required area is defined as

$$A_7 = K\,(t_{mh} - A)\,d_c$$

where K shall be taken as follows.

For d/D greater than 0.60,

$$K = 1.00$$

For d/D greater than 0.15 and not exceeding 0.60,

$$K = 0.6 + \tfrac{2}{3}\,d/D$$

For d/D equal to or less than 0.15,

$$K = 0.70$$

The design must meet criteria that the reinforcement area defined in (G.6) below is not less than the required area.

(G.6) Reinforcement Area. The reinforcement area shall be the sum of areas

$$A_1 + A_2 + A_4$$

as defined below.

(G.6.1) Area A_1 is the area lying within the reinforcement zone resulting from any excess thickness available in the run wall.

$$A_1 = d_c(t_n - t_{mh})$$

(G.6.2) Area A_2 is the area lying within the reinforcement zone resulting from any excess thickness available in the branch pipe wall.

$$A_2 = 2L_8(t_b - t_{mb})$$

(G.6.3) Area A_4 is the area lying within the reinforcement zone resulting from excess thickness available in the extruded outlet lip.

$$A_4 = 2r_o\,[T_o - (t_b - A)]$$

(G.7) Reinforcement of Multiple Openings. It is pre-

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ferred that multiple branch openings be spaced so that their reinforcement zones do not overlap. If closer spacing is necessary, the following requirements shall be met. The two or more openings shall be reinforced in accordance with (G) with a combined reinforcement that has a strength equal to the combined strength of the reinforcement that would be required for separate openings. No portion of the cross section shall be considered as applying to more than one opening, or be evaluated more than once in a combined area.

(G.8) In addition to the above, the manufacturer shall be responsible for establishing and marking on the section containing extruded outlets, the design pressure and temperature. The manufacturer's name or trademarks shall be marked on the section.

104.3.3 Miters. Miter joints, and the terminology related thereto, are described in Appendix D. A widely spaced miter with

$$\theta < 9\sqrt{\frac{t_n}{r}}\ \text{deg}$$

shall be considered to be equivalent to a girth buttwelded joint, and the rules of this paragraph do not apply. Miter joints, and fabricated pipe bends consisting of segments of straight pipe welded together, with θ equal to or greater than this calculated value may be used within the limitations described below.

(A) Pressure shall be limited to 10 psi (70 kPa) under the following conditions:

(A.1) the assembly includes a miter weld with $\theta >$ 22.5 deg, or contains a segment which has a dimension

$$B < 6t_n$$

(A.2) the thickness of each segment of the miter is not less than that determined in accordance with para. 104.1;

(A.3) the contained fluid is nonflammable, nontoxic, and incompressible, except for gaseous vents to atmosphere;

(A.4) the number of full pressure cycles is less than 7000 during the expected lifetime of the piping system; and

(A.5) full penetration welds are used in joining miter segments.

(B) Pressure shall be limited to 100 psi (700 kPa) under the conditions defined in (A.2), (A.3), (A.4), and (A.5) above, in addition to the following:

(B.1) the angle θ does not exceed 22.5 deg; and

(B.2) the assembly does not contain any segment which has a dimension

$$B < 6t_n$$

(C) Miters to be used in other services or at design pressures above 100 psi (700 kPa) shall meet the requirements of para. 104.7.

(C.1) When justification under para. 104.7 is based on comparable service conditions, such conditions must be established as comparable with respect to cyclic as well as static loadings.

(C.2) When justification under para. 104.7 is based on an analysis, that analysis and substantiating tests shall consider the discontinuity stresses which exist at the juncture between segments; both for static (including brittle fracture) and cyclic internal pressure.

(C.3) The wall thickness t_s of a segment of a miter shall not be less than specified in (C.3.1) or (C.3.2) below, depending on the spacing.

(C.3.1) For closely-spaced miter bends (see Appendix D for definition)

$$t_s = t_m \frac{2 - r/R}{2(1 - r/R)}$$

(C.3.2) For widely-spaced miters (see Appendix D for definition)

$$t_s = t_m(1 + 0.64\sqrt{r/t_s}\tan\theta)$$

(the above equation requires an iterative or quadratic solution for t_s).

104.3.4 Attachments. External and internal attachments to piping shall be designed so as not to cause flattening of the pipe, excessive localized bending stresses, or harmful thermal gradients in the pipe wall. It is important that such attachments be designed to minimize stress concentrations in applications where the number of stress cycles, due either to pressure or thermal effect, is relatively large for the expected life of the equipment.

104.4 Closures

104.4.1 General. Closures for power piping systems shall meet the applicable requirements of this Code and shall comply with the requirements described in (A) or (B) below. Closures may be made:

(A) by use of closure fittings, such as threaded or welded plugs, caps, or blind flanges, manufactured in

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accordance with standards listed in Table 126.1, and used within the specified pressure-temperature ratings; or

(B) in accordance with the rules contained in the ASME Boiler and Pressure Vessel Code, Section I, Power Boilers, PG-31, or Section VIII, Pressure Vessels, Division 1, UG-34 and UW-13, calculated from

$$t_m = t + A$$

where

t = pressure design thickness, calculated for the given closure shape and direction of loading using appropriate equations and procedures in Section I or Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code

The definition of A and the symbols used in determining t shall have the definitions shown herein, instead of those given in the ASME Boiler and Pressure Vessel Code.

Attachment of a welded flat permanent closure with only a single fillet weld is not permitted.

104.4.2 Openings in Closures. Openings in closures may be made by welding, extruding, or threading. Attachment to the closure shall be in accordance with the limitations provided for such connections in para. 104.3.1 for branch connections. If the size of the opening is greater than one-half of the inside diameter of the closure, the opening shall be designed as a reducer in accordance with para. 104.6.

Other openings in closures shall be reinforced in accordance with the requirements of reinforcement for a branch connection. The total cross-sectional area required for reinforcement in any plane passing through the center of the opening and normal to the surface of the closure shall not be less than the quantity of d_5t, where

d_5 = diameter of the finished opening, in. (mm), and t as defined in (B) above

104.5 Pressure Design of Flanges and Blanks

104.5.1 Flanges — General

(A) Flanges of sizes NPS 24 and smaller, that are manufactured in accordance with ASME B16.1 and B16.5, shall be considered suitable for use at the primary service ratings (allowable pressure at service temperature) except the slip-on flanges to ASME B16.5 shall be limited in application to no higher than Class 300 primary pressure service rating. Refer to para. 127.4.4.

For flanges larger than NPS 24, and manufactured in accordance with the Specifications and Standards listed in Table 126.1, the designer is cautioned about the dimensionally different designs that are available, as well as the limitations of their application.

Flanges not made in accordance with the Specifications and Standards listed in Table 126.1 shall be designed in accordance with Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, except that the requirements for fabrication, assembly, inspection, and testing, and the pressure and temperature limits for materials of this Code for Pressure Piping shall govern. Certain notations used in the ASME Code, namely, P, S_a, S_b, and S_f, shall have the meanings described below instead of those given in the ASME Code. All other notations shall be as defined in the ASME Code.

P = design pressure, psi (kPa) (see paras. 101.2.2 and 101.2.4)

S_a = bolt design stress at atmospheric temperature, psi (kPa)

S_b = bolt design stress at design temperature, psi (kPa)

S_f = allowable stress for flange material or pipe, psi (kPa) (see para. 102.3.1 and Allowable Stress Tables) (stress values converted from MPa to kPa)

For certain specific applications see the limitations of paras. 122.1.1 (F), (G), and (H).

(B) These flange design rules are not applicable to flat face designs employing full face gaskets which extend beyond the bolts.

(C) The bolt design stress in (A) above shall be as established in Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, Appendix P for ferrous materials.

(D) Application of bolting materials for flanged joints is covered in para. 108.5.

104.5.2 Blind Flanges

(A) Blind flanges manufactured in accordance with the standards listed in Table 126.1 shall be considered suitable for use at the pressure-temperature rating specified by such Standards.

(B) The required thickness of blind flanges not manufactured in accordance with standards in Table 126.1 shall be calculated from Formula (6).

$$t_m = t + A \qquad (6)$$

where

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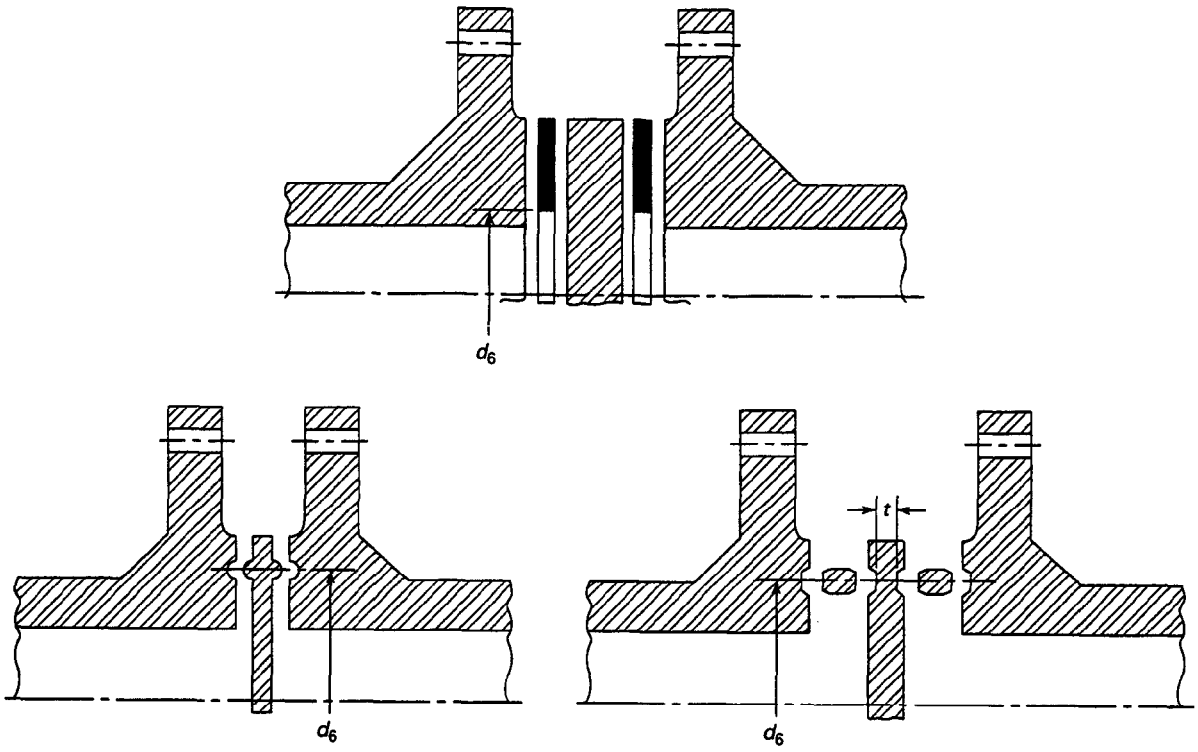

FIG. 104.5.3 TYPES OF PERMANENT BLANKS

t = pressure design thickness as calculated for the given style of blind flange from the appropriate equations for bolted flat cover plates in Section I of the ASME Boiler and Pressure Vessel Code. Certain notations used in these equations, namely, P and SE [see para. 104.1.2(A), footnote 1], shall be considered to have the meanings described in para. 104.1.2(A) instead of those given in the ASME Code. All other notations shall be as defined in the ASME Code.

104.5.3 Blanks

(A) The required thickness of permanent blanks (see Fig. 104.5.3) shall be calculated from the formula

$$t_m = t + A$$

where

t = pressure design thickness as calculated from Formula (7)

$$= d_6\sqrt{\frac{3P}{16SE}} \quad (7)$$

See para. 104.1.2(A), footnote 1.

d_6 = inside diameter of gasket for raised or flat (plain) face flanges, or the gasket pitch diameter for retained gasketed flanges, in. (mm)

(B) Blanks to be used for test purposes only shall have a minimum thickness not less than the pressure design thickness t specified above except that P shall be not less than the test pressure and SE [see para. 104.1.2(A), footnote 1] may be taken as the specified minimum yield strength of the blank material if the test fluid is incompressible.

(C) Attachment of a welded flat permanent blank with only a single fillet weld is not permitted.

104.6 Reducers

Flanged reducer fittings manufactured in accordance with the Standards listed in Table 126.1 shall be considered suitable for use at the specified pressure-temperature ratings. Where butt welding reducers are

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made to a nominal pipe thickness, the reducers shall be considered suitable for use with pipe of the same nominal thickness.

104.7 Other Pressure-Containing Components

104.7.1 Pressure-containing components manufactured in accordance with the standards listed in Table 126.1 shall be considered suitable for use under normal operating conditions at or below the specified pressure-temperature ratings. However, the user is cautioned that where certain standards or manufacturers may impose more restrictive allowances for variation from normal operation than those established by this Code, the more restrictive allowances shall apply.

104.7.2 Specially Designed Components. The pressure design of components not covered by the standards listed in Table 126.1 or for which design formulas and procedures are not given in this Code shall be based on calculations consistent with the design criteria of this Code. These calculations shall be substantiated by one or more of the means stated in (A), (B), (C), and (D) below:

(A) extensive, successful service experience under comparable conditions with similarly proportioned components of the same or similar material:

(B) experimental stress analysis, such as described in the ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Appendix 6;

(C) proof test in accordance with either ASME B16.9, MSS SP-97, or the ASME Boiler and Pressure Vessel Code, Section I. A-22; and

(D) detailed stress analysis, such as finite element method, in accordance with the ASME Boiler and Pressure Vessel Code, Division 2, Appendix 4, except that the basic material allowable stress from the Allowable Stress Tables of Appendix A shall be used in place of S_m.

For any of (A) through (D) above, it is permissible to interpolate between sizes, wall thicknesses, and pressure classes and to determine analogies among related materials.

Calculations and documentation showing compliance with this paragraph shall be available for the owner's approval, and, for boiler external piping, they shall be available for the Authorized Inspector's review.

104.8 Analysis of Piping Components

To validate a design under the rules in this paragraph, the complete piping system must be analyzed between anchors for the effects of thermal expansion, weight, other sustained loads, and other occasional loads. Each component in the system must meet the limits in this paragraph. For pipe and fittings, the pressure term in Eqs. (11) and (12) may be replaced with the alternative term for S_{lp} as defined in para. 102.3.2(D). The pressure term in Eqs. (11) and (12) may not apply for bellows and expansion joints. When evaluating stresses in the vicinity of expansion joints, consideration must be given to actual cross-sectional areas that exist at the expansion joint.

104.8.1 Stress due to Sustained Loads. The effects of pressure, weight, and other sustained mechanical loads shall meet the requirements of Eq. (11). 01

English units

$$S_L = \frac{PD_o}{4t_n} + \frac{0.75\ iM_A}{Z} \le 1.0\ S_h \qquad (11A)$$

Metric units

$$S_L = \frac{PD_o}{4t_n} + \frac{1000\ (0.75i)M_A}{Z} \le 1.0\ S_h \qquad (11B)$$

where

M_A = resultant moment loading on cross section due to weight and other sustained loads, in-lb (mm-N) (see para. 104.8.4)

Z = section modulus, in.^{3} (mm^3) (see para. 104.8.4)

i = stress intensification factor (see Appendix D). The product $0.75i$ shall never be taken as less than 1.0.

S_L = sum of the longitudinal stresses due to pressure, weight, and other sustained loads

104.8.2 Stress due to Occasional Loads. The effects of pressure, weight, other sustained loads, and occasional loads including earthquake must meet the requirements of Eq. (12). 01

English units

$$\frac{PD_o}{4t_n} + \frac{0.75iM_A}{Z} + \frac{0.75iM_B}{Z} \le k\ S_h \qquad (12A)$$

Metric units

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$$\frac{PD_o}{4t_n} + \frac{1000(0.75i)M_A}{Z} + \frac{1000(0.75i)M_B}{Z} \le k\,S_h \quad (12B)$$

Terms same as para. 104.8.1 except

k = 1.15 for occasional loads acting for no more than 8 hr at any one time and no more than 800 hr/year [see para. 102.3.3(A)]

k = 1.2 for occasional loads acting for no more than 1 hr at any one time and no more than 80 hr/year [see para. 102.3.3(A)]

M_B = resultant moment loading on cross section due to occasional loads [see para. 102.3.3(A)], such as thrusts from relief/safety valve loads, from pressure and flow transients, and earthquake (see para. 104.8.4). If calculation of moments due to earthquake is required, use only one-half the earthquake moment range. Effects of anchor displacement due to earthquake may be excluded from Eq. (12) if they are included in Eq. (13), in.-lb.

01 **104.8.3 Thermal Expansion Stress Range.** The effects of thermal expansion shall meet the requirements of Eq. (13).

English units

$$S_E = \frac{iM_C}{Z} \le S_A + f(S_h - S_L) \quad (13A)$$

Metric units

$$S_E = \frac{1000(iM_c)}{Z} \le S_A + f(S_h - S_L) \quad (13B)$$

Terms same as para. 104.8.1 except

M_C = range of resultant moments due to thermal expansion. Also include moments effects of anchor displacement due to earthquake if anchor displacement effects were omitted from Eq. (12) (see para. 104.8.4).

f = stress range reduction factor for cyclic conditions for total number N of full temperature cycles over total number of years during which system is expected to be in operation, from Table 102.3.2(C)

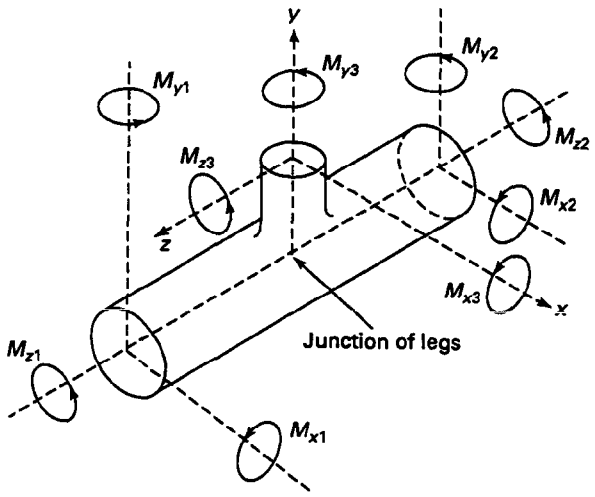

FIG. 104.8.4

104.8.4 Moments and Section Modulus

(A) For purposes of Eqs. (11), (12), and (13), the resultant moments for straight through components, curved pipe, or welding elbows may be calculated as follows:

$$M_j = (M_{xj}^2 + M_{yj}^2 + M_{zj}^2)^{1/2}$$

where

j = A, B, or C as defined in paras. 104.8.1, 104.8.2, and 104.8.3

Z = section modulus of piping, in.^{3} (mm^3)

(B) For full outlet branch connections, calculate the resultant moment of each leg separately in accordance with (A) above. Use Z, section modulus, in Eqs. (11) through (13) as applicable to branch or run pipe. Moments are taken at the junction point of the legs. See Fig. 104.8.4.

(C) For reduced outlets, calculate the resultant moment of each leg separately in accordance with (A) above. Moments are to be taken at the junction point of the legs, unless the designer can demonstrate the validity of a less conservative method. See Fig. 104.8.4. For the *reduced outlet branch*, except for branch connections covered by Fig. D-1:

$$M_A,\ M_B,\ M_C = \sqrt{M_{x3}^2 + M_{y3}^2 + M_{z3}^2}$$

and

Z = $\pi r_b^2 t_e$ (effective section modulus)

r_b = branch mean cross-sectional radius, in. (mm)

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t_e = effective branch wall thickness, in. (mm)
= lesser of t_{nh} or it_{nb} in Eq. (13) or lesser of t_{nh} or $0.75it_{nb}$, where $0.75i \geq 1.0$, in Eqs. (11) and (12)

For the *reduced outlet branch connections covered by Fig. D-1:*

$$M_A, M_B, M_C = \sqrt{M_{x3}^2 + M_{y3}^2 + M_{z3}^2}$$

and

$$Z = \pi r'^2_m T_b$$

If L_1 in Fig. D-1 sketches (a), (b), and (c) equals or exceeds $0.5\sqrt{r_i T_b}$, then r'_m can be taken as the radius to the center of T_b when calculating the section modulus and the stress intensification factor. For such a case the transition between branch pipe and nozzle must be evaluated separately from the branch connection.

For the *main run outlets:*

$$M_A, M_B, M_C = \sqrt{M_{x1}^2 + M_{y1}^2 + M_{z1}^2}$$

and

$$M_A, M_B, M_C = \sqrt{M_{x2}^2 + M_{y2}^2 + M_{z2}^2}$$

and

Z = section modulus of pipe, in.^{3} (mm^3)

PART 3
SELECTION AND LIMITATIONS OF PIPING COMPONENTS

105 PIPE

105.1 General

Pipe conforming to the standards and specifications listed in Appendix A shall be used within the range of temperatures for which allowable stresses are given within the limitations specified herein.

105.2 Metallic Pipe

105.2.1 Ferrous Pipe

(A) Furnace butt welded steel pipe shall not be used for flammable, combustible or toxic fluids.

(B) Cast iron pipe may be used for design pressures within the ratings established by the standards and specifications listed in Tables 126.1 and A-5 and Notes thereto, and the limitations herein and in para. 124.4. Cast iron pipe shall not be used for flammable, combustible, or toxic fluids.

105.2.2 Nonferrous Pipe

(A) Copper and brass pipe for water and steam service may be used for design pressures up to 250 psi (1750 kPa) and for design temperatures to 406°F (208°C).

(B) Copper and brass pipe for air may be used in accordance with the allowable stresses given in the Allowable Stress Tables.

(C) Copper tubing may be used for dead-end instrument service with the limitations stated in para. 122.3.2(D).

(D) Copper, copper alloy, or aluminum alloy pipe or tube may be used under the conditions stated in para. 124.7. Copper, copper alloy, or aluminum pipe or tube shall not be used for flammable, combustible, or toxic fluids except as permitted in paras. 122.7 and 122.8.

105.3 Nonmetallic Pipe 01

(A) Plastic pipe may be used for water and nonflammable liquids where experience or tests have demonstrated that the plastic pipe is suitable for the service conditions, and the pressure and temperature conditions are within the manufacturer's recommendations. Until such time as mandatory rules are established for these materials, pressure shall be limited to 150 psi (1000 kPa) and temperature to 140°F (60°C) for water service. Pressure and temperature limits for other services shall be based on the hazards involved, but in no application shall they exceed 150 psi (1000 kPa) and 140°F (60°C). For nonmandatory rules for nonmetallic piping, see Appendix III of this Code.

(B) Reinforced thermosetting resin pipe may be used, in addition to the services listed in para. 105.3(A), in buried flammable and combustible liquid service subject to the limitations described in para. 122.7.3(F).

(C) Reinforced concrete pipe may be used in accordance with the specifications listed in Table 126.1 for water service up to 150°F (65°C).

(D) A flexible nonmetallic pipe or tube assembly may be used in applications where:

(a) satisfactory service experience exists;

(b) the pressure and temperature conditions are within the manufacturer's recommendations; and

(c) the conditions described in paras. 104.7, 124.7, and 124.8 are met.

(E) Polyethylene pipe may be used, in addition to

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the service listed in para. 105.3(A), in buried flammable and combustible liquid and gas service subject to the limitations described in paras. 122.7.2(D) and 122.8.1(B.4).

106 FITTINGS, BENDS, AND INTERSECTIONS

106.1 Fittings

(A) Threaded, flanged, grooved and shouldered socket-welding, buttwelding, compression, and solder-joint fittings made in accordance with the applicable standards in Table 126.1 may be used in power piping systems within the material, size, pressure, and temperature limitations of those standards, and within any further limitations specified in this Code. Material for fittings in flammable, combustible, or toxic fluid systems shall in addition conform to the requirements of paras. 122.7 and 122.8.

(B) Fittings not covered by the Standards listed in Table 126.1 may be used if they conform to para. 104.7.

(C) Cast buttwelding steel fittings not covered by the dimensional standards listed in Table 126.1 may be used up to the manufacturer's pressure and temperature ratings, provided they are radiographed in accordance with the method of ASTM E 142 and meet the acceptance requirements of ASTM E 446, E 186, and E 280 as applicable for the thickness being radiographed.

(D) Fabricated ends for grooved and shouldered type joints are acceptable, provided they are attached by full penetration welds, double fillet welds, or by threading. Fabricated ends attached by single fillet welds are not acceptable.

106.1.1 Bell and Spigot Fittings. Bell and spigot fittings complying with applicable standards listed in Table 126.1 may be used for cold water and drainage service.

106.2 Bends and Intersections

Bends and extruded branch connections may be used when designed in accordance with the provisions of paras. 104.2 and 104.3, respectively. Miters may be used within the limitations of para. 104.3.3.

106.3 Pipe Couplings

(A) Cast iron and malleable iron pipe couplings shall be limited in application as referenced in paras. 124.4 and 124.5, respectively.

(B) Straight thread couplings shall not be used.

106.4 Flexible Metal Hose Assembly

(A) Flexible metal hose assemblies may be used to provide flexibility in a piping system, to isolate or control vibration, or to compensate for misalignment. The design conditions shall be in accordance with para. 101 and within the limitations of the assembly as recommended by the manufacturer. The basis for their application shall include the following service conditions: thermal cycling, bend radius, cycle life, and the possibility of corrosion and erosion. Installation shall be limited to a single-plane bend, free from any torsion effects during service conditions and nonoperating periods. Type of end-connector components shall be consistent with the requirements of this Code.

(B) A flexible metal hose assembly, consisting of one continuous length of seamless or butt welded tube with helical or annular corrugations, is not limited as to application in piping systems which are within the scope of this Code, provided that the conditions described in (A) above are met. For application subject to internal pressure the flexible element shall be contained within one or more separate layers of braided metal permanently attached at both coupling ends by welding or brazing. For application in toxic fluid systems, it is recommended that the designer also review the standards published by the relevant fluid industry for any additional safety and materials requirements that may be necessary.

(C) A flexible metal hose assembly consisting of wound interlocking metal strips may be applied to atmospheric vent systems only and shall not be used in systems which convey high temperature, flammable, toxic, or searching-type fluids. Where applicable, as determined by the designer and within the limitations described in para. 122.6 and those imposed by the manufacturer, this type of hose assembly may be used at pressure relieving devices.

107 VALVES

107.1 General

(A) Valves complying with the standards and specifications listed in Table 126.1 shall be used within the specified pressure-temperature ratings.

(B) Valves not complying with (A) above shall be of a design, or equal to the design, which the manufacturer recommends for the service as stipulated in para. 102.2.2.

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(C) Some valves are capable of sealing simultaneously against a pressure differential between an internal cavity of the valve and the adjacent pipe in both directions. Where liquid is entrapped in such a valve and is subsequently heated, a dangerous rise in pressure can result. Where this condition is possible, the Owner shall provide means in design, installation, and/or operation to assure that the pressure in the valve shall not exceed the rated pressure for the attained temperature. A relief device used solely for the over-pressure protection from such entrapped fluid and conforming to (A) or (B) above need not comply with the requirements of para. 107.8. Any penetration of the pressure retaining wall of the valve shall meet the requirements of this Code.

(D) Only valves designed such that the valve stem is retained from blow-out by an assembly which functions independently of the stem seal retainer shall be used.

(E) Materials used for pressure retention for valves in flammable, combustible, or toxic fluid systems shall in addition conform to the requirements of paras. 122.7 and 122.8.

107.2 Marking

Each valve shall bear the manufacturer's name or trademark and reference symbol to indicate the service conditions for which the manufacturer guarantees the valve. The marking shall be in accordance with ASME B16.5 and B16.34.

107.3 Ends

Valves may be used with flanged, threaded, butt welding, socket welding, or other ends in accordance with applicable standards as specified in para. 107.1(A).

107.4 Stem Threads

Stem threads of valves may be internal or external with reference to the valve bonnet. Outside screw and yoke design shall be used for valves NPS 3 and larger for pressures above 600 psi (4150 kPa).

107.5 Bonnet Joints

Bonnet joints may be of flanged, welded, pressure seal, union type, or other design, except that screwed bonnet connections in which the seal depends on a steam tight threaded joint shall not be permitted as source valves in steam service at pressures above 250 psi (1750 kPa).

107.6 Bypasses

Sizes of bypasses shall be in accordance with MSS SP-45 as a minimum standard. Pipe for bypasses shall be at least schedule 80 seamless, and of a material of the same nominal chemical composition and physical properties as that used for the main line. Bypasses may be integral or attached.

107.8 Safety, Safety Relief, and Relief Valves

107.8.1 General. Safety, safety relief, and relief valves shall conform to the requirements specified in this Code for flanges, valves, and fittings for the pressures and temperatures to which they may be subjected.

107.8.2 Safety, Safety Relief, and Relief Valves on Boiler External Piping. Safety, safety relief, and relief valves on boiler external piping shall be in accordance with para. 122.1.7(D.1) of this Code.

107.8.3 Safety, Safety Relief, and Relief Valves on Nonboiler External Piping. Safety, safety relief, and relief valves on nonboiler external piping (except for reheat safety valves) shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, UG-126 through UG-133. Reheat safety valves shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section I, PG-67 through PG-73.

107.8.4 Nonmandatory Appendix. For nonmandatory rules for the design of safety valve installations, see Appendix II of this Code.

108 PIPE FLANGES, BLANKS, FLANGE FACINGS, GASKETS, AND BOLTING

108.1 Flanges

Flanges shall conform to the design requirements of para. 104.5.1 or to the standards listed in Table 126.1. They may be integral or shall be attached to pipe by threading, welding, brazing, or other means within the applicable standards specified in Table 126.1.

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108.2 Blanks

Blanks shall conform to the design requirements of para. 104.5.3.

108.3 Flange Facings

Flange facings shall be in accordance with the applicable standards listed in Tables 126.1 and 112. When bolting Class 150 standard steel flanges to flat face cast iron flanges, the steel flange shall be furnished with a flat face. Steel flanges of Class 300 raised face standard may be bolted to Class 250 raised face cast iron.

108.4 Gaskets

Gaskets shall be made of materials which are not injuriously affected by the fluid or by temperature. They shall be in accordance with Table 112.

108.5 U. S. Customary Bolting

108.5.1 General

(A) Bolts, bolt studs, nuts, and washers shall comply with applicable standards and specifications listed in Table 126.1 and Table 112. Bolts and bolt studs shall extend completely through the nuts.

(B) Washers, when used under nuts, shall be of forged or rolled material with steel washers being used under steel nuts and bronze washers under bronze nuts.

(C) Nuts shall be provided in accordance with the requirements of the specification for the bolts and bolt studs.

(D) Alloy steel bolt studs shall be either threaded full length or provided with reduced shanks of a diameter not less than that at the root of the threads. They shall have ASME heavy hexagonal nuts. Headed alloy bolts shall not be used with other than steel or stainless steel flanges.

(E) All alloy steel bolt studs and carbon steel bolts or bolt studs and accompanying nuts shall be threaded in accordance with ASME B1.1 Class 2A for external threads and Class 2B for internal threads. Threads shall be the coarse-thread series except that alloy steel bolting $1\frac{1}{8}$ in. and larger in diameter shall be the 8-pitch-thread series.

(F) Carbon steel headed bolts shall have square, hex, or heavy hex heads (ANSI B18.2.1) and shall be used with hex or heavy hex nuts (ASME B18.2.2). For bolt sizes smaller than $\frac{3}{4}$ in., square or heavy hex heads and heavy hex nuts are recommended. For bolt sizes larger than $1\frac{1}{2}$ in., bolt studs with a hex or heavy hex nut on each end are recommended. For cast iron or bronze flanges using $\frac{3}{4}$ in. and larger carbon steel headed bolts, square nuts may be used.

108.5.2 For the various combinations of flange materials, the selection of bolting materials and related rules concerning flange faces and gaskets shall be in accordance with para. 108 and Table 112.

108.5.3 Bolting requirements for components not covered by para. 108.5.2 shall be in accordance with para. 102.2.2

108.6 Metric Bolting

108.6.1 General. The use of metric bolts, bolt studs, nuts, and washers shall conform to the general requirements of para. 108.5, but the following are allowed. 01

(A) Threads shall be in accordance with ASME B1.13M, M profile, with tolerance Class 6g for external threads and Class 6H for internal threads.

(B) Threads shall be the coarse-thread series for size M68 and smaller, and 6 mm fine-pitch for M70 and larger sizes, except that alloy steel bolting M30 and larger shall be the 3 mm fine-pitch.

(C) Nuts shall be heavy hex in accordance with ASME B18.2.4.6M. Headed bolts shall be either hex or heavy hex in accordance with ASME B18.2.3.5M and B18.2.3.6M, respectively. Heavy hex heads are recommended for headed bolt sizes M18 and smaller.

(D) Bolt studs are recommended in lieu of headed bolts for sizes M39 and larger.

(E) Metric bolting is not approved for boiler external piping applications.

108.6.2 Responsibilities When Specifying or Allowing Metric Bolting 01

(A) The piping designer is responsible for specifying the metric bolt size to be used with each class and size of flange.

(B) The designer shall ensure that the selected metric size will fit within the flange bolt holes, and that adequate space exists for bolt heads, nuts, and the assembly tool.

(C) In those instances where the selected metric bolt size is smaller in root thread area than the corresponding U.S. Customary size, the designer shall ensure that the selected size is capable of the required assembly torque and of producing the required gasket loading to adequately seal at design pressure. Further, the designer shall ensure sufficient contact area exists between the flange metal and both the nut and bolt head to withstand the required bolt loading. If not, larger bolting or a higher flange class shall be selected.

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PART 4
SELECTION AND LIMITATIONS OF PIPING JOINTS

110 PIPING JOINTS

The type of piping joint used shall be suitable for the design conditions and shall be selected with consideration of joint tightness, mechanical strength, and the nature of the fluid handled.

111 WELDED JOINTS

111.1 General

Welded joints may be used in any materials allowed by this Code for which it is possible to qualify WPSs, welders, and welding operators in conformance with the rules established in Chapter V.

All welds shall be made in accordance with the applicable requirements of Chapter V.

111.2 Butt Welds

111.2.1 Design of Butt Welds. The design of butt welds shall include the evaluation of any expected joint misalignment [para. 127.3(C)], which may result from specification of joint geometries at variance with the recommendations of this Code.

111.2.2 Backing Rings for Butt Welds. If backing rings are used in services where their presence will result in severe corrosion or erosion, the backing ring shall be removed and the internal surface ground smooth. In such services, where it is impractical to remove the backing ring, consideration shall be given to welding the joint without a backing ring, or with a consumable type insert ring.

111.3 Socket Welds

111.3.1 Restrictions on size of socket welded components are given in paras. 104.3.1(B.4), 122.1.1(H), and 122.8.2(C). Special consideration should be given to further restricting the use of socket welded piping joints where temperature or pressure cycling or severe vibration is expected to occur or where the service may accelerate crevice corrosion.

111.3.2 Dimensions for sockets of socket welding components shall conform to ASME B16.5 for flanges and ASME B16.11 for fittings. Assembly of socket welded joints shall be made in accordance with para. 127.3(E).

111.3.3 A branch connection socket welded directly into the wall of the run pipe shall be in accordance with requirements of para. 104.3.1(B.4).

111.3.4 Drains and bypasses may be attached to a fitting or valve by socket welding, provided the socket depth, bore diameter, and shoulder thickness conform to the requirements of ASME B16.11.

111.4 Fillet Welds

Fillet welds shall have dimensions not less than the minimum dimensions shown in Figs. 127.4.4(B), 127.4.4(C), and 127.4.8(D).

111.5 Seal Welds

Seal welding of connections, including threaded joints, may be used to avoid joint leakage but the welding shall not be considered as contributing any strength to the joint. Also see para. 127.4.5. Seal welded threaded joints are subject to the limitations of para. 114.

112 FLANGED JOINTS

Flanged joints shall conform to paras. 108 and 110 and Table 112.

113 EXPANDED OR ROLLED JOINTS

Expanded or rolled joints may be used where experience or test has demonstrated that the joint is suitable for the design conditions and where adequate provisions are made to prevent separation of the joint.

114 THREADED JOINTS

Threaded joints may be used within the limitations specified in para. 106 and within the other limitations specified herein.

114.1

All threads on piping components shall be taper pipe threads in accordance with the applicable Standards listed in Table 126.1. Threads other than taper pipe threads may be used for piping components where tightness of the joint depends on a seal weld or a seating surface other than the threads, and where experience or test has demonstrated that such threads are suitable.

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TABLE 112
PIPING FLANGE BOLTING, FACING, AND GASKET REQUIREMENTS
Refer to Paras. 108, 110, and 112

Item	Flange A Mating With Flange B		Bolting	Flange Facings	Gaskets
	Flange A	Flange B			
(a)	Class 25 cast iron	Class 25 cast iron	(a)(1) "Low strength" [Notes (1), (2), and (5)]	(a)(1) Flat	(a)(1) Flat ring nonmetallic to ASME B16.21, Table 1
			(a)(2) "Higher strength" or "low strength" [Notes (1) through (5)]	(a)(2) Flat	(a)(2) Full face nonmetallic to ASME B16.21, Table 1
(b)	Class 125 cast iron	Class 125 cast iron, Class 150 steel and stainless steel (excluding MSS SP-51), or Class 150 ductile iron	"Low strength" [Notes (1), (2), and (5)]	Flat	Flat ring; nonmetallic to ASME B16.21, Table 2
(c)	Class 125 cast iron, Class 150 bronze, MSS SP-51 stainless steel, or nonmetallic	Class 125 cast iron, Class 150 bronze, Class 150 steel and stainless steel (including MSS SP-51), Class 150 ductile iron, or nonmetallic	"Higher strength" or "low strength" [Notes (1) through (7)]	Flat	Full face nonmetallic to ASME B16.21, Table 2 [Notes (8), (9)]
(d)	Class 150 steel and stainless steel (excluding MSS SP-51), or Class 150 ductile iron	Class 150 steel and stainless steel (excluding MSS SP-51), or Class 150 ductile iron	(d)(1) "Low strength" [Notes (1), (2), and (5)]	(d)(1) Raised or flat on one or both flanges	(d)(1) Flat ring nonmetallic to ASME B16.5, Annex E, Group Ia, Fig. E3 [Note (11)]
			(d)(2) "Higher strength" [Notes (3), (4), and (5)]	(d)(2) Raised or flat on one or both flanges	(d)(2) Ring style to ASME B16.5, Annex E, Groups Ia and Ib, Fig. E3 [Notes (10) and (11)]
			(d)(3) "Higher strength" or "low strength" [Notes (1) through (5)]	(d)(3) Flat	(d)(3) Full face nonmetallic to ASME B16.5, Annex E, Group Ia material
(e)	Class 150 steel and stainless steel (excluding MSS SP-51)	Class 150 steel and stainless steel (excluding MSS SP-51)	"Higher strength" [Notes (3), (4), and (5)]	Ring joint	Ring joint to ASME B16.20

(continued)

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TABLE 112
PIPING FLANGE BOLTING, FACING, AND GASKET REQUIREMENTS (CONT'D)
Refer to Paras. 108, 110, and 112

Item	Flange A Mating With Flange B		Bolting	Flange Facings	Gaskets
	Flange A	Flange B			
(f)	Class 250 cast iron	Class 250 cast iron, Class 300 steel and stainless steel, or Class 300 ductile iron	(f)(1) "Low strength" [Notes (1), (2), and (5)]	(f)(1) Raised or flat on one or both flanges	(f)(1) Flat ring nonmetallic to ASME B16.21, Table 3
			(f)(2) "Higher strength" or "low strength" [Notes (1) through (5)]	(f)(2) Flat	(f)(2) Full face nonmetallic to ASME B16.21 Table 6 (Class 300)
(g)	Class 300 bronze	Class 250 cast iron, Class 300 bronze, Class 300 steel and stainless steel, or Class 300 ductile iron	"Higher strength" or "low strength" [Notes (1) through (7)]	Flat	Full face nonmetallic to ASME B16.21, Table 11 [Note (8)]
(h)	Class 300 ductile iron	Class 300 steel and stainless steel, or Class 300 ductile iron	(h)(1) "Low strength" [Notes (1), (2), and (5)]	(h)(1) Raised or flat on one or both flanges	(h)(1) Flat ring nonmetallic to ASME B16.5, Annex E, Group Ia, Fig. E3 [Note (11)]
			(h)(2) "Higher strength" [Notes (3), (4) and (5)]	(h)(2) Raised or flat on one or both flanges	(h)(2) Ring style to ASME B16.5, Annex E [Notes (10) and (11)]
			(h)(3) "Higher strength" or "low strength" [Notes (1) through (5)]	(h)(3) Flat	(h)(3) Full face nonmetallic to ASME B16.5, Annex E, Group Ia material [Note (11)]

(continued)

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TABLE 112
PIPING FLANGE BOLTING, FACING, AND GASKET REQUIREMENTS (CONT'D)
Refer to Paras. 108, 110, and 112

Item	Flange A Mating With Flange B		Bolting	Flange Facings	Gaskets
	Flange A	Flange B			
(i)	Class 300 and higher classes, steel and stainless steel	Class 300 and higher classes, steel and stainless steel	(i)(1) "Low strength" [Notes (1), (2), and (5)]	(i)(1) Raised or flat on one or both flanges; large or small male and female; large or small tongue and groove	(i)(1) Flat ring nonmetallic to ASME B16.5, Para. 6.11 and Annex E, Group Ia material [Note (11)]
			(i)(2) "Higher strength" [Notes (3), (4), and (5)]	(i)(2) Raised or flat on one or both flanges; large or small male and female; large or small tongue and groove	(i)(2) Ring style to ASME B16.5, Para. 6.11 and Annex E [Notes (10) and (11)]
			(i)(3) "Higher strength" [Notes (3), (4), and (5)]	(i)(3) Ring joint	(i)(3) Ring joint to ASME B16.20
(j)	Class 800 cast iron	Class 800 cast iron	"Low strength" [Notes (1), (2), and (5)]	Raised or large male and female	Flat ring nonmetallic to ASME B16.21, Table 4

GENERAL NOTES:

(a) Bolting (including nuts), flange facing, and gasket selection (materials, dimensions, bolt stress, gasket factor, seating stress, etc.) shall be suitable for the flanges, service conditions, and hydrostatic tests. There shall be no overstressing of the gasket or flanges from the expected bolt loading or external bending loads.

(b) Unless otherwise stated, the flange facing described applies to both flanges A and B.

(c) For flanges other than to ASME B16.1, in sizes larger than NPS 24 (NPS 12 in Class 2500), gasket dimensions should be verified against the flanges specified (e.g., MSS SP-44 and API 605).

(d) The effective seating of a full face gasket shall extend to the outside edge of the flange. For flat or raised face flanges, a flat ring or ring style gasket shall be self-centering, extending to the inner edge of the bolt holes or bolts. Where the joint contains a cast iron, bronze, nonmetallic, or MSS SP-51 stainless steel flange, the effective gasket seating shall extend to the outside diameter of the gasket.

(e) Unconfined nonmetallic gaskets shall not be used on flat or raised face flanges if the expected normal operating pressure exceeds 720 psi (4950 kPa) or the temperature exceeds 750°F (400°C). Metal gaskets, spiral wound gaskets of metal with nonmetallic filler, and confined nonmetallic gaskets are not limited as to pressure or temperature provided the gasket materials are suitable for the maximum fluid temperatures.

(continued)

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TABLE 112 (CONT'D)

NOTES:

(1) "Low strength" bolting shall conform to ASTM:

A 193, Grade B8A, B8CA, B8MA, or B8TA	A 307, Grade 8 [Bolting to A 307, Grade B shall not be used at temperatures greater than 400°F (200°C)]
A 193, Class 1, Grade B8, B8C, B8M, or B8T	A 320, Class 1, Grade B8, B8C, B8M, or B8T

(2) Nuts for "low strength" bolting shall conform to the grade of ASTM A 194 or A 563 as required by the bolting specification.

(3) "Higher strength" bolting shall conform to ASTM:

A 193, Grade B5, B6, B6X, B7, B7M, or B16	A 354, Grade BC or BD
A 193, Class 2, Grade B8, B8C, B8M, or B8T	A 437, Grade B4B, B4C, or B4D
A 320, Grade L7, L7A, L7B, L7C, or L43	
A 320, Class 2, Grade B8, B8C, B8F, B8M, or B8T	A 453, Grade 651 or 660

(4) Nuts for "higher strength" bolting shall conform to the grade of ASTM A 194, A 437, A 453, A 563, or A 564, as required by the bolting specification.

(5) For temperatures below −20°F (−29°C), bolting conforming to the ASTM A 320 classes and grades listed, respectively, in Note (3) "higher strength" and Note (1) "low strength" shall be used. For this bolting to ASTM A 320, Grades L7, L7A, L7B, L7C, and L43, the nuts shall conform to ASTM A 194, Grade 4 or 7 with impact requirements of A 320. For bolting to the other grades of A 320, the nuts shall conform to A 320.

(6) Additionally, for joints containing bronze flanges, nonferrous bolting conforming to the following may be used:

ASTM B 98, UNS C65100, C65500, and C66100; half hard; to 350°F (177°C) maximum	ASTM B 164, UNS N04400 and N04405; hot finish; 550°F (288°C) maximum
ASTM B 150, UNS C61400, to 500°F (260°C) maximum	ASTM B 164, UNS N04400, cold drawn, cold drawn and stress relieved, or cold drawn and stress equalized; and N04405, cold drawn, to 500°F (260°C) maximum
ASTM B 150, UNS C63000 and C64200, to 550°F (288°C) maximum	

(7) Where a flanged joint contains dissimilar materials (e.g., bronze flanges with steel bolting) and has a design temperature exceeding 300°F (149°C), the differences in coefficients of expansion shall be considered.

(8) For bronze flanges where "low strength" or nonferrous bolting is used, nonmetallic gaskets having seating stresses greater than 1600 psi shall not be used.

(9) For stainless steel flanges to MSS SP-51 and for nonmetallic flanges, preference shall be given to gasket materials having the lower minimum design seating stress as listed in ASME B16.5, Fig. E1, Group 1a.

(10) For items (d)(2), and (i)(2), where two flat face flanges are used in a joint and the gasket seating width (considering both the gasket and the flanges) is greater than that of an ASME B16.5 flange having a standard raised face, the gasket material shall conform to ASME B16.5, Annex E, Group 1a.

(11) Where asbestos sheet, fiber or filler material for gaskets is specified in ASME B16.5, this limitation shall not apply to ASME B31.1 applications. Any nonmetallic material suitable for the operating conditions may be used in lieu of asbestos provided the requirements of Table 112 are met.

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TABLE 114.2.1

Maximum Nominal Size, in.	Maximum Pressure psi	Maximum Pressure kPa
3	400	2 750
2	600	4 150
1	1200	8 300
3/4 and smaller	1500	10 350

GENERAL NOTE: For instrument, control and sampling lines, refer to para. 122.3.6(A.5)

114.2.1 Threaded joints shall not be used where severe erosion, crevice corrosion, shock, or vibration is expected to occur, nor at temperatures over 925°F (495°C). Size limits for steam and hot water service [above 220°F (105°C)] shall be as listed in Table 114.2.1.

114.2.2 Threaded access holes with plugs, which serve as openings for radiographic inspection of welds, are not subject to the limitations of para. 114.2.1 and Table 114.2.1, provided their design and installation meets the requirement of para. 114.1. A representative type of access hole and plug is shown in PFI ES-16.

114.2.3 Threaded connections for insertion type fluid temperature determination, flow measurement, and sampling devices are not subject to the temperature limitation stated in para. 114.2.1 nor the pressure limitations stated in Table 114.2.1 provided that design and installation meet the requirements of paras. 104.3.1 and 114.1. At temperatures greater than 925°F (495°C) or at pressures greater than 1500 psi (10 350 kPa), these threaded connections shall be seal welded in accordance with para. 127.4.5. The design and installation of insertion type fluid temperature determination, flow measurement, and sampling devices shall be adequate to withstand the effects of the fluid characteristics, fluid flow, and vibration.

114.3

Pipe with a wall thickness less than that of standard weight of ASME B36.10M steel pipe shall not be threaded, regardless of service. For additional threading limitations for pipe used in:

(A) steam service over 250 psi (1750 kPa); or

(B) water service over 100 psi (700 kPa) and 220°F (105°C).

See para. 104.1.2(C.1).

115 FLARED, FLARELESS, AND COMPRESSION JOINTS

Flared, flareless, and compression type tubing fittings may be used for tube sizes not exceeding 2 in. (50 mm) O.D. within the limitations of applicable standards and specifications listed in Table 126.1.

In the absence of standards, specifications, or allowable stress values for the material used to manufacture the fitting, the designer shall determine that the type and the material of the fitting selected is adequate and safe for the design conditions in accordance with the following requirements.

(A) The pressure design shall meet the requirements of para. 104.7.

(B) A suitable quantity of the type, size, and material of the fittings to be used shall meet successful performance tests to determine the safety of the joint under simulated service conditions. When vibration, fatigue, cyclic conditions, low temperature, thermal expansion, or hydraulic shock are expected, the applicable conditions shall be incorporated in the test.

115.1

Fittings and their joints shall be compatible with the tubing with which they are to be used and shall conform to the range of wall thicknesses and method of assembly recommended by the manufacturer.

115.2

Fittings shall be used at pressure-temperature ratings not exceeding the recommendations of the manufacturer. Service conditions, such as vibration and thermal cycling, shall be considered in the application.

115.3

See para. 114.1 for requirements of threads on piping components.

115.4

Flareless fittings shall be of a design in which the gripping member or sleeve shall grip or bite into the outer surface of the tube with sufficient strength to hold the tube against pressure, but without appreciably distorting the inside tube diameter. The gripping member shall also form a pressure seal against the fitting body.

When using bite type fittings, a spot check shall be made for adequate depth of bite and condition of tubing by disassembling and reassembling selected joints.

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Grip type fittings that are tightened in accordance with manufacturer's instructions need not be disassembled for checking.

116 CAULKED JOINTS

116.1

Caulked or leaded joints of the bell and spigot type which are caulked with lead and packing material may be used for cold water service.

116.2

Caulked joints may be used at pressures permitted for the pipe to which they are applied where provisions are made to prevent disengagement of the joints at bends and dead ends, and to support lateral reactions produced by branch connections or other causes.

117 BRAZED AND SOLDERED JOINTS

117.1

Brazed socket-type joints shall be made with suitable brazing alloys. The minimum socket depth shall be sufficient for the intended service. Brazing alloy shall either be end-fed into the socket or shall be provided in the form of a preinserted ring in a groove in the socket. The brazing alloy shall be sufficient to fill completely the annular clearance between the socket and the pipe or tube. The limitations of paras. 117.3(A) and (D) shall apply.

117.2

Soft soldered socket-type joints made in accordance with applicable standards listed in Table 126.1 may be used within their specified pressure-temperature ratings. The limitations in paras. 117.3 and 122.3.2(E.2.3) for instrument piping shall apply. The allowances of para. 102.2.4 do not apply.

117.3 Limitations

(A) Brazed socket-type joints shall not be used on systems containing flammable or toxic fluids in areas where fire hazards are involved.

(B) Soldered socket-type joints shall be limited to systems containing nonflammable and nontoxic fluids.

(C) Soldered socket-type joints shall not be used in piping subject to shock or vibration.

(D) Brazed or soldered joints depending solely upon a fillet, rather than primarily upon brazing or soldering material between the pipe and sockets, are not acceptable.

118 SLEEVE COUPLED AND OTHER PROPRIETARY JOINTS

Coupling type, mechanical gland type, and other proprietary joints may be used where experience or tests have demonstrated that the joint is safe for the operating conditions, and where adequate provision is made to prevent separation of the joint.

PART 5
EXPANSION, FLEXIBILITY, AND SUPPORTING

119 EXPANSION AND FLEXIBILITY

119.1 General

In addition to the design requirements for pressure, weight, and other loadings, power piping systems subject to thermal expansion or contraction or to similar movements imposed by other sources shall be designed in accordance with the requirements for the evaluation and analysis of flexibility and stresses specified herein.

119.2 Stress Range

Stresses caused by thermal expansion, when of sufficient initial magnitude, relax in the hot condition as a result of local yielding or creep. A stress reduction takes place and usually appears as a stress of reversed sign when the component returns to the cold condition. This phenomenon is designated as self-springing of the line and is similar in effect to cold springing. The extent of self-springing depends on the material, the magnitude of the initial expansion and fabrication stress, the hot service temperature and the elapsed time. While the expansion stress in the hot condition tends to diminish with time, the sum of the expansion strains for the hot and cold conditions during any one cycle remains substantially constant. This sum is referred to as the strain range; however, to permit convenient association with allowable stress, stress range is selected as the criterion for the thermal design of piping. The allowable stress range shall be determined in accordance with para. 102.3.2(C).

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119.3 Local Overstrain

All the commonly used methods of piping flexibility analysis assume elastic behavior of the entire piping system. This assumption is sufficiently accurate for systems where plastic straining occurs at many points or over relatively wide regions, but fails to reflect the actual strain distribution in unbalanced systems where only a small portion of the piping undergoes plastic strain, or where, in piping operating in the creep range, the strain distribution is very uneven. In these cases, the weaker or higher stressed portions will be subjected to strain concentrations due to elastic follow-up of the stiffer or lower stressed portions. Unbalance can be produced:

(A) by use of small pipe runs in series with larger or stiffer pipe, with the small lines relatively highly stressed;

(B) by local reduction in size or cross section, or local use of a weaker material; or

(C) in a system of uniform size, by use of a line configuration for which the neutral axis or thrust line is situated close to the major portion of the line itself, with only a very small offset portion of the line absorbing most of the expansion strain.

Conditions of this type should preferably be avoided, particularly where materials of relatively low ductility are used; if unavoidable, they may be mitigated by the judicious application of cold spring.

It is recommended that the design of piping systems of austentic steel materials be approached with greater over-all care as to inspection, material selection, fabrication quality, erection, and elimination of local stress raisers.

119.5 Flexibility

Power piping systems shall be designed to have sufficient flexibility to prevent pipe movements from causing failure from overstress of the pipe material or anchors, leakage at joints, or detrimental distortion of connected equipment resulting from excessive thrusts and moments. Flexibility shall be provided by changes of direction in the piping through the use of bends, loops, or offsets; or provisions shall be made to absorb thermal movements by utilizing expansion, swivel, or ball joints, corrugated pipe, or flexible metal hose assemblies.

119.5.1 Expansion, Swivel, or Ball Joints, and Flexible Metal Hose Assemblies. Except as stated in para. 101.7.2, these components may be used where experience or tests have demonstrated that they are suitable for expected conditions of pressure, temperature, service, and cyclic life.

Restraints and supports shall be provided, as required, to limit movements to those directions and magnitudes permitted for specific joint or hose assembly selected.

119.6 Properties

Thermal expansion data and moduli of elasticity shall be determined from Appendix B and Appendix C, Tables C-1 and C-2, which cover more commonly used piping materials. For materials not included in these Tables, reference shall be to authoritative source data such as publications of the National Institute of Standards and Technology.

119.6.1 Thermal Expansion Range. The thermal expansion range shall be determined from Appendix B as the difference between the unit expansion shown for the highest metal temperature and that for the lowest metal temperature resulting from operating or shutdown conditions.

119.6.2 Moduli of Elasticity. The cold and hot moduli of elasticity E_c and E_h shall be as shown in Appendix C, Table C-1 for ferrous materials and Table C-2 for nonferrous materials, based on the temperatures established in para. 119.6.1.

119.6.3 Poisson's Ratio. Poisson's ratio, when required for flexibility calculations, shall be taken as 0.3 at all temperatures for all materials.

119.6.4 Stresses. Calculations for the stresses shall be based on the least cross section area of the component, using nominal dimensions at the location of local strain. Calculations for the thermal expansion stress range S_E shall be based on the modulus of elasticity E_c at room temperature.

119.7 Analysis

119.7.1 Method of Analysis. All piping shall meet the following requirements with respect to thermal expansion and flexibility:

(A) It shall be the designer's responsibility to perform an analysis unless the system meets one of the following criteria.

(A.1) The piping system duplicates a successfully operating installation or replaces a system with a satisfactory service record.

(A.2) The piping system can be adjudged adequate by comparison with previously analyzed systems.

(A.3) The piping system is of uniform size, has not

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more than two anchors and no intermediate restraints, is designed for essentially noncyclic service (less than 7000 total cycles), and satisfies the following approximate criterion:

(a) English Units

$$\frac{DY}{(L-U)^2} \le 0.03$$

(b) SI Units

$$\frac{DY}{(L-U)^2} \le 208.3$$

where

D = nominal pipe size, in. (mm)
Y = resultant of movements to be absorbed by pipe lines, in. (mm)
L = developed length of line axis, ft (m)
U = anchor distance (length of straight line joining anchors), ft (m)

WARNING: No general proof can be offered that this equation will yield accurate or consistently conservative results. It was developed for ferrous materials and is not applicable to systems used under severe cyclic conditions. It should be used with caution in configurations such as unequal leg U-bends (L/U > 2.5), or near straight "saw-tooth" runs, or for large diameter thin-wall pipe, or where extraneous displacements (not in the direction connecting anchor points) constitute a large part of the total displacement. There is no assurance that terminal reactions will be acceptably low, even if a piping system falls within the above limitations.

(B) All systems not meeting the above criteria, or where reasonable doubt exists as to adequate flexibility of the system, shall be analyzed by simplified, approximate, or comprehensive methods of analysis that are appropriate for the specific case.

(C) Approximate or simplified methods may be applied only if they are used for the range of configurations for which their adequate accuracy has been demonstrated.

(D) Acceptable comprehensive methods of analysis include: analytical, model tests, and chart methods which provide an evaluation of the forces, moments and stresses caused by bending and torsion from the simultaneous consideration of terminal and intermediate restraints to thermal expansion of the entire piping system under consideration, and including all external movements transmitted to the piping by its terminal and intermediate attachments. Correction factors shall be applied for the stress intensification of curved pipe and branch connections, as provided by the details of these rules, and may be applied for the increased flexibility of such component parts.

119.7.3 Basic Assumptions and Requirements. In calculating the flexibility of a piping system between anchor points, the system between anchor points shall be treated as a whole. The significance of all parts of the line and of all restraints, such as supports or guides, including intermediate restraints introduced for the purpose of reducing moments and forces on equipment or small branch lines, shall be considered.

Flexibility calculations shall take into account stress intensifying conditions found in components and joints. Credit may be taken when extra flexibility exists in such components. In the absence of more directly applicable data, the flexibility factors and stress-intensification factors shown in Appendix D may be used.[2]

Dimensional properties of pipe and fittings used in flexibility calculations shall be based on nominal dimensions.

The total expansion range as determined from para. 119.6.1 shall be used in all calculations, whether or not the piping is cold sprung. Not only the expansion of the line itself, but also linear and angular movements of the equipment to which it is attached shall be considered.

Where simplifying assumptions are used in calculations or model tests, the likelihood of attendant underestimates of forces, moments, and stresses, including the effects of stress-intensification shall be evaluated.

119.8 Movements

Movements caused by thermal expansion and loadings shall be determined for consideration of obstructions and design of proper supports.

119.9 Cold Spring

The beneficial effect of judicious cold springing in assisting a system to attain its most favorable position sooner is recognized. Inasmuch as the life of a system under cyclic conditions depends on the stress range rather than the stress level at any one time, no credit for cold spring is allowed with regard to stresses. In

[2] The stress-intensification factors in Appendix D have been developed from fatigue tests of representative commercially available, matching product forms and assemblies manufactured from ductile ferrous materials. The allowable stress-range is based on tests of carbon and stainless steels. Caution should be exercised when applying Figs. (1) and (13) for the allowable stress-range for certain nonferrous materials (e.g., copper and aluminum alloys) for other than low cycle applications.

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calculating end thrusts and moments acting on equipment, the actual reactions at any one time, rather than their range, are significant. Credit for cold springing is accordingly allowed in the calculation of thrusts and moments, provided an effective method of obtaining the designed cold spring is specified and used.

119.10 Reactions

01 **119.10.1 Computing Hot and Cold Reactions.** In a piping system with no cold spring or an equal percentage of cold springing in all directions, the reactions (forces and moments) of R_h and R_c, in the hot and cold conditions, respectively, shall be obtained from the reaction R derived from the flexibility calculations based on the modulus of elasticity at room temperature E_c, using Eqs. (9) and (10).

$$R_h = \left(1 - \tfrac{2}{3}C\right)\left(\frac{E_h}{E_c}R\right) \tag{9}$$

$$R_c = -CR, \text{ or}$$

$$= -\left[1 - \frac{(S_h)}{(S_E)} \cdot \frac{(E_c)}{(E_h)}\right]R \tag{10}$$

whichever is greater, and with the further condition that

$$\frac{(S_h)}{(S_E)} \cdot \frac{(E_c)}{(E_h)} < 1$$

where

C = cold spring factor varying from zero for no cold spring to 1.00 for 100% cold spring

S_E = computed thermal expansion stress range, psi (MPa)

E_c = modulus of elasticity in the cold condition, psi (MPa)

E_h = modulus of elasticity in the hot condition, psi (MPa)

R = maximum reaction for full expansion range based on $E_c$which assumes the most severe condition (100% cold spring, whether such is used or not), lb and in-lb (N and mm-N)

R_c, R_h = maximum reactions estimated to occur in the cold and hot conditions, respectively, lb and in.-lb (N and mm-N)

If a piping system is designed with different percentages of cold spring in various directions, Eqs. (9) and (10) are not applicable. In this case, the piping system shall be analyzed by a comprehensive method. The calculated hot reactions shall be based on theoretical cold springs in all directions not greater than two-thirds of the cold springs as specified or measured.

119.10.2 Reaction Limits. The reactions computed shall not exceed limits which the attached equipment can sustain. Equipment allowable reaction limits (forces and moments) on piping connections are normally established by the equipment manufacturer.

120 LOADS ON PIPE SUPPORTING ELEMENTS

120.1 General

(A) The broad terms "Supporting Elements" or "Supports" as used herein shall encompass the entire range of the various methods of carrying the weight of pipe lines, insulation, and the fluid carried. It therefore includes "hangers" which are generally considered as those elements which carry the weight from above, with the supporting members being mainly in tension. Likewise, it includes "supports" which on occasion are delineated as those which carry the weight from below, with the supporting members being mainly in compression. In many cases a supporting element may be a combination of both of these.

(B) In addition to the weight effects of piping components, consideration shall be given in the design of pipe supports to other load effects introduced by service pressure, wind, earthquake, etc., as defined in para. 101. Hangers and supporting elements shall be fabricated and assembled to permit the free movement of piping caused by thermal expansion and contraction. The design of elements for supporting or restraining piping systems, or components thereof, shall be based on all the concurrently acting loads transmitted into the supporting elements.

(C) Where the resonance with imposed vibration and/or shock occurs during operation, suitable dampeners, restraints, anchors, etc., shall be added to remove these effects.

120.2 Supports, Anchors, and Guides

120.2.1 Rigid Type Supports

(A) The required strength of all supporting elements shall be based on the loadings as given in para. 120.1, including the weight of the fluid transported or the fluid used for testing, whichever is heavier. The allow-

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able stress in supporting equipment shall be as specified in para. 121.2.

(B) Exceptions may be made in the case of supporting elements for large size gas or air piping, exhaust steam, relief or safety valve relief piping, but only under the conditions where the possibility of the line becoming full of water or other liquid is very remote.

120.2.2 Variable and Constant Supports. Load calculations for variable and constant supports, such as springs or counterweights, shall be based on the design operating conditions of the piping. They shall not include the weight of the hydrostatic test fluid. However, the support shall be capable of carrying the total load under test conditions, unless additional support is provided during the test period.

120.2.3 Anchors or Guides. Where anchors or guides are provided to restrain, direct, or absorb piping movements, their design shall take into account the forces and moments at these elements caused by internal pressure and thermal expansion.

120.2.4 Supplementary Steel. Where it is necessary to frame structural members between existing steel members, such supplementary steel shall be designed in accordance with American Institute of Steel Construction specifications, the Uniform Building Code, or similar recognized structural design standards. Increases of allowable stress values for short duration loading, such as outlined in para. 121.2(I), are not permitted.

121 DESIGN OF PIPE SUPPORTING ELEMENTS

121.1 General

Design of standard pipe supporting elements shall be in accordance with the rules of MSS SP-58. Allowable stress values and other design criteria shall be in accordance with this paragraph. Supporting elements shall be capable of carrying the sum of all concurrently acting loads as listed in para. 120. They shall be designed to provide the required supporting effort and allow pipeline movement with thermal changes without causing overstress. The design shall also prevent complete release of the piping load in the event of spring failure or misalignment. All parts of the supporting equipment shall be fabricated and assembled so that they will not be disengaged by movement of the supported piping. The maximum safe loads for bolts, threaded hanger rods, and all other threaded members shall be based on the root area of the threads.

121.2 Allowable Stress Values 01

(A) Allowable stress values tabulated in MSS SP-58 or in Appendix A of this Code Section may be used for the base materials of all parts of pipe supporting elements.

(B) Where allowable stress values for a material specification listed in Table 126.1 are not tabulated in Appendix A or in MSS SP-58, allowable stress values from Section II, Part D, Tables 1A and 1B of the ASME Boiler and Pressure Vessel Code may be used, provided the requirements of para. 102.3.1(B) are met. Where there are no stress values given in Section II, Part D, Tables 1A and 1B, an allowable stress value of 25% of the minimum tensile strength given in the material specification may be used, for temperatures not exceeding 650°F (345°C).

(C) For a steel material of unknown specification, or of a specification not listed in Table 126.1 or MSS SP-58, an allowable stress value of 30% of yield strength (0.2% offset) at room temperature may be used at temperatures not exceeding 650°F (345°C). The yield strength shall be determined through a tensile test of a specimen of the material and shall be the value corresponding to 0.2% permanent strain (offset) of the specimen. The allowable stress values for such materials shall not exceed 9500 psi (65.5 MPa).

(D) The allowable shear stress shall not exceed 80% of the values determined in accordance with the rules of (A), (B), and (C) above.

(E) The allowable compressive stress shall not exceed the value as determined in accordance with the rules of (A), (B), or (C) above. In addition, consideration shall be given to structural stability.

(F) The allowable bearing stress shall not exceed 160% of the value as determined in accordance with the rules of (A), (B), or (C) above.

(G) The allowable base material tensile stress determined from (A), (B), or (C) above shall be reduced 25% for threaded hanger rods.

(H) The allowable stress in welds in support assemblies shall be reduced 25% from those determined in accordance with (A), (B), (C), or (D) above for the weaker of the two metals joined.

(I) Increases in the allowable stress values shall be permitted as follows:

(1) an increase of 20% for short time overloading during operation;

(2) an increase to 80% of the minimum yield strength at room temperature during hydrostatic testing. Where the material allowable stress has been established in accordance with the rules of (C) above, the allowable

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stress value during hydrostatic testing shall not exceed 16,000 psi (110.3 MPa).

121.3 Temperature Limitations

Parts of supporting elements which are subjected principally to bending or tension loads and which are subjected to working temperatures for which carbon steel is not recommended shall be made of suitable alloy steel, or shall be protected so that the temperature of the supporting member will be maintained within the appropriate temperature limits of the material.

121.4 Hanger Adjustments

Hangers used for the support of piping, NPS 2½ and larger, shall be designed to permit adjustment after erection while supporting the load. Screwed adjustments shall have threaded parts to conform to ASME B1.1.

Class 2 fit turnbuckles and adjusting nuts shall have the full length of thread in engagement. Means shall be provided for determining that full thread length is in engagement. All screw and equivalent adjustments shall be provided with suitable locking devices.

121.5 Hanger Spacing

Supports for piping with the longitudinal axis in approximately a horizontal position shall be spaced to prevent excessive sag, bending and shear stresses in the piping, with special consideration given where components, such as flanges and valves, impose concentrated loads. Where calculations are not made, suggested maximum spacing of supports for standard and heavier pipe are given in Table 121.5. Vertical supports shall be spaced to prevent the pipe from being overstressed from the combination of all loading effects.

121.6 Springs

The springs used in variable or constant effort type supports shall be designed and manufactured in accordance with MSS SP-58.

121.7 Fixtures

121.7.1 Anchors and Guides

(A) Anchors, guides, pivots, and restraints shall be designed to secure the desired points of piping in relatively fixed positions. They shall permit the piping to expand and contract freely in directions away from the anchored or guided point and shall be structurally suitable to withstand the thrusts, moments, and other loads imposed.

TABLE 121.5
SUGGESTED PIPE SUPPORT SPACING

Nominal Pipe Size, NPS	Suggested Maximum Span			
	Water Service		Steam, Gas, or Air Service	
	ft	m	ft	m
1	7	2.1	9	2.7
2	10	3.0	13	4.0
3	12	3.7	15	4.6
4	14	4.3	17	5.2
6	17	5.2	21	6.4
8	19	5.8	24	7.3
12	23	7.0	30	9.1
16	27	8.2	35	10.7
20	30	9.1	39	11.9
24	32	9.8	42	12.8

GENERAL NOTES:

(a) Suggested maximum spacing between pipe supports for horizontal straight runs of standard and heavier pipe at maximum operating temperature of 750°F (400°C).

(b) Does not apply where span calculations are made or where there are concentrated loads between supports, such as flanges, valves, specialties, etc.

(c) The spacing is based on a fixed beam support with a bending stress not exceeding 2300 psi (15.86 MPa) and insulated pipe filled with water or the equivalent weight of steel pipe for steam, gas, or air service, and the pitch of the line is such that a sag of 0.1 in. (2.5 mm) between supports is permissible.

(B) Rolling or sliding supports shall permit free movement of the piping, or the piping shall be designed to include the imposed load and frictional resistance of these types of supports, and dimensions shall provide for the expected movement of the supported piping. Materials and lubricants used in sliding supports shall be suitable for the metal temperature at the point of sliding contact.

(C) Where corrugated or slip-type expansion joints, or flexible metal hose assemblies are used, anchors and guides shall be provided where necessary to direct the expansion into the joint or hose assembly. Such anchors shall be designed to withstand the force specified by the manufacturer for the design conditions at which the joint or hose assembly is to be used. If this force is otherwise unknown, it shall be taken as the sum of the product of the maximum internal area times the design pressure plus the force required to deflect the joint or hose assembly. Where expansion joints or flexible metal hose assemblies are subjected to a combination of longitudinal and transverse movements, both movements shall be considered in the design and application of the joint or hose assembly.

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TABLE 121.7.2(A)
CARRYING CAPACITIES OF THREADED ASTM A 36, A 575, AND A 576 HOT ROLLED CARBON STEEL

Nominal Rod Diameter, in.	Root Area of Coarse Thread		Max. Safe Load at Rod Temp. of 650°F (345°C)	
	sq in.	sq mm	lb	kg
3/8	0.068	43.87	610	276
1/2	0.126	81.29	1,130	512
5/8	0.202	130.3	1,810	821
3/4	0.302	194.8	2,710	1 229
7/8	0.419	270.3	3,770	1 710
1	0.552	356.1	4,960	2 250
1 1/4	0.889	573.5	8,000	3 629
1 1/2	1.293	834.2	11,630	5 275
1 3/4	1.744	1 125	15,690	7 117
2	2.292	1 479	20,690	9 385
2 1/4	3.021	1 949	27,200	12 338
2 1/2	3.716	2 397	33,500	15 195
2 3/4	4.619	2 980	41,600	18 869
3	5.621	3 626	50,600	22 952
3 1/4	6.720	4 335	60,500	27 442
3 1/2	7.918	5 108	71,260	32 323
3 3/4	9.214	5 945	82,900	37 640
4	10.608	6 844	95,500	43 360
4 1/4	12.100	7 806	108,900	49 440
4 1/2	13.690	8 832	123,200	55 930
4 3/4	15.379	9 922	138,400	62 830
5	17.165	11 074	154,500	70 140

GENERAL NOTE: Tabulated loads are based on an allowable tensile stress of 12,000 psi (82.7 MPa) reduced by 25% using the root thread area as a base. [Refer to para. 121.2(A).]

Flexible metal hose assemblies, applied in accordance with para. 106.4, shall be supported in such a manner as to be free from any effects due to torsion and undue strain as recommended by the manufacturer.

121.7.2 Other Rigid Types

(A) Hanger Rods. Safe loads for threaded hanger rods shall be based on the root area of the threads and allowable stress of the material. In no case shall hanger rods less than 3/8 in. (9.5 mm) diameter be used for support of pipe NPS 2 and smaller, or less than 1/2 in. (12.5 mm) diameter rod for supporting pipe NPS 2 1/2 and larger. See Table 121.7.2(A) for carbon steel rods.

Pipe, straps, or bars of strength and effective area equal to the equivalent hanger rod may be used instead of hanger rods.

Hanger rods, straps, etc., shall be designed to permit the free movement of piping caused by thermal expansion and contraction.

(B) Welded link chain of 3/16 in. (5.0 mm) or larger diameter stock, or equivalent area, may be used for pipe hangers with a design stress of 9000 psi (62 MPa) maximum.

(C) Cast iron in accordance with ASTM A 48 may be used for bases, rollers, anchors, and parts of supports where the loading will be mainly compression. Cast iron parts shall not be used in tension.

(D) Malleable iron castings in accordance with ASTM A 47 may be used for pipe clamps, beam clamps, hanger flanges, clips, bases, swivel rings, and parts of pipe supports, but their use shall be limited to temperatures not in excess of 450°F (230°C). This material is

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not recommended for services where impact loads are anticipated.

(E) Brackets shall be designed to withstand forces and moments induced by sliding friction in addition to other loads.

121.7.3 Variable Supports

(A) Variable spring supports shall be designed to exert a supporting force equal to the load, as determined by weight balance calculations, plus the weight of all hanger parts (such as clamp, rod, etc.) that will be supported by the spring at the point of attachment to the pipe.

(B) Variable spring supports shall be provided with means to limit misalignment, buckling, eccentric loading, or to prevent overstressing of the spring.

(C) It is recommended that all hangers employing springs be provided with means to indicate at all times the compression of the spring with respect to the approximate hot and cold positions of the piping system, except where they are used either to cushion against shock or where the operating temperature of the piping system does not exceed 250°F (120°C).

(D) It is recommended that the support be designed for a maximum variation in supporting effort of 25% for the total travel resulting from thermal movement.

121.7.4 Constant Supports. On high temperature and critical service piping at locations subject to appreciable movement with thermal changes, the use of constant support hangers, designed to provide a substantially uniform supporting force throughout the range of travel, is recommended.

(A) Constant support hangers shall have a support variation of no more than 6% throughout the total travel range.

(B) Counterweight type supports shall be provided with stops, and the weights shall be positively secured. Chains, cables, hanger and rocker arm details, or other devices used to attach the counterweight load to the piping, shall be subject to requirements of para. 121.7.2.

(C) Hydraulic type supports utilizing a hydraulic head may be installed to give a constant supporting effort. Safety devices and stops shall be provided to support the load in case of hydraulic failure.

(D) Boosters may be used to supplement the operation of constant support hangers.

121.7.5 Sway Braces. Sway braces or vibration dampeners shall be used to control the movement of piping due to vibration.

121.7.6 Shock Suppressors. For the control of piping due to dynamic loads, hydraulic or mechanical types of shock suppressors are permitted. These devices do not support pipe weight.

121.8 Structural Attachments

121.8.1 Nonintegral Type

(A) Nonintegral attachments include clamps, slings, cradles, saddles, straps, and clevises.

(B) When clamps are used to support vertical lines, it is recommended that shear lugs be welded to the pipe to prevent slippage. The provisions of para. 121.8.2(B) shall apply.

(C) In addition to the provision of (B) above, clamps to support vertical lines should be designed to support the total load on either arm in the event the load shifts due to pipe and/or hanger movement.

121.8.2 Integral Type

(A) Integral attachments include ears, shoes, lugs, cylindrical attachments, rings, and skirts which are fabricated so that the attachment is an integral part of the piping component. Integral attachments shall be used in conjunction with restraints or braces where multiaxial restraint in a single member is to be maintained. Consideration shall be given to the localized stresses induced into the piping component by the integral attachments. Where applicable, the conditions of para. 121.8.1(C) are to apply.

(B) Integral lugs, plates, angle clips, etc., used as part of an assembly for the support or guiding of pipe may be welded directly to the pipe provided the materials are compatible for welding and the design is adequate for the temperature and load. The design of hanger lugs for attachment to piping for high temperature service shall be such as to provide for differential expansion between the pipe and the attached lug.

Welds shall be proportioned so that the shear stresses do not exceed either 0.8 times the applicable S values for the pipe material shown in the Allowable Stress Tables, or the allowable stress values determined in accordance with para. 121.2(A), (B), or (C). If materials for attachments have different allowable stress values than the pipe, the lower allowable stress value of the two shall be used.

121.9 Loads and Supporting Structures

121.9.1 Considerations shall be given to the load carrying capacity of equipment and the supporting structure. This may necessitate closer spacing of hangers on lines with extremely high loads.

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121.10 Requirements for Fabricating Pipe Supports

121.10.1 Pipe supports shall be fabricated in accordance with the requirements of para. 130.

PART 6
SYSTEMS

122 DESIGN REQUIREMENTS PERTAINING TO SPECIFIC PIPING SYSTEMS

Except as specifically stated otherwise in this Part 6, all provisions of the Code apply fully to the piping systems described herein.

122.1 Boiler External Piping; in Accordance With Para. 100.1.2(A) — Steam, Feedwater, Blowoff, and Drain Piping

122.1.1 General. The minimum pressure and temperature and other special requirements to be used in the design for steam, feedwater, blowoff, and drain piping from the boiler to the valve or valves required by para. 122.1 shall be as specified in the following paragraphs. Design requirements for desuperheater spray piping connected to desuperheaters located in the boiler proper are provided in para. 122.4.

(A) It is intended that the design pressure and temperature be selected sufficiently in excess of any expected operating conditions, not necessarily continuous, to permit satisfactory operation without operation of the overpressure protection devices. Also, since the operating temperatures of fired equipment can vary, the expected temperature at the connection to the fired equipment shall include the manufacturer's maximum temperature tolerance.

(B) In a forced flow steam generator with no fixed steam and waterline, it is permissible to design the external piping, valves, and fittings attached to the pressure parts for different pressure levels along the path through the steam generator of water-steam flow. The values of design pressure and the design temperature to be used for the external piping, valves, and fittings shall be not less than that required for the expected maximum sustained operating pressure and temperature to which the abutted pressure part is subjected except when one or more of the overpressure protection devices covered by PG-67.4 of Section I of the ASME Boiler and Pressure Vessel Code is in operation. The steam piping shall comply with the requirements for the maximum sustained operating conditions as used in (A) above, or for the design throttle pressure plus 5%, whichever is greater.

(C) Provision shall be made for the expansion and contraction of piping connected to boilers to limit forces and moments transmitted to the boiler, by providing substantial anchorage at suitable points, so that there shall be no undue strain transmitted to the boiler. Steam reservoirs shall be used on steam mains when heavy pulsations of the steam currents cause vibration.

(D) Piping connected to the outlet of a boiler for any purpose shall be attached by:

(D.1) welding to a nozzle or socket welding fitting;

(D.2) threading into a tapped opening with a threaded fitting or valve at the other end;

(D.3) screwing each end into tapered flanges, fittings, or valves with or without rolling or peening;

(D.4) bolted joints including those of the Van Stone type;

(D.5) blowoff piping of firetube boilers shall be attached in accordance with (D.2) above if exposed to products of combustion or in accordance with (D.2), (D.3), or (D.4) above if not so exposed.

(E) Nonferrous pipe or tubes shall not exceed NPS 3 in diameter.

(F) American National Standard slip-on flanges shall not exceed NPS 4. Attachment of slip-on flanges shall be by double fillet welds. The throats of the fillet welds shall not be less than 0.7 times the thickness of the part to which the flange is attached.

(G) Hub-type flanges shall not be cut from plate material.

(H) American National Standard socket welded flanges may be used in piping or boiler nozzles provided the dimensions do not exceed NPS 3 for Class 600 and lower and NPS $2\frac{1}{2}$ in Class 1500.

122.1.2 Steam Piping

(A) The value of P to be used in the formulas in para. 104 shall be as follows.

(A.1) For steam piping connected to the steam drum or to the superheater inlet header up to the first stop valve in each connection, the value of P shall be not less than the lowest pressure at which any drum safety valve is set to blow, and the S value shall not exceed that permitted for the corresponding saturated steam temperature.

(A.2) For steam piping connected to the superheater outlet header up to the first stop valve in each connection, the design pressure, except as otherwise provided in (A.4) below shall be not less than the lowest pressure at which any safety valve on the superheater is set to blow, or not less than 85% of the lowest pressure at

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which any drum safety valve is set to blow, whichever is greater, and the S value for the material used shall not exceed that permitted for the expected steam temperature.

(A.3) For steam piping between the first stop valve and the second valve, when one is required by para. 122.1.7, the design pressure shall be not less than the expected maximum sustained operating pressure or 85% of the lowest pressure at which any drum safety valve is set to blow, whichever is greater, and the S value for the material used shall not exceed that permitted for the expected steam temperature.

(A.4) For boilers installed on the unit system (i.e., one boiler and one turbine or other prime mover) and provided with automatic combustion control equipment responsive to steam header pressure, the design pressure for the steam piping shall be not less than the design pressure at the throttle inlet plus 5%, or not less than 85% of the lowest pressure at which any drum safety valve is set to blow, or not less than the expected maximum sustained operating pressure at any point in the piping system, whichever is greater, and the S value for the material used shall not exceed that permitted for the expected steam temperature at the superheater outlet. For forced-flow steam generators with no fixed steam and waterline, the design pressure shall also be no less than the expected maximum sustained operating pressure.

(A.5) The design pressure shall not be taken at less than 100 psig [700 kPa (gage)] for any condition of service or material.

122.1.3 Feedwater Piping

(A) The value of P to be used in the formulas in para. 104 shall be as follows.

(A.1) For piping from the boiler to and including the required stop valve and the check valve, the minimum value of P except as permitted in para. 122.1.3(A.4) shall exceed the maximum allowable working pressure of the boiler by either 25% or 225 psi (1550 kPa), whichever is the lesser. For an installation with an integral economizer without valves between the boiler and economizer, this paragraph shall apply only to the piping from the economizer inlet header to and including the required stop valve and the check valve.

(A.2) For piping between the required check valve and the globe or regulating valve, when required by para. 122.1.7(B), and including any bypass piping up to the shutoff valves in the bypass, the value of P shall be not less than the pressure required to feed the boiler.

(A.3) The value of P in the formula shall not be taken at less than 100 psig [700 kPa (gage)] for any condition of service or material, and shall never be less than the pressure required to feed the boiler.

(A.4) In a forced flow steam generator with no fixed steam and waterline, the value of P for feedwater piping from the boiler to and including the required stop valve may be in accordance with the requirements of para. 122.1.1(B).

(B) The S value used, except as permitted in (A.4) above, shall not exceed that permitted for the temperature of saturated steam at the maximum allowable working pressure of the boiler.

(C) The size of the feed piping between the boiler and the first required valve [para. 122.1.7(B)] or the branch feed connection [para. 122.1.7(B.4)] shall, as a minimum, be the same as the boiler connection.

122.1.4 Blowoff and Blowdown Piping. Blowoff and blowdown piping are defined as piping connected to a boiler and provided with valves or cocks through which the water in the boiler may be blown out under pressure. This definition is not intended to apply to (i) drain piping, and (ii) piping such as used on water columns, gage glasses, or feedwater regulators, etc., for the purpose of determining the operating condition of the equipment. Requirements for (i) and (ii) are described in paras. 122.1.5 and 122.1.6. Blowoff systems are operated intermittently to remove accumulated sediment from equipment and/or piping, or to lower boiler water level in a rapid manner. Blowdown systems are primarily operated continuously to control the concentrations of dissolved solids in the boiler water.

(A) Blowoff piping systems from water spaces of a boiler, up to and including the blowoff valves, shall be designed in accordance with (A.1) to (A.4) below. Two shutoff valves are required in the blowoff system; specific valve requirements and exceptions are given in para. 122.1.7(C).

(A.1) The value of P to be used in the formulas in para. 104 shall exceed the maximum allowable working pressure of the boiler by either 25% or 225 psi (1550 kPa) whichever is less, but shall not be less than 100 psig [700 kPa (gage)].

(A.2) The allowable stress value for the piping materials shall not exceed that permitted for the temperature of saturated steam at the maximum allowable working pressure of the boiler.

(A.3) All pipe shall be steel. Galvanized steel pipe and fittings shall not be used for blowoff piping. When the value of P does not exceed 100 psig [700 kPa (gage)], the fittings shall be bronze, cast iron, malleable

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iron, ductile iron, or steel. When the value of P exceeds 100 psig [700 kPa (gage)], the fittings shall be steel and the thickness of pipe and fittings shall not be less than that of Schedule 80 pipe.

(A.4) The size of blowoff piping shall be not less than the size of the connection on the boiler, and shall be in accordance with the rules contained in the ASME Boiler and Pressure Vessel Code, Section I, PG-59.3 and PEB-12.

(B) The blowdown piping system from the boiler, to and including the shutoff valve, shall be designed in accordance with (B.1) through (B.4) below. Only one shutoff valve is required in the blowdown system.

(B.1) The value of P to be used in the formulas in para. 104 shall be not less than the lowest set pressure of any safety valve on the boiler drum.

(B.2) The allowable stress value for the piping materials shall not exceed that permitted for the temperature of saturated steam at the maximum allowable working pressure of the boiler.

(B.3) All pipe shall be steel. Galvanized steel pipe and fittings shall not be used for blowdown piping. When the value of P does not exceed 100 psig [700 kPa (gage)], the fittings shall be bronze, cast iron, malleable iron, ductile iron, or steel. When the value of P exceeds 100 psig [700 kPa (gage)], the fittings shall be steel and the thickness of pipe and fittings shall not be less than that of Schedule 80 pipe.

(B.4) The size of blowdown piping shall be not less than the size of the connection on the boiler, and shall be in accordance with the rules contained in the ASME Boiler and Pressure Vessel Code, Section I, PG-59.3.

(C) The blowoff and blowdown piping beyond the required valves described in (A) and (B) above are classified as nonboiler external piping. The requirements are given in para. 122.2.

122.1.5 Boiler Drains

(A) Complete drainage of the boiler and attached piping shall be provided to the extent necessary to ensure proper operation of the steam supply system. The pipe, fittings, and valves of any drain line shall not be smaller than the drain connection.

(B) If the drain lines are intended to be used both as drains and as blowoffs, then two valves are required and all conditions of paras. 122.1.4, 122.1.7(C), and 122.2 shall be met.

(C) When a drain is intended for use only when the boiler is not under pressure (pressurizing the boiler for rapid drainage is an exception), a single shutoff valve is acceptable under the following conditions: either the valve shall be a type that can be locked in the closed position or a suitable flanged and bolted connection that accepts a blank insert shall be located on the downstream side of the valve. When a single valve is used, it need not be designed for blowoff service.

(D) Drain piping from the drain connection, including the required valve(s) or the blanked flange connection, shall be designed for the temperature and pressure of the drain connection. The remaining piping shall be designed for the expected maximum temperature and pressure. Static head and possible choked flow conditions shall be considered. In no case shall the design pressure and temperature be less than 100 psig [700 kPa (gage)] and 220°F (104°C), respectively.

122.1.6 Boiler External Piping — Miscellaneous Systems

(A) Materials, design, fabrication, examination, and erection of piping for miscellaneous accessories, such as water level indicators, water columns, gage cocks, and pressure gages, shall be in accordance with the applicable sections of this Code.

(B) The value of P to be used in the Formulas in para. 104 shall be not less than the maximum allowable working pressure of the boiler except as provided by para. 122.1.1(B).

(C) Valve requirements for water level indicators or water columns, special gage glass and gage cock requirements, minimum line sizes, and special piping configurations required specifically for cleaning, access, or reliability shall be in accordance with PG-60 of Section I of the ASME Boiler and Pressure Vessel Code.

122.1.7 Valves and Fittings. The minimum pressure and temperature rating for all valves and fittings in steam, feedwater, blowoff, and miscellaneous piping shall be equal to the pressure and temperature specified for the connected piping on the side that has the higher pressure, except that in no case shall the pressure be less than 100 psig [700 kPa (gage)], and for pressures not exceeding 100 psig [700 kPa (gage)] in feedwater and blowoff service, the valves and fittings shall be equal at least to the requirements of the ASME standards for Class 125 cast iron or Class 150 steel.

(A) Steam Stop Valves. Each boiler discharge outlet, except safety valve or safety relief valve connections, or reheater inlet and outlet connections, shall be fitted with a stop valve located at an accessible point in the steam-delivery line and as near to the boiler nozzle as is convenient and practicable.

(A.1) Boiler stop valves shall provide bidirectional shutoff at design conditions. The valve or valves shall meet the requirements of para. 107. Valves with resilient

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(nonmetallic) seats shall not be used where the boiler maximum allowable working pressure exceeds 1035 kPa (150 psig) or where the system design temperature exceeds 186°C (366°F). Valves of the outside screw and yoke, rising stem style are preferred. Valves other than those of the outside screw and yoke, rising stem style shall meet the following additional requirements.

(A.1.A) Each valve shall be equipped with a position indicator to visually indicate from a distance whether the valve is open or closed.

(A.1.B) Quarter turn valves shall be equipped with a slow operating mechanism to minimize dynamic loadings on the boiler and attached piping.

(A.2) In the case of a single boiler and prime mover installation, the stop valve required herein may be omitted provided the prime mover throttle valve is equipped with an indicator to show whether it is opened or closed, and it is designed to withstand the required boiler hydrostatic test.

01 *(A.3)* When two or more boilers are connected to a common header, or when a single boiler is connected to a header having another steam source, the connection from each boiler having a man-hole opening shall be fitted with two stop valves having an ample free-blow drain between them. The preferred arrangement consists of one stop-check valve (located closest to the boiler) and one valve of the style and design described in (A.1) above. Alternatively, both valves may be of the style and design described in (A.1) above.

When a second stop valve is required, it shall have a pressure rating at least equal to that required for the expected steam pressure and temperature at the valve, or a pressure rating at least equal to 85% of the lowest set pressure of any safety valve on the boiler drum at the expected temperature of the steam at the valve, whichever is greater.

(A.4) All valves and fittings on steam lines shall have a pressure rating of at least 100 psig [700 kPa (gage)] in accordance with the applicable ASME Standard.

(B) Feedwater Valves

(B.1) The feedwater piping for all boilers, except for high temperature water boilers complying with the requirements of (B.8) below, and for forced flow steam generators with no fixed steam and water line complying with the requirements of (B.9) below, shall be provided with a check valve and a stop valve or cock between the check valve and the boiler. The stop valve or cock shall comply with the requirements of (C.5) below.

(B.2) The relative locations of the check and stop (or cock) valves, as required in (B.1) above, may be reversed on a single boiler-turbine unit installation.

(B.3) If a boiler is equipped with a duplicate feed arrangement, each such arrangement shall be equipped as required by these rules.

(B.4) When the supply line to a boiler is divided into branch feed connections and all such connections are equipped with stop and check valves, the stop and check valves in the common source may be omitted.

(B.5) When two or more boilers are fed from a common source, there shall also be a globe or regulating valve in the branch to each boiler located between the check valve and the source of supply. A typical arrangement is shown in Fig. 100.1.2(B). Wherever globe style valves are used on feed piping, the inlet shall be under the disk of the valve.

(B.6) A combination stop and check valve in which there is only one seat and disk, and in which a valve stem is provided to close the valve, shall be considered only as a stop valve, and a check valve shall be installed as otherwise provided.

(B.7) Where an economizer or other feedwater heating device is connected directly to the boiler without intervening valves, the feed valves and check valves required shall be placed on the inlet of the economizer or feedwater heating device.

(B.8) The recirculating return line for a high temperature water boiler shall be provided with the same stop valve, or valves, required by (B.1) and (B.3) above. The use of a check valve in the recirculating return line is optional. A check valve shall not be a substitute for a stop valve.

(B.9) The feedwater boiler external piping for a forced flow steam generator with no fixed steam and water line may terminate up to and including the stop valve(s) and omitting the check valve(s) provided that a check valve having a pressure rating no less than the boiler inlet design pressure is installed at the discharge of each boiler feed pump or elsewhere in the feedline between the feed pump and the stop valve(s).

(C) Blowoff Valves

(C.1) Ordinary globe valves as shown in Fig. 122.1.7(C) sketch (1), and other types of valves that have dams or pockets where sediment can collect, shall not be used on blowoff connections.

(C.2) Y-type globe valves as shown in Fig. 122.1.7(C) sketch (2) or angle valves may be used in vertical pipes, or they may be used in horizontal runs of piping provided they are so constructed or installed that the lowest edge of the opening through the seat is at least 25% of the inside diameter below the center line of the valve.

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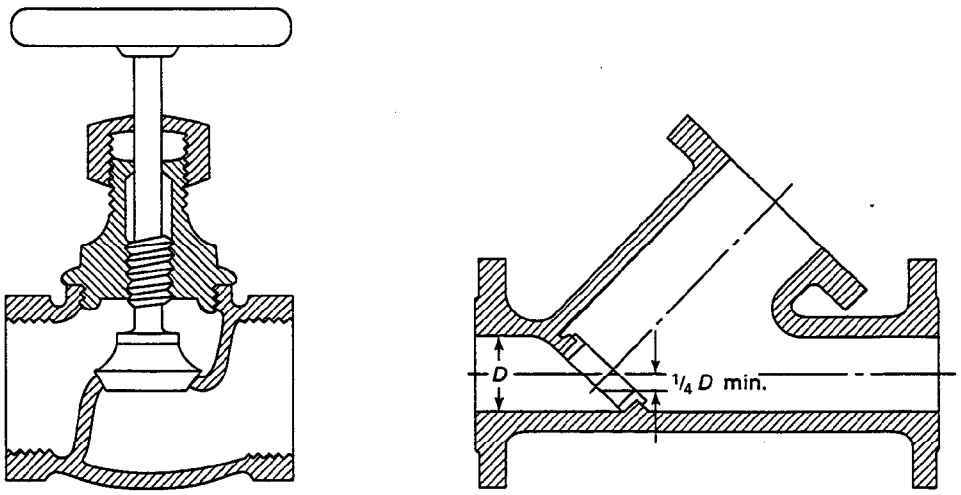

FIG. 122.1.7(C) TYPICAL GLOBE VALVES

(C.3) The blowoff valve or valves, the pipe between them, and the boiler connection shall be of the same size except that a larger pipe for the return of condensate may be used.

(C.4) For all boilers [except electric steam boilers having a normal water content not exceeding 100 gal (380 l), traction-purpose, and portable steam boilers; see (C.11) and (C.12) below] with allowable working pressure in excess of 100 psig [700 kPa (gage)], each bottom blowoff pipe shall have two slow-opening valves, or one quick-opening valve or cock, at the boiler nozzle followed by a slow-opening valve. All valves shall comply with the requirements of (C.5) and (C.6) below.

(C.5) When the value of P required by para. 122.1.4(A.1) does not exceed 250 psig [1750 kPa (gage)], the valves or cocks shall be bronze, cast iron, ductile iron, or steel. The valves or cocks, if of cast iron, shall not exceed NPS $2\frac{1}{2}$ and shall meet the requirements of the applicable ASME Standard for Class 250, as given in Table 126.1, and if of bronze, steel, or ductile iron construction, shall meet the requirements of the applicable standards as given in Table 126.1 or para. 124.6.

(C.6) When the value of P required by para. 122.1.4(A.1) is higher than 250 psig [1750 kPa (gage)], the valves or cocks shall be of steel construction equal at least to the requirements of Class 300 of the applicable ASME Standard listed in Table 126.1. The minimum pressure rating shall be equal to the value of P required by para. 122.1.4(A.1).

(C.7) If a blowoff cock is used, the plug shall be held in place by a guard or gland. The plug shall be distinctly marked in line with the passage.

(C.8) A slow-opening valve is a valve which requires at least five 360 deg turns of the operating mechanism to change from fully closed to fully opened.

(C.9) On a boiler having multiple blowoff pipes, a single master valve may be placed on the common blowoff pipe from the boiler, in which case only one valve on each individual blowoff is required. In such a case, either the master valve or the individual valves or cocks shall be of the slow-opening type.

(C.10) Two independent slow-opening valves, or a slow-opening valve and a quick-opening valve or cock, may be combined in one body and may be used provided the combined fitting is the equivalent of two independent slow-opening valves, or a slow-opening valve and a quick-opening valve or cock, and provided further that the failure of one to operate cannot affect the operation of the other.

(C.11) Only one blowoff valve, which shall be either a slow-opening or quick-opening blowoff valve or a cock, is required on traction and/or portable boilers.

(C.12) Only one blowoff valve, which shall be of a slow-opening type, is required on forced circulation and electric steam boilers having a normal water content not exceeding 100 gal (380 liter).

(D) Safety Valves

(D.1) Safety valves, relief valves, and safety relief valves shall conform to the requirements of PG-67,

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TABLE 122.2

Boiler or Vessel Pressure		Design Pressure		Design Temperature	
psig	kPa (gage)	psig	kPa (gage)	°F	°C
Below 250	1 750	Note (1)		...	...
250–600	1 750–4 150	250	1750	410	210
601–900	4 151–6 200	400	2750	450	230
901–1500	6 201–10 300	600	4150	490	255
1501 and higher	10 301 and higher	900	6200	535	280

NOTE:
(1) For boiler or vessel pressure(s) below 250 psig [1750 kPa (gage)], the design pressure shall be determined in accordance with para. 122.1.4(B.1) but need not exceed 250 psig [1750 kPa (gage)].

PG-68, PG-69, PG-70, PG-71, PG-72, and PG-73 of Section I of the ASME Boiler and Pressure Vessel Code.

122.2 Blowoff and Blowdown Piping in Nonboiler External Piping

(A) From Boilers

(A.1) Blowoff piping, located between the valves described in para. 122.1.4(A) and the blowoff tank or other point where the pressure is reduced approximately to atmospheric pressure and cannot be increased by closing a valve, shall be designed for saturated steam at the appropriate pressure and temperature in accordance with Table 122.2. The provisions of para. 122.1.4(A.3) shall apply.

(A.2) Blowdown piping, located after the valve described in para. 122.1.4(B) in which the pressure cannot be increased by closing a valve, shall be designed for the appropriate pressure and temperature in accordance with Table 122.2. The provisions of para. 122.1.4(B.3) shall apply.

(A.3) When design pressure of Table 122.2 can be exceeded due either to closing of a downstream valve, calculated pressure drop, or other means, the entire blowoff or blowdown piping system shall be designed in accordance with para. 122.1.4(A) or (B), respectively.

(B) From Pressure Vessels Other Than Boilers

(B.1) The design pressure and temperature of the blowoff piping from the pressure vessel to and including the blowoff valve(s) shall not be less than the vessel design conditions.

122.3 Instrument, Control, and Sampling Piping

(A) The requirements of this Code, as supplemented by para. 122.3, shall apply to the design of instrument, control, and sampling piping for safe and proper operation of the piping itself.

(B) The term "Instrument Piping" shall apply to all valves, fittings, tubing, and piping used to connect instruments to main piping or to other instruments or apparatus or to measuring equipment as used within the classification of para. 100.1.

(C) The term "Control Piping" shall apply to all valves, fittings, tubing, and piping used to interconnect pneumatically or hydraulically operated control apparatus, also classified in accordance with para. 100.1, as well as to signal transmission systems used to interconnect instrument transmitters and receivers.

(D) The term "Sampling Piping" shall apply to all valves, fittings, tubing, and piping used for the collection of samples, such as steam, water, oil, gas, and chemicals.

(E) Paragraph 122.3 does not apply to tubing used in permanently closed systems, such as fluid-filled temperature responsive devices, or the temperature responsive devices themselves.

(F) Paragraph 122.3 does not apply to the devices, apparatus, measuring, sampling, signalling, transmitting, controlling, receiving, or collecting instruments to which the piping is connected.

122.3.1 Materials and Design. The materials utilized for valves, fittings, tubing, and piping shall meet the particular conditions of service and the requirements of the applicable specifications listed under general paras. 105, 106, 107, and 108 with allowable stresses in accordance with the Allowable Stress Tables in Appendix A.

The materials for pressure retention components used for piping specialities such as meters, traps, and strainers in flammable, combustible, or toxic fluid systems shall in addition conform to the requirements of paras. 122.7 and 122.8.

122.3.2 Instrument Piping

(A) Takeoff Connections

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(A.1) Takeoff connections at the source, together with attachment bosses, nozzles, and adapters, shall be made of material at least equivalent to that of the pipe or vessel to which they are attached. The connections shall be designed to withstand the source design pressure and temperature and be capable of withstanding loadings induced by relative displacement and vibration. The nominal size of the takeoff connections shall not be less than NPS $\frac{1}{2}$ for service conditions not in excess of either 900 psi (6200 kPa) or 800°F (425°C), and NPS $\frac{3}{4}$ (for adequate physical strength) for design conditions which exceed either of these limits. Where the size of the main is smaller than the limits given above, the takeoff connection shall not be less than the size of the main line.

(A.2) To prevent thermal shock to the main steam line by contact with the colder condensate return from the instrument, steam meter or instrument takeoff connections shall be lagged in with the steam main. For temperature in excess of 800°F (425°C), they may also be arranged to make metallic contact lengthwise with the steam main.

(B) Valves

(B.1) Shutoff Valves. Shutoff valves shall be provided at takeoff connections. They shall be capable of withstanding the design pressure and temperature of the pipe or vessel to which the takeoff adapters or nipples are attached.

(B.2) Blowdown Valves

(B.2.1) Blowdown valves at or near the instrument shall be of the gradual opening type. For subcritical pressure steam service, the design pressure for blowdown valves shall be not less than the design pressure of the pipe or vessel; the design temperature shall be the corresponding temperature of saturated steam. For all other services, blowdown valves shall meet the requirements of (B.1) above.

(B.2.2) When blowdown valves are used, the valves at the instrument as well as any intervening fittings and tubing between such blowdown valves and the meter shall be suitable at 100°F (40°C) for at least $1\frac{1}{2}$ times the design pressure of the piping system, but the rating of the valve at the instrument need not exceed the rating of the blowdown valve.

(B.2.3) When blowdown valves are not used, instrument valves shall conform to the requirements of (B.2.1) above.

(C) Reservoirs or Condensers. In dead end steam service, the condensing reservoirs and connecting nipples, which immediately follow the shutoff valves, shall be made of material suitable for the saturated steam temperature corresponding to the main line design pressure.

(D) Materials for Lines Between Shutoff Valves and Instruments

(D.1) Copper, copper alloys, and other nonferrous materials may be used in dead end steam or water services up to the design pressure and temperature conditions used for calculating the wall thickness in accordance with para. 104 provided that the temperature within the connecting lines for continuous services does not exceed 406°F (208°C).

Where water temperature in the reservoir of condensers is above 406°F (208°C), a length of uninsulated steel tubing at least 5 ft (1.5 m) long shall immediately follow the condenser ahead of the connecting copper tubing to the instrument.

(D.2) The minimum size of the tubing or piping is a function of its length, the volume of fluid required to produce full scale deflections of the instrument, and the service of the instrument. When required to prevent plugging as well as to obtain sufficient mechanical strength, the inside diameter of the pipe or tube should not be less than 0.36 in. (9.14 mm), with a wall thickness of not less than 0.049 in. (1.25 mm). When these requirements do not apply, smaller sizes with wall thickness in due proportions may be used. In either case, wall thickness of the pipe or tube shall meet the requirements of (D.3) below.

(D.3) The piping or tubing shall be designed in accordance with para. 104 with consideration for water hammer.

(E) Fittings and Joints

(E.1) For dead end steam service and for water above 150°F (65°C), fittings of the. flared, flareless, or socket welding type, or other suitable type of similar design shall be used. The fittings shall be suitable for the header pressure and corresponding saturated steam temperature or water temperature, whichever applies. For supercritical pressure conditions the fittings shall be suitable for the design pressure and temperature of the main fluid line.

(E.2) For water, oil and similar instrument services, any of the following types may be used, within the pressure-temperature limitations of each.

(E.2.1) For main line hydraulic pressures above 500 psi (3450 kPa) and temperatures up to 150°F (65°C), steel fittings either of the flared, flareless, socket welded, fusion welded, or silver brazed socket type shall be used.

(E.2.2) For main line pressures up to 500 psi (3450 kPa) and temperatures up to 150°F (65°C), the fittings may be: (E.2.2.1) flared or silver brazed socket type,

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inverted flared or flareless compression type, all of brass or bronze.

(E.2.3) For pressures up to 175 psi (1200 kPa) or temperatures up to 250°F (120°C), soldered type fittings may be used with water-filled or air-filled tubing under adjusted pressure-temperature ratings. These fittings are not recommended where mechanical vibration, hydraulic shock, or thermal shock are encountered.

122.3.3 Control Piping

(A) Takeoff Connections

(A.1) Takeoff connections shall be in accordance with para. 122.3.2(A.1).

(B) Valves

(B.1) Shutoff valves shall be in accordance with para. 122.3.2(B.1).

(C) Materials

(C.1) The same materials may be used for control lines as for instrument lines, except that the minimum inside diameter shall be 0.178 in. (4.52 mm) with a minimum wall thickness of 0.028 in. (0.71 mm), provided that this wall thickness is not less than that required by para. 122.3.2(D.3). If a control device has a connection smaller than $\frac{1}{4}$ in. (6.0 mm), the size reduction from the control tubing to the control device shall be made as close to the control device as possible.

(D) Fittings and Joints

(D.1) Fittings and joints shall be in accordance with para. 122.3.2(E.2).

122.3.4 Sampling Piping

(A) Takeoff Connections

(A.1) Takeoff connections shall be in accordance with para. 122.3.2(A.1).

(B) Valves

(B.1) Shutoff valves shall be in accordance with para. 122.3.2(B.1).

(B.2) Blowdown valves shall be of the gradual opening type and shall be suitable for main line design pressure and temperature.

(C) Materials

(C.1) The materials to be used for sampling lines shall conform to minimum requirements for the main line to which they connect.

(D) Fittings and Joints

(D.1) For subcritical and supercritical pressure steam, and for water above 150°F (65°C), fittings of the flared, flareless, or socket welding type, or other suitable type of similar design shall be used. The fittings shall be suitable for main line design pressure and temperature.

(D.2) For water below 150°F (65°C), fittings and joints shall be suitable for main line design pressure and temperature and shall be in accordance with para. 122.3.2(E.2).

122.3.6 Fittings and Joints

(A) All fittings shall be in accordance with standards and specifications listed in Table 126.1.

(A.1) Socket welded joints shall comply with the requirements of para. 111.3.

(A.2) Flared, flareless, and compression type fittings and their joints shall comply with the requirements of para. 115.

(A.3) Silver brazed socket type joints shall comply with the requirements of paras. 117.1 and 117.3.

(A.4) Solder type joints shall comply with the requirements of paras. 117.2 and 117.3.

(A.5) The use of taper threaded joints up to and including NPS $\frac{1}{2}$ is permitted at pressures up to 5000 psi (34 500 kPa) in dead end service from outlet end and downstream of shutoff valve located at instrument, at control apparatus, or at discharge of sample cooler.

122.3.7 Special Safety Provisions

(A) Connecting piping subject to clogging from solids or deposits shall be provided with suitable connections for cleaning.

(B) Connecting piping handling air and gases containing moisture or other extraneous materials shall be provided with suitable drains or settling chambers or traps.

(C) Connecting piping which may contain liquids shall be protected from damage due to freezing by heating or other adequate means.

122.3.8 Supports. Supports shall be furnished as specified in para. 121 not only for safety but also to protect the piping against detrimental sagging, external mechanical injury abuse, and exposure to unusual service conditions.

122.3.9 Installations

(A) Instrument, control, and sampling piping shall be inspected and tested in accordance with paras. 136 and 137.

(B) The inside of all piping, tubing, valves, and fittings shall be smooth, clean, and free from blisters, loose mill scale, sand, and dirt when erected. All lines shall be cleaned after installation and before placing in service.

122.4 Spray Type Desuperheater Piping for Use on Steam Generators and Reheat Piping 01

(A) Valves and Piping Arrangement

(A.1) Each spraywater pipe connected to a desuper-

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heater shall be provided with a stop valve and a regulating (spray control) valve. The regulating valve shall be installed upstream of the stop valve. In addition, if the steam generator supplies steam to a steam turbine, a power-operated block valve[3] shall be installed upstream of the regulating valve.

(A.2) A bypass valve around the regulating valve is permitted.

(A.3) A bypass valve around the power-operated block valve is prohibited.

(A.4) On a reheater desuperheater, a drain valve shall be installed between the power-operated block valve and the regulating valve.

(A.5) If the spraywater supply is from the boiler feedwater system and its source is not downstream of the feedwater check valve required by para. 122.1.7, a check valve shall be provided in the spraywater piping between the desuperheater and the spraywater source.

(A.6) It is recommended that the valves and piping be arranged to provide a head of water on the downstream side of the stop valve.

(A.7) A typical arrangement is shown in Fig. 122.4.

(A.8) Provisions shall be made to both steam and water systems to accommodate the operating conditions associated with this service including: water hammer, thermal shock and direct water impingement. The connection for the spraywater pipe should be located per the requirements established by the manufacturer so that complete flow mixing is achieved prior to any bends, elbows, or other flow directional changes being encountered.

(A.9) Insertable-type desuperheaters, which include an integral stop and spraywater regulating valve, may be used within the limitations established by the manufacturer. If this type is used, the individual stop and regulating valves shown in Fig. 122.4 may be omitted. All other requirements described in para. 122.4 shall apply.

(A.10) For Desuperheaters Located Within Reheat Piping. The steam system to be desuperheated shall be provided with proper drainage during all water flow conditions. The drainage system shall function both manually and automatically.

(B) Design Requirements

(B.1) The value of P to be used in the formulas of para. 104 shall be as follows.

(B.1.1) For piping from the desuperheater back to the stop valve required by (A.1) above, the value of P shall be equal to or greater than the maximum allowable working pressure of the desuperheater.

(B.1.2) For the remainder of the spraywater piping system, the value of P shall be not less than the maximum sustained pressure exerted by the spraywater.

(B.2) The stop valve required by (A.1) above shall be designed for the pressure requirement of (B.1.1) above or the maximum sustained pressure exerted by the spraywater, whichever is greater.

(B.3) The S value used for the spraywater piping shall not exceed that permitted for the expected temperature.

NOTE: The temperature varies from that of the desuperheater to that of the spraywater source and is highly dependent on the piping arrangement. It is the responsibility of the designer to determine the design temperature to be used for the various sections of the piping system.

122.5 Pressure Reducing Valves

122.5.1 General. Where pressure reducing valves are used, one or more relief devices or safety valves shall be provided on the low pressure side of the system. Otherwise, the piping and equipment on the low pressure side of the system shall be designed to withstand the upstream design pressure. The relief or safety devices shall be located adjoining or as close as practicable to the reducing valve. The combined relieving capacity provided shall be such that the design pressure of the low pressure system will not be exceeded if the reducing valve fails open.

122.5.2 Bypass Valves. Hand controlled bypass valves having a capacity no greater than the reducing valve may be installed around pressure reducing valves if the downstream piping is protected by relief valves as required in para. 122.5.1 or if the design pressure of the downstream piping system and equipment is at least as high as the upstream pressure.

122.5.3 Design of Valves and Relief Devices. Pressure reducing and bypass valves, and relief devices, shall be designed for inlet pressure and temperature conditions. Safety and relief valves shall be in accordance with the requirements of para. 107.8 of this Code.

122.6 Pressure Relief Piping

Pressure relief piping within the scope of this Code shall be supported to sustain reaction forces, and shall conform to the following requirements.

[3] For information on the prevention of water damage to steam turbines used for electric power generation, see ASME TDP-1.

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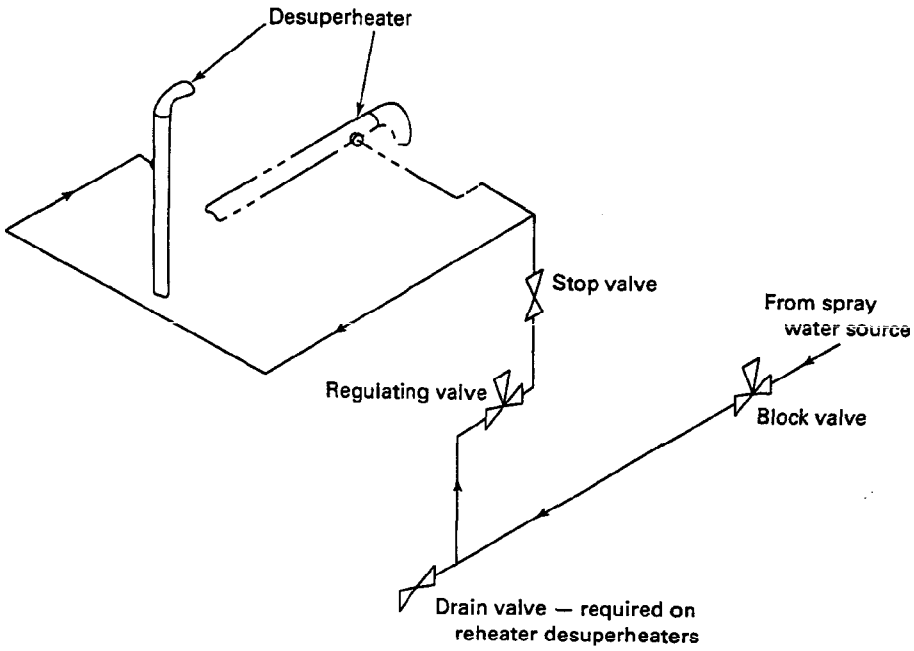

GENERAL NOTE: This figure is a schematic only and is not intended to show equipment layout or orientation.

01 FIG. 122.4 DESUPERHEATER SCHEMATIC ARRANGEMENT

122.6.1 Piping to Pressure-Relieving Safety Devices

(A) There shall be no intervening stop valve(s) between piping being protected and the protective device(s).

(B) Diverter or changeover valves designed to allow servicing of redundant protective devices without system depressurization may be installed between the piping to be protected and the required protective devices under the following conditions.

(B.1) Diverter or changeover valves are prohibited on boiler external piping or reheat piping.

(B.2) One hundred percent (100%) of the required relieving capacity shall be continuously available any time the system is in service.

(B.3) Positive position indicators shall be provided on diverter or changeover valves.

(B.4) Positive locking mechanisms and seals shall be provided on diverter or changeover valves to preclude unauthorized or accidental operation.

(B.5) Diverter or changeover valves shall be designed for the most severe conditions of pressure, temperature, and loading to which they are exposed, and shall be in accordance with para. 107.

(B.6) Provision shall be made to safely bleed off the pressure between the isolated protective device and the diverter or changeover valve.

122.6.2 Discharge Piping From Pressure Relieving Safety Devices

(A) There shall be no intervening stop valve between the protective device or devices and the point of discharge.

(B) When discharging directly to the atmosphere, discharge shall not impinge on other piping or equipment and shall be directed away from platforms and other areas used by personnel.

(C) It is recommended that individual discharge lines be used, but if two or more reliefs are combined, the discharge piping shall be designed with sufficient flow area to prevent blowout of steam or other fluids. Sectional areas of a discharge pipe shall not be less than the full area of the valve outlets discharging thereinto and the discharge pipe shall be as short and straight as possible and so arranged as to avoid undue stresses on the valve or valves.

(D) Discharge lines from pressure-relieving safety devices within the scope of this Code shall be designed to facilitate drainage.

(E) When the umbrella or drip pan type of connection

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is used, the discharge piping shall be so designed as to prevent binding due to expansion movements.

(F) Drainage shall be provided to remove water collected above the safety valve seat.

(G) Carbon steel materials listed in Appendix A may be used for discharge piping which is subjected to temperatures above 800°F (427°C) only during operation of pressure relieving safety devices provided that:

(G.1) the duration of pressure relieving safety device operation is self-limiting;

(G.2) the piping discharges directly to atmosphere;

(G.3) material allowable stresses at temperatures above 800°F (427°C) shall be taken from Section II, Part D, Tables 1A and 1B for materials applicable to Section I and Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

122.7 Piping for Flammable or Combustible Liquids

122.7.1 General. Piping for flammable or combustible liquids including fuel and lubricating oils is within the scope of this Code. Piping for synthetic lubricants having no flash or fire point need not meet the requirements of para. 122.7.

The designer is cautioned that, among other criteria, static electricity may be generated by the flowing fluid. Additionally, the designer is cautioned of the extreme chilling effect of a liquefied gas flashing to vapor during loss of pressure. This is a factor for determining the lowest expected service temperature relative to the possibility of brittle fracture of materials. Consideration shall also be given to the pressure rise that may occur as a cold fluid absorbs heat from the surroundings.

122.7.2 Materials

(A) Seamless steel or nickel alloy piping materials shall be used in all areas where the line is within 25 ft (7.6 m) of equipment or other lines having an open flame or exposed parts with an operating temperature above 400°F (204°C). Seamless steel or nickel alloy pipe shall also be used for fuel oil systems located downstream of burner shutoff valve(s). The burner shutoff valve(s) shall be located as close to the burner as is practical.

(B) In all other areas, piping systems may include pipe or tube of steel, nickel alloy, ductile iron, copper, or brass construction. Copper tubing shall have a thickness not less than that required by para. 104.1.2(C.3), regardless of pressure. Refer also to paras. 105, 124.6, and 124.7(A)

Wherever materials other than steel or nickel alloy are used, they shall be so located that any spill resulting from the failure of these materials will not unduly expose persons, buildings, or structures, or can be readily controlled by remote valves.

(C) For lubricating oil systems, steel tubing is an acceptable alternative to steel pipe.

(D) Polyethylene (PE) and reinforced thermosetting resin (RTR) pipe may be used for flammable or combustible liquids in buried installations only. The fluid temperatures shall not exceed 140°F (60°C) and pressures shall be limited to 150 psi (1000 kPa). Where such PE or RTR pipe is used in flammable or combustible liquid service, the rules of Appendix III shall be considered mandatory. Where jurisdictional requirements mandate that double containment pipe be used, the rules of Appendix III shall be applied to both the inner and outer pipe.

Particular care must be exercised to prevent damage to RTR piping at the connection to the main or other facility. Precautions shall be taken to prevent crushing or shearing of RTR piping due to external loading or settling of backfill and to prevent damage or pull out from the terminal connection resulting from thermal expansion or contraction.

RTR piping may terminate above ground and outside a building, provided that:

(1) the above ground portion of the RTR pipe is completely enclosed in a conduit or casing of sufficient strength to provide protection from external damage and deterioration. Where a flexible conduit is used, the top of the riser must be attached to a solid support. The conduit or casing shall extend a minimum of 6 in. below grade.

(2) the RTR pipe is not subjected to excessive stresses due to external loading.

122.7.3 Piping Joints

(A) Welded joints shall be used between steel or nickel alloy piping components where practicable. Where bolted flanged joints are necessary, the gasket material shall be suitable for the service. Threaded joints, where unavoidable for connecting to equipment, valves, specialties, or instruments, shall be:

(A.1) in piping of a thickness no less than extra strong regardless of pressure;

(A.2) limited as prescribed in para. 114; and

(A.3) assembled with extreme care to assure leak tightness, using thread sealant suitable for the service.

(B) Threaded joints in copper or brass pipe shall be subject to the same limitations as for steel pipe in (A.1), (A.2), and (A.3), above.

(C) Copper tubing shall be assembled with flared, flareless, or compression type joints as prescribed in

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para. 115, or brazed in accordance with para. 117. Soft solder type joints are prohibited.

(D) RTR pipe shall be adhesive bonded in accordance with the pipe manufacturer's recommended procedures.

(E) Pipe joints dependent on the friction characteristics or resiliency of combustible materials for mechanical or leak tightness of piping shall not be used inside buildings.

(F) Steel tubing shall be assembled with fittings in accordance with para. 115, or with socket weld fittings.

122.7.4 Valves and Specialties. Valves, strainers, meters, and other specialties shall be of steel or nickel alloy construction. As an alternative, ductile or malleable iron or copper alloy valves and specialties may be used, subject to the restrictions in paras. 124.6 and 124.7, where metal temperatures do not exceed 400°F (204°C).

122.8 Piping for Flammable Gases, Toxic Gases or Liquids, or Nonflammable Nontoxic Gases

Although some gases are liquefied for storage or transport, they shall be considered as gases if their Reid vapor pressure is greater than 40 psia [2068.6 mm Hg (absolute)] at 100°F (37.8°C).

122.8.1 Flammable Gas

(A) Some of the common flammable gases are acetylene, ethane, ethylene, hydrogen, methane, propane, butane, and natural or manufactured gas used for fuel. It shall be the designers' responsibility to determine the limiting concentrations (upper and lower explosive limits) and the properties of the gas under consideration. The use of explosive concentrations shall be avoided, or the piping shall be designed to withstand explosive forces.

The designer is further cautioned of the extreme chilling effect of gas during rapid expansion. This is a factor for determining the lowest expected service temperature relative to the possibility of brittle fracture of materials.

(B) Materials. Steel piping, subject to the limitations in para. 105, shall be used for all flammable gases, except as otherwise permitted in (B.2), (B.3), and (B.4) below.

(B.1) Pipe joints shall be welded where practicable, except bolted flanged joints with suitable gaskets may be used where necessary. Threaded joints, where unavoidable for connecting to equipment, valves, specialties, or instruments, shall be:

(B.1.1) in piping of a thickness no less than extra strong regardless of pressure or material;

(B.1.2) limited as prescribed in para. 114, except threaded joints and compression fittings to maximum nominal size of NPS $\frac{3}{4}$ (DN 20) for pressure to 5000 psi (34,000 kPa) are permitted at the connection to the refillable storage containers pressure regulators; and

(B.1.3) assembled with extreme care to assure leak tightness, using thread sealant suitable for the service.

(B.2) For hydrogen systems, the following alternative materials may be used:

(B.2.1) seamless steel tubing with welded joints;

(B.2.2) seamless copper or brass pipe or tubing with brazed, threaded, or compression fitting joints. Threaded fittings shall not exceed NPS $\frac{3}{4}$ (DN 20). For protection against damage, tubing shall be installed in a guarded manner that will prevent damage during construction, operation, or service. Valves with suitable packing, gages, regulators, and other equipment may also consist of copper alloy materials. Safety relief devices shall be vented individually, and connected vent piping shall be designed to convey the fluid, without pockets, to the outside atmosphere; and then directed away from equipment ventilation systems, and vents from other systems.

(B.3) For fuel gas instrumentation and control, seamless copper tubing subject to the following restrictions may be used:

(B.3.1) the design pressure shall not exceed 100 psi (690 kPa);

(B.3.2) tubing shall not exceed $\frac{5}{8}$ in. (15.9 mm) nominal outside diameter;

(B.3.3) all joints shall be made with compression or flared fittings;

(B.3.4) copper tubing shall not be used if the fuel gas contains more than 0.3 grains (19.4 mg) of hydrogen sulfide per 100 cu ft/min (47 liters/sec) of gas at standard conditions;

(B.3.5) consideration shall be given in the design to the lower strength and melting point of copper compared to steel. Adequate support and protection from high ambient temperatures and vibration shall be provided.

(B.3.6) tubing shall be installed in a guarded manner that will prevent damage during construction, operation, and service.

(B.4) Polyethylene (PE) pipe may be used for natural gas service in buried installations only. The fluid temperatures shall not exceed 140°F (60°C), nor be below −20°F (−30°C) and pressures shall be limited to 100 psi (690 kPa). Pipe joints shall be heat fused in accordance with manufacturer's recommended procedures. Where PE pipe is used in flammable gas service, the rules of Appendix III shall be considered mandatory.

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(C) Valves and Specialties. Valves, strainers, meters, and other specialities shall be of steel or nickel alloy construction. As as alternative, ductile iron or copper alloy valves and specialities may be used, subject to the restrictions in paras. 124.6 and 124.7, where metal temperatures do not exceed 400°F (204°C).

(D) For in-plant fuel gas distribution system(s) where the use of a full-relieving-capacity relief valve(s) as described in para. 122.5 could create an undue venting hazard, an alternative pressure limiting design may be substituted. The alternative design shall include all provisions below:

(D.1) Tandem Gas Pressure Reducing Valves. To protect the low pressure system, two gas pressure reducing valves capable of independent operation shall be installed in series. Each shall have the capability of closing off against the maximum upstream pressure, and of controlling the pressure on the low pressure side at or below the design pressure of the low pressure system, in the event that the other valve fails open. Control lines must be suitably protected, designed, and installed so that damage to any one control line will not result in over pressurizing the downstream piping.

(D.2) Trip Stop Valve. A fail-safe trip stop valve shall be installed to automatically close, in less than 1 sec, at or below the design pressure of the downstream piping. It shall be a manually reset design. The pressure switch for initiating closure of the trip stop valve shall be hardwired directly to the valve tripping circuit. The pressure switch shall be mounted directly on the low pressure piping without an intervening isolation valve. The trip stop valve shall be located so that it is accessible and protected from mechanical damage and from weather or other ambient conditions which could impair its proper functioning. It may be located upstream or downstream of the tandem gas pressure reducing valves. The trip stop valve and all upstream piping shall be designed for the maximum upstream supply pressure. The trip stop valve may also serve as the upstream isolation valve of a double-block and vent gas supply isolation system. Provision shall be made to safely bleed off the pressure downstream of the trip stop valve.

(D.3) Safety Relief Device. The low pressure system shall be protected from any leakage through the pressure reducing valves, when closed, by a safety relief device(s) constructed and designed in accordance with paras. 107.8.3 and 122.5.3, and sized for the possible leakage rate.

01 **122.8.2 Toxic Fluids (Gas or Liquid)**

(A) For the purpose of this Code, a toxic fluid is one that may be lethal, or capable of producing injury and/or serious illness through contact, inhalation, ingestion, or absorption through any body surface. It shall be the designers' responsibility to adopt the safety precautions published by the relevant fluid industry which may be more stringent than those described in this Code for toxic fluids. In addition, the piping shall be installed in such a manner that will minimize the possibility of damage from external sources.

TABLE 122.8.2(B)
MINIMUM WALL THICKNESS REQUIREMENTS FOR TOXIC FLUID PIPING

	Carbon & Low Alloy Steel (App. A, Tables A-1 & A-2)	Stainless & Nickel Alloy Steel (App. A, Tables A-3 & A-4)
DN 50 (NPS 2) & smaller	Extra strong	Sch. 10S
Larger than DN 50 (NPS 2)	Standard weight	Sch. 5S

(B) Preferably, pipe and pipe fittings should be seamless steel. Wall thickness shall not be less than that in Table 122.8.2(B).

If the fluid is known to be corrosive to the steels in Table 122.8.2(B), the materials and wall thickness selected shall be suitable for the service. (Refer to para. 104.1.2.)

(C) Piping joints shall be made by welding, or by steel socket welding or welding neck flanges with suitable gaskets. Socket welded joints shall not be larger than DN 65 (NPS 2½). Backing rings used for making girth butt welds shall be removed after welding. Miter welds are not permitted. Fabricated branch connections (branch pipe welded directly to run pipe) are not permitted. Threaded joints, where unavoidable, may be used provided that all of the following requirements are met.

(C.1) The pipe thickness shall not be less than extra strong regardless of pressure or type of material.

(C.2) The requirements of para. 114 shall be met except that threaded joints to a maximum nominal size of DN 20 (NPS ¾) for pressure to 34,500 kPa [gage] (5000 psig), or to a maximum nominal size of DN 50 (NPS 2) for pressure to 345 kPa [gage] (50 psig) are permitted at the connections to the refillable storage containers and their associated pressure regulators, shut-off valves, pumps, and meters.

(C.3) Threaded joints are assembled with extreme care to assure leak tightness. The requirements of para.

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135.5 shall be met. A thread sealant, suitable for the service, shall be used, except where the joint is to be seal welded.

(D) Steel valves shall be used. Bonnet joints with tapered threads are not permitted. Special consideration shall be given to valve design to prevent stem leakage to the environment. Bonnet or cover plate closures and other body joints shall be one of the following types:

(D.1) union;

(D.2) flanged with suitable gasketing and secured by at least four bolts;

(D.3) proprietary, attached by bolts, lugs, or other substantial means, and having a design that increases gasket compression as fluid pressure increases;

(D.4) threaded with straight threads sufficient for mechanical strength, metal-to-metal seats, and a seal weld made in accordance with para. 127.4.5, all acting in series.

(E) Tubing not larger than $\frac{5}{8}$ in. (16 mm) O.D. with socket welding fittings may be used to connect instruments to the process line. An accessible root valve shall be provided at the process lines to permit isolating the tubing from the process piping. The layout and mounting of tubing shall minimize vibration and exposure to possible damage.

(F) The provisions of para. 102.2.4 are not permitted. The simplified rules for analysis in para. 119.7.1 (A.3) are not permitted. The piping system shall be designed to minimize impact and shock loads. Suitable dynamic analysis shall be made where necessary to avoid or minimize vibration, pulsation, or resonance effects in the piping. The designer is cautioned to consider the possibility of brittle fracture of the steel material selected over the entire range of temperatures to which it may be subjected.

(G) For dry chlorine service between –29°C (–20°F) and 149°C (300°F), the pipe material shall not be less in thickness than seamless extra strong steel.

(H) Toxic fluid piping shall be pneumatic leak tested in accordance with para. 137.5. Alternatively, mass spectrometer or halide leak testing in accordance with para. 137.6, and a hydrostatic test in accordance with para. 137.3 may be performed.

122.8.3 Nonflammable Nontoxic Gas

(A) Piping for nonflammable and nontoxic gases, such as air, oxygen, carbon dioxide, and nitrogen, shall comply with the requirements of this Code, except as otherwise permitted in (B) (below). The designer is cautioned of the extreme chilling effect during rapid expansion. This is a factor for determining the lowest expected service temperature relative to the brittle fracture of the material selected.

(B) Threaded joints with or without compression fittings to a maximum nominal size of NPS $\frac{3}{4}$ for pressures to 5000 psi (34,500 kPa) are permitted at the connection to the refillable storage containers, pressure regulators, shutoff valves, and meters. Refer to Para. 114.

122.9 Piping for Corrosive Liquids and Gases

Where it is necessary to use special material, such as glass and plastics, not listed in Table 126.1, for conveying corrosive or hazardous liquids and gases, the design shall meet the requirements of para. 104.7.

122.10 Temporary Piping Systems

Prior to test and operation of the power plant and its included piping systems, most power and auxiliary service piping are subjected to flushing or chemical cleaning to remove internal foreign material such as rust particles, scale, welding or brazing residue, dirt, etc., which may have accumulated within the piping during the construction period. The flushing or cleaning operation may be accomplished by blowing out with steam or air, by hot oil circulation of oil systems, by acid or caustic fluid circulation, or by other flushing or cleaning methods. Temporary piping, that is piping attached to the permanent piping system whose function is to provide means for introducing and removing the fluids used in the flushing or cleaning operations, shall be designed and constructed to withstand the operating conditions during flushing and cleaning. The following minimum requirements shall apply to temporary piping systems.

(A) Each such system shall be analyzed for compliance with para. 103.

(B) Connections for temporary piping to the permanent piping systems which are intended to remain, shall meet the design and construction requirements of the permanent system to which they are attached.

(C) The temporary systems shall be supported such that forces and moments due to static, dynamic and expansion loadings will not be transferred in an unacceptable manner to the connected permanent piping system. Paragraphs 120 and 121 shall be used as guidance for the design of the temporary piping systems supporting elements.

(D) The temporary systems shall be capable of withstanding the cyclic loadings which occur during the flushing and cleaning operations. Particular attention

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shall be given to the effects of large thrust forces which may be generated during high velocity blowing cycles. Where steam piping is to be subjected to high velocity blowing operations, continuous or automatic draining of trapped or potentially trapped water within the system shall be incorporated. Supports at the exhaust terminals of blowdown piping shall provide for restraint of potential pipe whip.

(E) Where necessary, temporary systems containing cast iron or carbon steel material subject to chemical cleaning shall be prewarmed to avoid the potential for brittle failure of the material.

(F) Where temporary piping has been installed and it does not comply with the requirements of this Code for permanent piping systems, it shall be physically removed or separated from the permanent piping to which it is attached prior to testing of the permanent piping system and prior to plant startup.

122.11 Steam Trap Piping

122.11.1 Drip Lines. Drip lines from piping or equipment operating at different pressures shall not be connected to discharge through the same trap.

122.11.2 Discharge Piping. Trap discharge piping shall be designed to the same pressure as the inlet piping unless the discharge is vented to atmosphere, or is operated under low pressure and has no stop valves. In no case shall the design pressure of trap discharge piping be less than the maximum discharge pressure to which it may be subjected. Where two or more traps discharge into the same header, a stop valve shall be provided in the discharge line from each trap. Where the pressure in the discharge piping can exceed the pressure in the inlet piping, a check valve shall be provided in the trap discharge line. A check valve is not required if either the stop valve or the steam trap is designed to automatically prevent reverse flow and is capable of withstanding a reverse differential pressure equal to the design pressure of the discharge piping.

122.12 Exhaust and Pump Suction Piping

Exhaust and pump suction lines for any service and pressure shall have relief valves of suitable size unless the lines and attached equipment are designed for the maximum pressure to which they may accidentally or otherwise be subjected, or unless a suitable alarm indicator, such as a whistle or free blowing relief valve, is installed where it will warn the operator.

122.13 Pump Discharge Piping

Pump discharge piping from the pump up to and including the valve normally used for isolation or flow control shall be designed for the maximum sustained pressure exerted by the pump and for the highest coincident fluid temperature, as a minimum. Variations in pressure and temperature due to occasional inadvertent operation are permitted as limited in para. 102.2.4 under any of the following conditions:

(A) during operation of overpressure relief devices designed to protect the piping system and the attached equipment;

(B) during a short period of abnormal operation, such as pump overspeed; or

(C) during uncontrolled transients of pressure or temperature.

122.14 District Heating and Steam Distribution Systems

122.14.1 General. Where pressure reducing valves are used, one or more relief devices or safety valves shall be provided on the low pressure side of the system. Otherwise, the piping and equipment on the low pressure side of the system shall be designed to withstand the upstream design pressure. The relief or safety devices shall be located adjoining or as close as practicable to the reducing valve. The combined relieving capacity provided shall be such that the design pressure of the low pressure system will not be exceeded if the reducing valve fails open.

122.14.2 Alternative Systems. In district heating and steam distribution systems where the steam pressure does not exceed 400 psi (2750 kPa) and where the use of relief valves as described in para. 122.14.1 is not feasible (e.g., because there is no acceptable discharge location for the vent piping), alternative designs may be substituted for the relief devices. In either case, it is recommended that alarms be provided which will reliably warn the operator of failure of any pressure reducing valve.

(A) Tandem Steam Pressure Reducing Valves. Two or more steam pressure reducing valves capable of independent operation may be installed in series, each set at or below the safe working pressure of the equipment and piping system served. In this case, no relief device is required.

Each pressure reducing valve shall have the capability of closing off against full line pressure, and of controlling the reduced pressure at or below the design pressure

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of the low pressure system, in the event that the other valve fails open.

(B) Trip Stop Valves. A trip stop steam valve set to close at or below the design pressure of the low pressure system may be used in place of a second reducing valve or a relief valve.

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CHAPTER III
MATERIALS

01 **123 General Requirements**

Chapter III contains limitations and required qualifications for materials based on their inherent properties. Use of these materials in piping systems is also subject to requirements and limitations in other parts of this Code.

123.1 Materials and Specifications

123.1.1 Listed Materials. Material meeting the following requirements shall be considered listed and acceptable materials.

(A) Materials for which allowable stress values are listed in Appendix A or which have been approved by the procedure established by (C) below.

(B) A material conforming to a specification for which allowable stresses are not listed in Appendix A is acceptable provided its use is not specifically prohibited by this Code Section and it satisfies one of the following requirements.

(B.1) It is referenced in a standard listed in Table 126.1. Such a material shall be used only within the scope of and in the product form covered by the referencing standard listed in Table 126.1.

(B.2) It is referenced in other parts of this Code Section and shall be used only within the scope of and in the product form permitted by the referencing text.

(C) Where it is desired to use materials which are not currently acceptable under the rules of this Code Section, written application shall be made to the Committee fully describing the proposed material and the contemplated use. Such material shall not be considered listed and not used as a listed material until it has been approved by the Committee and allowable stress values have been assigned. Details of information which should be included in such applications are given in Appendix VI. See para. 123.1.2.

(D) Materials conforming to ASME SA or SB specifications may be used interchangeably with material specified to the listed ASTM A or B specifications of the same number, except where the requirements of para. 123.2.2 apply.

123.1.2 Unlisted Materials Materials other than those meeting the requirements of para. 123.1.1 shall be considered unlisted materials. Such unlisted materials may only be used for nonboiler external piping provided they satisfy all of the following requirements:

(A) Unlisted materials are certified by the material manufacturer to satisfy the requirements of a specification listed in any Code Section of the ASME B31 Code for Pressure Piping, the ASME Boiler and Pressure Vessel Code, Section II, Part D, or to a published specification covering chemistry, physical and mechanical properties, method and process of manufacture, heat treatment, and quality control.

(B) The allowable stresses of the unlisted materials shall be determined in accordance with the rules of para. 102.3.1(C).

(C) Unlisted materials shall be qualified for service within a stated range of minimum and maximum temperatures based upon data associated with successful experience, tests, or analysis; or a combination thereof.

(D) The designer shall document the owner's acceptance for use of unlisted material.

(E) All other requirements of this Code are satisfied.

123.1.5 Size or Thickness. Materials outside the limits of size or thickness given in the title or scope clause of any specification listed in Table 126.1 may be used if the material is in compliance with the other requirements of the specification, and no other similar limitation is given in the rules for construction.

123.1.6 Marking of Materials or Products. Materials or products marked as meeting the requirements for more than one grade, type, or alloy of a material specification or multiple specifications, are acceptable provided: 01

(A) one of the markings includes the material specification, grade, class, and type or alloy of the material permitted by this Code and the material meets all the requirements of that specification;

(B) the appropriate allowable stress for the specified grade, type, or alloy of a material specification from Appendix A is used;

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(C) all other requirements of this Code are satisfied for the material permitted.

123.2 Piping Components

123.2.1 General. Materials which do not comply with the rules of para. 123.1 may be used for flared, flareless, and compression type tubing fittings, provided that the requirements of para. 115 are met.

123.2.2 Boiler External Piping

(A) Materials for boiler external piping, as defined in para. 100.1.2(A), shall be specified in accordance with ASME SA, SB, or SFA specifications. Material produced under an ASTM specification may be used, provided that the requirements of the ASTM specification are identical or more stringent than the ASME specification for the Grade, Class, or Type produced. The material manufacturer or component manufacturer shall certify, with evidence acceptable to the Authorized Inspector, that the ASME specification requirements have been met. Materials produced to ASME or ASTM material specifications are not limited as to country of origin.

(B) Materials which are not fully identified shall comply with PG-10 of Section I of the ASME Boiler and Pressure Vessel Code.

123.3 Pipe Supporting Elements

Except as permitted by paras. 121.7.2(C) and (D), steel materials shall be used for pipe supporting elements. Steel materials which do not comply with the rules of para. 123.1 may be used for pipe supporting elements, provided the rules of para. 121.2(C) are met.

124 LIMITATIONS ON MATERIALS

124.1 General

The materials listed in the Allowable Stress Tables A-1 through A-9, Appendix A, shall not be used at design temperatures above those for which stress values are given except as permitted by para. 122.6.2(G).

124.2 Steel

(A) Upon prolonged exposure to temperatures above 775°F (415°C), the carbide phase of plain carbon steel, plain nickel alloy steel, carbon-manganese alloy steel, manganese-vanadium alloy steel, and carbon-silicon steel may be converted to graphite.

(B) Upon prolonged exposure to temperatures above 875°F (470°C), the carbide phase of alloy steels, such as carbon-molybdenum, manganese-molybdenum-vanadium, manganese-chromium-vanadium, and chromium-vanadium, may be converted to graphite.

(C) Carbon or alloy steel having carbon content of more than 0.35% shall not be used in welded construction or be shaped by oxygen cutting process or other thermal cutting processes.

(D) Where low alloy (3% chromium or less) steels are used at temperatures above 850°F, the carbon content of the base material and weld filler metal shall be 0.05% or higher.

124.4 Cast Gray Iron

The low ductility of cast gray iron may result in sudden failure if shock loading (pressure, temperature or mechanical) should occur. Possible shock loadings and consequences of failure must be considered before specifying the use of such material. Cast iron components may be used within the nonshock pressure-temperature ratings established by the standards and specifications herein and in para. 105.2.1(B). Castings to ASME SA-278 and ASTM A 278 shall have maximum limits of 250 psig [1725 kPa (gage)] and 450°F (230°C).

The following referenced paragraphs prohibit or restrict the use of gray cast iron for certain applications or to certain pressure-temperature ratings:

Pipe Supports	121.7.2(C)
BEP Blowoff	122.1.4(A.3)
BEP Blowdown	122.1.4(B.3)
BEP Valves and Fittings	122.1.7
Blowoff Valves	122.1.7(C.5) & (C.6)
Non-BEP Blowoff	122.2(A.1)
Non-BEP Blowdown	122.2(A.2)
Flammable or Combustible Liquids	122.7.3
Flammable Gases	122.8.1(B)
Toxic Gases or Liquids	122.8.2

124.5 Malleable Iron

Certain types of malleable iron have low ductility characteristics and may be subject to brittle fracture. Malleable iron may be used for design conditions not to exceed 350 psig [2415 kPa (gage)] or 450°F (230°C).

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The following referenced paragraphs prohibit or restrict the use of malleable iron for certain applications or to certain pressure-temperature ratings:

Pipe Supports	121.7.2(D)
BEP Blowoff	122.1.4(A.3)
BEP Blowdown	122.1.4(B.3)
Non-BEP Blowoff	122.2(A.1)
Non-BEP Blowdown	122.2(A.2)
Flammable or Combustible Liquids	122.7.3(C)
Flammable Gases	122.8.1(B)
Toxic Gases or Liquids	122.8.2

124.6 Ductile (Nodular) Iron

Ductile (nodular) iron components conforming to ANSI B16.42 may be used under the following conditions.

(A) Components for boiler external piping shall be used only within the following limitations.

(A.1) Only ASME SA-395 material may be used.

(A.2) Design pressure shall not exceed 350 psig [2415 kPa (gage)].

(A.3) Design temperature shall not exceed 450°F (230°C).

(B) Welding shall not be used, either in fabrication of the components or in their assembly as a part of a piping system.

(C) The following referenced paragraphs prohibit or restrict the use of ductile iron for certain applications or to certain pressure-temperature ratings:

BEP Blowoff	122.1.4(A.3)
BEP Blowdown	122.1.4(B.3)
BEP Blowoff Valves	122.1.7(C.5)&(C.6)
Non-BEP Blowoff	122.2(A.1)
Non-BEP Blowdown	122.2(A.2)
Flammable or Combustible Liquids	122.7.3(B)
Flammable Gases	122.8.1(D)
Toxic Gases or Liquids	122.8.2
Pipe Supports	123.3

124.7 Nonferrous Metals

Nonferrous metals may be used in piping systems under the following conditions.

(A) The melting points of copper, copper alloys, aluminum, and aluminum alloys must be considered particularly where there is a fire hazard.

(B) The Designer shall consider the possibility of galvanic corrosion when combinations of dissimilar metals, such as copper, aluminum, and their alloys, are used in conjunction with each other or with steel or other metals in the presence of an electrolyte.

(C) Threaded Connections. A suitable thread compound shall be used in making up threaded joints in aluminum pipe to prevent seizing which might cause leakage and perhaps prevent disassembly. Pipe in the annealed temper should not be threaded.

124.8 Nonmetallic Pipe

This Code recognizes the existence of a wide variety of nonmetallic piping materials which may be used on corrosive (either internal or external) or other specialized applications. Extreme care must be taken in their selection as their design properties vary greatly and depend upon the material, type and grade. Particular consideration shall be given to the possibility of:

(A) destruction where fire hazard is involved;

(B) decrease in tensile strength at slight increase in temperature; and

(C) effects of toxicity. Another consideration is that of providing adequate support for the flexible pipe.

For nonmandatory rules for nonmetallic piping, see Appendix III of this Code.

124.9 Deterioration of Materials in Service

It is the responsibility of the engineer to select materials suitable for the intended application. Some guideline for selection of protective coatings for metallic piping are provided in Appendix IV.

125 MATERIALS APPLIED TO MISCELLANEOUS PARTS

125.1 Gaskets

Limitations on gasket materials are covered in para. 108.4.

125.2 Bolting

Limitations on bolting materials are covered in para. 108.5.

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CHAPTER IV
DIMENSIONAL REQUIREMENTS

126 MATERIAL SPECIFICATIONS AND STANDARDS FOR STANDARD AND NONSTANDARD PIPING COMPONENTS

126.1 Standard Piping Components

Dimensions of standard piping components shall comply with the standards and specifications listed in Table 126.1 in accordance with para. 100.

126.2 Nonstandard Piping Components

When nonstandard piping components are designed in accordance with para. 104, adherence to dimensional standards of ANSI and ASME is strongly recommended when practicable.

126.3 Referenced Documents

The documents listed in Table 126.1 may contain references to codes, standards, or specifications not listed in this Table. Such unlisted codes, standards, or specifications are to be used only in the context of the listed documents in which they appear.

Where documents listed in Table 126.1 contain design rules which are in conflict with this Code, the design rules of this Code shall govern.

The fabrication, assembly, examination, inspection, and testing requirements of Chapters V and VI apply to the construction of piping systems. These requirements are not applicable to piping components manufactured in accordance with the documents listed in Table 126.1 unless specifically so stated.

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TABLE 126.1
SPECIFICATIONS AND STANDARDS

ASTM Ferrous Material Specifications

Bolts, Nuts, and Studs

A 193	Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
A 194	Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service
A 307	Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength
A 320	Alloy-Steel Bolting Materials for Low-Temperature Service
A 354	Quenched and Tempered Alloy Steel Bolts, Studs and Other Externally-Threaded Fasteners
A 437	Alloy-Steel Turbine-Type Bolting Material Specially Heat Treated for High Temperature Service
A 449	Quenched and Tempered Steel Bolts and Studs
A 453	Bolting Materials, High-Temperature, 50 to 120 ksi Yield Strength, With Expansion Coefficients Comparable to Austenitic Steels

Castings

A 47	Ferritic Malleable Iron Castings
A 48	Gray Iron Castings
A 126	Gray Iron Castings for Valves, Flanges, and Pipe Fittings
A 197	Cupola Malleable Iron
A 216	Steel Castings, Carbon Suitable for Fusion Welding for High Temperature Service
A 217	Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts Suitable for High-Temperature Service
A 278	Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F
A 351	Steel Castings, Austenitic, for High-Temperature Service
A 389	Steel Castings, Alloy, Specially Heat-Treated for Pressure-Containing Parts Suitable for High-Temperature Service
A 395	Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures
A 536	Ductile Iron Castings

Forgings

A 105	Forgings, Carbon Steel, for Piping Components
A 181	Forgings, Carbon Steel for General Purpose Piping
A 182	Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
A350	Forgings, Carbon and Low-Alloy Steel, Requiring Notch Toughness Testing for Piping Components

Cast Pipe

A 377	Ductile Iron Pressure Pipe
A 426	Centrifugally Cast Ferritic Alloy Steel Pipe for High-Temperature Service
A 451	Centrifugally Cast Austenitic Steel Pipe for High-Temperature Service
A 452	Centrifugally Cast Austenitic Steel Cold-Wrought Pipe for High-Temperature Service

Seamless Pipe and Tube

A 106	Seamless Carbon Steel Pipe for Hight-Temperature Service
A 179	Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes
A 192	Seamless Carbon Steel Boiler Tubes for High-Pressure Service
A 199	Seamless Cold-Drawn Intermediate Alloy-Steel Heat-Exchanger and Condenser Tubes
A 210	Seamless Medium-Carbon Steel Boiler and Superheater Tubes
A 213	Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes
A 335	Seamless Ferritic Alloy Steel Pipe for High-Temperature Service
A 369	Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service
A 376	Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service
A 430	Austenitic Steel Forged and Bored Pipe for High-Temperature Service

Seamless and Welded Pipe and Tube

A 53	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
A 268	Seamless and Welded Ferritic Stainless Steel Tubing for General Service
A 312	Seamless and Welded Austenitic Stainless Steel Pipe
A 333	Seamless and Welded Steel Pipe for Low-Temperature Service
A 450	General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes
A 530	General Requirements for Specialized Carbon and Alloy Steel Pipe
A 714	High-Strength Low-Alloy Welded and Seamless Steel Pipe

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TABLE 126.1
SPECIFICATIONS AND STANDARDS (CONT'D)

ASTM Ferrous Material Specifications (Cont'd)

Welded Pipe and Tube

A 134	Pipe, Steel, Electric-Fusion (ARC)-Welded (Sizes NPS 16 and Over)
A 135	Electric-Resistance-Welded Steel Pipe
A 139	Electric-Fusion (ARC)-Welded Steel Pipe (NPS 4 in. and Over)
A 178	Electric-Resistance-Welded Carbon Steel Boiler Tubes
A 211	Spiral Welded-Steel or Iron Pipe
A 214	Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes
A 226	Electric-Resistance-Welded Carbon Steel Boiler and Superheater Tubes for High-Pressure Service
A 249	Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes
A 254	Copper Brazed Steel Tubing
A 358	Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High-Temperature Service
A 409	Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service
A 587	Electric-Welded Low-Carbon Steel Pipe for the Chemical Industry
A 671	Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures
A 672	Electrc-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures
A 691	Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures

Fittings

A 234	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures
A 403	Wrought Austenitic Stainless Steel Piping Fittings
A 420	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service

Plate, Sheet, and Strip

A 240	Heat-Resistant Chromium and Chromium-Nickel Stainless Steel Plate Sheet and Strip for Pressure Vessels
A 283	Low and Intermediate Tensile Strength Carbon Steel Plates
A 285	Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
A 299	Pressure Vessel Plates, Carbon Steel, Managanese-Silicon
A 387	Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum
A 515	Pressure Vessel Plates, Carbon Steel for Intermediate- and Higher-Temperature Service
A 516	Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service

Rods, Bars, and Shapes

A 276	Stainless and Heat Resisting Steel Bars and Shapes
A 322	Steel Bars, Alloy, Standard Grades
A 479	Stainless and Heat-Resisting Steel Wire, Bars, and Shapes for Use in Boilers and Other Pressure Vessels
A 564	Hot-Rolled and Cold-Finished Age-Hardening Stainless and Heat-Resisting Steel Bars, Wire, and Shapes
A 575	Steel Bars, Carbon, Merchant Quality, M-Grades
A 576	Steel Bars, Carbon, Hot-Wrought, Special Quality

Structural Components

A 36	Structural Steel
A 125	Steel Springs, Helical, Heat Treated
A 229	Steel Wire, Oil-Tempered for Mechanical Springs
A 242	High-Strength Low Alloy Structural Steel

ASTM Nonferrous Material Specifications

Castings

B 26	Aluminum-Alloy Sand Castings
B 61	Steam or Valve Bronze Castings
B 62	Composition Bronze or Ounce Metal castings
B 108	Aluminum-Alloy Permanent Mold Castings
B 148	Aluminum-Bronze Castings
B 367	Titanium and Titanium Alloy Castings
B 584	Copper Alloy Sand Castings

Forgings

B 247	Aluminum and Aluminum-Alloy Die, Hand, and Rolled Ring Forgings
B 283	Copper and Copper-Alloy Die Forgings (Hot Pressed)
B 381	Titanium and Titanium Alloy Forgings
B 462	UNS N08020, UNS N08024, UNS N08026, and UNS N08367 Alloy Pipe Flanges, Forged Fittings and Valves and Parts for Corrosive High-Temperature Service
B 564	Nickel and Alloy Forgings

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TABLE 126.1
SPECIFICATIONS AND STANDARDS (CONT'D)

ASTM Nonferrous Material Specifications (Cont'd)

Seamless Pipe and Tube

B 42	Seamless Copper Pipe, Standard Sizes
B 43	Seamless Red Brass Pipe, Standard Sizes
B 68	Seamless Copper Tube, Bright Annealed
B 75	Seamless Copper Tube
B 88	Seamless Copper Water Tube
B 111	Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock
B 161	Nickel Seamless Pipe and Tube
B 163	Seamless Nickel and Nickel-Alloy Condenser and Heat-Exchanger Tubes
B 165	Nickel-Copper Alloy (UNS N04400) Seamless Pipe and Tube
B 167	Nickel-Chromium-Iron Alloy (UNS N06600–N06690) Seamless Pipe and Tube
B 210	Aluminum Alloy Drawn Seamless Tubes
B 234	Aluminum and Aluminum-Alloy Drawn Seamless Tubes for Condensers and Heat Exchangers
B 241	Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube
B 251	General Requirements for Wrought Seamless Copper and Copper-Alloy Tube
B 280	Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
B 302	Threadless Copper Pipe
B 315	Seamless Copper Alloy Pipe and Tube
B 407	Nickel-Iron-Chromium Alloy Seamless Pipe and Tube
B 423	Nickel-Iron-Chromium-Molybdenum-Copper Alloy (UNS N08825 and N08821) Seamless Pipe and Tube
B 466	Seamless Copper-Nickel Pipe and Tube
B 677	UNS N08904, UNS N08925, and UNS N08926 Seamless Pipe and Tube
B 729	Seamless UNS N08020, UNS N08026, and UNS N08024 Nickel-Alloy Pipe and Tube

Seamless and Welded Pipe and Tube

B 337	Seamless and Welded Titanium and Titanium-Alloy Pipe
B 338	Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers

Welded Pipe and Tube

B 464	Welded Chromium-Nickel-Iron-Molybdenum-Copper-Colombium Stablized Alloy (UNS N08020) Pipe
B 467	Welded Copper-Nickel Pipe
B 468	Welded Chromium-Nickel-Iron-Molybdenum-Copper-Columbium Stabilized Alloy (UNS N08020) Tubes

Welded Pipe and Tube (Cont'd)

B 547	Aluminum-Alloy Formed and Arc-Welded Round Tube
B 603	Welded Copper-Alloy Pipe
B 673	UNS N08904, UNS N08925, and UNS N08926 Welded Pipe
B 674	UNS N08904, UNS N08925, and UNS N08926 Welded Tube

Fittings

B 361	Factory-Made Wrought Aluminum and Aluminum-Alloy Welding Fittings
B 366	Nickel Alloy Fittings

Plate, Sheet, and Strip

B 168	Nickel-Chromium-Iron Alloy (UNS N06600–N06690) Plate, Sheet, and Strip
B 209	Aluminum and Aluminum-Alloy Sheet and Plate
B 265	Titanium and Titanium-Alloy Strip, Sheet, and Plate
B 402	Copper-Nickel Alloy Plate and Sheet for Pressure Vessels
B 409	Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip
B 424	Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and N08221) Plate, Sheet, and Strip
B 463	Chromium-Nickel-Iron-Molybdenum-Copper-Columbium Stabilized Alloy (UNS N08020) Plate, Sheet, and Strip
B 625	UNS N08904, UNS N08925, and UNS N08031, UNS N08932, and UNS N08926 Plate, Sheet, and Strip

Rods, Bars, and Shapes

B 150	Aluminum Bronze Rod, Bar, and Shape
B 151	Copper-Nickel-Zinc Alloy (Nickel Silver) and Copper-Nickel Rod and Bar
B 221	Aluminum Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes
B 348	Titanium and Titanium Alloy Bars and Billets
B 408	Nickel-Iron-Chromium Alloy Rod and Bar
B 425	Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and N08221) Rod and Bar
B 473	UNS N08020, UNS N08024, and UNS N08026 Nickel Alloy Bar and Wire
B 649	Ni-Fe-Cr-Mo-Cu Low-Carbon Alloy (N08904) and Ni-Fe-Cr-Mo-Cu-N Low Carbon Alloys (UNS N08925, UNS N08031, and UNS N08926) Bar and Wire

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TABLE 126.1
SPECIFICATIONS AND STANDARDS (CONT'D)

ASTM Nonferrous Material Specifications (Cont'd)

Solder

B 32	Solder Metal

API Specifications

Seamless and Welded Pipe

5L	Line Pipe

American National Standards

B1.20.3	Dryseal Pipe Threads (Inch)
B16.18	Cast Copper Alloy Solder-Joint Pressure Fittings
B18.2.1	Square and Hex Bolts and Screws — Inch Series
B18.2.4.6M	Metric Heavy Hex Nuts
B18.22M	Metric Plain Washers
B18.22.1[2]	Plain Washers
Z223.1	National Fuel Gas Code (NFPA 54)

MSS Standard Practices

SP-6	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP-9	Spot-Facing for Bronze, Iron & Steel Flanges
SP-25	Standard Marking System for Valves, Fittings, Flanges and Unions
SP-42[1]	Class 150 Corrosion Resistant Gate, Globe, Angle and Check Valves With Flanged and Buttweld Ends
SP-43	Wrought Stainless Steel Butt-Welding Fittings
SP-45	Bypass & Drain Connection
SP-51	Class 150 LW Corrosion Resistant Cast Flanges and Flanged Fittings
SP-53	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Magnetic Particle Examination Method
SP-54	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Radiographic Examination Method
SP-55	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Visual Method for Evaluation of Surface Irregularities.
SP-58	Pipe Hangers & Supports, Materials, Design, and Manufacture
SP-61	Hydrostatic Testing Steel Valves
SP-67[1]	Butterfly Valves
SP-69	Pipe Hangers & Supports — Selection and Application
SP-75	Specification for High Test Wrought Butt-Welding Fittings
SP-79	Socket Welding Reducer Inserts
SP-80	Bronze Gate, Globe, Angle & Check Valve
SP-89	Pipe Hangers and Supports — Fabrication and Installation Practices
SP-93	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Liquid Penetrant Examination Method
SP-94	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Ultrasonic Examination Method
SP-97	Integrally Reinforced Forged Branch Outlet Fittings — Socket Welding, Threaded and Buttwelding Ends
SP-105	Instrument Valves for Code Applications

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TABLE 126.1
SPECIFICATIONS AND STANDARDS (CONT'D)

01

ASME Codes and Standards

...	ASME Boiler and Pressure Vessel Code
B1.1	Unified Inch Screw Threads
B1.13M	Metric Screw Threads — M Profile
B1.20.1	Pipe Threads, General Purpose (Inch)
B16.1	C.I. Pipe Flanges and Flanged Fittings — 25, 125, 250 & 800 Classes
B16.3	M.I. Thd. Fittings
B16.4	G.I. Thd. Fittings
B16.5	Pipe Flanges & Flanged Fittings
B16.9	Wrought Steel Butt Welding Fittings
B16.10	Face-to-Face and End-to-End Dimensions of Valves
B16.11	Forged Steel Fittings, S.W. & Threaded
B16.14	Ferrous Plugs, Bushings & Locknuts with Pipe Threads
B16.15	Cast Bronze Threaded Fittings, Classes 125 and 250
B16.20	Metallic Gaskets for Pipe Flanges — Ring Joint, Spiral Wound, & Jacketed
B16.21	Non-Metallic Flat Gaskets for Pipe Flanges
B16.22	Wrought Copper & Copper Alloy Solder Joint Pressure Fittings
B16.24	Cast Copper Alloy Pipe Flanges & Flanged Fittings — Class 150, 300, 400, 600, 900, 1500, and 2500
B16.25	Butt Welding Ends
B16.28	Wrought Steel Butt Welding Short Radius Elbows and Returns
B16.34	Valves — Flanged, Threaded, and Welding End
B16.42	Ductile Iron Pipe Flanges and Flanged Fittings — Classes 150 and 300
B16.47	Large Diameter Steel Flanges
B16.48	Steel Line Blanks
B18.2.2	Square and Hex Nuts (Inch Series)
B18.2.3.5M	Metric Hex Bolts
B18.2.3.6M	Metric Heavy Hex Bolts
B18.21.1	Lock Washers (Inch Series)
B31.3	Process Piping
B31.4	Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols
B31.8	Gas Transmission & Distribution Piping Systems
B36.10M	Welded and Seamless Wrought Steel Pipe
B36.19M	Stainless Steel Pipe
TDP-1	Recommended Practices for the Prevention of Water Damage to Steam Turbines Used for Electric Power Generation — Fossil Fueled Plants

ASNT Specifications

CP-189	ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel
SNT-TC-1A	Personnel Qualification and Certification in Nondestructive Testing

AWS Specifications

A3.0	Standard Welding Terms and Definitions
QC1	Qualification and Certification of Welding Inspectors

AWWA and ANSI/AWWA Standards

C-110/ A21.10	C.I. Fittings 2" thru 48"
C-111/ A21.11	Rubber Gasketed Joint for C.I. Pipe and Fittings
C-115/ A21.15	Flanged .C.I. Pipe with Thread Flanges
C-150/ A21.50	Thickness Design of Ductile-Iron Pipe
C-151/ A21.51	Ductile Iron Pipe Centrifugally Cast in metal or Sandlined Molds
C-200	Fabricated Electrically Welded Steel Pipe
C-207	Steel Pipe Flanges
C-208	Dimensions for Steel Water Pipe Fittings
C-300	Reinforced Concrete Water Pipe-Steel Cylinder Type Not Prestressed
C-301	Reinforced Concrete Water Pipe-Steel Cylinder Type Prestressed
C-302	Reinforced Concrete Water Pipe-Non Cylinder Type — Not Prestressed
C-500	Gate Valves for Ordinary Water Works Service
C-504[1]	Rubber Seated Butterfly Valves
C-600	Installation of C.I. Water Mains
C-606	Grooved and Shouldered Type Joints

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TABLE 126.1
SPECIFICATIONS AND STANDARDS (CONT'D)

National Fire Codes

NFPA 8503 Standard for Pulverized Fuel Systems
NFPA 1963 Screw Threads and Gaskets for Fire Hose Connections

PFI Standards

ES-16 Access Holes and Plugs for Radiographic Inspection of Pipe Welds

GENERAL NOTES:
(a) For boiler external piping application, see para. 123.2.2.
(b) For all other piping, materials conforming to an ASME SA or SB specification may be used interchangeably with material specified to an ASTM A or B spefication of the same number listed in Table 126.1.
(c) The approved year of issue of the specifications and standards is not given in this Table. This information is given in Appendix F of this Code.
(d) The addresses and phone numbers of organizations whose specifications and standards are listed in this Table are given at the end of Appendix F.
(e) Abbreviations which are used in this Table are:

B.W.	Butt welding	H.T.	High temperature	S.W.	Socket welding
C.I.	Cast iron	L.T.	Low temperature	Temp.	Temperature
Engr.	Engineering	M.I.	Malleable iron	Thd.	Threaded
Gen.	General	Serv.	Service(s)	T.S.	Tensile strength
G.I.	Gray iron	S.S.	Stainless steel		

NOTES:
(1) See para. 107.1(D) for valve stem retention requirements.
(2) ANSI B18.22.1 is nonmetric.

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CHAPTER V
FABRICATION, ASSEMBLY, AND ERECTION

127 WELDING

127.1 General

Piping systems shall be constructed in accordance with the requirements of this Chapter and of materials that have been manufactured in accordance with the requirements of Chapter IV. These requirements apply to all fabrication, assembly, and erection operations, whether performed in a shop or at a construction site. The following applies essentially to the welding of ferrous materials. The welding of aluminum, copper, etc., requires different preparations and procedures.

127.1.1 The welding processes that are to be used under this part of this Code shall meet all the test requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

127.2 Material

127.2.1 Filler Metal. All filler metal, including consumable insert material, shall comply with the requirements of Section IX, ASME Boiler and Pressure Vessel Code. A filler metal not incorporated in Section IX may be used if a procedure qualification test is first successfully made in accordance with Section IX. Filler metals with less than 0.05% carbon content shall not be used for high temperature applications (above 850°F) in low alloy steels due to reduced creep rupture properties.

127.2.2 Backing Rings. Backing rings, when used, shall conform to the following requirements:

(A) Ferrous Rings. Ferrous metal backing rings which become a permanent part of the weld shall be made from material of weldable quality, compatible with the base material and the sulfur content shall not exceed 0.05%.

(A.1) Backing rings may be of the continuous machined or split band type.

(A.2) If two abutting surfaces are to be welded to a third member used as a backing ring and one or two of the three members are ferritic and the other member or members are austenitic, the satisfactory use of such materials shall be determined by the WPS qualified as required in para. 127.5.

(A.3) Backing strips used at longitudinal welded joints shall be removed.

(B) Nonferrous and Nonmetallic Rings. Backing rings of nonferrous or nonmetallic materials may be used for backing provided they are included in a WPS as required in para. 127.5. Nonmetallic or nonfusing rings shall be removed.

127.2.3 Consumable Inserts. Consumable inserts may be used provided they are made from material compatible with the chemical and physical properties of the base material. Qualification of the WPS shall be as required by para. 127.5.

127.3 Preparation for Welding

(A) End Preparation

(A.1) Oxygen or arc cutting is acceptable only if the cut is reasonably smooth and true, and all slag is cleaned from the flame cut surfaces. Discoloration which may remain on the flame cut surface is not considered to be detrimental oxidation.

(A.2) Butt-welding end preparation dimensions contained in ASME B16.25 or any other end preparation which meets the WPS are acceptable.

(A.3) If piping component ends are bored, such boring shall not result in the finished wall thickness after welding less than the minimum design thickness. Where necessary, weld metal of the appropriate analysis may be deposited on the inside or outside of the piping component to provide sufficient material for machining to insure satisfactory fitting of rings.

(A.4) If the piping component ends are upset, they may be bored to allow for a completely recessed backing ring, provided the remaining net thickness of the finished ends is not less than the minimum design thickness.

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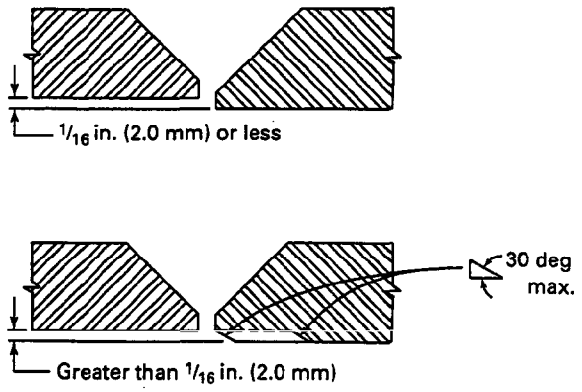

FIG 127.3 BUTT WELDING OF PIPING COMPONENTS WITH INTERNAL MISALIGNMENT

(B) Cleaning. Surfaces for welding shall be clean and shall be free from paint, oil, rust, scale, or other material which is detrimental to welding.

(C) Alignment. The inside diameters of piping components to be butt welded shall be aligned as accurately as is practicable within existing commercial tolerances on diameters, wall thicknesses, and out-of-roundness. Alignment shall be preserved during welding. The internal misalignment of the ends to be joined shall not exceed 1/16 in. (2.0 mm) unless the piping design specifically states a different allowable misalignment.

When the internal misalignment exceeds the allowable, it is preferred that the component with the wall extending internally be internally trimmed per Fig. 127.3. However, trimming shall result in a piping component thickness not less than the minimum design thickness and the change in contour shall not exceed 30 deg (see Fig. 127.3).

(D) Spacing. The root opening of the joint shall be as given in the WPS.

(E) Socket Weld Assembly. In assembly of the joint before welding, the pipe or tube shall be inserted into the socket to the maximum depth and then withdrawn approximately 1/16 in. (2.0 mm) away from contact between the end of the pipe and the shoulder of the socket [see Figs. 127.4.4(B) and (C)]. In sleeve type joints without internal shoulder, there shall be a distance of approximately 1/16 in. (2.0 mm) between the butting ends of the pipe or tube.

The fit between the socket and the pipe shall conform to applicable standards for socket weld fittings and in no case shall the inside diameter of the socket or sleeve exceed the outside diameter of the pipe or tube by more than 0.080 in. (2.0 mm).

127.4 Procedure

127.4.1 General

(A) Qualification of the WPS to be used, and of the performance of welders and operators, is required, and shall comply with the requirements of para. 127.5.

(B) No welding shall be done if there is impingement of rain, snow, sleet, or high wind on the weld area.

(C) Tack welds permitted to remain in the finished weld shall be made by a qualified welder. Tack welds made by an unqualified welder shall be removed. Tack welds which remain shall be made with an electrode and WPS which is the same as or equivalent to the electrode and WPS to be used for the first pass. The stopping and starting ends shall be prepared by grinding or other means so that they can be satisfactorily incorporated into the final weld. Tack welds which have cracked shall be removed.

(D) CAUTION: Arc strikes outside the area of the intended weld should be avoided on any base metal.

127.4.2 Girth Butt Welds

(A) Girth butt welds shall be complete penetration welds and shall be made with a single vee, double vee, or other suitable type of groove, with or without backing rings or consumable inserts. The depth of the weld measured between the inside surface of the weld preparation and the outside surface of the pipe shall not be less than the minimum thickness required by Chapter II for the particular size and wall of pipe used.

(B) In order to avoid abrupt transitions in the contour of the finished weld, the requirements of (B.1) through (B.4) below shall be met.

(B.1) When components with different outside diameters or wall thicknesses are welded together, the welding end of the component with the larger outside diameter shall fall within the envelope defined by solid lines in Fig. 127.4.2. The weld shall form a gradual transition not exceeding a slope of 30 deg from the smaller to the larger diameter component. This condition may be met by adding welding filler material, if necessary, beyond what would otherwise be the edge of the weld.

(B.2) When both components to be welded (other than pipe to pipe) have a transition from a thicker section to the weld end preparation, the included angle between the surface of the weld and the surface of either of the components shall not be less than 150 deg Refer to para. 119.3(B) for additional concerns related to this design.

(B.3) When welding pipe to pipe, the surface of the

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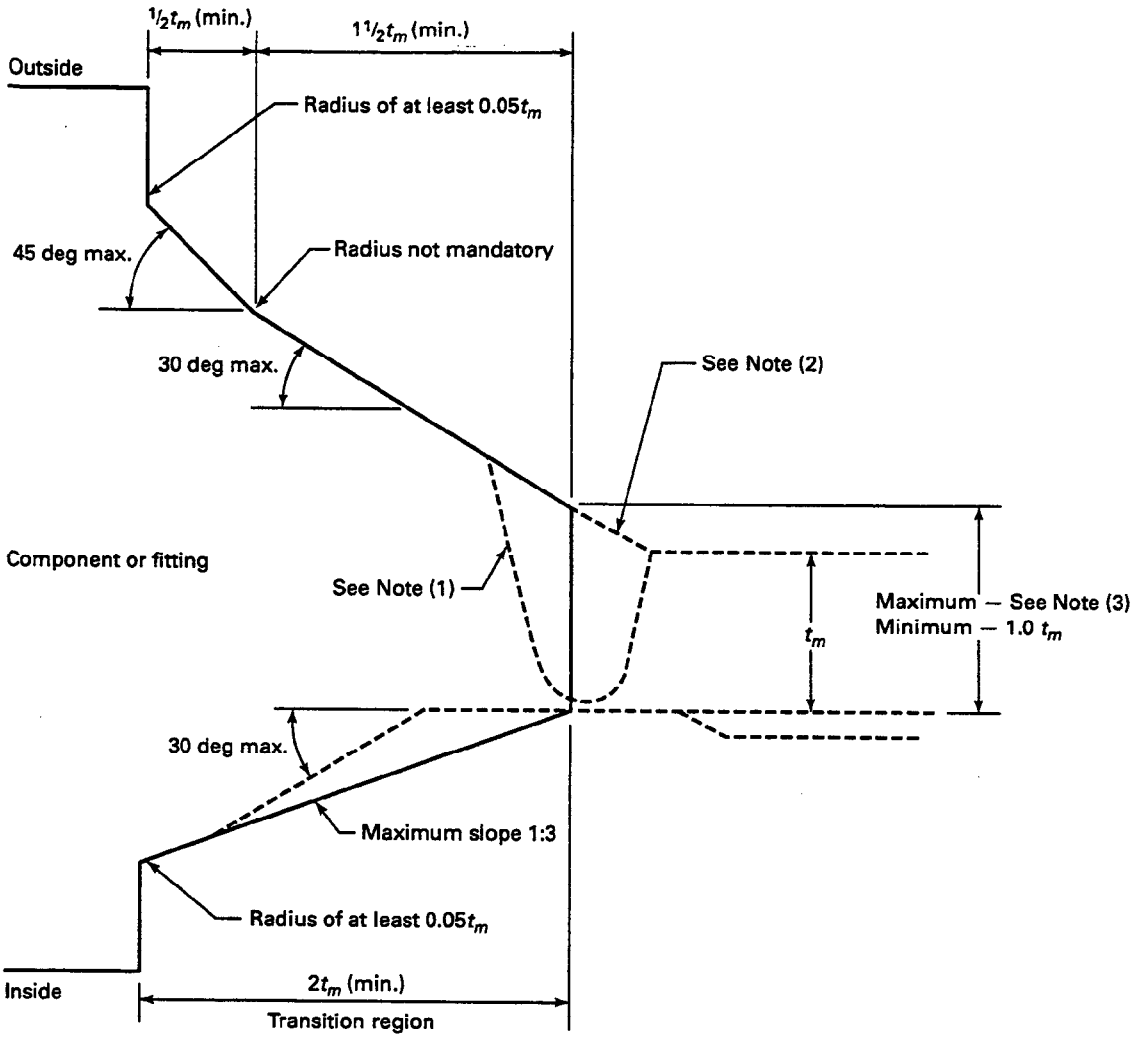

GENERAL NOTES:

(a) The value of t_m is whichever of the following is applicable:
  (1) as defined in para. 104.1.2(A);
  (2) the minimum ordered wall thickness of the cylindrical welding end of a component or fitting (or the thinner of the two) when the joint is between two components.

(b) The maximum envelope is defined by solid lines.

NOTES:

(1) Weld is shown for illustration only.
(2) The weld transition and weld reinforcement shall comply with paras. 127.4.2(B) and (C-2) and may be outside the maximum envelope.
(3) The maximum thickness at the end of the component is:
  (a) the greater of (t_m + 0.15 in.) or $1.15t_m$ when ordered on a minimum wall basis;
  (b) the greater of (t_m + 0.15 in.) or $1.10t_{nom}$ when ordered on a nominal wall basis.

FIG. 127.4.2 WELDING END TRANSITION — MAXIMUM ENVELOPE

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TABLE 127.4.2
REINFORCEMENT OF GIRTH AND LONGITUDINAL BUTT WELDS

Thickness of Base Metal, in. (mm)	Maximum Thickness of Reinforcement for Design Temperature					
	> 750°F (400°C)		350°F–750°F (175°C–400°C)		< 350°F (175°C)	
	in.	mm	in.	mm	in.	mm
Up to 1/8 (3.0), incl.	1/16	2.0	3/32	2.5	3/16	5.0
Over 1/8 to 3/16 (3.0 to 5.0), incl.	1/16	2.0	1/8	3.0	3/16	5.0
Over 3/16 to 1/2 (5.0 to 13.0), incl.	1/16	2.0	5/32	4.0	3/16	5.0
Over 1/2 to 1 (13.0 to 25.0), incl.	3/32	2.5	3/16	5.0	3/16	5.0
Over 1 to 2 (25.0 to 50.0), incl.	1/8	3.0	1/4	6.0	1/4	6.0
Over 2 (50.0)	5/32	4.0	The greater of 1/4 in. (6 mm) or 1/8 times the width of the weld in inches (millimeters).			

GENERAL NOTES:

(a) For double welded butt joints, this limitation on reinforcement given above shall apply separately to both inside and outside surfaces of the joint.

(b) For single welded butt joints, the reinforcement limits given above shall apply to the outside surface of the joint only.

(c) The thickness of weld reinforcement shall be based on the thickness of the thinner of the materials being joined.

(d) The weld reinforcement thicknesses shall be determined from the higher of the abutting surfaces involved.

(e) Weld reinforcement may be removed if so desired.

weld shall, as a minimum, be flush with the outer surface of the pipe, except as permitted in para. 127.4.2(B.4).

(B.4) For welds made without the addition of filler metal, concavity shall be limited to 1/32 in. (1 mm) below the outside surface of the pipe, but shall not encroach upon minimum required thickness.

(C) As-welded surfaces are permitted; however, the surface of welds shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys to meet the following.

(C.1) The surface condition of the finished welds shall be suitable for the proper interpretation of radiographic and other nondestructive examinations when nondestructive examinations are required by Table 136.4. In those cases where there is a question regarding the surface condition on the interpretation of a radiographic film, the film shall be compared to the actual weld surface for interpretation and determination of acceptability.

(C.2) Reinforcements are permitted in accordance with Table 127.4.2.

(C.3) Undercuts shall not exceed 1/32 in. (1.0 mm) and shall not encroach on the minimum required section thickness.

(C.4) If the surface of the weld requires grinding to meet the above criteria, care shall be taken to avoid reducing the weld or base material below the minimum required thickness.

(C.5) Concavity on the root side of a single welded circumferential butt weld is permitted when the resulting thickness of the weld is at least equal to the thickness of the thinner member of the two sections being joined and the contour of the concavity is smooth without sharp edges. The internal condition of the root surface of a girth weld, which has been examined by radiography, is acceptable only when there is a gradual change in the density, as indicated in the radiograph. If a girth weld is not designated to be examined by radiography, a visual examination may be performed at welds which are readily accessible.

127.4.3 Longitudinal Butt Welds. Longitudinal butt welds not covered by the applicable material specifications listed in Table 126.1 shall meet the requirements for girth butt welds in para. 127.4.2.

127.4.4 Fillet Welds. In making fillet welds, the weld metal shall be deposited in such a way as to secure adequate penetration into the base metal at the root of the weld.

Fillet welds may vary from convex to concave. The size of a fillet weld is determined as shown in Fig. 127.4.4(A). Typical minimum fillet weld details for slip-on flanges and socket-welding components are shown in Figs. 127.4.4(B) and (C).

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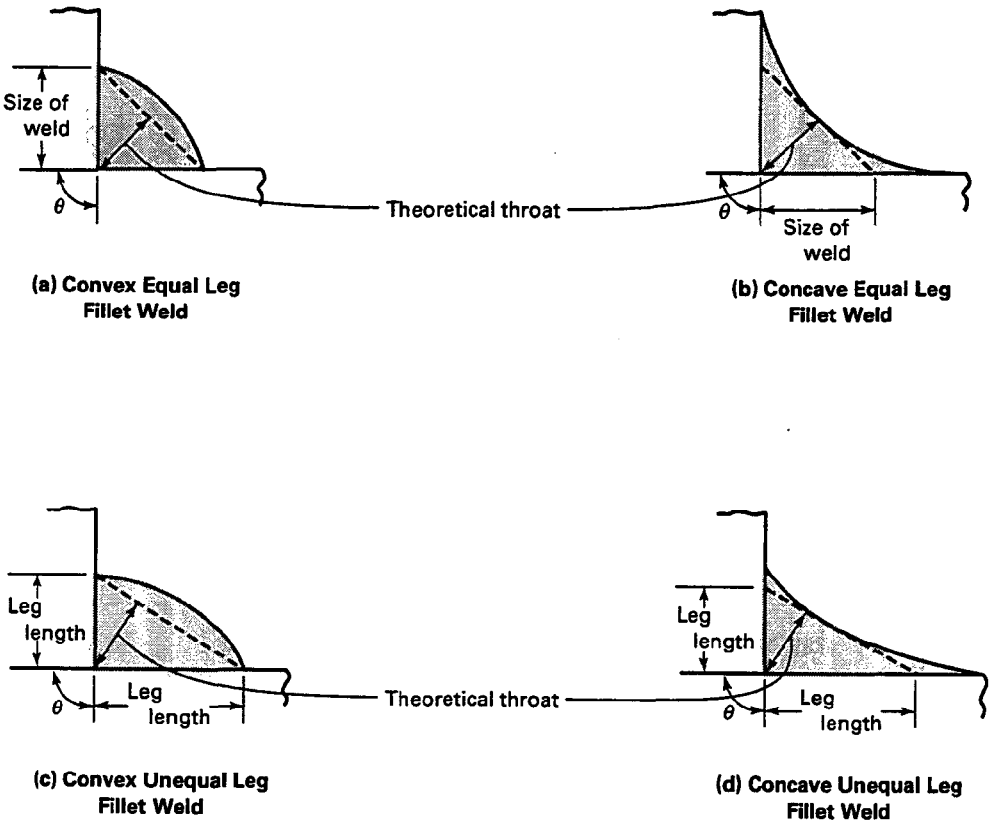

(a) Convex Equal Leg Fillet Weld

(b) Concave Equal Leg Fillet Weld

(c) Convex Unequal Leg Fillet Weld

(d) Concave Unequal Leg Fillet Weld

GENERAL NOTES:

(a) The "size" of an equal leg fillet weld shall be described by the leg length of the largest inscribed isoceles triangle.

(b) The "size" of an unequal leg fillet weld shall be described using both leg lengths and their location on the members to be joined.

(c) Angle θ, as noted in the above figures, may vary from the 90 deg angle as shown based on the angle between the surfaces to be welded.

(d) For an equal leg fillet weld where the angle θ between the members being joined is 90 deg, the theoretical throat shall be 0.7 × leg length. For other fillet welds, the theoretical throat shall be based on the leg lengths and the angle θ between the members to be joined.

(e) For all fillet welds, particularly unequal leg fillet welds with angle θ less than 90 deg, the theoretical throat shall lie within the cross section of the deposited weld metal and shall not be less than the minimum distance through the weld.

FIG. 127.4.4(A) FILLET WELD SIZE

127.4.5 Seal Welds. Where seal welding of threaded joints is performed, threads shall be entirely covered by the seal weld. Seal welding shall be done by qualified welders.

127.4.8 Welded Branch Connections

(A) Welded branch connections shall be made with full penetration welds, except as allowed in para. 127.4.8(F). Figures 127.4.8(A), (B), and (C) show typical details of branch connections with and without added reinforcement. No attempt has been made to show all acceptable types of construction and the fact that a certain type of construction is illustrated does not indicate that it is recommended over other types not illustrated.

(B) Figure 127.4.8(D) shows basic types of weld attachments used in the fabrication of branch connections. The location and minimum size of these attach-

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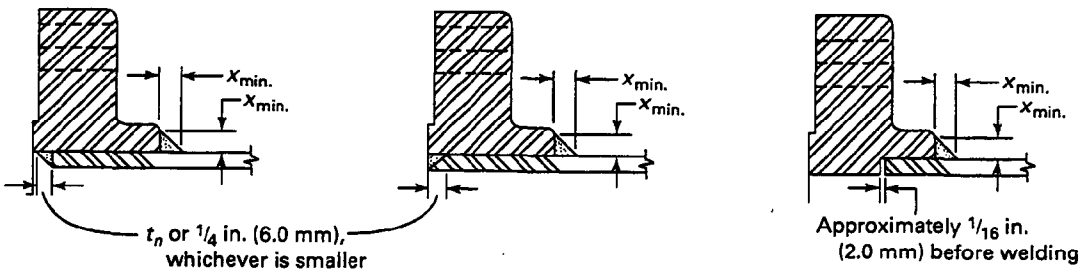

(a) Front and Back Weld [See Notes (1) and (2)]

(b) Face and Back Welds [See Notes (1) and (2)]

(c) Socket Welding Flange [See Notes (2) and (3)]

t_n = nominal pipe wall thickness
$x_{min.} = 1.09t_n$ or thickness of the hub, whichever is smaller

NOTES:
(1) Refer to para. 122.1.1(F) for limitations of use.
(2) Refer to para. 104.5.1 for limitations of use.
(3) Refer to para. 122.1.1(H) for limitations of use.

FIG. 127.4.4(B) WELDING DETAILS FOR SLIP-ON AND SOCKET-WELDING FLANGES; SOME ACCEPTABLE TYPES OF FLANGE ATTACHMENT WELDS

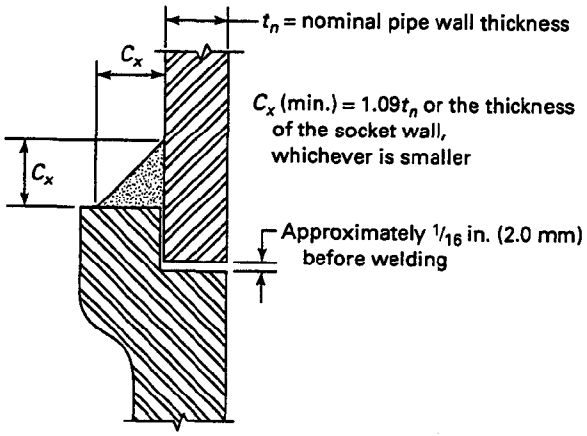

FIG. 127.4.4(C) MINIMUM WELDING DIMENSIONS REQUIRED FOR SOCKET WELDING COMPONENTS OTHER THAN FLANGES

ment welds shall conform to the requirements of para. 127.4.8. Welds shall be calculated in accordance with para. 104.3.1 but shall not be less than the sizes shown in Fig. 127.4.8(D).

The notations and symbols used in this paragraph and in Fig. 127.4.8(D) are as follows:

t_c = the smaller of 1/4 in. (6.0 mm) or $0.7t_{nb}$

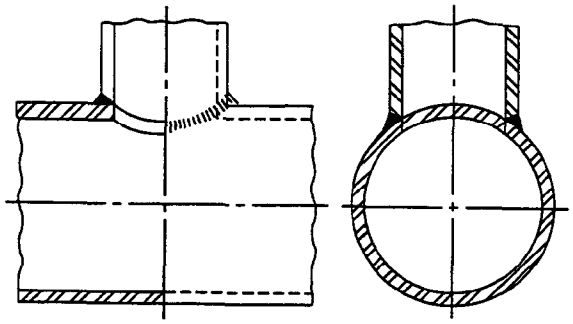

FIG. 127.4.8(A) TYPICAL WELDED BRANCH CONNECTION WITHOUT ADDITIONAL REINFORCEMENT

t_{nr} = nominal thickness of reinforcing element (ring or saddle), in. (mm)
t_{min} = the smaller of t_{nb} or t_{nr}
t_{nb} = nominal thickness of branch wall, in. (mm)
t_{nh} = nominal thickness of header wall, in. (mm)

(C) Figure 127.4.8(E) shows branch connections made by welding half couplings or adapters directly to the run pipe.

These branch connections and specially made integrally reinforced branch connection fittings which abut the outside surface of the run wall, or which are inserted through an opening cut in the run wall, shall have

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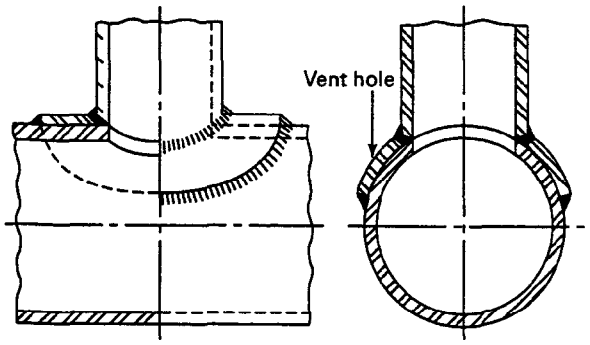

FIG. 127.4.8(B) TYPICAL WELDED BRANCH CONNECTION WITH ADDITIONAL REINFORCEMENT

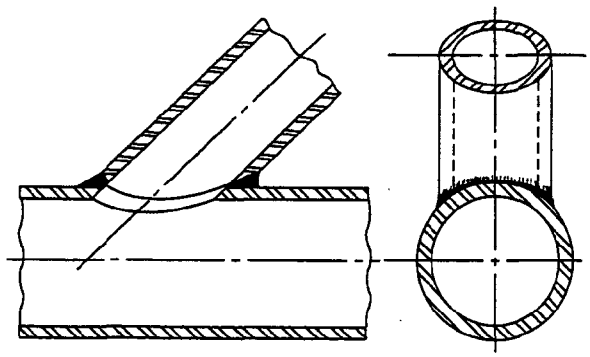

FIG. 127.4.8(C) TYPICAL WELDED ANGULAR BRANCH CONNECTION WITHOUT ADDITIONAL REINFORCEMENT

opening and branch contour to provide a good fit and shall be attached by means of full penetration groove welds except as otherwise permitted in (F) below.

The full penetration groove welds shall be finished with cover fillet welds and meet the requirements of para. 104. The cover fillet welds shall have a minimum throat dimension not less than that shown in Fig. 127.4.8(E).

(D) In branch connections having reinforcement pads or saddles, the reinforcement shall be attached by welds at the outer edge and at the branch periphery as follows.

(D.1) If the weld joining the added reinforcement to the branch is a full penetration groove weld, it shall be finished with a cover fillet weld having a minimum throat dimension not less than t_c; the weld at the outer edge, joining the added reinforcement to the run, shall be a fillet weld with a minimum throat dimension of $0.5t_{nr}$.

(D.2) If the weld joining the added reinforcement to the branch is a fillet weld, the throat dimension shall not be less than $0.7t_{min}$. The weld at the outer edge joining the outer reinforcement to the run shall also be a fillet weld with a minimum throat dimension of $0.5t_{nr}$.

(E) When rings or saddles are used, a vent hole shall be provided (at the side and not at the crotch) in the ring or saddle to reveal leakage in the weld between branch and main run and to provide venting during welding and heat treating operations. Rings or saddles may be made in more than one piece if the joints between the pieces have strength equivalent to ring or saddle parent metal and if each piece is provided with a vent hole. A good fit shall be provided between reinforcing rings or saddles and the parts to which they are attached.

(F) Branch connections NPS 2 and smaller which do not require reinforcements (see para. 104.3) may be constructed as shown in Fig. 127.4.8(F). The groove welds shall be finished with cover fillet welds with a minimum throat dimension not less than that shown in Fig. 127.4.8(F). This construction shall not be used at design temperatures greater than 750°F (400°C) nor at design pressures greater than 1025 psi (7100 kPa).

127.4.9 Attachment Welds. Structural attachments may be made by complete penetration, partial penetration, or fillet welds.

(A) Low energy capacitor discharge welding may be used for the welding of temporary attachments directly to pressure parts, provided that they be removed prior to subjecting the piping system to operating pressure or temperature. After their removal, the affected areas shall be examined in accordance with para. 136.4. Performance and procedure qualifications are not required.

This method of welding may also be used for the permanent attachment of nonstructural items, such as strain gages or thermocouples, provided that:

(A.1) a welding procedure specification is prepared describing the capacitor discharge equipment, the materials to be joined, and the techniques of application; the qualification of the procedure is not required;

(A.2) the minimum thickness of the material to which the attachment is to be made is 0.090 in. (2.3 mm);

(A.3) the power input is limited to less than 125 W-sec.

127.4.10 Heat Treatment. Preheat and postweld heat treatment for welds shall be in accordance with para. 131 or 132 as applicable.

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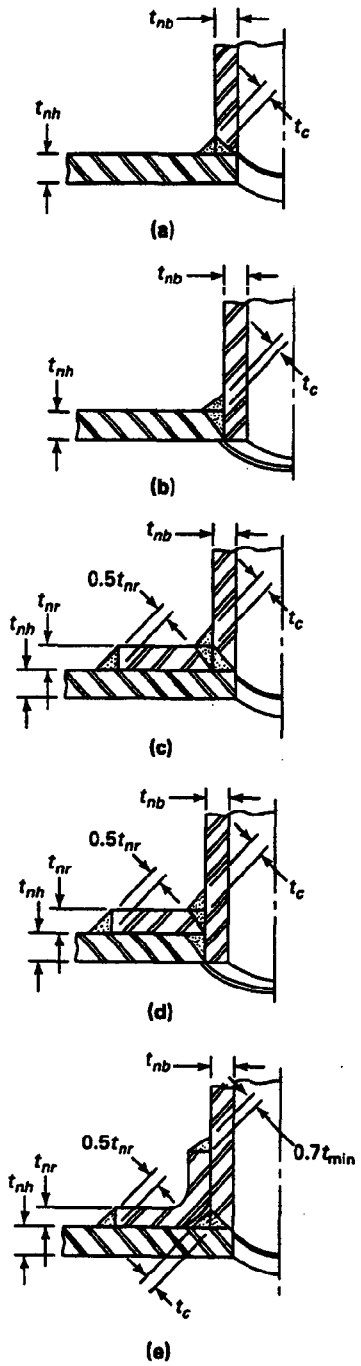

GENERAL NOTE: Weld dimensions may be larger than the minimum values shown here.

FIG. 127.4.8(D) SOME ACCEPTABLE TYPES OF WELDED BRANCH ATTACHMENT DETAILS SHOWING MINIMUM ACCEPTABLE WELDS

127.4.11 Repair Welding

(A) Defect Removal. All defects in welds or base materials requiring repair shall be removed by flame or arc gouging, grinding, chipping, or machining. Preheating may be required for flame or arc gouging on certain alloy materials of the air hardening type in order to prevent surface checking or cracking adjacent to the flame or arc gouged surface.

(B) Repair Welds. Repair welds shall be made in accordance with a WPS using qualified welders or welding operators (see para. 127.5), recognizing that the cavity to be repair welded may differ in contour and dimension from a normal joint preparation and may present different restraint conditions. The types, extent, and methods of examination shall be in accordance with Table 136.4. For repairs to welds the minimum examination shall be the same method that revealed the defect in the original weld. For repairs to base material, the minimum examination shall be the same as required for butt welds.

127.5 Qualification

127.5.1 General. Qualification of the WPS to be used, and of the performance of welders and welding operators, is required, and shall comply with the requirements of the ASME Boiler and Pressure Vessel Code (Section IX) except as modified herein.

Certain materials listed in Appendix A do not appear in ASME Section IX P-Number groups. Where these materials have been assigned P-Numbers in Appendix A, they may be welded under this Code for nonboiler external piping only without separate qualification as if they were listed in ASME Section IX.

127.5.2 Welding Responsibility. Each employer (see para. 100.2) shall be responsible for the welding performed by his organization and the performance of welders or welding operators employed by that organization.

127.5.3 Qualification Responsibility

(A) Procedures. Each employer shall be responsible for qualifying any WPS that he intends to have used by personnel of his organization. However, to avoid duplication of effort, and subject to approval of the owner, a WPS qualified by a technically competent group or agency may be used:

(A.1) if the group or agency qualifying the WPS meets all of the procedure qualification requirements of this Code;

(A.2) if the fabricator accepts the WPS thus qualified;

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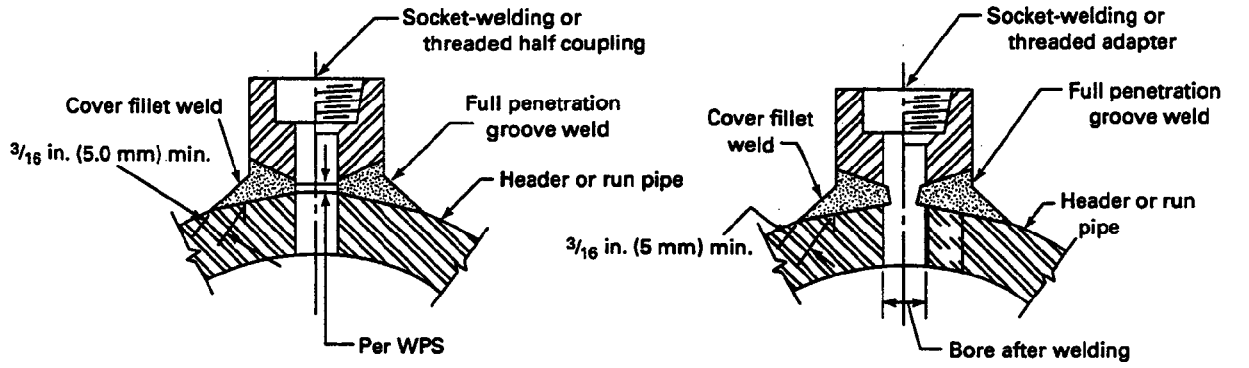

(a) Branch Connection Using ASME B16.11 Forged Steel Socket-Welding or Threaded Half Coupling [See Note (1)]

(b) Branch Connection Using Forged Steel Socket-Welding or Threaded Adapter for Pressure and Temperature Conditions Greater Than Permitted for ASME B16.11 Forged Steel Fittings

NOTE:
(1) Refer to para. 104.3.1(C.2) for branch connections not requiring reinforcement calculations.

FIG. 127.4.8(E) TYPICAL FULL PENETRATION WELD BRANCH CONNECTIONS FOR NPS 3 AND SMALLER HALF COUPLINGS OR ADAPTERS

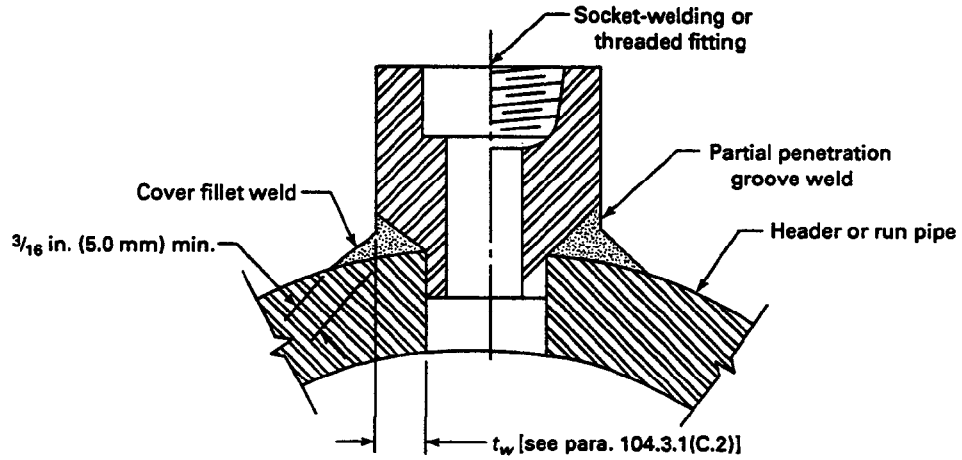

FIG. 127.4.8(F) TYPICAL PARTIAL PENETRATION WELD BRANCH CONNECTION FOR NPS 2 AND SMALLER FITTINGS

(A.3) if the user of the WPS has qualified at least one welder using the WPS;

(A.4) if the user of the WPS assumes specific responsibility for the procedure qualification work done for him by signing the records required by para. 127.6.

All four of the above conditions shall be met before a WPS thus qualified may be used.

(B) Welders and Welding Operators. Each employer shall be responsible for qualifying all the welders and welding operators employed by him.

However, to avoid duplication of effort, he may accept a Welder/Welding Operator Performance Qualification (WPQ) made by a previous employer (subject to the approval of the owner or his agent) on piping using the same or an equivalent procedure wherein the essential variables are within the limits established in Section IX,

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ASME Boiler and Pressure Vessel Code. An employer accepting such qualification tests by a previous employer shall obtain a copy (from the previous employer) of the WPQ, showing the name of the employer by whom the welders or welding operators were qualified, the dates of such qualification, and evidence that the welder or welding operator has maintained qualification in accordance with QW-322 of Section IX, ASME Boiler and Pressure Vessel Code. The employer shall then prepare and sign the record required in para. 127.6 accepting responsibility for the ability of the welder or welding operator.

01 **127.5.4 Standard Welding Procedure Specifications.** Standard Welding Procedure Specifications published by the American Welding Society and listed in Appendix E of Section IX of the ASME Boiler and Pressure Vessel Code are permitted for Code construction within the limitations established by Article V of ASME Section IX.

127.6 Welding Records

The employer shall maintain a record (WPS and/or WPQ) signed by him, and available to the purchaser or his agent and the inspector, of the WPSs used and the welders and/or welding operators employed by him, showing the date and results of procedure and performance qualification.

The WPQ shall also show the identification symbol assigned to the welder or welding operator employed by him, and the employer shall use this symbol to identify the welding performed by the welder or welding operator. This may be accomplished by the application of the symbol on the weld joint in a manner specified by the employer. Alternatively, the employer shall maintain records which identify the weld(s) made by the welder or welding operator.

128 BRAZING

128.1 General

128.1.1 The brazing processes that are to be used under this part of the Code shall meet all the test requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

128.2 Materials

128.2.1 Filler Metal. The filler metal shall melt and flow freely within the desired temperature range and, in conjunction with a suitable flux or controlled atmosphere, shall wet and adhere to the surfaces to be joined.

128.2.2 Flux. Fluxes that are fluid and chemically active at the brazing temperature shall be used when necessary to prevent oxidation of the filler metal and the surfaces to be joined and to promote free flowing of the filler metal.

128.3 Preparation

128.3.1 Surface Preparation. The surfaces to be brazed shall be clean and free from grease, oxides, paint, scale, dirt, or other material that is detrimental to brazing. A suitable chemical or mechanical cleaning method can be used to provide a clean wettable surface for brazing.

128.3.2 Joint Clearance. The clearance between surfaces to be joined shall be no larger than is necessary to complete capillary distribution of the filler metal.

128.4 Procedure

128.4.1 General

(A) Qualification of the brazing procedures to be used and of the performance of the brazer and brazing operators is required and shall comply with the requirements of para. 128.5.

(B) No brazing shall be done if there is impingement of rain, snow, sleet, or high wind on the area to be brazed.

128.4.2 Heating. The joint shall be brought to brazing temperature in as short a time as possible to minimize oxidation.

128.5 Qualification

128.5.1 General. The qualification of the brazing procedure and of the performance of brazers and brazing operators shall be in accordance with the requirements of Part QB, Section IX, ASME Boiler and Pressure Vessel Code, except as modified herein.

128.5.2 Brazing Responsibility. Each employer (see para. 100.2) shall be responsible for the brazing performed by his organization and the performance of brazers or brazing operators employed by that organization.

128.5.3 Qualification Responsibility

(A) Procedures. Each employer shall be responsible for qualifying any Brazing Procedure Specification

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(BPS) that he intends to have used by personnel of his organization. However, to avoid duplication of effort, and subject to approval of the owner, a BPS qualified by a technically competent group or agency may be used:

(A.1) if the group or agency qualifying the procedures meets all of the procedure qualification requirements of this Code;

(A.2) if the fabricator accepts the procedure thus qualified;

(A.3) if the user of the procedure has qualified at least one brazer using the BPS;

(A.4) if the user of the procedure assumes specific responsibility for the procedure qualification work done by him by signing the records required by para. 128.6.

All four of the above conditions shall be met before a procedure thus qualified may be used.

(B) Brazers and Brazing Operators. Each employer shall be responsible for qualifying all the brazers and brazing operators employed by him.

However, to avoid duplication of effort, he may accept a Brazer/Brazing Operator Performance Qualification (BPQ) made by a previous employer (subject to the approval of the owner or his agent) on piping using the same or an equivalent procedure wherein the essential variables are within the limits established in Section IX, ASME Boiler and Pressure Vessel Code. An employer accepting such qualification tests by a previous employer shall obtain a copy (from the previous employer) of the BPQ, showing the name of the employer by whom the brazers or brazing operators were qualified, the dates of such qualification, and the date the brazer last brazed pressure piping components under such qualification. The employer shall then prepare and sign the record required in para. 128.6 accepting responsibility for the ability of the brazer or brazing operator.

128.6 Brazing Records

The employer shall maintain a record signed by him and available to the purchaser or his agent and the inspector, showing the date and results of procedure and performance qualification.

The BPQ shall also show the identification symbol assigned to the brazer or brazing operator employed by him, and the employer shall use this symbol to identify the brazing performed by the brazer or brazing operator. This may be accomplished by the application of the symbol on the braze joint in a manner specified by the employer. Alternatively, the employer shall maintain records which identify the braze joints(s) made by the brazer or brazing operator.

TABLE 129.3.2
APPROXIMATE LOWER CRITICAL TEMPERATURES

Material	Approximate Lower Critical Temperature (1), °F (°C)
Carbon Steel (P-No. 1)	1340 (725)
Carbon Molybdenum Steel (P-No. 3)	1350 (730)
1Cr–½Mo (P-No 4, Gr. No. 1)	1375 (745)
1¼Cr–½Mo (P-No. 4, Gr. No. 2)	1430 (775)
2¼Cr–1Mo, 3Cr–1Mo (P-No. 5A)	1480 (805)
5Cr–½Mo (P-No. 5B, Gr. No. 1)	1505 (820)
9Cr–½Mo (P-No. 5B, Gr. No. 2)	1490 (810)

NOTE:
(1) These values are intended for guidance only. The user may apply values obtained for the specific material in lieu of these values.

129 BENDING AND FORMING

129.1 Bending

Pipe may be bent by any hot or cold method and to any radius which will result in a bend surface free of cracks, as determined by a method of inspection specified in the design, and substantially free of buckles. Such bends shall meet the design requirements of paras. 102.4.5 and 104.2.1. This shall not prohibit the use of bends designed as creased or corrugated.

129.2 Forming

Piping components may be formed (swedging, lapping, or upsetting of pipe ends, extrusion of necks, etc.) by any suitable hot or cold working method, provided such processes result in formed surfaces which are uniform and free of cracks or other defects, as determined by method of inspection specified in the design.

129.3 Heat Treatment of Bends and Formed Components

129.3.1 Hot bending or forming is performed at a temperature above T_{crit} – 100°F (56°C) where T_{crit} is the lower critical temperature of the material. Cold bending or forming is performed at a temperature below T_{crit} – 100°F (56°C). (See Table 129.3.2 for lower critical temperatures.)

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129.3.2 A postbending or postforming heat treatment at the time and temperature cycles listed for postweld heat treatment in Table 132 is required on all carbon steel (P-No. 1) materials with a nominal wall thickness in excess of $\frac{3}{4}$ in. (19.0 mm) unless the bending or forming operations are performed and completed at temperatures of 1650°F (900°C) or greater.

129.3.3 A postforming or postbending heat treatment as defined below is required for all ferritic alloy steel (excluding P-No. 1) materials with a nominal pipe size 4 in. and larger or with a nominal thickness of $\frac{1}{2}$ in. (13.0 mm) or greater.

(A) If hot bending or forming is performed, the material shall receive a full anneal, normalize and temper, or tempering heat treatment as specified by the designer.

(B) If cold bending or forming is performed, a heat treatment is required at the time and temperature cycle listed for the material in Table 132.

129.3.4 Postbending or postforming heat treatment of other materials including austenitic stainless steel is neither required nor prohibited. If a postbending or postforming heat treatment is to be performed, the designer shall fully describe the procedure to be used.

130 REQUIREMENTS FOR FABRICATING AND ATTACHING PIPE SUPPORTS

130.1

Standard pipe hangers and supports shall be fabricated in accordance with the requirements of MSS SP-58. Welders, welding operators, and WPSs shall be qualified in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section IX.

130.2

Special hangers, supports, anchors, and guides, not defined as standard types of hanger components in MSS SP-58, shall be welded in accordance with the requirements of para. 127 (Paragraph 132 is not applicable except as required by the weld procedure used.) and inspected in accordance with the requirement of para. 136.4.2.

130.3

Welds attaching hangers, supports, guides, and anchors to the piping system shall conform to the requirements of Chapters V and VI of this Code.

131 WELDING PREHEAT

131.1

The preheat requirements listed herein are mandatory minimum values.

The base metal temperature prior to welding shall be at or above the specified minimum temperature in all directions from the point of welding for a distance of 3 in. or 1.5 times the base metal thickness (as defined in para. 131.4.1), whichever is greater.

The base metal temperature for tack welds shall be at or above the specified minimum temperature for a distance not less than 1 in. in all directions from the point of welding.

131.2

When welding two different P-Number materials, the minimum preheat temperature required shall be the higher temperature for the material to be welded.

131.3

The preheat temperature shall be checked by use of temperature-indicating crayons, thermocouple pyrometers, or other suitable methods to assure that the required preheat temperature is obtained prior to and uniformly maintained during the welding operation.

131.4 Preheat Temperature

The minimum preheat for all materials shall be 50°F (10°C) unless stated otherwise in the following paragraphs.

131.4.1 Thickness referred to is the greater of the nominal thicknesses at the weld of the parts to be joined.

131.4.2 P-No. 1. 175°F (80°C) for material which has both a specified maximum carbon content in excess of 0.30% and a thickness at the joint in excess of 1 in. (25.0 mm). Preheat may be based on the actual carbon content as determined from a ladle or product analysis in accordance with the material specification in lieu of the maximum carbon content specified in the material specification.

131.4.3 P-No. 3. 175°F (80°C) for material or product form which has either a specified minimum tensile strength in excess of 60,000 psi (413.7 MPa) or a thickness at the joint in excess of $\frac{1}{2}$ in. (13.0 mm).

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131.4.4 P-No. 4. 250°F (120°C) for all materials.

131.4.5 P-Nos. 5A and 5B

(A) 400°F (200°C) for material which has either a specified minimum tensile strength in excess of 60,000 psi (413.7 MPa), or has both a specified minimum chromium content above 6.0% and a thickness at the joint in excess of $\frac{1}{2}$ in. (13.0 mm);

(B) 300°F (150°C) for all other materials having this P-Number.

131.4.6 P-No. 6. 400°F (200°C) for all materials.

131.4.7 P-Nos. 9A and 9B

(A) 250°F (120°C) for P-No. 9A materials;

(B) 300°F (150°C) for P-No. 9B materials.

131.4.8 P-No. 10I. 300°F (150°C) with an interpass temperature of 450°F (230°C) maximum.

131.5

For inert gas tungsten arc root pass welding, a lower preheat temperature in accordance with the temperature established in the WPS may be used.

131.6 Interruption of Welding

131.6.1 After welding commences, the minimum preheat temperature shall be maintained until any required PWHT is performed on P-Nos. 3, 4, 5A, 5B, and 6, except when all of the following conditions are satisfied.

(A) A minimum of at least $\frac{3}{8}$ in. thickness of weld is deposited or 25% of the welding groove is filled, whichever is less (the weldment shall be sufficiently supported to prevent overstressing the weld if the weldment is to be moved or otherwise loaded).

(B) For P-Nos. 3, 4, and 5A (with a chromium content of 3.0% maximum) materials, the weld is allowed to cool slowly to room temperature.

(C) For P-No. 5B (with a chromium content greater than 3.0%) and P-No. 6 materials, the weld is subjected to an adequate intermediate heat treatment with a controlled rate of cooling.

(D) After cooling and before welding is resumed, visual examination of the weld shall be performed to assure that no cracks have formed.

(E) Required preheat shall be applied before welding is resumed.

132 POSTWELD HEAT TREATMENT

132.1

Before applying the detailed requirements and exemptions in these paragraphs, satisfactory qualification of the WPS to be used shall be performed in accordance with the essential variables of the ASME Boiler and Pressure Vessel Code, Section IX including the conditions of postweld heat treatment or lack of postweld heat treatment and including other restrictions listed below. Except as otherwise provided in paras. 132.2 and 132.3, all welds in materials included in the P-Numbers listed in Table 132 shall be given a postweld heat treatment within the temperature range specified in Table 132. (The range specified in Table 132 may be modified by Table 132.1 for the lower limit and para. 132.2 for the upper limit.) The materials in Table 132 are listed in accordance with the material P-Number grouping of Appendix A. Welds of materials not included in Table 132 shall be heat treated in accordance with the WPS.

132.2

Heat treatment may be accomplished by a suitable heating method which will provide the desired heating and cooling rates, the required metal temperature, temperature uniformity, and temperature control.

(A) The upper limit of the PWHT temperature range in Table 132 is a recommended value which may be exceeded provided the actual temperature does not exceed the lower critical temperature of either material (see Table 129.3.2).

(B) When parts of two different P-Numbers are joined by welding, the postweld heat treatment shall be that specified for the material requiring the higher PWHT temperature. When a nonpressure part is welded to a pressure part and PWHT is required for either part, the maximum PWHT temperature shall not exceed the maximum temperature acceptable for the pressure retaining part.

(C) Caution is necessary to preclude metallurgical damage to some materials or welds not intended or qualified to withstand the PWHT temperatures required.

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TABLE 132
POSTWELD HEAT TREATMENT

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 1 Gr. Nos. 1, 2, 3	1100 (600) to 1200 (650)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTES:
(A) PWHT of P-No. 1 materials is not mandatory, provided that all of the following conditions are met:
(1) the nominal thickness, as defined in para. 132.4.1, is $\frac{3}{4}$ in. (19.0 mm) or less;
(2) a minimum preheat of 200°F (95°C) is applied when the nominal material thickness of either of the base metals exceeds 1 in. (25.0 mm).
(B) When it is impractical to PWHT at the temperature range specified in Table 132, it is permissible to perform the PWHT of this material at lower temperatures for longer periods of time in accordance with Table 132.1.

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 3 Gr. Nos. 1, 2	1100 (600) to 1200 (650)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTES:
(A) PWHT of P-No. 3 materials is not mandatory, provided all of the following conditions are met:
(1) the nominal thickness, as defined in para. 132.4.1, is $\frac{5}{8}$ in. (16.0 mm) or less;
(2) a minimum preheat of 200°F (95°C) is applied when the nominal material thickness of either of the base metals exceeds $\frac{5}{8}$ in. (16.0 mm);
(3) the specified carbon content of the P-No. 3 base material is 0.25% or less.
(B) When it is impractical to PWHT at the temperature range specified in Table 132, it is permissible to perform the PWHT of this material at lower temperatures for longer periods of time in accordance with Table 132.1.

132.3 Exemptions to Mandatory PWHT Requirements

132.3.1 Postweld heat treatment is not required for the following conditions:

(A) welds in nonferrous materials;

(B) welds exempted in Table 132;

(C) welds subject to temperatures above the lower critical temperature (see Table 129.3.2) during fabrication provided the WPS has been qualified with PWHT (see para. 132.1) at the temperature range to be reached during fabrication.

132.3.2 The postweld heat treatment exemption of Table 132 may be based on the actual chemical composition as determined by a ladle or product analysis in accordance with the material specification in lieu of the specified or maximum specified chemical composition limits.

132.4 Definition of Thickness Governing PWHT

132.4.1 The term *nominal thickness* as used in Table 132 and Notes is the lesser thickness of (A) or (B) as follows:

(A) the thickness of the weld;

(B) the thicker of the materials being joined at the weld.

132.4.2 Thickness of the weld, which is a factor in determining the nominal thickness, is defined as follows:

(A) groove welds (girth and longitudinal)—the thicker of the two abutting ends after weld preparation, including I.D. machining;

(B) fillet welds—the throat thickness of the weld;

(C) partial penetration welds—the depth of the weld groove;

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TABLE 132
POSTWELD HEAT TREATMENT (CONT'D)

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 4 Gr. Nos. 1, 2	1300 (700) to 1375 (750)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTE:
(A) PWHT is not mandatory for P-No. 4 material under the following conditions:
- (1) welds in pipe or attachment welds to pipe complying with all of the following conditions:
  - (A) a nominal material thickness of $\frac{1}{2}$ in. (13.0 mm) or less;
  - (B) a specified carbon content of the material to be welded of 0.15% or less;
  - (C) application of 250°F (120°C) minimum preheat during welding.
- (2) for seal welding of threaded or other mechanical joints provided:
  - (A) the seal weld has a throat thickness of $\frac{3}{8}$ in. (9.0 mm) or less;
  - (B) a minimum preheat of 250°F (120°C) is maintained during welding.
- (3) Attachment welds for non-load-carrying attachments provided in addition to (A)(2) and (A)(3) above:
  - (A) stud welds or fillet welds made by the SMAW or GTAW process shall be used;
  - (B) the hardened portion of the heat affected zone (HAZ) shall not encroach on the minimum wall thickness of the pipe, as determined by welding procedure qualification using the maximum welding heat input. The depth of the HAZ shall be taken as the point where the HAZ hardness does not exceed the average unaffected base metal hardness by more than 10%.
  - (C) if SMAW is used, the electrode shall be the low hydrogen type;
  - (D) the thickness of the test plate used in making the welding procedure qualification of Section IX shall not be less than that of the material to be welded;
  - (E) the attachment weld has a throat thickness of $\frac{3}{16}$ in. or less.

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 5A Gr. No. 1	1300 (700) to 1400 (760)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTE:
(A) PWHT is not mandatory for P-No. 5A material under the following conditions:
- (1) welds in pipe or attachment welds to pipe complying with all of the following conditions:
  - (A) a nominal material thickness of $\frac{1}{2}$ in. (13.0 mm) or less;
  - (B) a specified carbon content of the material to be welded of 0.15% or less;
  - (C) a minimum preheat of 300°F (150°C) is maintained during welding.
- (2) attachment welds for non-load-carrying attachments provided in addition to (A)(2) and (A)(3) above:
  - (A) stud welds or fillet welds made by the SMAW or GTAW process shall be used;
  - (B) the hardened portion of the heat affected zone (HAZ) shall not encroach on the minimum wall thickness of the pipe, as determined by welding procedure qualification using the maximum welding heat input. The depth of the HAZ shall be taken as the point where the HAZ hardness does not exceed the average unaffected base metal hardness by more than 10%.
  - (C) if SMAW is used, the electrode shall be the low hydrogen type;
  - (D) the thickness of the test plate used in making the welding procedure qualification of Section IX shall not be less than that of the material to be welded;
  - (E) the attachment weld has a throat thickness of $\frac{3}{16}$ in. or less.

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TABLE 132
POSTWELD HEAT TREATMENT (CONT'D)

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 5B Gr. Nos. 1, 2	1300 (700) to 1400 (760)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 6 Gr. Nos. 1, 2, 3	1400 (760) to 1475 (800)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTE:
(A) PWHT is not mandatory for P-No. 6 Type 410 material provided all of the following conditions are met:
(1) the specified carbon content is not more than 0.08%;
(2) the nominal material thickness is $\frac{3}{8}$ in. (10 mm) or less;
(3) the weld is made with A-No. 8, A-No. 9, or F-No. 43 filler metal.

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 7 Gr. Nos. 1, 2	1350 (730) to 1425 (775)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTES:
(A) In lieu of the cooling rate described in para. 132.5, P-No. 7 material cooling rate shall be not greater than 100°F (55°C) per hr in the range above 1200°F (650°C) after which the cooling rate shall be sufficiently rapid to prevent embrittlement.
(B) PWHT is not mandatory for P-No. 7 Type 405 material provided all of the following conditions are met:
(1) the specified carbon content is not more than 0.08%;
(2) the nominal material thickness is $\frac{3}{8}$ in. (10 mm) or less;
(3) the weld is made with A-No. 8, A-No. 9, or F-No. 43 filler metal.

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 8 Gr. Nos. 1, 2, 3, 4	None	None	None

GENERAL NOTE:
(A) PWHT is neither required nor prohibited for joints between P-No. 8 austenitic stainless steels.

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TABLE 132
POSTWELD HEAT TREATMENT (CONT'D)

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 9A Gr. No. 1	1100 (600) to 1200 (650)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTES:

(A) PWHT is not mandatory for P-No. 9A material when welds on pipe or attachment welds to pipe comply with all of the following conditions:
(1) a nominal material thickness of ½ in. (13.0 mm) or less;
(2) a specified carbon content of the material to be welded of 0.15% or less;
(3) a minimum preheat of 250°F (120°C) is maintained during welding.

(B) When it is impractical to PWHT at the temperature range specified in Table 132, it is permissible to perform the PWHT of this material at lower temperatures for longer periods of time in accordance with Table 132.1 but the minimum PWHT shall not be less than 1000°F (550°C).

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 9B Gr. No. 1	1100 (600) to 1175 (630)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTES:

(A) PWHT of P-No. 9B material is not mandatory for a nominal material thickness of ⅝ in. (16.0 mm) or less provided the Welding Procedure Qualification has been made using material of thickness equal to or greater than the production weld.

(B) When it is impractical to PWHT at the temperature range specified in Table 132, it is permissible to perform the PWHT of this material at lower temperatures for longer periods of time in accordance with Table 132.1, but the minimum PWHT temperature shall not be less than 1000°F (550°C).

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 10H Gr. No. 1	...	...	...

GENERAL NOTE:

(A) Postweld heat treatment is neither required nor prohibited. If any heat treatment is performed after forming or welding, it shall be performed within the temperature range listed below for the particular alloy, followed by a rapid cool:

Alloy S31803	1870°F–2010°F
Alloy S32550	1900°F–2050°F
Alloy S32750	1880°F–2060°F
All others	1800°F–1900°F

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TABLE 132
POSTWELD HEAT TREATMENT (CONT'D)

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 10I Gr. No. 1	1350 (730) to 1500 (815)	1 hr/in. (25 mm) 15 min minimum	1 hr/in. (25 mm)

GENERAL NOTES:
(A) In lieu of the cooling rate described in para. 132.5, the P-No. 10 I material cooling rate shall be not greater than 100°F/hr in the range above 1200°F (650°C), after which the cooling rate shall be sufficiently rapid to prevent embrittlement.
(B) Postweld heat treatment is neither required nor prohibited for a nominal thickness of ½ in. or less.

(D) material repair welds—the depth of the cavity to be repaired;

(E) branch welds—the weld thickness is the dimension existing in the plane intersecting the longitudinal axes and is calculated as indicated for each detail using:

t_c = the smaller of ¼ in. or $0.7t_{nb}$

(1) for welds described in Fig. 127.4.8(D):

Detail (a)

$$\text{weld thickness} = t_{nb} + t_c$$

Detail (b)

$$\text{weld thickness} = t_{nh} + t_c$$

Detail (c)

$$\text{weld thickness} = \text{greater of } t_{nr} + t_c \text{ or } t_{nb} + t_c$$

Detail (d)

$$\text{weld thickness} = t_{nh} + t_{nr} + t_c$$

Detail (e)

$$\text{weld thickness} = t_{nb} + t_c$$

(2) for welds described in Figs. 127.4.8(E) and (F):

$$\text{weld thickness} = \text{depth of groove weld} + \text{throat thickness of cover fillet}$$

132.4.3 The term *nominal material thickness* as used in Table 132 is the thicker of the materials being joined at the weld.

132.5 PWHT Heating and Cooling Requirements

Above 600°F (315°C), the rate of heating and cooling shall not exceed 600°F (335°C) per hr divided by ½ the maximum thickness of material in inches at the weld but in no case shall the rate exceed 600°F (335°C) per hr. (See Table 132 for cooling rate requirements for P-Nos. 7 and 10I materials.)

132.6 Furnace Heating

(A) Heating an assembly in a furnace should be used when practical; however, the size or shape of the unit or the adverse effect of a desired heat treatment on one or more components where dissimilar materials are involved, may dictate alternative procedures such as heating a section before assembly, or by applying local heating in accordance with para. 132.7.

(B) An assembly may be postweld heat treated in more than one heat in a furnace provided there is at least a 1 ft (300 mm) overlap of the heated sections and the portion of the assembly outside the furnace is shielded so that the temperature gradient is not harmful.

(C) Direct impingement of flame on the assembly is prohibited.

132.7 Local Heating

Welds may be locally PWHT by heating a circumferential band around the entire component with the weld located in the center of the band. The width of the band heated to the PWHT temperature for girth welds shall be at least three times the wall thickness at the weld of the thickest part being joined. For nozzle and attachment welds, the width of the band heated to the PWHT temperature shall extend beyond the nozzle weld or attachment weld on each side at least two

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TABLE 132.1
ALTERNATE POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS

Decrease in Temperatures Below Minimum Specified Temperature, °F (°C)	Minimum Holding Time at Decreased Temperature, hr [Note (2)]
50 (28)	2
100 (56)	4
150 (84) [Note (1)]	10
200 (112) [Note (1)]	20

GENERAL NOTE:
Postweld heat treatment at lower temperatures for longer periods of time, in accordance with this Table, shall be used only where permitted in Table 132.

NOTES:
(1) A decrease of more than 100°F (56°C) below the minimum specified temperature is allowable only for P-No. 1, Gr. Nos. 1 and 2 materials.
(2) Times shown apply to thicknesses up to 1 in. (25 mm). Add 15 min/in. (15 min/25 mm) of thicknesses for thicknesses greater than 1 in. (25 mm).

times the header thickness and shall extend completely around the header.

133 STAMPING

Stamping, if used, shall be performed by a method that will not result in sharp discontinuities. In no case shall stamping infringe on the minimum wall thickness or result in dimpling or denting of the material being stamped.

CAUTIONARY NOTE: Detrimental effects can result from stamping of material which will be in operation under long term creep or creep fatigue conditions.

135 ASSEMBLY

135.1 General

The assembly of the various piping components, whether done in a shop or as field erection, shall be done so that the completely erected piping conforms with the requirements of the engineering design.

135.2 Alignment

135.2.1 Equipment Connections. When making connections to equipment, such as pumps or turbines or other piping components which are sensitive to externally induced loading, forcing the piping into alignment is prohibited if this action introduces end reactions which exceed those permitted by design.

135.2.2 Cold Springs. Before assembling joints in piping to be cold sprung, an examination shall be made of guides, supports, and anchors for obstructions which might interfere with the desired movement or result in undesired movement. The gap or overlap of piping prior to assembly shall be checked against the design specifications and corrected if necessary.

135.3 Bolted Flanged Connections

135.3.1 Fit Up. All flanged joints shall be fitted up so that the gasket contact surfaces bear uniformly on the gasket and then shall be made up with relatively uniform bolt stress.

135.3.2 Gasket Compression. When bolting gasketed flange joints, the gasket shall be properly compressed in accordance with the design principles applicable to the type of gasket being used.

135.3.3 Cast Iron to Steel Joints. Cast iron to steel flanged joints in accordance with para 108.3 shall be assembled with care to prevent damage to the cast iron flange.

135.3.4 Bolt Engagement. All bolts shall be engaged so that there is visible evidence of complete threading through the nut or threaded attachment.

135.3.5 Nonmetallic Lined Joints. When assembling nonmetallic lined joints, such as plastic lined steel pipe, consideration should be given to maintaining electrical continuity between flanged pipe sections where required.

135.4 Packed Joints and Caulked Joints

Care shall be used to assure adequate engagement of joint members. Where packed joints are used to absorb thermal expansion, proper clearance shall be provided at the bottom of the sockets to permit movement.

135.5 Threaded Piping

135.5.1 Thread Compound. Any compound or lubricant used in threaded joints shall be suitable for the service conditions, and shall be compatible with the piping material and the service fluid.

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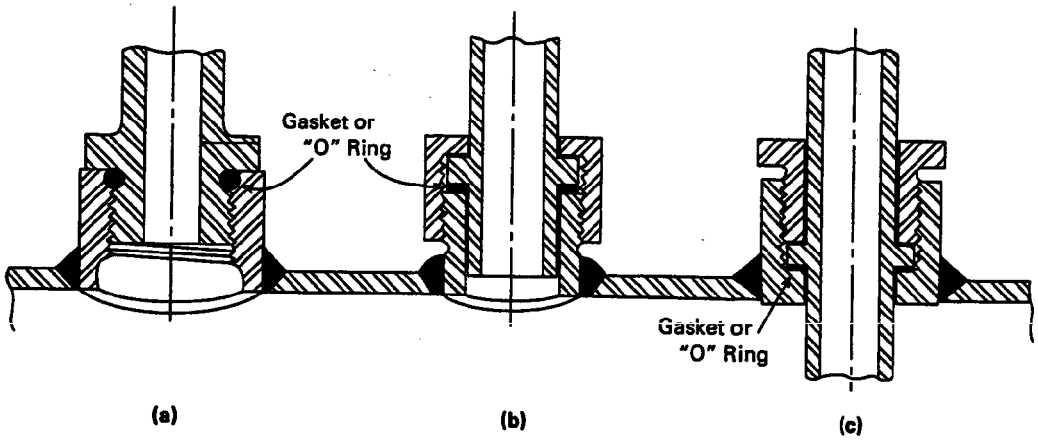

GENERAL NOTE: Threads are ASME B1.1 straight threads.

FIG. 135.5.3 TYPICAL THREADED JOINTS USING STRAIGHT THREADS

135.5.2 Joints for Seal Welding. Threaded joints which are intended to be seal welded in accordance with para. 127.4.5 *should* be made up without any thread compound.

135.5.3 Joints Using Straight Threads. Some joints using straight threads, with sealing at a surface other than threads, are shown in Fig. 135.5.3. Care shall be used to avoid distorting the seal when incorporating such joints into piping assemblies by welding or brazing.

135.5.4 Backing Off. Backing off threaded joints to allow for alignment is prohibited.

135.6 Tubing Joints

135.6.1 Flared. The sealing surface shall be free of injurious defects before installation.

135.6.2 Flareless and Compression. Flareless and compression joints shall be assembled in accordance with manufacturer's recommendations.

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CHAPTER VI
INSPECTION, EXAMINATION, AND TESTING

136 INSPECTION AND EXAMINATION

136.1 Inspection

136.1.1 General. This Code distinguishes between "examination" and "inspection." Inspection is the responsibility of the Owner and may be performed by employees of the Owner or a party authorized by the Owner, except for the inspections required by para. 136.2. Prior to initial operation, a piping installation shall be inspected to assure compliance with the engineering design and with the material, fabrication, assembly, examination, and test requirements of this Code.

136.1.2 Verification of Compliance. Compliance with the requirements of this Code shall be verified by an Authorized Inspector when a Code stamp is required by Section I of the ASME Boiler and Pressure Vessel Code. The rules of this Code and the quality control system requirements of Appendix A-300 of Section I of the ASME Boiler and Pressure Vessel Code shall apply. The quality control system requirments are shown in Appendix J of this Code. The duty of the Inspector shall be as defined in PG-90, Section I, of the ASME Boiler and Pressure Vessel Code. Data Report Forms are included in the Appendix of ASME Section I for use in developing the necessary inspection records. The Inspector shall assure himself/herself that the piping has been constructed in accordance with the applicable requirements of this Code.

136.1.3 Rights of Inspectors. Inspectors shall have access to any place where work concerned with the piping is being performed. This includes manufacture, fabrication, heat treatment, assembly, erection, examination, and testing of the piping. They shall have the right to audit any examination, to inspect the piping using any appropriate examination method required by the engineering design or this Code, and to review all certifications and records necessary to satisfy the Owner's responsibility as stated in para. 136.1.1.

136.1.4 Qualifications of the Owner's Inspector

(A) The Owner's Inspector shall be designated by the Owner and shall be an employee of the Owner, an employee of an engineering or scientific organization, or of a recognized insurance or inspection company acting as the Owner's agent. The Owner's Inspector shall not represent nor be an employee of the piping manufacturer, fabricator, or erector unless the Owner is also the manufacturer, fabricator, or erector.

(B) The Owner's Inspector shall have not less than 10 years experience in the design, manufacture, erection, fabrication, or inspection of power piping. Each year of satisfactorily completed work toward an engineering degree recognized by the Accreditation Board for Engineering and Technology shall be considered equivalent to 1 year of experience, up to 5 years total.

(C) In delegating the performance of inspections, the Owner is responsible for determining that a person to whom an inspection function is delegated is qualified to perform that function.

136.2 Inspection and Qualification of Authorized Inspector for Boiler External Piping

136.2.1 Piping for which inspection and stamping is required as determined in accordance with para. 100.1.2(A) shall be inspected during construction and after completion and at the option of the Authorized Inspector at such stages of the work as he/she may designate. For specific requirements see the applicable parts of Section I of the ASME Boiler and Pressure Vessel Code, PG-104 through PG-113. Each manufacturer, fabricator, or assembler is required to arrange for the services of Authorized Inspectors.

136.2.1.1 The inspections required by this Section shall be performed by an Inspector employed by an ASME accredited Authorized Inspection Agency.

136.2.2 Certification by stamping and Data Reports, where required, shall be as per PG-104, PG-105, PG-109, PG-110, PG-111, and PG-112 of Section I of the ASME Boiler and Pressure Vessel Code.

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136.3 Examination

136.3.1 General. Examination denotes the functions performed by the manufacturer, fabricator, erector, or a party authorized by the Owner which include nondestructive examinations (NDE), such as visual, radiography, ultrasonic, eddy current, liquid penetrant, and magnetic particle methods. The degree of examination and the acceptance standards beyond the requirements of this Code shall be a matter of prior agreement between the manufacturer, fabricator, or erector and the Owner.

136.3.2 Qualification of NDE Personnel. Personnel who perform nondestructive examination of welds shall be qualified and certified for each examination method in accordance with a program established by the employer of the personnel being certified, which shall be based on the following minimum requirements:

(A) instruction in the fundamentals of the nondestructive examination method;

(B) on-the-job training to familiarize the NDE personnel with the appearance and interpretation of indications of weld defects. The length of time for such training shall be sufficient to assure adequate assimilation of the knowledge required;

(C) an eye examination performed at least once each year to determine optical capability of NDE personnel to perform the required examinations;

(D) upon completion of (A) and (B) above, the NDE personnel shall be given an oral or written examination and performance examination by the employer to determine if the NDE personnel are qualified to perform the required examinations and interpretation of results;

(E) certified NDE personnel whose work has not included performance of a specific examination method for a period of 1 year or more shall be recertified by successfully completing the examination of (D) above and also passing the visual examination of (C) above. Substantial changes in procedures or equipment shall require recertification of the NDE personnel.

The following may be used as alternatives to the preceding program, as applicable: SNT-TC-1A or CP-189; and personnel qualified to AWS QC-1 may be used for the visual examination of welds.

136.4 Examination Methods of Welds

136.4.1 Nondestructive Examination. Nondestructive examinations shall be performed in accordance with the requirements of this Chapter. The types and extent of mandatory examinations for pressure welds and welds to pressure retaining components are specified in Table 136.4. For welds other than those covered by Table 136.4, only visual examination is required. Welds requiring nondestructive examination shall comply with the applicable acceptance standards for indications as specified in paras. 136.4.2 through 136.4.6. As a guide, the detection capabilities for the examination method are shown in Table 136.4.1. Welds not requiring examination (i.e., RT, UT, MT, or PT) by this Code or the engineering design shall be judged acceptable if they meet the examination requirements of para. 136.4.2 and the pressure test requirements specified in para. 137.

136.4.2 Visual Examination. Visual examination as defined in para. 100.2. shall be performed, as necessary, during the fabrication and erection of piping components to provide verification that the design and WPS requirements are being met. In addition, visual examination shall be performed to verify that all completed welds in pipe and piping components comply with the acceptance standards specified in (A) below or with the limitations on imperfections specified in the material specification under which the pipe or component was furnished.

(A) Acceptance Standards. The following indications are unacceptable:

(A.1) cracks—external surface;

(A.2) undercut on surface which is greater than $^1/_{32}$ in. (1.0 mm) deep;

(A.3) weld reinforcement greater than specified in Table 127.4.2;

(A.4) lack of fusion on surface;

(A.5) incomplete penetration (applies only when inside surface is readily accessible);

(A.6) any other linear indications greater than $^3/_{16}$ in. (5.0 mm) long;

(A.7) surface porosity with rounded indications having dimensions greater than $^3/_{16}$ in. (5.0 mm) or four or more rounded indications separated by $^1/_{16}$ in. (2.0 mm) or less edge to edge in any direction. Rounded indications are indications which are circular or elliptical with their length less than three times their width.

136.4.3 Magnetic Particle Examination. Whenever required by this Chapter (see Table 136.4), magnetic particle examination shall be performed in accordance with the methods of Article 7, Section V, of the ASME Boiler and Pressure Vessel Code.

(A) Evaluation of Indications

(A.1) Mechanical discontinuities at the surface will be indicated by the retention of the examination medium. All indications are not necessarily defects; however,

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TABLE 136.4
MANDATORY MINIMUM NONDESTRUCTIVE EXAMINATIONS FOR PRESSURE WELDS OR WELDS TO PRESSURE RETAINING COMPONENTS

	Piping Design Conditions and Nondestructive Examination		
Type Weld	Temperatures Over 750°F (400°C) and at All Pressures	Temperatures Between 350°F (175°C) and 750°F (400°C) Inclusive With All Pressures Over 1025 psig [7100 kPa (gage)]	All Others
Butt welds (girth and longitudinal) [Note (1)]	RT or UT for over NPS 2. MT or PT for NPS 2 and less [Note (2)]	RT or UT for over NPS 2 with thickness over 3/4 in. (19.0 mm). VT for all sizes with thickness 3/4 in. (19.0 mm) or less.	Visual for all sizes and thicknesses
Welded branch connections (size indicated is branch size) [Notes (3) and (4)]	RT or UT for over NPS 4. MT or PT for NPS 4 and less [Note (2)]	RT or UT for branch over NPS 4 and thickness of branch over 3/4 in. (19.0 mm) MT or PT for branch NPS 4 and less with thickness of branch over 3/4 in. (19 mm) VT for all sizes with branch thickness 3/4 in. (19.0 mm) or less	VT for all sizes and thicknesses
Fillet, socket, attachment, and seal welds	PT or MT for all sizes and thicknesses [Note (5)]	VT for all sizes and thicknesses	VT for all sizes and thicknesses

GENERAL NOTES:

(A) All welds shall be given a visual examination in addition to the type of specific nondestructive examination specified.

(B) NPS — nominal pipe size.

(C) RT — radiographic examination; UT — ultrasonic examination; MT — magnetic particle examination; PT — liquid penetrant examination; VT — visual examination.

(D) For nondestructive examinations of the pressure retaining component, refer to the standards listed in Table 126.1 or manufacturing specifications.

(E) Acceptance standards for nondestructive examinations performed are as follows: MT — see para. 136.4.3; PT — see para. 136.4.4; VT — see para. 136.4.2; RT — see para. 136.4.5; UT — see para. 136.4.6.

NOTES:

(1) The thickness of butt welds is defined as the thicker of the two abutting ends after end preparation.

(2) RT may be used as an alternative to PT or MT when it is performed in accordance with para. 136.4.5.

(3) RT or UT of branch welds shall be performed before any nonintegral reinforcing material is applied.

(4) In lieu of volumetric examination (RT, UT) of welded branch connections when required above, surface examination (PT, MT) is acceptable and, when used, shall be performed at the lesser of one-half of the weld thickness or each 1/2 in. (12.5 mm) of weld thickness and all accessible final weld surfaces.

(5) Fillet welds not exceeding 1/4 in. (6 mm) throat thickness which are used for the permanent attachment of nonpressure retaining parts are exempt from the PT or MT requirements of the above Table.

TABLE 136.4.1
WELD IMPERFECTIONS INDICATED BY VARIOUS TYPES OF EXAMINATION

Imperfection	Visual	Magnetic Particle	Liquid Penetrant	Radiography	Ultrasonic
Crack — surface	X [Note (1)]	X [Note (1)]	X [Note (1)]	X	X
Crack — internal	...	...	...	X	X
Undercut — surface	X [Note (1)]	X [Note (1)]	X [Note (1)]	X	...
Weld reinforcement	X [Note (1)]	...	...	X	...
Porosity	X [Notes (1), (2)]	X [Notes (1), (2)]	X [Notes (1), (2)]	X	...
Slag inclusion	X [Note (2)]	X [Note (2)]	X [Note (2)]	X	X
Lack of fusion (on surface)	X [Notes (1), (2)]	X [Notes (1), (2)]	X [Notes (1), (2)]	X	X
Incomplete penetration	X [Note (3)]	X [Note (3)]	X [Note (3)]	X	X

NOTES:
(1) Applies when the outside surface is accessible for examination and/or when the inside surface is readily accessible.
(2) Discontinuities are detectable when they are open to the surface.
(3) Applies *only* when the inside surface is readily accessible.

certain metallurgical discontinuities and magnetic permeability variations may produce similar indications which are not relevant to the detection of unacceptable discontinuities.

(A.2) Any indication which is believed to be nonrelevant shall be reexamined to verify whether or not actual defects are present. Surface conditioning may precede the reexamination. Nonrelevant indications which would mask indications of defects are unacceptable.

(A.3) Relevant indications are those which result from unacceptable mechanical discontinuities. Linear indications are those indications in which the length is more than three times the width. Rounded indications are indications which are circular or elliptical with the length less than three times the width.

(A.4) An indication of a discontinuity may be larger than the discontinuity that causes it; however, the size of the indication and not the size of the discontinuity is the basis of acceptance or rejection.

(B) Acceptance Standards. The following relevant indications are unacceptable:

(B.1) any cracks or linear indications;

(B.2) rounded indications with dimensions greater than $^3/_{16}$ in. (5.0 mm);

(B.3) four or more rounded indications in a line separated by $^1/_{16}$ in. (2.0 mm) or less edge to edge;

(B.4) Ten or more rounded indications in any 6 sq in. (3870 mm^2) of surface with the major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavorable location relative to the indications being evaluated.

136.4.4 Liquid Penetrant Examination. Whenever required by this Chapter (see Table 136.4), liquid penetrant examination shall be performed in accordance with the methods of Article 6, Section V, of the ASME Boiler and Pressure Vessel Code.

(A) Evaluation of Indications

(A.1) Mechanical discontinuities at the surface will be indicated by bleeding out of the penetrant; however, localized surface imperfections, such as may occur from machining marks or surface conditions, may produce similar indications which are nonrelevant to the detection of unacceptable discontinuities.

(A.2) Any indication which is believed to be nonrelevant shall be regarded as a defect and shall be reexamined to verify whether or not actual defects are present. Surface conditioning may precede the reexamination. Nonrelevant indications and broad areas of pigmentation which would mask indications of defects are unacceptable.

(A.3) Relevant indications are those which result from mechanical discontinuities. Linear indications are those indications in which the length is more than three times the width. Rounded indications are indications which are circular or elliptical with the length less than three times the width.

(A.4) An indication of a discontinuity may be larger

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than the discontinuity that causes it; however, the size of the indication and not the size of the discontinuity is the basis of acceptance or rejection.

(B) Acceptance Standards. Indications whose major dimensions are greater than $^1/_{16}$ in. (2.0 mm) shall be considered relevant. The following relevant indications are unacceptable:

(B.1) any cracks or linear indications;

(B.2) rounded indications with dimensions greater than $^3/_{16}$ in. (5.0 mm);

(B.3) four or more rounded indications in a line separated by $^1/_{16}$ in. (2.0 mm) or less edge to edge;

(B.4) ten or more rounded indications in any 6 sq in. (3870 mm^2) of surface with the major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavorable location relative to the indications being evaluated.

136.4.5 Radiography. When required by this Chapter (see Table 136.4), radiographic examination shall be performed in accordance with Article 2 of Section V of the ASME Boiler and Pressure Vessel Code, except that the requirements of T-285 are to be used as a guide but not for the rejection of radiographs unless the geometrical unsharpness exceeds 0.07 in. (2.0 mm).

(A) Acceptance Standards. Welds that are shown by radiography to have any of the following types of discontinuities are unacceptable:

(A.1) any type of crack or zone of incomplete fusion or penetration;

(A.2) any other elongated indication which has a length greater than:

(A.2.1) $^1/_4$ in. (6.0 mm) for t up to $^3/_4$ in. (19.0 mm), inclusive;

(A.2.2) $^1/_3t$ for t from $^3/_4$ in. (19.0 mm) to $2^1/_4$ in. (57.0 mm), incl.;

(A.2.3) $^3/_4$ in. (19.0 mm) for t over $2^1/_4$ in. (57.0 mm) where t is the thickness of the thinner portion of the weld.

NOTE: t referred to in (A.2.1), (A.2.2), and (A.2.3) above pertains to the thickness of the weld being examined; if a weld joins two members having different thickness at the weld, t is the thinner of these two thickness.

(A.3) any group of indications in line that have an aggregate length greater than t in a length of $12t$, except where the distance between the successive indications exceeds $6L$ where L is the longest indication in the group;

(A.4) porosity in excess of that shown as acceptable in Appendix A-250 of Section I of the ASME Boiler and Pressure Vessel Code;

(A.5) root concavity when there is an abrupt change in density, as indicated on the radiograph.

136.4.6 Ultrasonic Examination. When required by this Chapter (see Table 136.4), ultrasonic examination (UT) shall be performed in accordance with the ASME Boiler and Pressure Vessel Code, Section V, Article 5 and the following additional requirements.

(A) The following criteria shall also be met when performing ultrasonic examinations.

(A.1) The nominal thickness of the material being examined shall be greater that $^1/_2$ in (12.5 mm).

(A.2) The equipment used to perform the examination shall be capable of recording the UT data including the scanning positions.

(A.3) NDE personnel collecting and analyzing UT data shall have demonstrated their ability to perform an acceptable examination using written procedures. The procedure shall have been demonstrated to perform acceptably on a qualification block with imbedded flaws.

(B) Acceptance Standards. Welds that are shown by ultrasonic examination to have discontinuities which produce an indication greater than 20% of the reference level shall be investigated to the extent that ultrasonic examination personnel can determine their shape, identity, and location so that they may evaluate each discontinuity for acceptance in accordance with (B.1) and (B.2) below.

(B.1) Discontinuities evaluated as being cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length.

(B.2) Other discontinuities are unacceptable if the indication exceeds the reference level and their length exceeds the following:

(B.2.1) $^1/_4$ in. (6.0 mm) for t up to $^3/_4$ in. (19.0 mm);

(B.2.2) $^1/_3t$ for t from $^3/_4$ in. (19.0 mm) to $2^1/_4$ in. (57.0 mm)

(B.2.3) $^3/_4$ in. (19.0 mm) for t over $2^1/_4$ in. (57.0 mm) where t is the thickness of the weld being examined. If the weld joins two members having different thicknesses at the weld, t is the thinner of these two thicknesses.

137 PRESSURE TESTS

137.1 General Requirements

137.1.1 Subassemblies. When conducted in accordance with the requirements of this Code, the pressure testing of piping systems to ensure leak tightness shall

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be acceptable for the determination of any leaks in piping subassemblies.

137.1.2 Temperature of Test Medium. The temperature of the test medium shall be that of the available source unless otherwise specified by the Owner. The test pressure shall not be applied until the system and the pressurizing medium are approximately at the same temperature. When conducting pressure tests at low metal temperatures, the possibility of brittle fracture shall be considered.

137.1.3 Personnel Protection. Suitable precautions in the event of piping system rupture shall be taken to eliminate hazards to personnel in the proximity of lines being tested.

137.1.4 Maximum Stress During Test. At no time during the pressure test shall any part of the piping system be subjected to a stress greater than that permitted by para. 102.3.3(B).

137.1.5 Testing Schedule. Pressure testing shall be performed following the completion of postweld heat treatment, required by para. 132, nondestructive examinations required by Table 136.4, and all other fabrication, assembly and erection activities required to provide the system or portions thereof subjected to the pressure test with pressure retaining capability.

137.2 Preparation for Testing

137.2.1 Exposure of Joints. All joints including welds not previously pressure tested shall be left uninsulated and exposed for examination during the test. By prior agreement the complete system or portions thereof subject to test may be insulated prior to the test period provided an extended holding time pressurization of the system is performed to check for possible leakage through the insulation barrier.

137.2.2 Addition of Temporary Supports. Piping systems designed for vapor or gas shall be provided with additional temporary supports if necessary to support the weight of the test liquid. Such supports shall meet the requirements for testing and system cleanup procedures described in para. 122.10.

137.2.3 Restraint or Isolation of Expansion Joints. Expansion joints shall be provided with temporary restraint if required for the additional pressure load under test, or they shall be isolated during the system test.

137.2.4 Isolation of Equipment and Piping Not Subjected to Pressure Test. Equipment that is not to be subjected to the pressure test shall be either disconnected from the system or isolated by a blank or similar means. Valves may be used for this purpose provided that valve closure is suitable for the proposed test pressure. Owner shall be aware of the limitations of pressure and temperature for each valve subject to test conditions and as further described in para. 107.1(C). Isolated equipment and piping must be vented.

137.2.5 Treatment of Flanged Joints Containing Blanks. Flanged joints at which blanks are inserted to blank off other equipment during the test need not be tested after removal of the blank provided the requirements of para. 137.7.1 are subsequently performed.

137.2.6 Precautions Against Test Medium Expansion. If a pressure test is to be maintained for a period of time during which the test medium in the system is subject to thermal expansion, precautions shall be taken to avoid excessive pressure. A pressure relief device set at $1\frac{1}{3}$ times the test pressure is recommended during the pressure test provided the requirements of paras. 137.1.4, 137.4.5, and 137.5.5 are not exceeded.

137.3 Requirements for Specific Piping Systems

137.3.1 Boiler External Piping. Boiler external piping [see para. 100.1.2(A)] shall be hydrostatically tested in accordance with PG-99 of Section I of the ASME Boiler and Pressure Vessel Code. The test shall be conducted in the presence of the Authorized Inspector.

137.3.2 Nonboiler External Piping. All nonboiler external piping shall be hydrostatically tested in accordance with para. 137.4. As an alternative, when specified by the owner, the piping may be leak tested in accordance with para. 137.5, 137.6, or 137.7. Lines open to the atmosphere, such as vents or drains downstream of the last shutoff valve, need not be tested.

137.4 Hydrostatic Testing

137.4.1 Material. When permitted by the Material Specification, a system hydrostatic test may be performed in lieu of the hydrostatic test required by the material specifications for material used in the piping subassembly or system provided the minimum test pressure required for the piping system is met.

137.4.2 Provision of Air Vents at High Points. Vents shall be provided at all high points of the piping system in the position in which the test is to be

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conducted to purge air pockets while the component or system is filling. Venting during the filling of the system may be provided by the loosening of flanges having a minimum of four bolts or by the use of equipment vents.

137.4.3 Test Medium. Water shall normally be used as the test medium unless otherwise specified by the Owner. Test water shall be clean and shall be of such quality as to minimize corrosion of the materials in the piping system. Further recommended precautions on the quality of test water used for hydrotesting of austenitic (300 series) and ferritic (400 series) stainless steels are contained in Appendix IV, para. IV-3.4.

137.4.4 Check of Test Equipment Before Applying Pressure. The test equipment shall be examined before pressure is applied to ensure that it is tightly connected. All low-pressure filling lines and all other items not subject to the test pressure shall be disconnected or isolated by valves or other suitable means.

137.4.5 Required Hydrostatic Test Pressure. The hydrostatic test pressure at any point in the piping system shall not be less than 1.5 times the design pressure, but shall not exceed the maximum allowable test pressure of any nonisolated components, such as vessels, pumps, or valves, nor shall it exceed the limits imposed by para. 102.3.3(B). The pressure shall be continuously maintained for a minimum time of 10 minutes and may then be reduced to the design pressure and held for such time as may be necessary to conduct the examinations for leakage. Examinations for leakage shall be made of all joints and connections. The piping system, exclusive of possible localized instances at pump or valve packing, shall show no visual evidence of weeping or leaking.

137.5 Pneumatic Testing

137.5.1 General. Except for preliminary testing in accordance with para. 137.5.4, pneumatic testing shall not be used unless the Owner specifies pneumatic testing or permits its use as an alternative. It is recommended that pneumatic testing be used only when one of the following conditions exists:

(A) when piping systems are so designed that they cannot be filled with water;

(B) when piping systems are to be used in services where traces of the testing medium cannot be tolerated.

137.5.2 Test Medium. The gas used as the test medium shall be nonflammable and nontoxic. Since compressed gas may be hazardous when used as a testing medium, it is recommended that special precautions for protection of personnel be observed when a gas under pressure is used as the test medium.

137.5.3 Check of Test Equipment Before Applying Pressure. The test equipment shall be examined before pressure is applied to ensure that it is tightly connected. All items not subjected to the test pressure shall be disconnected or isolated by valves or other suitable means.

137.5.4 Preliminary Test. A preliminary pneumatic test not to exceed 25 psig [175 kPa (gage)] may be applied, prior to other methods of leak testing, as a means of locating major leaks. If used, the preliminary pneumatic test shall be performed in accordance with the requirements of paras. 137.5.2 and 137.5.3.

137.5.5 Required Pneumatic Test Pressure. The pneumatic test pressure shall be not less than 1.2 nor more than 1.5 times the design pressure of the piping system. The test pressure shall not exceed the maximum allowable test pressure of any nonisolated component, such as vessels, pumps, or valves, in the system. The pressure in the system shall gradually be increased to not more than one-half of the test pressure, after which the pressure shall be increased in steps of approximately one-tenth of the test pressure until the required test pressure has been reached. The pressure shall be continuously maintained for a minimum time of 10 minutes. It shall then be reduced to the lesser of design pressure or 100 psig [700 kPa (gage)] and held for such time as may be necessary to conduct the examination for leakage. Examination for leakage detected by soap bubble or equivalent method shall be made of all joints and connections. The piping system, exclusive of possible localized instances at pump or valve packing, shall show no evidence of leaking.

137.6 Mass-Spectrometer and Halide Testing

137.6.1 When specified by the Owner, systems with conditions of operation and design that require testing methods having a greater degree of sensitivity than can be obtained by a hydrostatic or pneumatic test shall be tested by a method, such as helium mass-spectrometer test or halide test, which has the required sensitivity.

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137.6.2 When a mass-spectrometer or halide test is performed, it shall be conducted in accordance with the instructions of the manufacturer of the test equipment. In all cases a calibrated reference leak, with a leak rate not greater than the maximum permissible leakage from the system, shall be used. The equipment shall be calibrated against the reference leak in such a way that the system leakage measured by the equipment can be determined to be not greater than the leak rate of the reference leak.

137.7 Initial Service Testing

137.7.1 When specified by the owner, an initial service test and examination is acceptable when other types of tests are not practical or when leak tightness is demonstrable due to the nature of the service. One example is piping where shut-off valves are not available for isolating a line and where temporary closures are impractical. Others may be systems where during the course of checking out of pumps, compressors, or other equipment, ample opportunity is afforded for examination for leakage prior to full scale operation. An initial service test is not applicable to boiler external piping.

137.7.2 When performing an initial service test, the piping system shall be gradually brought up to normal operating pressure and continuously held for a minimum time of 10 minutes. Examination for leakage shall be made of all joints and connections. The piping system exclusive of possible localized instances at pump or valve packing shall show no visual evidence of weeping or leaking.

137.8 Retesting After Repair or Additions

137.8.1 Repairs may be made to the pressure parts of boiler external piping after the hydrostatic test required by para. 137.3.1, provided the requirements of PW-54.2 of Section I of the ASME Boiler and Pressure Vessel Code are met.

137.8.2 Nonpressure parts may be welded to the pressure parts of boiler external piping after the hydrostatic test required by para. 137.3.1, provided the requirements of PW-54.3 of Section I of the ASME Boiler and Pressure Vessel Code are met.

137.8.3 In the event repairs or additions to nonboiler external piping are made following a test, the affected piping shall be retested in accordance with the provisions of para. 137.3.2. However, a system need not be retested after seal welding or after attachments of lugs, brackets, insulation supports, nameplates, or other nonpressure retaining attachments provided:

(A) the attachment fillet weld does not exceed $^3/_8$ in. (10.0 mm) thickness or, if a full penetration weld is used, the material attached does not exceed the nominal thickness of the pressure retaining member or $^1/_2$ in. (12.0 mm), whichever is less;

(B) welds shall be preheated as required by para. 131;

(C) welds shall be examined as required by Table 136.4;

(D) seal welds shall be examined for leakage after system startup.

137.8.4 All weld defect repairs shall be made in accordance with para. 127.4.11.

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APPENDIX A

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TABLE A-1
CARBON STEEL

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube								
A 53	A	S	C	1	(2)	48	30	1.00
	B	S	C–Mn	1	(2)	60	35	1.00
A 106	A	...	C–Si	1	(2)	48	30	1.00
	B	...	C–Si	1	(2)	60	35	1.00
	C	...	C–Si	1	(2)	70	40	1.00
A 179	...	...	C	1	(1)(2)(5)	(47)	26	1.00
A 192	...	...	C–Si	1	(2)(5)	(47)	26	1.00
A 210	A1	...	C–Si	1	(2)	60	37	1.00
	C	...	C–Mn–Si	1	(2)	70	40	1.00
A 333	1	...	C–Mn	1	(1)	55	30	1.00
	6	...	C–Mn–Si	1	(1)	60	35	1.00
A 369	FPA	...	C–Si	1	(2)	48	30	1.00
	FPB	...	C–Mn	1	(2)	60	35	1.00
API-5L	A	...	C	1	(1)(2)(14)	48	30	1.00
	B	...	C–Mn	1	(1)(2)(14)	60	35	1.00
Furnace Butt Welded Pipe								
A 53	...	F	C	1	(4)	48	30	0.60
API-5L	A25	I & II	C	1	(1)(4)(14)	45	25	0.60
Electric Resistance Welded Pipe and Tube								
A 53	A	E	C	1	(2)	48	30	0.85
	B	E	C–Mn	1	(2)	60	35	0.85
A 135	A	...	C	1	(1)(2)	48	30	0.85
	B	...	C–Mn	1	(1)(2)	60	35	0.85

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TABLE A-1
CARBON STEEL

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
-20 to 100	200	300	400	500	600	650	-20 to 650	700	750	800	Grade	Spec. No.
											Seamless Pipe and Tube	
...	...	...	...	...	...	...	12.0	11.7	10.7	9.0	A	A 53
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	B	
...	...	...	...	...	...	...	12.0	11.7	10.7	9.0	A	A 106
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	B	
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	C	
...	...	...	...	...	...	...	11.8	11.5	10.6	9.2	...	A 179
...	...	...	...	...	...	...	11.8	11.5	10.7	9.0	...	A 192
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	A1	A 210
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	C	
...	...	...	...	...	...	...	13.8	...	...	...	1	A 333
...	...	...	...	...	...	...	15.0	14.4	...	...	6	
...	...	...	...	...	...	...	12.0	11.7	10.7	9.0	FPA	A 369
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	FPA	
...	...	...	...	...	...	...	12.0	11.7	10.7	9.0	A	API-5L
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	B	
											Furnace Butt Welded Pipe	
...	...	...	...	...	...	...	7.2	7.0	...	...	...	A 53
6.8	6.8	6.8	6.8	...	...	...	...	...	...	...	A 25	API-5L
											Electric Resistance Welded Pipe and Tube	
...	...	...	...	...	...	...	10.2	9.9	9.1	7.7	A	A 53
...	...	...	...	...	...	...	12.8	12.2	11.0	9.2	B	
...	...	...	...	...	...	...	10.2	9.9	9.1	7.9	A	A 135
...	...	...	...	...	...	...	12.8	12.2	11.0	9.2	B	

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TABLE A-1
CARBON STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Resistance Welded Pipe and Tube (Cont'd)								
A 178	A	...	C	1	(2)(5)	(47)	26	0.85
	C	...	C	1	(2)	60	37	0.85
A 214	...	...	C	1	(1)(2)(5)	(47)	26	0.85
A 226	...	...	C–Si	1	(2)(5)	(47)	26	0.85
A 333	1	...	C–Mn	1	(1)	55	30	0.85
	6	...	C–Mn–Si	1	...	60	35	0.85
API-5L	A25	I & II	C	1	(1)(14)	45	25	0.85
	A	...	C	1	(1)(2)(14)	48	30	0.85
	B	...	C–Mn	1	(1)(2)(14)	60	35	0.85
A 587	...	...	C	1	(1)(2)	48	30	0.85
Electric Fusion Welded Pipe — Filler Metal Added								
A 134	A283A	...	C	1	(1)(7)	45	24	0.80
	A283B	...	C	1	(1)(7)	50	27	0.80
	A283C	...	C	1	(1)(7)	55	30	0.80
	A283D	...	C	1	(1)(7)	60	33	0.80
A 134	A285A	...	C	1	(1)(2)(8)	45	24	0.80
	A285B	...	C	1	(1)(2)(8)	50	27	0.80
	A285C	...	C	1	(1)(2)(8)	55	30	0.80
A 139	A	...	C	1	(1)(2)(14)	48	30	0.80
	B	...	C–Mn	1	(1)(2)(14)	60	35	0.80
API-5L	A	...	C	1	(1)(2)(14)	48	30	0.90
	B	...	C–Mn	1	(1)(2)(14)	60	35	0.90
A 211	A570-30	...	C	1	(1)(7)(14)(16)	49	30	0.75
	A570-33	...	C	1	(1)(7)(14)(16)	52	33	0.75
	A570-40	...	C	1	(1)(7)(14)(16)	55	40	0.75

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TABLE A-1
CARBON STEEL (CONT'D)

01

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
-20 to 100	200	300	400	500	600	650	-20 to 650	700	750	800	Grade	Spec. No.
											Electric Resistance Welded Pipe and Tube (Cont'd)	
...	...	...	...	...	...	...	10.0	9.8	9.1	7.7	A	A 178
...	...	...	...	...	...	...	12.8	12.2	11.0	9.2	C	
...	...	...	...	...	...	...	10.0	9.8	9.1	7.8	...	A 214
...	...	...	...	...	...	...	10.0	9.8	9.1	7.8	...	A 226
...	...	...	...	...	...	...	11.7	...	...	...	1	A 333
...	...	...	...	...	...	...	12.8	12.2	...	...	6	
9.5	9.5	9.5	9.5	...	...	...	...	...	...	...	A25	API-5L
...	...	...	...	...	...	...	10.2	9.9	9.1	7.7	A	
...	...	...	...	...	...	...	12.8	12.2	11.0	9.2	B	
...	...	...	...	...	...	...	10.2	9.9	9.1	7.9	...	A 587
											Electric Fusion Welded Pipe — Filler Metal Added	
...	...	...	...	...	...	...	9.0	...	...	...	A283A	A 134
...	...	...	...	...	...	...	10.0	...	...	...	A283B	
...	...	...	...	...	...	...	11.0	...	...	...	A283C	
...	...	...	...	...	...	...	12.0	...	...	...	A283D	
...	...	...	...	...	...	...	9.0	8.8	8.2	7.2	A285A	A 134
...	...	...	...	...	...	...	10.0	9.7	9.0	7.7	A285B	
...	...	...	...	...	...	...	11.0	10.6	9.7	8.2	A285C	
...	...	...	...	...	...	...	9.6	9.4	8.6	7.2	A	A 139
...	...	...	...	...	...	...	12.0	11.5	10.4	8.6	B	
...	...	...	...	...	...	...	10.8	10.5	9.6	8.1	A	API-5L
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	B	
9.2	9.2	...	...	...	...	...	...	...	...	...	A570-30	A 211
9.8	9.8	...	...	...	...	...	...	...	...	...	A570-33	
10.3	10.3	...	...	...	...	...	...	...	...	...	A570-40	

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TABLE A-1
CARBON STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)								
A 671	CA55	10,13	C	1	(1)(2)(15)	55	30	0.90
	CA55	11,12	C	1	(1)(2)(15)	55	30	1.00
	CA55	20,23,30,33	C	1	(1)(2)	55	30	0.90
	CA55	21,22,31,32	C	1	(1)(2)	55	30	1.00
A 671	CB60	10,13	C-Si	1	(1)(2)(15)	60	32	0.90
	CB60	11,12	C-Si	1	(1)(2)(15)	60	32	1.00
	CB60	20,23,30,33	C-Si	1	(1)(2)	60	32	0.90
	CB60	21,22,31,32	C-Si	1	(1)(2)	60	32	1.00
A 671	CB65	10,13	C-Si	1	(1)(2)(15)	65	35	0.90
	CB65	11,12	C-Si	1	(1)(2)(15)	65	35	1.00
	CB65	20,23,30,33	C-Si	1	(1)(2)	65	35	0.90
	CB65	21,22,31,32	C-Si	1	(1)(2)	65	35	1.00
A 671	CB70	10,13	C-Si	1	(1)(2)(15)	70	38	0.90
	CB70	11,12	C-Si	1	(1)(2)(15)	70	38	1.00
	CB70	20,23,30,33	C-Si	1	(1)(2)	70	38	0.90
	CB70	21,22,31,32	C-Si	1	(1)(2)	70	38	1.00
A 671	CC60	10,13	C-Mn-Si	1	(1)(2)(15)	60	32	0.90
	CC60	11,12	C-Mn-Si	1	(1)(2)(15)	60	32	1.00
	CC60	20,23,30,33	C-Mn-Si	1	(1)(2)	60	32	0.90
	CC60	21,22,31,32	C-Mn-Si	1	(1)(2)	60	32	1.00
A 671	CC65	10,13	C-Mn-Si	1	(1)(2)(15)	65	35	0.90
	CC65	11,12	C-Mn-Si	1	(1)(2)(15)	65	35	1.00
	CC65	20,23,30,33	C-Mn-Si	1	(1)(2)	65	35	0.90
	CC65	21,22,31,32	C-Mn-Si	1	(1)(2)	65	35	1.00
A 671	CC70	10,13	C-Mn-Si	1	(1)(2)(15)	70	38	0.90
	CC70	11,12	C-Mn-Si	1	(1)(2)(15)	70	38	1.00
	CC70	20,23,30,33	C-Mn-Si	1	(1)(2)	70	38	0.90
	CC70	21,22,31,32	C-Mn-Si	1	(1)(2)	70	38	1.00
A 671	CK75	10,13	C-Mn-Si	1	(1)(2)(15)	75	42	0.90
	CK75	11,12	C-Mn-Si	1	(1)(2)(15)	75	42	1.00
	CK75	20,23,30,33	C-Mn-Si	1	(1)(2)	75	40	0.90
	CK75	21,22,31,32	C-Mn-Si	1	(1)(2)	75	40	1.00

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TABLE A-1
CARBON STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
-20 to 100	200	300	400	500	600	650	-20 to 650	700	750	800	Grade	Spec. No.
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)												
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	CA55	A 671
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	CA55	
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	CA55	
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	CA55	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	CB60	A 671
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	CB60	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	CB60	
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	CB60	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	CB65	A 671
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	CB65	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	CB65	
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	CB65	
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	CB70	A 671
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	CB70	
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	CB70	
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	CB70	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	CC60	A 671
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	CC60	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	CC60	
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	CC60	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	CC65	A 671
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	CC65	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	CC65	
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	CC65	
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	CC70	A 671
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	CC70	
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	CC70	
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	CC70	
...	...	...	...	...	...	...	16.9	15.9	14.1	11.3	CK75	A 671
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	CK75	
...	...	...	...	...	...	...	16.9	15.9	14.1	11.3	CK75	
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	CK75	

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TABLE A-1
CARBON STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)								
A 671	CD70	10,13	C-Mn-Si	1	(1)(2)(15)	70	50	0.90
	CD70	11,12	C-Mn-Si	1	(1)(2)(15)	70	50	1.00
	CD70	20,23,30,33	C-Mn-Si	1	(1)(3)	70	50	0.90
	CD70	21,22,31,32	C-Mn-Si	1	(1)(3)	70	50	1.00
A 671	CD80	10,13	C-Mn-Si	1	(1)(15)	80	60	0.90
	CD80	11,12	C-Mn-Si	1	(1)(15)	80	60	1.00
	CD80	20,23	C-Mn-Si	1	(1)(3)	80	60	0.90
	CD80	21,22	C-Mn-Si	1	(1)(3)	80	60	1.00
A 672	A45	10,13	C	1	(1)(2)(15)	45	24	0.90
	A45	11,12	C	1	(1)(2)(15)	45	24	1.00
	A45	20,23,30,33	C	1	(1)(2)	45	24	0.90
	A45	21,22,31,32	C	1	(1)(2)	45	24	1.00
A 672	A50	10,13	C	1	(1)(2)(15)	50	27	0.90
	A50	11,12	C	1	(1)(2)(15)	50	27	1.00
	A50	20,23,30,33	C	1	(1)(2)	50	27	0.90
	A50	21,22,31,32	C	1	(1)(2)	50	27	1.00
A 672	A55	10,13	C	1	(1)(2)(15)	55	30	0.90
	A55	11,12	C	1	(1)(2)(15)	55	30	1.00
	A55	20,23,30,33	C	1	(1)(2)	55	30	0.90
	A55	21,22,31,32	C	1	(1)(2)	55	30	1.00
A 672	B55	10,13	C	1	(1)(2)(15)	55	30	0.90
	B55	11,12	C	1	(1)(2)(15)	55	30	1.00
	B55	20,23,30,33	C	1	(1)(2)	55	30	0.90
	B55	21,22,31,32	C	1	(1)(2)	55	30	1.00
A 672	B60	10,13	C	1	(1)(2)(15)	60	32	0.90
	B60	11,12	C	1	(1)(2)(15)	60	32	1.00
	B60	20,23,30,33	C	1	(1)(2)	60	32	0.90
	B60	21,22,31,32	C	1	(1)(2)	60	32	1.00
A672	B65	10,13	C	1	(1)(2)(15)	65	35	0.90
	B65	11,12	C	1	(1)(2)(15)	65	35	1.00
	B65	20,23,30,33	C	1	(1)(2)	65	35	0.90
	B65	21,22,31,32	C	1	(1)(2)	65	35	1.00

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TABLE A-1
CARBON STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
-20 to 100	200	300	400	500	600	650	-20 to 650	700	750	800	Grade	Spec. No.
											Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)	
15.8	15.8	15.8	15.7	15.7	15.7	15.5	...	...	...	...	CD70	A 671
17.5	17.5	17.5	17.4	17.4	17.4	17.2	...	...	...	...	CD70	
15.8	15.8	15.8	15.7	15.7	15.7	15.5	...	...	...	...	CD70	
17.5	17.5	17.5	17.4	17.4	17.4	17.2	...	...	...	...	CD70	
18.0	18.0	18.0	17.8	17.8	17.8	17.8	...	...	...	...	CD80	A 671
20.0	20.0	20.0	19.8	19.8	19.8	19.8	...	...	...	...	CD80	
18.0	18.0	18.0	17.8	17.8	17.8	17.8	...	...	...	...	CD80	
20.0	20.0	20.0	19.8	19.8	19.8	19.8	...	...	...	...	CD80	
...	...	...	...	...	...	...	10.2	9.9	9.3	8.1	A45	A 672
...	...	...	...	...	...	...	11.3	11.0	10.3	9.0	A45	
...	...	...	...	...	...	...	10.2	9.9	9.3	8.1	A45	
...	...	...	...	...	...	...	11.3	11.0	10.3	9.0	A45	
...	...	...	...	...	...	...	11.3	10.9	10.1	8.6	A50	A 672
...	...	...	...	...	...	...	12.5	12.1	11.2	9.6	A50	
...	...	...	...	...	...	...	11.3	10.9	10.1	8.6	A50	
...	...	...	...	...	...	...	12.5	12.1	11.2	9.6	A50	
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	A55	A 672
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	A55	
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	A55	
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	A55	
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	B55	A 672
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	B55	
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	B55	
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	B55	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	B60	A 672
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	B60	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	B60	
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	B60	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	B65	A 672
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	B65	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	B65	
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	B65	

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TABLE A-1
CARBON STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)								
A 672	B70	10,13	C	1	(1)(2)(15)	70	38	0.90
	B70	11,12	C	1	(1)(2)(15)	70	38	1.00
	B70	20,23,30,33	C	1	(1)(2)	70	38	0.90
	B70	21,22,31,32	C	1	(1)(2)	70	38	1.00
A 672	C55	10,13	C	1	(1)(2)(15)	55	30	0.90
	C55	11,12	C	1	(1)(2)(15)	55	30	1.00
	C55	20,23,30,33	C	1	(1)(2)	55	30	0.90
	C55	21,22,31,32	C	1	(1)(2)	55	30	1.00
A 672	C60	10,13	C	1	(1)(2)(15)	60	32	0.90
	C60	11,12	C	1	(1)(2)(15)	60	32	1.00
	C60	20,23,30,33	C	1	(1)(2)	60	32	0.90
	C60	21,22,31,32	C	1	(1)(2)	60	32	1.00
A 672	C65	10,13	C	1	(1)(2)(15)	65	35	0.90
	C65	11,12	C	1	(1)(2)(15)	65	35	1.00
	C65	20,23,30,33	C	1	(1)(2)	65	35	0.90
	C65	21,22,31,32	C	1	(1)(2)	65	35	1.00
A 672	C70	10,13	C	1	(1)(2)(15)	70	38	0.90
	C70	11,12	C	1	(1)(2)(15)	70	38	1.00
	C70	20,23,30,33	C	1	(1)(2)	70	38	0.90
	C70	21,22,31,32	C	1	(1)(2)	70	38	1.00
A 672	D70	10,13	C-Mn-Si	1	(1)(15)	70	50	0.90
	D70	11,12	C-Mn-Si	1	(1)(15)	70	50	1.00
	D70	20,23,30,33	C-Mn-Si	1	(1)(3)	70	50	0.90
	D70	21,22,31,32	C-Mn-Si	1	(1)(3)	70	50	1.00
A 672	D80	10,13	C-Mn-Si	1	(1)(15)	80	60	0.90
	D80	11,12	C-Mn-Si	1	(1)(15)	80	60	1.00
	D80	20,23	C-Mn-Si	1	(1)(3)	80	60	0.90
	D80	21,22	C-Mn-Si	1	(1)(3)	80	60	1.00
A 672	N75	10,13	C-Mn-Si	1	(1)(2)(15)	75	42	0.90
	N75	11,12	C-Mn-Si	1	(1)(2)(15)	75	42	1.00
	N75	20,23,30,33	C-Mn-Si	1	(1)(2)	75	40	0.90
	N75	21,22,31,32	C-Mn-Si	1	(1)(2)	75	40	1.00

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TABLE A-1
CARBON STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
-20 to 100	200	300	400	500	600	650	-20 to 650	700	750	800	Grade	Spec. No.
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)												
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	B70	A 672
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	B70	
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	B70	
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	B70	
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	C55	A 672
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	C55	
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	C55	
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	C55	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	C60	A 672
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	C60	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	C60	
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	C60	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	C65	A 672
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	C65	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	C65	
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	C65	
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	C70	A 672
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	C70	
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	C70	
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	C70	
15.8	15.8	15.8	15.7	15.7	15.7	15.5	...	...	...	...	D70	A 672
17.5	17.5	17.5	17.4	17.4	17.4	17.2	...	...	...	...	D70	
15.8	15.8	15.8	15.7	15.7	15.7	15.5	...	...	...	...	D70	
17.5	17.5	17.5	17.4	17.4	17.4	17.2	...	...	...	...	D70	
18.0	18.0	18.0	17.8	17.8	17.8	17.8	...	...	...	...	D80	A 672
20.0	20.0	20.0	19.8	19.8	19.8	19.8	...	...	...	...	D80	
18.0	18.0	18.0	17.8	17.8	17.8	17.8	...	...	...	...	D80	
20.0	20.0	20.0	19.8	19.8	19.8	19.8	...	...	...	...	D80	
...	...	...	...	...	...	...	16.9	15.9	14.1	11.3	N75	A 672
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	N75	
...	...	...	...	...	...	...	16.9	15.9	14.1	11.3	N75	
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	N75	

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TABLE A-1
CARBON STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)								
A 691	CMSH70	10,13	C–Mn–Si	1	(1)(15)	70	50	0.90
	CMSH70	11,12	C–Mn–Si	1	(1)(15)	70	50	1.00
	CMSH70	20,23,30,33	C–Mn–Si	1	(1)(3)	70	50	0.90
	CMSH70	21,22,31,32	C–Mn–Si	1	(1)(3)	70	50	1.00
A 691	CMSH80	10,13	C–Mn–Si	1	(1)(15)	80	60	0.90
	CMSH80	11,12	C–Mn–Si	1	(1)(15)	80	60	1.00
	CMSH80	20,23	C–Mn–Si	1	(1)(3)	80	60	0.90
	CMSH80	21,22	C–Mn–Si	1	(1)(3)	80	60	1.00
A 691	CMS75	10,13	C–Mn–Si	1	(1)(2)(15)	75	42	0.90
	CMS75	11,12	C–Mn–Si	1	(1)(2)(15)	75	42	1.00
	CMS75	20,23,30,33	C–Mn–Si	1	(1)(2)	75	40	0.90
	CMS75	21,22,31,32	C–Mn–Si	1	(1)(2)	75	40	1.00
Copper Brazed Tubing								
A 254	...	...	C	...	(1)(9)(10)	42	25	1.00
Plate								
A 36	...	...	C–Mn–Si	1	(1)(7)(21)	58	36	0.92
A 283	A	...	C	1	(1)(7)	45	24	0.92
	B	...	C	1	(1)(7)	50	27	0.92
	C	...	C	1	(1)(7)	55	30	0.92
	D	...	C	1	(1)(7)	60	33	0.92
A 285	A	...	C	1	(2)	45	24	1.00
	B	...	C	1	(2)	50	27	1.00
	C	...	C	1	(2)	55	30	1.00
A 299	...	...	C–Mn–Si	1	(2)(23)	75	40	1.00
	...	...	C–Mn–Si	1	(2)(22)	75	42	1.00
A 515	55	...	C–Si	1	(2)	55	30	1.00
	60	...	C–Si	1	(2)	60	32	1.00
	65	...	C–Si	1	(2)	65	35	1.00
	70	...	C–Si	1	(2)	70	38	1.00

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TABLE A-1
CARBON STEEL (CONT'D)

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Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
-20 to 100	200	300	400	500	600	650	-20 to 650	700	750	800	Grade	Spec. No.
											Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)	
15.8	15.8	15.8	15.7	15.7	15.7	15.5	...	...	...	...	CMSH70	A 691
17.5	17.5	17.5	17.4	17.4	17.4	17.2	...	...	...	...	CMSH70	
15.8	15.8	15.8	15.7	15.7	15.7	15.5	...	...	...	...	CMSH70	
17.5	17.5	17.5	17.4	17.4	17.4	17.2	...	...	...	...	CMSH70	
18.0	18.0	18.0	17.8	17.8	17.8	17.8	...	...	...	...	CMSH80	A 691
20.0	20.0	20.0	19.8	19.8	19.8	19.8	...	...	...	...	CMSH80	
18.0	18.0	18.0	17.8	17.8	17.8	17.8	...	...	...	...	CMSH80	
20.0	20.0	20.0	19.8	19.8	19.8	19.8	...	...	...	...	CMSH80	
...	...	...	...	...	...	...	16.9	15.9	14.1	11.3	CMS75	A 691
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	CMS75	
...	...	...	...	...	...	...	16.9	15.9	14.1	11.3	CMS75	
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	CMS75	
											Copper Brazed Tubing	
6.0	5.5	4.8	3.0	...	...	...	...	...	...	...	...	A 254
											Plate	
...	...	...	...	...	...	...	12.7	...	...	...	...	A 36
...	...	...	...	...	...	...	10.4	...	...	...	A	A 283
...	...	...	...	...	...	...	11.5	...	...	...	B	
...	...	...	...	...	...	...	12.7	...	...	...	C	
...	...	...	...	...	...	...	13.8	...	...	...	D	
...	...	...	...	...	...	...	11.3	11.0	10.3	9.0	A	A 285
...	...	...	...	...	...	...	12.5	12.1	11.2	9.6	B	
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	C	
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	...	A 299
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	...	
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	55	A 515
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	60	
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	65	
...	...	...	...	...	...	...	17.5	16.6	14.8	12.6	70	

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TABLE A-1
CARBON STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Plate (Cont'd)								
A 516	55	...	C–Si	1	(2)	55	30	1.00
	60	...	C–Mn–Si	1	(2)	60	32	1.00
	65	...	C–Mn–Si	1	(2)	65	35	1.00
	70	...	C–Mn–Si	1	(2)	70	38	1.00
Forgings								
A 105	...	...	C–Si	1	(2)	70	36	1.00
A 181	...	60	C–Si	1	(2)	60	30	1.00
	...	70	C–Si	1	(2)	70	36	1.00
Wrought Fittings (Seamless and Welded)								
A 234	WPB	...	C–Si	1	(2)	60	35	1.00
	WPC	...	C–Si	1	(2)	70	40	1.00
Castings								
A 216	WCA	...	C–Si	1	(2)(6)	60	30	0.80
	WCB	...	C–Si	1	(2)(6)	70	36	0.80
	WCC	...	C–Mn–Si	1	(2)(6)	70	40	0.80
Bars and Shapes								
A 36	...	...	C–Mn–Si	1	(1)(2)	58	36	1.00
Bolts, Nuts, and Studs								
A 193	...	...	...	...	(11)	...	...	...
A 194	1,2,2H	...	...	...	(12)	...	...	...

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TABLE A-1
CARBON STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
−20 to 100	200	300	400	500	600	650	−20 to 650	700	750	800	Grade	Spec. No.
												Plate (Cont'd)
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	55	A 516
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	60	
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	65	
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	70	
												Forgings
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	...	A 105
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	...	A 181
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	...	
												Wrought Fittings (Seamless and Welded)
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	WPB	A 234
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	WPC	
												Castings
...	...	...	...	...	...	...	12.0	11.5	10.4	8.6	WCA	A 216
...	...	...	...	...	...	...	14.0	13.3	11.8	9.6	WCB	
...	...	...	...	...	...	...	14.0	13.3	11.8	9.6	WCC	
												Bars and Shapes
...	...	...	...	...	...	...	14.5	13.9	12.6	10.5	...	A 36
												Bolts, Nuts, and Studs
...	...	...	...	...	...	...	...	...	...	...	...	A 193
...	...	...	...	...	...	...	...	...	...	...	1,2,2H	A 194

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TABLE A-1
CARBON STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Bolts, Nuts, and Studs (Cont'd)								
A 307	B	...	C	...	(1)(13)(21)	60	...	...
A 449	...	...	C	...	(1)(17)(18)	120	...	...
	...	...	C	...	(1)(17)(19)	105	...	...
	...	...	C	...	(1)(17)(20)	90	...	...

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM, except API-5L. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.

(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.

(c) The P-Numbers indicated in this Table are identical to those adopted by ASME Boiler and Pressure Vessel Code. Qualification of welding procedures, welders and welding operators is required and shall comply with the ASME Boiler and Pressure Vessel Code (Section IX) except as modified by para. 127.5.

(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."

(e) The materials listed in this Table shall not be used at design temperatures above those for which allowable stress values are given except as permitted by para. 122.6.2(G).

(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. Weld joint efficiency factors are shown in Table 102.4.3.

(g) Pressure–temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.

(h) All the materials listed are classifed as ferritic [see Table 104.1.2(A)].

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR CONSTRUCTION OF PRESSURE RETAINING PARTS OF BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) AND (B).

(2) Upon prolonged exposure to temperatures above 775°F, the carbide phase of carbon steel may be converted to graphite.

(3) The allowable stress values given are for pipe fabricated from plate not exceeding $2^1/_2$ in. in thickness.

(4) This material shall not be used for flammable fluids. Refer to para. 105.2.1(A).

(5) Tensile value in parentheses is expected minimum.

(6) The 0.80 material quality factor for casting may be increased in accordance with para. 102.4.6.

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TABLE A-1
CARBON STEEL (CONT'D)

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Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
−20 to 100	200	300	400	500	600	650	−20 to 650	700	750	800	Grade	Spec. No.
											Bolts, Nuts, and Studs (Cont'd)	
7.0	7.0	7.0	7.0	...	...	...	...	...	...	...	B	A 307
23.0	23.0	23.0	23.0	23.0	23.0	23.0	...	...	...	...	...	A 449
23.0	20.3	20.3	20.3	20.3	20.3	20.3	...	...	...	...	...	
14.5	14.5	14.5	14.5	14.5	14.5	14.5	...	...	...	...	...	

NOTES (CONT'D)

(7) The stress values for structural quality plate include a material quality factor of 0.92. The allowable stresses for A 283 Grade D and A 36 plate have been limited to 12.7 ksi.
(8) These stress values are permitted only if killed or semikilled steels are used.
(9) A 254 is copper brazed (not welded) steel pipe.
(10) For saturated steam at 250 psi (406°F), the values given for 400°F may be used.
(11) For A 193 alloy and stainless steel bolts for use with carbon steel piping, see Tables A-2 and A-3.
(12) This is a product specification. Allowable stresses are not necessary. Limitations on metal temperature for materials covered by this specification for use under B31.1 are:

Grades 1 and 2	−20°F to 600°F
Grade 2H	−20°F to 800°F

(13) This material shall not be used above 400°F. The allowable stress value is 7000 psi.
(14) This material is not listed in the ASME Boiler and Pressure Vessel Code, Section IX. However, weld procedures shall be qualified in accordance with the P-Number shown. See para. 127.5.1.
(15) This material shall not be used in nominal wall thicknesses exceeding $^3/_4$ in.
(16) These allowable stress values are for pipe made using a butt-welded joint process. Pipe made by other processes shall not be used.
(17) These allowable stress values are established from a consideration of strength only and will be satisfactory for average service. For bolted joints, where freedom from leakage over a long period of time without retightening is required, lower stress values may be necessary as determined from the relative flexibility of the flange, bolts, and corresponding relaxation properties.
(18) These allowable stress values apply to bolting materials less than or equal to 1 in. diameter.
(19) These allowable stress values apply to bolting materials greater than 1 in. diameter and less than or equal to $1^1/_2$ in.
(20) These allowable stress values apply to bolting materials greater than $1^1/_2$ in. diameter and less than or equal to 3 in. diameter.
(21) The allowable stress values listed in MSS SP-58 for this material may be used for pipe supporting elements designed in accordance with MSS SP-58.
(22) These values apply to material less than or equal to 1 in. thick.
(23) These values apply to material greater than 1 in. thick.

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube								
A 199	T5	...	5Cr–$^1/_2$ Mo	5B	(1)(5)	60	25	1.00
	T9	...	9Cr–1Mo	5B	(1)(5)	60	25	1.00
A 199	T11	...	1$^1/_4$Cr–$^1/_2$ Mo	4	(1)	60	25	1.00
	T21	...	3Cr–1Mo	5A	(1)	60	25	1.00
	T22	...	2$^1/_4$Cr–1Mo	5A	(1)(17)	60	25	1.00
A 213	T2	...	$^1/_2$Cr–$^1/_2$Mo	3	...	60	30	1.00
	T5	...	5Cr–$^1/_2$ Mo	5B	(5)	60	30	1.00
	T5b	...	5Cr–$^1/_2$ Mo–1$^1/_2$ Si	5B	(5)	60	30	1.00
A 213	T5c	...	5Cr–$^1/_2$ Mo–Ti	5B	(5)	60	30	1.00
	T9	...	9Cr–1Mo	5B	(5)	60	30	1.00
	T11	...	1$^1/_4$Cr–$^1/_2$ Mo	4	...	60	30	1.00
A 213	T12	...	1Cr–$^1/_2$Mo	4	...	60	30	1.00
	T21	...	3Cr–1Mo	5A	...	60	30	1.00
	T22	...	2$^1/_4$Cr–1Mo	5A	(17)	60	30	1.00
	T91	...	9Cr–1Mo–V	5B	(5)(19)	85	60	1.00
	T91	...	9Cr–1Mo–V	5B	(5)(20)	85	60	1.00
A 333	3	...	3$^1/_2$Ni	9B	(1)	65	35	1.00
	4	...	$^3/_4$Cr–$^3/_4$Ni–Cu–Al	4	(1)	60	35	1.00
	7	...	2$^1/_2$Ni	9A	(1)	65	35	1.00
	9	...	2Ni–1Cu	9A	(1)(5)	63	46	1.00
A 335	P1	...	C–$^1/_2$ Mo	3	(2)	55	30	1.00
	P2	...	$^1/_2$Cr–$^1/_2$Mo	3	...	55	30	1.00
	P5	...	5Cr–$^1/_2$ Mo	5B	(5)	60	30	1.00
	P5b	...	5Cr–$^1/_2$ Mo–1$^1/_2$ Si	5B	(5)	60	30	1.00
A 335	P5c	...	5Cr–$^1/_2$ Mo–Ti	5B	(5)	60	30	1.00
	P9	...	9Cr–1Mo	5B	(5)	60	30	1.00
	P11	...	1$^1/_4$Cr–$^1/_2$ Mo–Si	4	...	60	30	1.00
A 335	P12	...	1Cr–$^1/_2$ Mo	4	...	60	32	1.00
	P21	...	3Cr–1Mo	5A	...	60	30	1.00
	P22	...	2$^1/_4$Cr–1Mo	5A	(17)	60	30	1.00
	P91	...	9Cr–1Mo–V	5B	(5)(19)	85	60	1.00
	P91	...	9Cr–1Mo–V	5B	(5)(20)	85	60	1.00

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
-20 to 400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
															Seamless Pipe and Tube	
...	13.3	13.1	12.9	12.8	12.4	12.1	11.6	10.9	8.0	5.8	4.2	2.9	2.0	1.3	T5	A 199
...	13.3	13.1	12.9	12.8	12.4	12.1	11.6	11.0	10.3	7.4	5.0	3.3	2.2	1.5	T9	
14.0	13.5	13.1	12.8	12.6	12.3	12.0	11.7	11.3	9.3	6.3	4.2	2.8	1.9	1.2	T11	A 199
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	2.7	1.5	T21	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	2.4	1.4	T22	
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.7	9.2	5.9	...	...	...	...	T2	A 213
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	T5	
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	T5b	
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	T5c	A 213
...	14.4	14.2	13.9	13.7	13.2	12.8	12.1	11.4	10.6	7.4	5.0	3.3	2.2	1.5	T9	
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	...	...	T11	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.6	14.0	11.3	7.2	4.5	2.8	...	...	T12	A 213
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	...	...	T21	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	T22	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	10.3	7.0	4.3	T91	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	9.6	7.0	4.3	T91	
16.3	16.3	16.3	16.3	...	...	...	...	...	...	...	...	...	...	...	3	A 333
15.0	15.0	15.0	15.0	...	...	...	...	...	...	...	...	...	...	...	4	
16.3	16.3	16.3	16.3	...	...	...	...	...	...	...	...	...	...	...	7	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9	
13.8	13.8	13.8	13.8	13.8	13.8	13.5	13.1	...	...	...	...	...	...	...	P1	A 335
13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.3	9.2	5.9	...	...	...	...	P2	
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	P5	
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	P5b	
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	P5c	A 335
...	14.4	14.2	13.9	13.7	13.2	12.8	12.1	11.4	10.6	7.4	5.0	3.3	2.2	1.5	P9	
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	...	...	P11	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.6	14.0	11.3	7.2	4.5	2.8	...	...	P12	A 335
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	...	...	P21	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	P22	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	10.3	7.0	4.3	P91	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	9.6	7.0	4.3	P91	

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube (Cont'd)								
A 369	FP1	...	C–$^1/_2$ Mo	3	(2)	55	30	1.00
	FP2	...	$^1/_2$ Cr–$^1/_2$ Mo	3	...	55	30	1.00
	FP5	...	5Cr–$^1/_2$ Mo	5B	(5)	60	30	1.00
A 369	FP9	...	9Cr–1Mo	5B	(5)	60	30	1.00
	FP11	...	1$^1/_4$ Cr–$^1/_2$ Mo–Si	4	...	60	30	1.00
A 369	FP12	...	1Cr–$^1/_2$ Mo	4	...	60	32	1.00
	FP21	...	3Cr–1Mo	5A	...	60	30	1.00
	FP22	...	2$^1/_4$ Cr–1Mo	5A	(17)	60	30	1.00
A 714	V	...	2Ni–1Cu	9A	(1)(5)	65	46	1.00
Centrifugally Cast Pipe								
A 426	CP1	...	C–$^1/_2$ Mo	3	(1)(2)(3)(4)(7)	65	35	0.85
	CP2	...	$^1/_2$ Cr–$^1/_2$ Mo	3	(1)(3)(4)(7)	60	30	0.85
	CP5	...	5Cr–$^1/_2$ Mo	5B	(1)(3)(4)(5)(7)	90	60	0.85
	CP5B	...	5Cr–$^1/_2$ Mo–Si	5B	(1)(3)(4)(5)(7)	60	30	0.85
A 426	CP9	...	9Cr–1Mo	5B	(1)(3)(4)(5)(7)	90	60	0.85
	CP11	...	1$^1/_4$ Cr–$^1/_2$ Mo	4	(1)(3)(4)(7)	70	40	0.85
A 426	CP12	...	1Cr–$^1/_2$ Mo	4	(1)(3)(4)(7)	60	30	0.85
	CP21	...	3Cr–1Mo	5A	(1)(3)(4)(5)(7)	60	30	0.85
	CP22	...	2$^1/_4$ Cr–1Mo	5A	(1)(3)(4)(5)(7)(17)	70	40	0.85
Electric Resistance Welded Pipe								
A 333	3	...	3$^1/_2$ Ni	9B	(1)	65	35	0.85
	7	...	2$^1/_2$ Ni	9A	(1)	65	35	0.85
	9	...	2Ni–1Cu	9A	(1)(5)	63	46	0.85
A 714	V	E	2Ni–Cu	9A	(1)(5)	65	46	0.85

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
−20 to 400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
															Seamless Pipe and Tube (Cont'd)	
13.8	13.8	13.8	13.8	13.8	13.8	13.5	13.2	...	...	...	...	...	...	...	FP1	A 369
13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.3	9.2	5.9	...	...	...	...	FP2	
...	14.4	14.2	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	FP5	
...	14.4	14.2	13.9	13.7	13.2	12.8	12.1	11.4	10.6	7.4	5.0	3.3	2.2	1.5	FP9	A 369
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	...	...	FP11	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.6	14.0	11.3	7.2	4.5	2.8	...	...	FP12	A 369
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	...	...	FP21	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	FP22	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V	A 714
															Centrifugally Cast Pipe	
13.9	13.9	13.9	13.9	13.9	13.8	13.4	13.0	...	...	...	...	...	...	...	CP1	A 426
12.8	12.8	12.8	12.8	12.8	12.6	12.2	11.9	11.6	7.8	5.0	...	...	...	...	CP2	
...	18.4	18.1	17.8	17.4	16.8	16.2	12.1	9.2	6.8	4.9	3.6	2.5	1.5	0.85	CP5	
...	12.2	12.1	11.8	11.6	11.2	10.9	10.3	9.3	6.8	4.9	3.6	2.5	1.5	0.85	CP5b	
...	18.4	18.1	17.7	17.4	16.8	16.2	15.5	14.0	9.4	6.3	4.3	2.8	1.9	1.3	CP9	A 426
14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.5	11.6	7.9	5.4	3.6	2.4	...	...	CP11	
12.8	12.8	12.8	12.8	12.6	12.4	12.2	11.9	11.6	9.6	6.1	3.8	2.4	...	...	CP12	A 426
...	12.3	12.3	12.3	12.3	12.3	11.8	11.2	10.2	7.7	6.0	4.7	3.4	...	...	CP21	
...	14.3	14.3	14.2	14.1	13.7	13.3	12.8	12.1	9.7	6.6	4.3	2.7	...	...	CP22	
															Electric Resistance Welded Pipe	
13.8	13.8	13.8	13.8	...	...	...	...	...	...	...	...	...	...	...	3	A 333
13.8	13.8	13.8	13.8	...	...	...	...	...	...	...	...	...	...	...	7	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V	A 714

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Fusion Welded Pipe — Filler Metal Added								
A 672	L65	20,23,30,33,40,43	C-½Mo	3	(1)	65	37	0.90
	L65	21,22,31,32,41,42	C-½Mo	3	(1)	65	37	1.00
A 672	L70	20,23,30,33,40,43	C-½Mo	3	(1)	70	40	0.90
	L70	21,22,31,32,41,42	C-½Mo	3	(1)	70	40	1.00
A 672	L75	20,23,30,33,40,43	C-½Mo	3	(1)	75	43	0.90
	L75	21,22,31,32,41,42	C-½Mo	3	(1)	75	43	1.00
A 691	CM65	20,23,30,33,40,43	C-½Mo	3	(1)	65	37	0.90
	CM65	21,22,31,32,41,42	C-½Mo	3	(1)	65	37	1.00
A 691	CM70	20,23,30,33,40,43	C-½Mo	3	(1)	70	40	0.90
	CM70	21,22,31,32,41,42	C-½Mo	3	(1)	70	40	1.00
A 691	CM75	20,23,30,33,40,43	C-½Mo	3	(1)	75	43	0.90
	CM75	21,22,31,32,41,42	C-½Mo	3	(1)	75	43	1.00
A 691	½Cr	20,23	½Cr-½Mo	3	(1)(11)	55	33	0.90
	½Cr	21,22	½Cr-½Mo	3	(1)(11)	55	33	1.00
	½Cr	20,23,30,33,40,43	½Cr-½Mo	3	(1)(12)	70	45	0.90
	½Cr	21,22,31,32,41,42	½Cr-½Mo	3	(1)(12)	70	45	1.00
A 691	1Cr	20,23	1Cr-½Mo	4	(1)(11)	55	33	0.90
	1Cr	21,22	1Cr-½Mo	4	(1)(11)	55	33	1.00
	1Cr	20,23,30,33,40,43	1Cr-½Mo	4	(1)(12)	65	40	0.90
	1Cr	21,22,31,32,41,42	1Cr-½Mo	4	(1)(12)	65	40	1.00
A 691	1¼Cr	20,23	1¼Cr-½Mo-Si	4	(1)(11)	60	35	0.90
	1¼Cr	21,22	1¼Cr-½Mo-Si	4	(1)(11)	60	35	1.00
	1¼Cr	20,23,30,33,40,43	1¼Cr-½Mo-Si	4	(1)(12)	75	45	0.90
	1¼Cr	21,22,31,32,41,42	1¼Cr-½Mo-Si	4	(1)(12)	75	45	1.00
A 691	2¼Cr	20,23	2¼Cr-1Mo	5A	(1)(11)(17)	60	30	0.90
	2¼Cr	21,22	2¼Cr-1Mo	5A	(1)(11)(17)	60	30	1.00
	2¼Cr	20,23,30,33,40,43	2¼Cr-1Mo	5A	(1)(5)(12)(17)	75	45	1.00
	2¼Cr	21,22,31,32,41,42	2¼Cr-1Mo	5A	(1)(5)(12)(17)	75	45	1.00

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
−20 to 400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
											Electric Fusion Welded Pipe — Filler Metal Added					
14.7	14.7	14.7	14.7	14.7	14.7	14.2	13.8	...	...	...	...	...	...	...	L65	A 672
16.3	16.3	16.3	16.3	16.3	16.3	15.8	15.3	...	...	...	...	...	...	...	L65	
15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.4	...	...	...	...	...	...	...	L70	A 672
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.1	...	...	...	...	...	...	...	L70	
16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.5	...	...	...	...	...	...	...	L75	A 672
18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.3	...	...	...	...	...	...	...	L75	
14.7	14.7	14.7	14.7	14.7	14.7	14.2	13.8	...	...	...	...	...	...	...	CM65	A 691
16.3	16.3	16.3	16.3	16.3	16.3	15.8	15.3	...	...	...	...	...	...	...	CM65	
15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.4	...	...	...	...	...	...	...	CM70	A 691
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.1	...	...	...	...	...	...	...	CM70	
16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.5	...	...	...	...	...	...	...	CM75	A 691
18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.3	...	...	...	...	...	...	...	CM75	
12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.1	11.5	8.3	5.3	...	...	...	...	½Cr	A 691
13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.4	12.8	9.2	5.9	...	...	...	...	½Cr	
15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.2	8.3	5.3	...	...	...	...	½Cr	
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	16.9	9.2	5.9	...	...	...	...	½Cr	
12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.1	11.5	10.2	6.5	4.1	2.5	...	...	1Cr	A 691
13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.4	12.9	11.3	7.2	4.5	2.8	...	...	1Cr	
14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.2	13.6	10.2	6.5	4.1	2.5	...	...	1Cr	
16.3	16.3	16.3	16.3	16.3	16.3	16.3	15.8	15.2	11.3	7.2	4.5	2.8	...	...	1Cr	
13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.1	12.3	8.4	5.7	3.8	2.5	...	...	1¼Cr	A 691
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.6	13.7	9.3	6.3	4.2	2.8	...	...	1¼Cr	
16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.5	12.3	8.4	5.7	3.8	2.5	...	...	1¼Cr	
18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.3	13.7	9.3	6.3	4.2	2.8	...	...	1¼Cr	
13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.0	12.2	9.7	7.2	5.1	3.4	...	...	2¼Cr	A 691
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	2¼Cr	
...	16.1	16.0	15.9	15.8	15.5	15.2	14.8	14.2	10.3	7.0	4.6	2.9	...	...	2¼Cr	
...	17.9	17.8	17.7	17.5	17.2	16.9	16.4	15.8	11.4	7.8	5.1	3.2	...	...	2¼Cr	

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)								
A 691	3Cr	20,23	3Cr–1Mo	5A	(1)(11)	60	30	0.90
	3Cr	21,22	3Cr–1Mo	5A	(1)(11)	60	30	1.00
	3Cr	20,23,30,33,40,43	3Cr–1Mo	5A	(1)(5)(12)	75	45	0.90
	3Cr	21,22,31,32,41,42	3Cr–1Mo	5A	(1)(5)(12)	75	45	1.00
A 691	5Cr	20,23	5Cr–$^1/_2$Mo	5B	(1)(5)(11)	60	30	0.90
	5Cr	21,22	5Cr–$^1/_2$Mo	5B	(1)(5)(11)	60	30	1.00
	5Cr	20,23,30,33,40,43	5Cr–$^1/_2$Mo	5B	(1)(5)(12)	75	45	0.90
	5Cr	21,22,31,32,41,42	5Cr–$^1/_2$Mo	5B	(1)(5)(12)	75	45	1.00
A 691	91	40,43,50,53	9Cr–1Mo–V	5B	(1)(5)(12)(17)	85	60	0.90
	91	41,42,52,53	9Cr–1Mo–V	5B	(1)(5)(12)(17)	85	60	1.00
Plate								
A 387	2	1	$^1/_2$Cr–$^1/_2$Mo	3	...	55	33	1.00
	2	2	$^1/_2$Cr–$^1/_2$Mo	3	(1)...	70	45	1.00
	5	1	5Cr–$^1/_2$Mo	5B	(5)	60	30	1.00
	5	2	5Cr–$^1/_2$Mo	5B	(1)(5)	75	45	1.00
A 387	11	1	1$^1/_4$Cr–$^1/_2$Mo–Si	4	...	60	35	1.00
	11	2	1$^1/_2$Cr–$^1/_2$Mo–Si	4	...	75	45	1.00
	12	1	1Cr–$^1/_2$Mo	4	...	55	33	1.00
	12	2	1Cr–$^1/_2$Mo	4	...	65	40	1.00
A 387	21	1	3Cr–1Mo	5A	...	60	30	1.00
	21	2	3Cr–1Mo	5A	(5)	75	45	1.00
	22	1	2$^1/_4$Cr–1Mo	5A	(17)	60	30	1.00
	22	2	2$^1/_4$Cr–1Mo	5A	(5)(17)	75	45	1.00
A 387	91	2	9Cr–1Mo–V	5B	(5)(19)	85	60	1.00
	91	2	9Cr–1Mo–V	5B	(5)(20)	85	60	1.00
Forgings								
A 182	F1	...	C–$^1/_2$Mo	3	(2)	70	40	1.00
	F2	...	$^1/_2$Cr–$^1/_2$Mo	3	...	70	40	1.00
	F5	...	5Cr–$^1/_2$Mo	5B	(5)	70	40	1.00
	F5a	...	5Cr–$^1/_2$Mo	5B	(5)	90	65	1.00

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
-20 to 400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
															Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)	
13.5	13.5	13.5	13.5	13.3	13.1	12.5	11.9	10.8	8.1	6.3	5.0	3.6	...	...	3Cr	A 691
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	...	...	3Cr	
...	16.1	16.0	15.9	15.8	15.5	15.2	14.8	11.8	8.6	6.1	4.4	2.9	...	...	3Cr	
...	17.9	17.8	17.7	17.5	17.2	16.9	16.4	13.1	9.5	6.8	4.9	3.2	...	...	3Cr	
...	13.0	12.7	12.5	12.3	11.9	11.5	10.9	9.8	7.2	5.2	3.8	2.6	1.6	0.90	5Cr	A 691
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	5Cr	
...	16.2	15.9	15.7	15.4	14.9	14.4	13.6	9.8	7.2	5.2	3.8	2.6	1.6	0.90	5Cr	
...	18.0	17.7	17.4	17.1	16.5	16.0	15.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	5Cr	
...	18.9	18.7	18.4	18.0	17.4	16.8	16.0	15.0	13.9	12.8	11.6	8.6	6.3	3.8	91	A 691
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	9.6	7.0	4.3	91	
																Plate
13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.4	12.8	9.2	5.9	...	...	...	...	2	A 387
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	16.9	9.2	5.9	...	...	...	...	2	
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	5	
...	18.0	17.7	17.4	17.1	16.5	16.0	15.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	5	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.6	13.7	9.3	6.3	4.2	2.8	...	...	11	A 387
18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.3	13.7	9.3	6.3	4.2	2.8	...	...	11	
13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.4	12.9	11.3	7.2	4.5	2.8	...	...	12	
16.3	16.3	16.3	16.3	16.3	16.3	16.3	15.8	15.2	11.3	7.2	4.5	2.8	...	...	12	
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	...	...	21	A 387
...	17.9	17.8	17.7	17.5	17.2	16.9	16.4	13.1	9.5	6.8	4.9	3.2	...	...	21	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	22	
...	17.9	17.8	17.7	17.5	17.2	16.9	16.4	15.8	11.4	7.8	5.1	3.2	...	...	22	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	10.3	7.0	4.3	91	A 387
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	9.6	7.0	4.3	91	
																Forgings
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.1	...	...	...	...	...	...	...	F1	A 182
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	16.9	9.2	5.9	...	...	...	...	F2	
...	16.8	16.5	16.3	16.0	15.4	14.9	14.1	10.8	8.0	5.8	4.2	2.9	1.8	1.0	F5	
...	21.6	21.3	20.9	20.5	19.8	19.1	14.3	10.9	8.0	5.8	4.2	2.9	1.8	1.0	F5a	

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Forgings (Cont'd)								
A 182	F9	...	9Cr–1Mo	5B	(5)	85	55	1.00
	F91	...	9Cr–1Mo–V	5B	(5)	85	60	1.00
	F11	Class 1	$1\frac{1}{2}$Cr–$\frac{1}{2}$Mo–Si	4	...	60	30	1.00
	F11	Class 2	$1\frac{1}{4}$Cr–$\frac{1}{4}$Mo–Si	4	...	70	40	1.00
	F12	Class 1	1Cr–$\frac{1}{2}$Mo	4	...	60	30	1.00
	F12	Class 2	1Cr–$\frac{1}{2}$Mo	4	...	70	40	1.00
	F21	...	3Cr–1Mo	5A	(5)	75	45	1.00
	F22	Class 1	$2\frac{1}{4}$Cr–1Mo	5A	(17)	60	30	1.00
	F22	Class 3	$2\frac{1}{4}$Cr–1Mo	5A	(5)(17)	75	45	1.00
A 336	F11	Class 1	$1\frac{1}{4}$Cr–$\frac{1}{2}$Mo–Si	4	...	60	30	1.00
	F11	Class 2	$1\frac{1}{4}$Cr–$\frac{1}{2}$Mo–Si	4	...	70	40	1.00
	F12	...	1Cr–$\frac{1}{2}$Mo	4	...	70	40	1.00
	F22	Class 1	$2\frac{1}{4}$Cr–1Mo	5A	(17)	60	30	1.00
	F22	Class 3	$2\frac{1}{4}$Cr–1Mo	5A	(5)(17)	75	45	1.00
	F91	...	9Cr–1Mo–V	5B	(5)(19)	85	60	1.00
	F91	...	9Cr–1Mo–V	5B	(5)(20)	85	60	1.00
A 350	LF3	...	$3\frac{1}{2}$Ni	9B	(1)	70	40	1.00
	LF4	...	$\frac{3}{4}$Cr–$\frac{3}{4}$Ni–Cu–Al	4	(1)	60	...	1.00
	LF5	Class 1	$1\frac{1}{2}$Ni	9A	(1)(5)	60	30	1.00
	LF5	Class 2	$1\frac{1}{2}$Ni	9A	(1)(5)	70	37	1.00
	LF9	...	2Ni–1Cu	9A	(1)(5)	63	46	1.00
Wrought Fittings (Seamless and Welded)								
A 234	WP1	...	C–$\frac{1}{2}$Mo	3	(2)	55	30	1.00
	WP5	...	5Cr–$\frac{1}{2}$Mo	5B	...	60	30	1.00
	WP11	...	$1\frac{1}{4}$Cr–$\frac{1}{2}$Mo	4	...	60	30	1.00
	WP12	(1)	1Cr–$\frac{1}{2}$Mo	4	(6)	60	30	1.00
A 234	WP22	...	$2\frac{1}{4}$Cr–1Mo	5A	(17)	60	30	1.00
	WP91	...	9Cr–1Mo–V	5B	(5)(19)	85	60	1.00
	WP91	...	9Cr–1Mo–V	5B	(5)(20)	85	60	1.00

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
-20 to 400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
															Forgings (Cont'd)	
...	20.4	20.1	19.7	19.4	18.7	18.1	17.1	16.2	11.0	7.4	5.0	3.3	2.2	1.5	F9	A 182
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	10.3	7.0	4.3	F91	
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	...	...	F11	
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.1	13.7	9.3	6.3	4.2	2.8	...	...	F11	
15.0	15.0	15.0	15.0	14.8	14.6	14.3	14.0	13.6	11.3	7.2	4.5	2.8	...	...	F12	
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.0	16.4	11.3	7.2	4.5	2.8	...	...	F12	
...	17.9	17.8	17.7	17.5	17.2	16.9	16.4	13.1	9.5	6.8	4.9	3.2	...	...	F21	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	F22	
...	17.9	17.8	17.7	17.5	17.2	16.9	16.4	15.8	11.4	7.8	5.1	3.2	...	...	F22	
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	...	...	F11	A 336
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.1	13.7	9.3	6.3	4.2	2.8	...	...	F11	
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.0	16.4	11.3	7.2	4.5	2.8	...	...	F12	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	F22	
...	17.9	17.8	17.7	17.5	17.2	16.9	16.4	15.8	11.4	7.8	5.1	3.2	...	...	F22	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	10.3	7.0	4.3	F91	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	9.6	7.0	4.3	F91	
17.5	17.5	17.5	17.5	...	...	...	...	...	...	...	...	...	...	...	LF3	A 350
15.0	15.0	15.0	15.0	...	...	...	...	...	...	...	...	...	...	...	LF4	
...	13.4	...	...	...	...	...	...	...	...	...	...	...	...	...	LF5	
...	15.6	...	...	...	...	...	...	...	...	...	...	...	...	...	LF5	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	LF9	
															Wrought Fittings (Seamless and Welded)	
13.8	13.8	13.8	13.8	13.8	13.8	13.5	13.2	...	...	...	...	...	...	...	WP1	A 234
14.4	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	WP5	
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	...	...	WP11	
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	...	...	WP12	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	WP22	A 234
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	10.3	7.0	4.3	WP91	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	9.6	7.0	4.3	WP91	

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Castings								
A 217	WC1	...	C–½Mo	3	(2)(3)(4)	65	35	0.80
	WC4	...	1Ni–½Cr–½Mo	4	(3)(4)	70	40	0.80
	WC5	...	¾Ni–1Mo–¾Cr	4	(3)(4)	70	40	0.80
	WC6	...	1¼Cr–½Mo	4	(3)(4)	70	40	0.80
A 217	WC9	...	2¼Cr–1Mo	5A	(3)(4)(5)	70	40	0.80
	C5	...	5Cr–½Mo	5B	(3)(4)(5)	90	60	0.80
	C12	...	9Cr–1Mo	5B	(3)(4)(5)	90	60	0.80
	C12A	...	9Cr–1Mo–V	5B	(3)(4)(5)	85	...	0.80
Bolts, Nuts, and Studs								
A 193	B5	...	5Cr–½Mo	...	(8)(9)(13)	100	80	1.00
	B7	...	1Cr–⅕Mo	...	(14)	125	105	1.00
	B7	...	1Cr–⅕Mo	...	(15)	115	95	1.00
	B7	...	1Cr–⅕Mo	...	(16)	100	75	1.00
	B7M	...	1Cr–⅕Mo	...	(1)(14)	100	80	1.00
A 193	B16	...	1Cr–½Mo–V	...	(14)	125	105	1.00
	B16	...	1Cr–½Mo–V	...	(15)	110	95	1.00
	B16	...	1Cr–½Mo–V	...	(16)	100	85	1.00
A 194	3	...	5Cr–½Mo–V	...	(10)	...	...	...
	4	...	C–Mo	...	(2)(10)	...	...	...
	7	...	Cr–Mo	...	(10)	...	...	...
A 320	L7	...	1Cr–⅕Mo	...	(1)(8)(18)	125	105	1.00
	L7M	...	1Cr–⅕Mo	...	(1)(14)	100	80	1.00
	L43	...	1¾Ni–¾Cr–¼Mo	...	(1)(8)(18)	125	105	1.00
A 354	BC	...	Alloy Steel	...	(8)(9)(14)	125	109	1.00
	BC	...	Alloy Steel	...	(8)(9)(15)	115	99	1.00
	BD	...	Alloy Steel	...	(8)(9)(14)	150	130	1.00
	BD	...	Alloy Steel	...	(8)(9)(15)	140	120	1.00

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
–20 to 400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
																Castings
13.0	13.0	13.0	13.0	13.0	13.0	12.6	12.2	...	...	...	...	...	...	...	WC1	A 217
14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.7	12.0	7.4	4.7	...	...	...	...	WC4	
14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.7	13.0	8.8	5.5	3.7	2.2	...	...	WC5	
14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.7	11.0	7.4	5.0	3.4	2.2	...	...	WC6	
...	13.4	13.4	13.4	13.3	12.9	12.6	12.0	11.4	9.1	6.2	4.1	2.6	...	...	WC9	A 217
...	17.3	17.0	16.7	16.4	15.8	15.3	11.4	8.7	6.4	4.6	3.4	2.3	1.4	0.80	C5	
...	17.3	17.0	16.7	16.4	15.8	15.3	14.6	13.2	8.8	5.9	4.0	2.6	1.7	1.2	C12	
...	15.4	15.0	14.7	14.5	14.2	13.8	13.4	12.9	12.4	11.4	9.1	7.0	5.2	3.4	C12A	
																Bolts, Nuts, and Studs
20.0	20.0	20.0	20.0	20.0	20.0	18.5	14.5	10.4	7.6	5.6	4.2	3.1	2.0	1.3	B5	A 193
25.0	25.0	25.0	25.0	25.0	23.5	21.0	17.0	12.5	8.5	4.5	...	...	...	...	B7	
23.0	23.0	23.0	23.0	23.0	22.2	20.0	16.3	12.5	8.5	4.5	...	...	...	...	B7	
18.8	18.8	18.8	18.8	18.8	18.8	18.0	16.3	12.5	8.5	4.5	...	...	...	...	B7	
20.0	20.0	20.0	20.0	20.0	20.0	13.5	16.2	12.5	8.5	4.5	...	...	...	...	B7M	
25.0	25.0	25.0	25.0	25.0	25.0	25.0	23.5	20.5	16.0	11.0	6.3	2.8	...	...	B16	A 193
22.0	22.0	22.0	22.0	22.0	22.0	22.0	21.0	18.5	15.3	11.0	6.3	2.8	...	...	B16	
20.0	20.0	20.0	20.0	20.0	20.0	20.0	18.8	16.7	14.3	11.0	6.3	2.8	...	...	B16	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	A 194
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7	
25.0	25.0	25.0	25.0	25.0	...	...	...	...	...	...	...	...	...	...	L7	A 320
20.0	20.0	20.0	20.0	20.0	20.0	18.5	16.2	12.5	8.5	4.5	...	...	...	...	L7M	
25.0	25.0	25.0	25.0	25.0	...	...	...	...	...	...	...	...	...	...	L43	
25.0	25.0	25.0	25.0	...	...	...	...	...	...	...	...	...	...	...	BC	A 354
23.0	23.0	23.0	23.0	...	...	...	...	...	...	...	...	...	...	...	BC	
30.0	30.0	30.0	30.0	...	...	...	...	...	...	...	...	...	...	...	BD	
28.0	28.0	28.0	28.0	...	...	...	...	...	...	...	...	...	...	...	BD	

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TABLE A-2 (CONT'D)

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.
(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.
(c) The P-Numbers indicated in this Table are identical to those adopted by the ASME Boiler and Pressure Vessel Code, Section IX, except as modified by para. 127.5
(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."
(e) The materials listed in this Table shall not be used at design temperatures above those for which allowable stress values are given.
(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. Weld joint efficiency factors are shown in Table 102.4.3.
(g) Pressure-temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.
(h) All the materials listed are classifed as ferritic [see Table 104.1.2(A)].

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR USE ON BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) AND (B).
(2) Upon prolonged exposure to temperature above 875°F, the carbide phase of carbon-molybdenum steel may be converted to graphite.
(3) These allowable stress values apply to normalized and tempered material only.
(4) The material quality factors and allowable stress values for these materials may be increased in accordance with para. 102.4.6.
(5) At 400°F and below, the following allowable stress values apply:

Spec. No.	Grade	Type or Class	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F	Metal Temperature, °F: −20 to 100	200	300	400
A 182	F5	...	70	40	1.00	17.5	17.5	17.0	16.8
	F5a	...	90	65	1.00	22.5	22.4	21.8	21.6
	F9	...	85	55	1.00	21.3	21.2	20.6	20.4
A 182	F21	...	75	45	1.00	18.8	18.8	18.3	18.0
	F22	Class 3	75	45	1.00	18.8	18.8	18.3	18.0
	F91	...	85	60	1.00	21.3	21.3	21.2	21.2
A 199	T5	...	60	25	1.00	15.0	14.1	13.6	13.4
	T9	...	60	25	1.00	15.0	14.1	13.6	13.4
A 213	T5	...	60	30	1.00	15.0	15.0	14.5	14.4
	T5b	...	60	30	1.00	15.0	15.0	14.5	14.4
	T5c	...	60	30	1.00	15.0	15.0	14.5	14.4
A 213	T9	...	60	30	1.00	15.0	15.0	14.5	14.4
	T91	...	85	60	1.00	21.3	21.3	21.2	21.2
A 217	WC9	...	70	40	0.80	14.0	14.0	13.8	13.5
	C5	...	90	60	0.80	18.0	17.9	17.4	17.3
	C12	...	90	60	0.80	18.0	17.9	17.4	17.3
	C12A	...	85	...	0.80	17.0	17.0	16.5	15.9
A 333	9	Seamless	63	46	1.00	15.8	...	...	...
	9	Welded	63	46	0.85	13.4	...	...	...
A 335	P5	...	60	30	1.00	15.0	15.0	14.5	14.4
	P5b	...	60	30	1.00	15.0	15.0	14.5	14.4
	P5c	...	60	30	1.00	15.0	15.0	14.5	14.4
	P9	...	60	30	1.00	15.0	15.0	14.5	14.4
	P91	...	85	60	1.00	21.3	21.3	21.2	21.2
A 336	F22	Class 3	75	45	1.00	18.8	18.8	18.3	18.0
	F91	...	85	60	1.00	21.3	21.3	21.2	21.2

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TABLE A-2 (CONT'D)

01

NOTES (CONT'D):

Spec. No.	Grade	Type or Class	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F	Metal Temperature, °F: -20 to 100	200	300	400
A 350	LF5	Class 1	60	30	1.00	15.0	14.4	13.7	13.4
	LF5	Class 2	70	37	1.00	17.5	16.8	16.0	15.6
	LF9	...	63	46	1.00	15.8	...	...	...
A 369	FP5	...	60	30	1.00	15.0	15.0	14.5	14.4
	FP9	...	60	30	1.00	15.0	15.0	14.5	14.4
A 387	5	1	60	30	1.00	15.0	15.0	14.5	14.4
	5	2	75	45	1.00	18.8	18.7	18.2	18.0
	21	2	75	45	1.00	18.8	18.8	18.3	18.0
	22	2	75	45	1.00	18.8	18.8	18.3	18.0
A 387	91	2	85	60	1.00	21.3	21.3	21.2	21.2
	91	2	85	60	0.90	19.1	19.1	19.0	19.0
A 426	CP5	...	90	60	0.85	19.1	19.0	18.5	18.4
	CP5b	...	60	30	0.85	12.8	12.8	12.3	12.2
	CP9	...	90	60	0.85	19.1	19.0	18.5	18.4
	CP21	...	60	...	0.85	12.8	12.8	12.5	12.3
	CP22	...	70	40	0.85	14.9	14.9	14.7	14.4
A 691	$2^1/_4$Cr	20,23,30,33,40,43	75	45	0.90	16.9	16.9	16.5	16.2
	$2^1/_4$Cr	21,22,31,32,41,42	75	45	1.00	18.8	18.8	18.3	18.0
A 691	3Cr	20,23,30,33,40,43	75	45	0.90	16.9	16.9	16.5	16.2
	3Cr	21,22,31,32,41,42	75	45	1.00	18.8	18.8	18.3	18.0
A 691	5Cr	20,23	60	30	0.90	13.5	13.5	13.1	13.0
	5Cr	21,22	60	30	1.00	15.0	15.0	14.5	14.4
	5Cr	20,23,30,33,40,43	75	45	0.90	16.9	16.8	16.4	16.2
	5Cr	21,22,31,32,41,42	75	45	1.00	18.8	18.7	18.2	18.0
A 714	V	S	65	46	1.00	15.8	...	...	...
	V	E	65	46	0.85	13.4	...	...	...

(6) If A 234 Grade WP-12 fittings are made from A 387 Grade 12 annealed plate, the allowable stress values shall be reduced by the ratio of 55 divided by 60 in the temperature range −20°F through 850°F. At 900°F through 1100°F, the values shown may be used.

(7) The mutual quality factor for centrifugally cast pipe (0.85) is based on all surfaces being machined, after heat treatment, to a surface finish of 250 μin. arithmetic average deviation or better.

(8) These allowable stress values are established from a consideration of strength only and will be satisfactory for average service. For bolted joints, where freedom from leakage over a long period of time without retightening is required, lower stress values may be necessary as determined from the relative flexibility of the flange and bolts and corresponding relaxation properties.

(9) Between temperatures of −20°F and 400°F, allowable stress values equal to the lower of the following may be used: 20% of the specified tensile strength, or 25% of the specified yield strength.

(10) This is a product specification. Allowable stress values are not necessary. Limitations on metal temperature for materials covered by this specification for use under ASME B31.1 are:

Grade 3	−20°F to 1100°F
Grade 4	−20°F to 900°F

(11) These allowable stress values are for pipe fabricated from ASTM A 387 Class 1 plate in the annealed condition.

(12) These allowable stress values are for pipe fabricated from ASTM A 387 Class 2 plate.

(13) These allowable stress values apply to bolting materials 4 in. in diameter and smaller.

(14) These allowable stress values apply to bolting materials $2^1/_2$ in. but not larger than 4 in. in diameter.

(15) These allowable stress values apply to bolting materials larger than $2^1/_2$ in. but not larger than 4 in. in diameter.

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01 TABLE A-2 (CONT'D)

NOTES (CONT'D):

(16) These allowable stress values apply to bolting materials larger than 4 in. but not larger than 7 in. in diameter.
(17) For use at temperatures above 850°F, the carbon content of the base material and, where applicable, weld filler metal shall be 0.05% or higher. See para. 124.2(D).
(18) Minimum tempering temperature shall be 800°F.
(19) These allowable stress values apply to thickness less than 3 in.
(20) These allowable stress values apply to thickness 3 in. or greater.

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APPENDIX A, TABLE A-3

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TABLE A-3
STAINLESS STEELS

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube									
Austenitic									
A 213	TP304	...	S30400	18Cr–8Ni	8	(10)	75	30	1.00
	TP304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	1.00
	TP304H	...	S30409	18Cr-8Ni	8	...	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	(9)	75	30	1.00
A 213	TP304L	...	S30403	18Cr–8Ni	8	(1)	70	25	1.00
	TP304L	...	S30403	18Cr–8Ni	8	(1)(9)	70	25	1.00
	TP304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	1.00
	TP304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	1.00
A 213	TP309H		S30909	23Cr–12Ni	8	(9)	75	30	1.00
	TP309H		S30909	23Cr–12Ni	8	...	75	30	1.00
	TP310H		S31009	25Cr–20Ni	8	(9)	75	30	1.00
	TP310H		S31009	25Cr–20Ni	8	...	75	30	1.00
A 213	TP316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	1.00
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	1.00
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	1.00
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	1.00
A 213	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	1.00
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	1.00
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	1.00
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	1.00
A 213	TP321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	1.00
	TP321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	1.00
	TP321H	...	S32109	18Cr–10Ni–Ti	8	...	75	30	1.00
	TP321H	...	S32109	18Cr–10Ni–Ti	8	(9)	75	30	1.00
A 213	TP347	...	S34700	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	TP347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
	TP347H	...	S34709	18Cr–10Ni–Cb	8	...	75	30	1.00
	TP347H	...	S34709	18Cr–10Ni–Cb	8	(9)	75	30	1.00
A 213	TP348	...	S34800	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	TP348	...	S34800	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
	TP348H	...	S34809	18Cr–10Ni–Cb	8	...	75	30	1.00
	TP348H	...	S34809	18Cr–10Ni–Cb	8	(9)	75	30	1.00

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TABLE A-3
STAINLESS STEELS

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Seamless Pipe and Tube Austenitic	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304	A 213
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304H	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304H	
15.7	13.4	12.0	11.0	10.3	9.7	9.5	9.4	9.2	9.1	...	...	...	...	...	...	...	...	TP304L	A 213
15.7	15.7	15.3	14.7	14.4	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	TP304L	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.8	11.6	11.3	11.1	10.8	10.6	10.3	9.8	7.7	6.1	TP304N	
20.0	20.0	19.0	18.3	17.6	17.4	17.3	17.2	16.9	16.7	16.3	15.9	15.6	15.0	12.4	9.8	7.7	6.1	TP304N	
18.8	18.8	18.7	18.3	17.9	17.5	17.3	17.1	16.8	16.5	16.1	15.6	15.1	13.8	10.3	7.6	5.5	4.0	TP309H	A 213
18.8	17.6	16.1	15.1	14.1	13.9	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	10.3	7.6	5.5	4.0	TP309H	
18.8	18.4	17.6	17.4	17.4	17.4	17.4	17.4	17.2	17.0	16.7	16.3	15.9	13.8	10.3	7.6	5.5	4.0	TP310H	
18.8	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	12.1	10.3	7.6	5.5	4.0	TP310H	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316	A 213
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316H	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316H	
15.7	13.3	11.9	10.8	10.0	9.4	9.2	9.0	8.8	8.6	8.4	...	...	...	...	...	...	...	TP316L	A 213
15.7	15.7	15.7	15.5	14.4	13.5	13.2	12.9	12.6	12.4	12.1	...	...	...	...	...	...	...	TP316L	
20.0	19.4	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	TP316N	
20.0	20.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1	17.8	17.4	15.8	12.4	9.8	7.4	TP316N	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	TP321	A 213
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	TP321	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	TP321H	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	TP321H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP347	A 213
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP347	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.8	12.8	12.7	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	TP347H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	TP347H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP348	A 213
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP348	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.8	12.8	12.7	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	TP348H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	TP348H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube (Cont'd)									
Austenitic (Cont'd)									
A 312	TP304	...	S30400	18Cr–8Ni	8	(10)	75	30	1.00
	TP304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	...	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	(9)	75	30	1.00
A 312	TP304L	...	S30403	18Cr–8Ni	8	(1)	70	25	1.00
	TP304L	...	S30403	18Cr–8Ni	8	(1)(9)	70	25	1.00
	TP304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	1.00
	TP304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	1.00
A 312	TP309H		S30909	23Cr–12Ni	8	(9)	75	30	1.00
	TP309H		S30909	23Cr–12Ni	8	...	75	30	1.00
	TP310H		S31009	25Cr–20Ni	8	(9)	75	30	1.00
	TP310H		S31009	25Cr–20Ni	8	...	75	30	1.00
A 312	TP316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	1.00
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	1.00
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	1.00
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	1.00
A 312	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	1.00
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	1.00
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	1.00
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	1.00
A 312	TP317	...	S31700	18Cr–13Ni–3Mo	8	(1)(10)	75	30	1.00
	TP317	...	S31700	18Cr–13Ni–3Mo	8	(1)(9)(10)	75	30	1.00
	TP321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	1.00
	TP321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	1.00
	TP321H	...	S32109	18Cr–10Ni–Ti	8	...	75	30	1.00
	TP321H	...	S32109	18Cr–10Ni–Ti	8	(9)	75	30	1.00
A 312	TP347	...	S34700	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	TP347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
	TP347H	...	S34709	18Cr–10Ni–Cb	8	...	75	30	1.00
	TP347H	...	S34709	18Cr–10Ni–Cb	8	(9)	75	30	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Type or Grade	Spec. No.
																		Seamless Pipe and Tube (Cont'd) Austenitic (Cont'd)	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304	A 312
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304H	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304H	
15.7	13.4	12.0	11.0	10.3	9.7	9.5	9.4	9.2	9.1	...	...	...	...	...	...	...	...	TP304L	A 312
15.7	15.7	15.3	14.7	14.4	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	TP304L	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.8	11.6	11.3	11.1	10.8	10.6	10.3	9.8	7.7	6.1	TP304N	
20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.2	16.9	16.7	16.3	15.9	15.6	15.0	12.4	9.8	7.7	6.1	TP304N	
18.8	18.8	18.7	18.3	17.9	17.5	17.3	17.1	16.8	16.5	16.1	15.6	15.1	13.8	10.3	7.6	5.5	4.0	TP309H	A 312
18.8	17.6	16.1	15.1	14.1	13.9	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.8	10.3	7.6	5.5	4.0	TP309H	
18.8	18.4	17.6	17.4	17.4	17.4	17.4	17.4	17.2	17.0	16.7	16.3	15.9	13.8	10.3	7.6	5.5	4.0	TP310H	
18.8	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	12.1	10.3	7.6	5.5	4.0	TP310H	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316	A 312
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316H	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316H	
15.7	13.3	11.9	10.8	10.0	9.4	9.2	9.0	8.8	8.6	8.4	...	...	...	...	...	...	...	TP316L	A 312
15.7	15.7	15.7	15.5	14.4	13.5	13.2	12.9	12.6	12.4	12.1	...	...	...	...	...	...	...	TP316L	
20.0	19.4	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	TP316N	
20.0	20.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1	17.8	17.4	15.8	12.4	9.8	7.4	TP316N	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP317	A 312
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	14.5	12.4	9.8	7.4	TP317	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	TP321	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	TP321	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	TP321H	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	TP321H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP347	A 312
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP347	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.8	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	TP347H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	TP347H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube (Cont'd)									
Austenitic (Cont'd)									
A 312	TP348	...	S34800	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	TP348	...	S34800	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
	TP348H	...	S34809	18Cr–10Ni–Cb	8	...	75	30	1.00
	TP348H	...	S34809	18Cr–10Ni–Cb	8	(9)	75	30	1.00
A 312	TPXM15	...	S38100	18Cr–18Ni–2Si	8	(1)	75	30	1.00
	TPXM15	...	S38100	18Cr–18Ni–2Si	8	(1)(9)	75	30	1.00
	TPXM19	...	S20910	22Cr–13Ni–5Mn	8	(1)	100	35	1.00
	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(32)	94	44	1.00
	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(9)(32)	94	44	1.00
A 376	TP304	...	S30400	18Cr–8Ni	8	(10)	75	30	1.00
	TP304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	...	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	(9)	75	30	1.00
	TP304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	1.00
	TP304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	1.00
A 376	TP316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	1.00
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	1.00
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	1.00
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	1.00
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	1.00
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	1.00
A 376	TP321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	1.00
	TP321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	1.00
	TP321H	...	S32109	18Cr–10Ni–Ti	8	...	75	30	1.00
	TP321H	...	S32109	18Cr–10Ni–Ti	8	(9)	75	30	1.00
A 376	TP347	...	S34700	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	TP347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
	TP347H	...	S34709	18Cr–10Ni–Cb	8	...	75	30	1.00
	TP347H	...	S34709	18Cr–10Ni–Cb	8	(9)	75	30	1.00
A 376	TP348	...	S34800	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	TP348	...	S34800	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Type or Grade	Spec. No.
																		Seamless Pipe and Tube (Cont'd) Austenitic (Cont'd)	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP348	A 312
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP348	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.8	12.7	12.6	12.6	12.5	12.5	12.1	10.5	7.9	TP348H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	TP348H	
18.8	15.6	14.0	12.9	12.1	11.4	11.2	11.0	10.8	10.5	10.3	10.1	9.9	9.7	...	...	...	...	TPXM15	A 312
18.8	17.7	16.6	16.1	15.9	15.9	15.9	15.9	15.5	15.1	14.9	14.6	14.3	13.7	...	...	...	...	TPXM15	
21.3	21.2	20.1	19.3	19.0	18.6	18.5	18.4	18.2	18.0	17.8	17.5	17.2	16.9	16.6	...	...	...	TPXM19	
23.5	23.5	21.4	19.9	18.5	17.9	17.7	17.5	17.3	...	...	...	...	...	...	...	...	...	...	
23.5	23.5	22.4	21.3	20.5	20.1	19.9	19.9	19.8	...	...	...	...	...	...	...	...	...	...	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304	A 376
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304H	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304H	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.8	11.6	11.3	11.1	10.8	10.6	10.3	9.8	7.7	6.1	TP304N	
20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.2	16.9	16.7	16.3	15.9	15.6	15.0	12.4	9.8	7.7	6.1	TP304N	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316	A 376
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316H	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316H	
20.0	19.4	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	TP316N	
20.0	20.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1	17.8	17.4	15.8	12.4	9.8	7.4	TP316N	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	TP321	A 376
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	TP321	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	TP321H	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	TP321H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP347	A 376
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP347	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.8	12.7	12.7	12.6	12.6	12.5	12.1	10.5	7.9	TP347H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	TP347H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP348	A 376
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP348	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube (Cont'd)									
Austenitic (Cont'd)									
A 430	FP304	...	S30400	18Cr–8Ni	8	(10)(11)	70	30	1.00
	FP304	...	S30400	18Cr–8Ni	8	(9)(10)(11)	70	30	1.00
	FP304H	...	S30409	18Cr–8Ni	8	...	70	30	1.00
	FP304H	...	S30409	18Cr–8Ni	8	(9)	70	30	1.00
	FP304N	...	S30451	18Cr–8Ni–N	8	(10)	75	35	1.00
	FP304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	75	35	1.00
A 430	FP316	...	S31600	16Cr–12Ni–2Mo	8	(10)(11)	70	30	1.00
	FP316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)(11)	70	30	1.00
	FP316H	...	S31609	16Cr–12Ni–2Mo	8	...	70	30	1.00
	FP316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	70	30	1.00
	FP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	75	35	1.00
	FP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	75	35	1.00
A 430	FP321	...	S32100	18Cr–10Ni–Ti	8	(10)(11)	70	30	1.00
	FP321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)(11)	70	30	1.00
	FP321H	...	S32109	18Cr–10Ni–Ti	8	...	70	30	1.00
	FP321H	...	S32109	18Cr–10Ni–Ti	8	(9)	70	30	1.00
A 430	FP347	...	S34700	18Cr–10Ni–Cb	8	(10)(11)	70	30	1.00
	FP347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)(11)	70	30	1.00
	FP347H	...	S34709	18Cr–10Ni–Cb	8	...	70	30	1.00
	FP347H	...	S34709	18Cr–10Ni–Cb	8	(9)	70	30	1.00
Ferritic/Martensitic									
A 268	TP405	...	S40500	12Cr–Al	7	(3)	60	30	1.00
	TP410	...	S41000	13Cr	6	...	60	30	1.00
	TP429	...	S42900	15Cr	6	(3)	60	35	1.00
	TP430	...	S43000	17Cr	7	(3)	60	35	1.00
	TPXM27	...	S44627	26Cr–1Mo	10I	(1)(2)(32)	65	40	1.00
	TP446-1	...	S44600	27Cr	10I	(32)	70	40	1.00
	TPXM33	...	S44626	27Cr–1Mo–Ti	10I	(2)(32)	68	45	1.00
A 731	TPXM27	...	S44627	27Cr–1Mo	10I	(2)(32)	65	40	1.00
	TPXM33	...	S44626	27Cr–1Mo–Ti	10I	(2)(32)	65	40	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Seamless Pipe and Tube (Cont'd) Austenitic (Cont'd)	
17.5	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	FP304	A 430
17.5	16.6	15.5	15.1	14.8	14.8	14.8	14.8	14.7	14.6	14.4	14.2	13.9	13.4	12.0	9.7	7.7	6.1	FP304	
17.5	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	FP304H	
17.5	16.6	15.5	15.1	14.8	14.8	14.8	14.8	14.7	14.6	14.4	14.2	13.9	13.4	12.0	9.7	7.7	6.1	FP304H	
18.8	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.8	11.6	11.3	11.1	10.8	10.6	10.3	9.8	7.7	6.1	FP304N	
18.8	18.8	17.8	17.1	16.7	16.3	16.2	16.1	15.9	15.8	15.6	15.4	15.1	14.5	12.4	9.8	7.7	6.1	FP304N	
17.5	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	FP316	A 430
17.5	17.5	17.1	16.8	16.8	16.8	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.0	14.1	12.4	9.8	7.4	FP316	
17.5	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	FP316H	
17.5	17.5	17.1	16.8	16.8	16.8	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.0	14.1	12.4	9.8	7.4	FP316H	
18.8	18.8	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	FP316N	
18.8	18.8	18.0	17.6	17.4	17.4	17.4	17.4	17.4	17.3	17.1	17.0	16.7	16.3	15.7	12.4	9.8	7.4	FP316N	
17.5	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	FP321	A 430
17.5	17.2	16.2	16.0	16.0	16.0	16.0	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	FP321	
17.5	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	FP321H	
17.5	17.2	16.2	16.0	16.0	16.0	16.0	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	FP321H	
17.5	16.7	15.3	14.4	13.9	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	FP347	A430
17.5	16.7	15.3	14.4	13.9	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.6	13.2	12.0	9.1	6.1	4.4	FP347	
17.5	16.7	15.3	14.4	13.9	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	FP347H	
17.5	16.7	15.3	14.4	13.9	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.6	13.5	13.2	12.5	10.5	7.9	FP347H	
																		Ferritic/Martensitic	
15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	...	...	...	...	...	...	...	...	...	...	TP405	A 268
15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	...	...	...	...	...	...	...	...	...	...	TP410	
15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	...	...	...	...	...	...	...	...	...	...	TP429	
15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	...	...	...	...	...	...	...	...	...	...	TP430	
16.2	16.2	15.9	15.9	15.9	15.9	15.9	...	...	...	...	...	...	...	...	...	...	...	TPXM27	
17.5	16.6	16.1	15.6	15.0	14.5	14.3	...	...	...	...	...	...	...	...	...	...	...	TP446-1	
17.0	17.0	16.8	16.6	16.4	16.1	15.9	...	...	...	...	...	...	...	...	...	...	...	TPXM33	
16.2	16.2	15.9	15.9	15.9	15.9	15.9	...	...	...	...	...	...	...	...	...	...	...	TPXM27	A 731
16.3	16.3	16.1	15.9	15.7	15.4	15.2	...	...	...	...	...	...	...	...	...	...	...	TPXM33	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Centrifugally Cast Pipe Austenitic									
A 451	CPF8	...	J92600	18Cr–8Ni	8	(1)(8)(10)(26)	70	30	0.85
	CPF8	...	J92600	18Cr–8Ni	8	(1)(8)(9)(10)(26)	70	30	0.85
	CPF8C	...	J92710	18Cr–10Ni–Cb	8	(1)(8)(10)(26)	70	30	0.85
	CPF8C	...	J92710	18Cr–10Ni–Cb	8	(1)(8)(9)(10)(26)	70	30	0.85
	CPF8M	...	J92900	18Cr–9Ni–2Mo	8	(1)(8)(13)(26)	70	30	0.85
	CPF8M	...	J92900	18Cr–9Ni–2Mo	8	(1)(8)(9)(13)(26)	70	30	0.85
A 451	CPH8	...	J93400	25Cr–12Ni	8	(1)(8)(10)(26)	65	28	0.85
	CPH8	...	J93400	25Cr–12Ni	8	(1)(8)(9)(10)(26)	65	28	0.85
	CPH10	...	J93410	25Cr–12Ni	8	(1)(6)(8)(10)(26)	(70)	30	0.85
	CPH10	...	J93410	25Cr–12Ni	8	(1)(6)(8)(9)(10)(26)	(70)	30	0.85
A 451	CPH20	...	J93402	25Cr–12Ni	8	(1)(6)(8)(10)(26)	(70)	30	0.85
	CPH20	...	J93402	25Cr–12Ni	8	(1)(6)(8)(9)(10)(26)	(70)	30	0.85
	CPK20	...	J94202	25Cr–20Ni	8	(1)(8)(10)(26)	65	28	0.85
	CPK20	...	J94202	25Cr–20Ni	8	(1)(8)(9)(10)(26)	65	28	0.85
A 452	TP304H	...	J92590	18Cr–8Ni	8	(1)(8)(26)	75	30	0.85
	TP304H	...	J92590	18Cr–8Ni	8	(1)(8)(9)(26)	75	30	0.85
	TP316H	...	J92920	16Cr–12Ni–2Mo	8	(1)(8)(26)	75	30	0.85
	TP316H	...	J92920	16Cr–12Ni–2Mo	8	(1)(8)(9)(26)	75	30	0.85
	TP347H	...	J92660	18Cr–10Ni–Cb	8	(1)(8)(26)	75	30	0.85
	TP347H	...	J92660	18Cr–10Ni–Cb	8	(1)(8)(9)(26)	75	30	0.85
Welded Pipe and Tube — Without Filler Metal Austenitic									
A 249	TP304	...	S30400	18Cr–8Ni	8	(10)	75	30	0.85
	TP304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	0.85
	TP304H	...	S30409	18Cr–8Ni	8	...	75	30	0.85
	TP304H	...	S30409	18Cr–8Ni	8	(9)	75	30	0.85
A 249	TP304L	...	S30403	18Cr–8Ni	8	(1)	70	25	0.85
	TP304L	...	S30403	18Cr–8Ni	8	(1)(9)	70	25	0.85
	TP304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	0.85
	TP304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	0.85

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Centrifugally Cast Pipe Austenitic	
14.9	13.3	11.9	11.0	10.3	9.7	9.5	9.4	9.2	8.9	8.8	8.6	8.4	8.1	7.7	6.4	4.9	3.8	CPF8	A 451
14.9	14.0	12.8	12.8	12.6	12.6	12.6	12.6	12.5	12.4	12.2	12.0	11.4	10.2	8.2	6.4	4.9	3.8	CPF8	
14.9	14.1	13.0	12.2	11.8	11.4	11.1	11.0	10.9	10.8	10.7	10.7	10.6	10.1	9.5	8.9	6.8	4.2	CPF8C	
14.9	14.1	13.0	12.2	11.8	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.5	11.2	10.2	8.8	6.8	4.2	CPF8C	
14.9	13.7	12.4	11.3	10.5	10.0	9.8	9.6	9.4	9.4	9.3	9.2	9.1	9.0	8.6	8.0	6.8	5.1	CPF8M	
14.9	14.9	14.5	14.3	14.3	14.3	14.1	13.9	13.6	13.4	13.3	13.2	13.1	12.7	10.2	8.0	6.8	5.1	CPF8M	
13.9	12.7	12.1	11.7	11.2	10.6	10.4	10.1	9.9	9.7	9.4	9.3	9.2	8.4	7.2	5.5	4.3	3.2	CPH8	A 451
13.9	12.7	12.1	11.7	11.5	11.3	11.2	11.1	11.1	11.1	10.9	10.6	10.0	8.9	7.2	5.5	4.3	3.2	CPH8	
14.9	13.7	13.0	12.6	12.0	11.4	11.1	10.8	10.6	10.4	10.1	9.9	9.5	8.7	7.2	5.5	4.3	3.2	CPH10	
14.9	13.7	13.0	12.6	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.3	10.6	8.9	7.2	5.5	4.0	3.2	CPH10	
14.9	13.7	13.0	12.6	12.0	11.4	11.1	10.8	10.6	10.4	10.1	9.9	9.5	8.7	7.2	5.5	4.3	3.2	CPH20	A 451
14.9	13.7	13.0	12.6	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.3	10.6	8.9	7.2	5.5	4.0	3.2	CPH20	
13.9	12.7	12.1	11.7	11.2	10.6	10.4	10.1	9.9	9.7	9.4	9.3	9.0	8.8	8.3	7.2	6.2	5.1	CPK20	
13.9	12.7	12.1	11.7	11.5	11.3	11.2	11.1	11.1	11.1	10.9	10.6	10.1	9.4	8.3	7.2	6.2	5.1	CPK20	
16.0	13.3	12.0	11.0	10.3	9.7	9.5	9.4	9.2	9.0	8.8	8.7	8.5	8.3	8.1	7.6	6.5	5.2	TP304H	A 452
16.0	15.1	14.1	13.8	13.5	13.5	13.5	13.5	13.2	12.9	12.7	12.5	12.2	11.7	10.4	8.3	6.5	5.2	TP304H	
16.0	13.8	12.4	11.4	10.6	10.0	9.9	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	7.9	6.3	TP316H	
16.0	16.0	15.6	15.4	15.3	14.5	13.2	13.9	13.7	13.5	13.3	13.2	13.1	13.0	12.3	10.5	8.3	6.3	TP316H	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.7	...	...	...	...	TP347H	
16.0	15.2	13.9	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	12.2	...	...	...	...	TP347H	
																		Welded Pipe and Tube – Without Filler Metal Austenitic	
16.0	13.3	12.0	11.0	10.5	9.7	9.5	9.4	9.2	9.0	8.8	8.7	8.5	8.3	8.1	7.6	6.5	5.2	TP304	A 249
16.0	15.1	14.1	13.8	13.5	13.5	13.5	13.5	13.2	12.9	12.7	12.5	12.2	11.7	10.4	8.3	6.5	5.2	TP304	
16.0	13.3	12.0	11.0	10.5	9.7	9.5	9.4	9.2	9.0	8.8	8.7	8.5	8.3	8.1	7.6	6.5	5.2	TP304H	
16.0	15.1	14.1	13.8	13.5	13.5	13.5	13.5	13.2	12.9	12.7	12.5	12.2	11.7	10.4	8.3	6.5	5.2	TP304H	
13.3	11.4	10.2	9.3	8.7	8.3	8.1	8.0	7.8	7.7	...	...	...	...	...	...	...	...	TP304L	A 249
13.3	13.3	13.0	12.5	12.3	11.9	11.7	11.5	11.3	11.1	...	...	...	...	...	...	...	...	TP304L	
17.0	15.2	13.3	12.0	11.1	10.5	10.4	10.1	10.0	9.8	9.6	9.4	9.2	9.0	8.8	8.3	6.5	5.1	TP304N	
17.0	17.0	16.2	15.6	15.1	14.8	14.7	14.6	14.4	14.2	13.9	13.5	13.3	12.8	10.5	8.3	6.5	5.1	TP304N	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Welded Pipe and Tube — Without Filler Metal (Cont'd) Austenitic (Cont'd)									
A 249	TP309H	...	S30909	23Cr–12Ni	8	(9)	75	30	0.85
	TP309H	...	S30909	23Cr–12Ni	8	...	75	30	0.85
A 249	TP316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	0.85
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	0.85
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	0.85
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	0.85
A 249	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	0.85
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	0.85
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	0.85
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	0.85
A 249	TP317	...	S31700	19Cr–13Ni–3Mo	8	(1)(10)	75	30	0.85
	TP317	...	S31700	19Cr–13Ni–3Mo	8	(1)(9)(10)	75	30	0.85
	TP321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	0.85
	TP321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	0.85
	TP321H	...	S32109	18Cr–10Ni–Ti	8	...	75	30	0.85
	TP321H	...	S32109	18Cr–10Ni–Ti	8	(9)	75	30	0.85
A 249	TP347	...	S34700	18Cr–10Ni–Cb	8	(10)	75	30	0.85
	TP347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	0.85
	TP347H	...	S34709	18Cr–10Ni–Cb	8	...	75	30	0.85
	TP347H	...	S34709	18Cr–10Ni–Cb	8	(9)	75	30	0.85
A 249	TP348	...	S34800	18Cr–10Ni–Cb	8	(10)	75	30	0.85
	TP348	...	S34800	18Cr–10Ni–Cb	8	(9)(10)	75	30	0.85
	TP348H	...	S34809	18Cr–10Ni–Cb	8	...	75	30	0.85
	TP348H	...	S34809	18Cr–10Ni–Cb	8	(9)	75	30	0.85
A 249	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(32)	94	44	0.85
	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(9)(32)	94	44	0.85
A 312	TP304	...	S30400	18Cr–8Ni	8	(10)	75	30	0.85
	TP304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	0.85
	TP304H	...	S30409	18Cr–8Ni	8	...	75	30	0.85
	TP304H	...	S30409	18Cr–8Ni	8	(9)	75	30	0.85

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Type or Grade	Spec. No.
Welded Pipe and Tube – Without Filler Metal (Cont'd)																			
Austenitic (Cont'd)																			
16.0	16.0	15.9	15.6	15.2	14.9	14.7	14.5	14.3	14.1	13.7	13.3	12.8	11.7	8.8	6.5	4.7	3.4	TP309H	A 249
16.0	15.0	13.7	12.8	12.0	11.8	11.6	11.5	11.3	11.1	11.0	10.8	10.6	10.5	8.8	6.5	4.7	3.4	TP309H	
16.0	13.8	12.4	11.4	10.6	10.1	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	7.9	6.3	TP316	A 249
16.0	16.0	15.6	15.4	15.3	14.5	14.2	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.3	10.6	8.4	6.3	TP316	
16.0	13.8	12.4	11.4	10.6	10.1	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	7.9	6.3	TP316H	
16.0	16.0	15.6	15.4	15.3	14.5	14.2	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.3	10.6	8.4	6.3	TP316H	
13.3	11.3	10.1	9.2	8.5	8.0	7.8	7.6	7.5	7.3	7.2	...	...	...	...	...	...	...	TP316L	A 249
13.3	13.3	13.3	13.2	12.3	11.5	11.1	10.9	10.7	10.5	10.3	...	...	...	...	...	...	...	TP316L	
17.0	16.5	15.1	14.0	13.1	12.4	12.1	11.8	11.6	11.3	11.1	10.9	10.7	10.5	10.4	9.9	8.3	6.3	TP316N	
17.0	17.0	16.3	16.0	15.8	15.8	15.8	15.8	15.7	15.6	15.6	15.4	15.1	14.8	13.4	10.5	8.3	6.3	TP316N	
16.0	13.8	12.4	11.4	10.6	10.1	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	7.9	6.3	TP317	A 249
16.0	16.0	15.6	15.4	15.3	14.5	14.2	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.3	10.6	8.4	6.3	TP317	
16.0	13.5	12.1	11.0	10.2	9.7	9.5	9.3	9.2	9.2	9.1	9.0	9.0	8.9	7.8	5.9	4.3	3.1	TP321	
16.0	15.6	14.7	14.6	14.6	13.9	13.7	13.5	13.3	13.2	13.1	13.0	12.9	11.8	8.2	5.9	4.3	3.1	TP321	
16.0	13.5	12.1	11.0	10.2	9.7	9.5	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.6	7.5	5.9	4.6	TP321H	
16.0	15.6	14.7	14.6	14.6	13.9	13.7	13.5	13.3	13.2	13.1	13.0	12.9	11.9	10.0	7.7	5.9	4.6	TP321H	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.6	10.1	7.8	5.2	3.8	TP347	A 249
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	11.9	10.3	7.8	5.2	3.8	TP347	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.7	10.6	10.3	8.9	6.7	TP347H	
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	12.3	12.0	11.1	8.9	6.7	TP347H	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.7	10.7	10.6	10.1	7.8	5.2	3.8	TP348	A 249
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	11.9	10.3	7.8	5.2	3.8	TP348	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.7	10.6	10.3	8.9	6.7	TP348H	
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	12.3	12.0	11.1	8.9	6.7	TP348H	
20.0	20.0	18.2	16.9	15.7	15.2	15.0	14.9	14.7	...	...	...	...	...	...	...	...	...	S31254	A 249
20.0	20.0	19.0	18.1	17.4	17.1	16.9	16.9	16.8	...	...	...	...	...	...	...	...	...	S31254	
16.0	13.3	12.0	11.0	10.5	9.7	9.5	9.4	9.2	9.0	8.8	8.7	8.5	8.3	8.1	7.6	6.5	5.2	TP304	A312
16.0	15.1	14.1	13.8	13.5	13.5	13.5	13.5	13.2	12.9	12.7	12.5	12.2	11.7	10.4	8.3	6.5	5.2	TP304	
16.0	13.3	12.0	11.0	10.5	9.7	9.5	9.4	9.2	9.0	8.8	8.7	8.5	8.3	8.1	7.6	6.5	5.2	TP304H	
16.0	15.1	14.1	13.8	13.5	13.5	13.5	13.5	13.2	12.9	12.7	12.5	12.2	11.7	10.4	8.3	6.5	5.2	TP304H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Welded Pipe and Tube — Without Filler Metal (Cont'd)									
Austenitic (Cont'd)									
A 312	TP304L	...	S30403	18Cr–8Ni	8	(1)	70	25	0.85
	TP304L	...	S30403	18Cr–8Ni	8	(1)(9)	70	25	0.85
	TP304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	0.85
	TP304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	0.85
A 312	TP309H	...	S30909	23Cr–12Ni	8	(9)	75	30	0.85
	TP309H	...	S30909	23Cr–12Ni	8	...	75	30	0.85
	TP310H	...	S31009	23Cr–20Ni	8	(9)	75	30	0.85
	TP310H	...	S31009	23Cr–20Ni	8	...	75	30	0.85
A 312	TP316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	0.85
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	0.85
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	0.85
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	0.85
A 312	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	0.85
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	0.85
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	0.85
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	0.85
A 312	TP317	...	S31700	19Cr–13Ni–3Mo	8	(1)(10)	75	30	0.85
	TP317	...	S31700	19Cr–13Ni–3Mo	8	(1)(9)(10)	75	30	0.85
	TP321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	0.85
	TP321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	0.85
	TP321H	...	S32109	18Cr–10Ni–Ti	8	...	75	30	0.85
	TP321H	...	S32109	18Cr–10Ni–Ti	8	(9)	75	30	0.85
A 312	TP347	...	S34700	18Cr–10Ni–Cb	8	(10)	75	30	0.85
	TP347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	0.85
	TP347H	...	S34709	18Cr–10Ni–Cb	8	...	75	30	0.85
	TP347H	...	S34709	18Cr–10Ni–Cb	8	(9)	75	30	0.85
A 312	TP348	...	S34800	18Cr–10Ni–Cb	8	(1)(10)	75	30	0.85
	TP348	...	S34800	18Cr–10Ni–Cb	8	(1)(9)(10)	75	30	0.85
	TP348H	...	S34809	18Cr–10Ni–Cb	8	(1)	75	30	0.85
	TP348H	...	S34809	18Cr–10Ni–Cb	8	(1)(9)	75	30	0.85

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
–20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Welded Pipe and Tube – Without Filler Metal (Cont'd) Austenitic (Cont'd)	
13.3	11.4	10.2	9.3	8.7	8.3	8.1	8.0	7.8	7.7	...	...	...	...	...	...	...	...	TP304L	A 312
13.3	13.3	13.0	12.5	12.3	11.9	11.7	11.5	11.3	11.1	...	...	...	...	...	...	...	...	TP304L	
17.0	15.2	13.3	12.0	11.1	10.5	10.4	10.1	10.0	9.8	9.6	9.4	9.2	9.0	8.8	8.3	6.5	5.1	TP304N	
17.0	17.0	16.2	15.6	15.1	14.8	14.7	14.6	14.4	14.2	13.9	13.5	13.3	12.8	10.5	8.3	6.5	5.1	TP304N	
16.0	16.0	15.9	15.6	15.2	14.9	14.7	14.5	14.3	14.0	13.7	13.3	12.8	9.7	8.8	6.5	4.7	3.4	TP309H	A 312
16.0	15.0	13.7	12.8	12.0	11.8	11.6	11.5	11.3	11.1	11.0	10.8	10.6	10.5	8.8	6.5	4.7	3.4	TP309H	
16.0	15.6	15.0	14.8	14.8	14.8	14.8	14.8	14.6	14.5	14.2	13.9	13.5	11.7	8.8	6.5	4.7	3.4	TP310H	
16.0	15.0	13.7	12.8	12.2	11.6	11.5	11.3	11.1	11.0	10.8	10.6	10.5	10.3	8.8	6.5	4.7	3.4	TP310H	
16.0	13.8	12.4	11.4	10.6	10.1	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	7.9	6.3	TP316	A 312
16.0	16.0	15.6	15.4	15.3	14.5	14.2	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.3	10.6	8.4	6.3	TP316	
16.0	13.8	12.4	11.4	10.6	10.1	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	7.9	6.3	TP316H	
16.0	16.0	15.6	15.4	15.3	14.5	14.2	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.3	10.6	8.4	6.3	TP316H	
13.3	11.3	10.1	9.2	8.5	8.0	7.8	7.6	7.5	7.3	7.2	...	...	...	...	...	...	...	TP316L	A 312
13.3	13.3	13.3	13.2	12.3	11.5	11.2	10.9	10.7	10.5	10.3	...	...	...	...	...	...	...	TP316L	
17.0	16.5	15.1	14.0	13.1	12.4	12.1	11.8	11.6	11.3	11.1	10.9	10.7	10.5	10.4	9.9	8.3	6.3	TP316N	
17.0	17.0	16.3	16.0	15.8	15.8	15.8	15.8	15.7	15.6	15.6	15.4	15.1	14.8	13.4	10.5	8.3	6.3	TP316N	
16.0	13.8	12.4	11.4	10.6	10.1	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	7.9	6.3	TP317	A 312
16.0	16.0	15.6	15.4	15.3	14.5	14.2	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.3	10.6	8.4	6.3	TP317	
16.0	13.5	12.1	11.0	10.2	9.7	9.5	9.3	9.2	9.2	9.1	9.0	9.0	8.8	7.8	5.9	4.3	3.1	TP321	
16.0	15.6	14.7	14.6	14.6	13.9	13.7	13.5	13.3	13.2	13.1	13.0	12.9	11.8	8.2	5.9	4.3	3.1	TP321	
16.0	13.5	12.1	11.0	10.2	9.7	9.5	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.6	7.5	5.9	4.6	TP321H	
16.0	15.6	14.7	14.6	14.6	13.9	13.7	13.5	13.3	13.2	13.1	13.0	12.9	11.9	10.0	7.7	5.9	4.6	TP321H	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.6	10.1	7.8	5.2	3.8	TP347	A 312
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	11.9	10.3	7.8	5.2	3.8	TP347	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.7	10.6	10.3	8.9	6.7	TP347H	
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	12.3	12.0	11.1	8.9	6.7	TP347H	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.6	10.1	7.8	5.2	3.8	TP348	A 312
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	11.9	10.3	7.8	5.2	3.8	TP348	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.7	10.6	10.3	8.9	6.7	TP348H	
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	12.3	12.0	11.1	8.9	6.7	TP348H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Welded Pipe and Tube — Without Filler Metal (Cont'd)									
Austenitic (Cont'd)									
A 312	TPXM15	...	S38100	18Cr–18Ni–2Si	8	(1)	75	30	0.85
	TPXM15	...	S38100	18Cr–18Ni–2Si	8	(1)(9)	75	30	0.85
	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(32)	94	44	0.85
	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(9)(32)	94	44	0.85
Ferritic/Martensitic									
A 268	TP405	...	S40500	12Cr–Al	7	...	60	30	0.85
	TP410	...	S41000	13Cr	6	...	60	30	0.85
	TP429	...	S42900	15Cr	6	...	60	35	0.85
	TP430	...	S43000	17Cr	7	...	60	35	0.85
	TP446-1	...	S44600	27Cr	10I	(1)(32)	70	40	0.85
	TPXM27	...	S44627	26Cr–1Mo	10I	(1)(2)(32)	65	40	0.85
	TPXM33	...	S44626	27Cr–1Mo–Ti	10I	(2)(32)	68	45	0.85
A 731	TPXM27	...	S44627	27Cr–1Mo	10I	(2)(32)	65	40	0.85
	TPXM33	...	S44626	27Cr–1Mo–Ti	10I	(2)(32)	65	40	0.85
Welded Pipe — Filler Metal Added									
Austenitic									
A 358	304	1 & 3	S30400	18Cr–8Ni	8	(1)(10)(11)	75	30	1.00
	304	2	S30400	18Cr–8Ni	8	(1)(10)(11)	75	30	0.90
	304	1 & 3	S30400	18Cr–8Ni	8	(1)(9)(10)(11)	75	30	1.00
	304	2	S30400	18Cr–8Ni	8	(1)(9)(10)(11)	75	30	0.90
A 358	304L	1 & 3	S30403	18Cr–8Ni	8	(1)	70	25	1.00
	304L	2	S30403	18Cr–8Ni	8	(1)	70	25	0.90
	304L	1 & 3	S30403	18Cr–8Ni	8	(1)(9)	70	25	1.00
	304L	2	S30403	18Cr–8Ni	8	(1)(9)	70	25	0.90
A 358	304N	1 & 3	S30451	18Cr–8Ni–N	8	(1)(10)	80	35	1.00
	304N	2	S30451	18Cr–8Ni–N	8	(1)(10)	80	35	0.90
	304N	1 & 3	S30451	18Cr–8Ni–N	8	(1)(9)(10)	80	35	1.00
	304N	2	S30451	18Cr–8Ni–N	8	(1)(9)(10)	80	35	0.90

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
Welded Pipe and Tube – Without Filler Metal (Cont'd)																			
Austenitic (Cont'd)																			
15.9	13.3	11.9	11.0	10.3	9.7	9.5	9.4	9.2	8.9	8.8	8.6	8.4	8.3	...	...	...	...	TPXM15	A 312
15.9	15.1	14.1	13.7	13.5	13.5	13.5	13.5	13.2	12.8	12.7	12.4	12.2	11.6	...	...	...	...	TPXM15	
20.0	20.0	18.2	16.9	15.7	15.2	15.0	14.9	14.7	...	...	...	...	...	...	...	...	...	...	
20.0	20.0	19.0	18.1	17.4	17.1	16.9	16.9	16.8	...	...	...	...	...	...	...	...	...	...	
Ferritic/Martensitic																			
12.8	12.2	11.8	11.3	10.9	10.6	10.4	10.3	...	...	...	...	...	...	...	...	...	...	TP405	A 268
12.8	12.2	11.8	11.3	10.9	10.6	10.4	10.3	...	...	...	...	...	...	...	...	...	...	TP410	
12.8	12.2	11.8	11.3	10.9	10.6	10.4	10.3	...	...	...	...	...	...	...	...	...	...	TP429	
12.8	12.2	11.8	11.3	10.9	10.6	10.4	10.3	...	...	...	...	...	...	...	...	...	...	TP430	
14.9	14.2	13.7	13.3	12.8	12.3	12.2	12.0	...	...	...	...	...	...	...	...	...	...	TP446-1	
13.8	13.8	13.5	13.5	13.5	13.5	13.5	...	...	...	...	...	...	...	...	...	...	...	TPXM27	
14.5	14.5	14.3	14.1	13.9	13.7	13.5	...	...	...	...	...	...	...	...	...	...	...	TPXM33	
13.8	13.8	13.5	13.5	13.5	13.5	13.5	...	...	...	...	...	...	...	...	...	...	...	TPXM27	A 731
13.9	13.9	13.7	13.5	13.3	13.1	12.9	...	...	...	...	...	...	...	...	...	...	...	TPXM33	
Welded Pipe – Filler Metal Added																			
Austenitic																			
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	304	A358
16.9	14.1	12.7	11.7	11.0	10.3	10.2	10.0	9.7	9.5	9.4	9.2	9.0	8.8	8.6	8.0	6.9	5.5	304	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	304	
16.9	16.0	14.9	14.6	14.3	14.3	14.3	14.3	14.0	13.7	13.4	13.2	13.0	12.4	11.0	8.8	6.9	5.5	304	
15.7	13.4	12.0	11.0	10.3	9.7	9.5	9.4	9.2	9.1	...	...	...	...	...	...	...	...	304L	A 358
14.1	12.1	10.8	9.9	9.3	8.7	8.6	8.5	8.3	8.2	...	...	...	...	...	...	...	...	304L	
15.7	15.7	15.3	14.7	14.4	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	304L	
14.1	14.1	13.8	13.2	13.0	12.6	12.3	12.2	12.0	11.7	...	...	...	...	...	...	...	...	304L	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.7	11.5	11.3	11.1	10.8	10.5	10.3	9.7	7.7	6.0	304N	A 358
18.0	16.1	14.1	12.7	11.7	11.2	11.0	10.7	10.5	10.4	10.2	10.0	9.7	9.5	9.3	8.7	6.9	5.4	304N	
20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.1	16.9	16.6	16.3	15.9	15.6	15.0	12.4	9.7	7.7	6.0	304N	
18.0	18.0	17.1	16.5	16.0	15.7	15.6	15.4	15.2	14.9	14.7	14.3	14.0	13.5	11.2	8.7	6.9	5.4	304N	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Welded Pipe — Filler Metal Added (Cont'd)									
Austenitic (Cont'd)									
A 358	309	1 & 3	S30900	23Cr–12Ni	8	(1)(10)	75	30	1.00
	309	2	S30900	23Cr–12Ni	8	(1)(10)	75	30	0.90
	309	1 & 3	S30900	23Cr–12Ni	8	(1)(9)(10)	75	30	1.00
	309	2	S30900	23Cr–12Ni	8	(1)(9)(10)	75	30	0.90
A 358	310	1 & 3	S31000	25Cr–20Ni	8	(1)(10)(14)	75	30	1.00
	310	2	S31000	25Cr–20Ni	8	(1)(10)(14)	75	30	0.90
	310	1 & 3	S31000	25Cr–20Ni	8	(1)(9)(10)(14)	75	30	1.00
	310	2	S31000	25Cr–20Ni	8	(1)(9)(10)(14)	75	30	0.90
A 358	310	1 & 3	S31000	25Cr–20Ni	8	(1)(10)(15)	75	30	1.00
	310	2	S31000	25Cr–20Ni	8	(1)(10)(15)	75	30	0.90
	310	1 & 3	S31000	25Cr–20Ni	8	(1)(9)(10)(15)	75	30	1.00
	310	2	S31000	25Cr–20Ni	8	(1)(9)(10)(15)	75	30	0.90
A358	316	1 & 3	S31600	16Cr–12Ni–2Mo	8	(1)(10)(11)	75	30	1.00
	316	2	S31600	16Cr–12Ni–2Mo	8	(1)(10)(11)	75	30	0.90
	316	1 & 3	S31600	16Cr–12Ni–2Mo	8	(1)(9)(10)(11)	75	30	1.00
	316	2	S31600	16Cr–12Ni–2Mo	8	(1)(9)(10)(11)	75	30	0.90
A 358	316L	1 & 3	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	1.00
	316L	2	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	0.90
	316L	1 & 3	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	1.00
	316L	2	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	0.90
A 358	316N	1 & 3	S31651	16Cr–12Ni–2Mo–N	8	(1)(10)	80	35	1.00
	316N	2	S31651	16Cr–12Ni–2Mo–N	8	(1)(10)	80	35	0.90
	316N	1 & 3	S31651	16Cr–12Ni–2Mo–N	8	(1)(9)(10)	80	35	1.00
	316N	2	S31651	16Cr–12Ni–2Mo–N	8	(1)(9)(10)	80	35	0.90
A 358	321	1 & 3	S32100	18Cr–10Ni–Ti	8	(1)(10)(11)	75	30	1.00
	321	2	S32100	18Cr–10Ni–Ti	8	(1)(10)(11)	75	30	0.90
	321	1 & 3	S32100	18Cr–10Ni–Ti	8	(1)(9)(10)(11)	75	30	1.00
	321	2	S32100	18Cr–10Ni–Ti	8	(1)(9)(10)(11)	75	30	0.90
A 358	347	1 & 3	S34700	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	1.00
	347	2	S34700	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	0.90
	347	1 & 3	S34700	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	1.00
	347	2	S34700	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	0.90

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
Welded Pipe – Filler Metal Added (Cont'd)																			
Austenitic (Cont'd)																			
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.2	10.2	8.5	6.5	5.0	3.8	309	A 358
16.9	15.2	14.3	13.4	12.7	12.1	11.8	11.4	11.3	11.0	10.7	10.5	10.1	9.2	7.7	5.9	4.5	3.4	309	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	10.5	8.5	6.5	5.0	3.8	309	
16.9	15.5	14.8	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.1	12.5	11.3	9.5	7.7	5.9	4.5	3.4	309	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.4	10.8	9.8	8.5	7.3	6.0	310	A 358
16.9	15.2	14.3	13.4	12.7	12.1	11.8	11.4	11.3	11.0	10.7	10.5	10.3	9.7	8.8	7.7	6.6	5.4	310	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	9.8	8.5	7.3	6.0	310	
16.9	15.5	14.8	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.1	12.5	11.3	9.9	8.8	7.7	6.6	5.4	310	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.1	9.9	7.1	5.0	3.6	2.5	310	A 358
16.9	15.2	14.3	13.4	12.7	12.1	11.8	11.4	11.3	11.0	10.7	10.5	10.0	8.9	6.4	4.5	3.2	2.3	310	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	7.1	5.0	3.6	2.5	310	
16.9	15.5	14.8	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.1	12.5	11.3	9.9	6.4	4.5	3.2	2.3	310	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	316	A 358
16.9	14.6	13.1	12.1	11.3	10.6	10.4	10.2	10.1	9.9	9.8	9.7	9.6	9.5	9.5	9.3	8.4	6.7	316	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	316	
16.9	16.9	16.6	16.3	16.2	15.3	15.0	14.7	14.5	14.3	14.1	14.0	13.9	13.8	13.1	11.2	8.8	6.7	316	
15.7	13.3	11.9	10.8	10.0	9.4	9.2	9.0	8.8	8.6	8.4	...	...	...	...	...	...	...	316L	A 358
14.1	12.0	10.7	9.7	9.0	8.5	8.3	8.1	7.9	7.7	7.6	...	...	...	...	...	...	...	316L	
15.7	15.7	15.7	15.5	14.4	13.5	13.2	12.9	12.6	12.4	12.1	...	...	...	...	...	...	...	316L	
14.1	14.1	14.1	14.0	13.0	12.2	11.9	11.6	11.3	11.2	10.9	...	...	...	...	...	...	...	316L	
20.0	19.4	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	316N	A 358
18.0	17.5	16.0	14.9	13.9	13.1	12.8	12.5	12.2	12.0	11.8	11.5	11.3	11.2	11.0	10.5	8.8	6.7	316N	
20.0	20.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1	17.8	17.4	15.8	12.4	9.8	7.4	316N	
18.0	18.0	17.3	16.9	16.7	16.7	16.7	16.7	16.7	16.6	16.5	16.3	16.0	15.7	14.2	11.2	8.8	6.7	316N	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	321	A 358
16.9	14.3	12.8	11.6	10.8	10.3	10.1	9.9	9.8	9.7	9.6	9.5	9.5	9.4	8.3	6.2	4.5	3.2	321	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	321	
16.9	16.6	15.6	15.4	15.4	14.8	14.5	14.2	14.1	14.0	13.9	13.8	13.7	12.4	8.6	6.2	4.5	3.2	321	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	347	A 358
16.9	15.6	14.5	13.5	12.7	12.1	11.9	11.6	11.5	11.4	11.4	11.3	11.3	11.3	10.7	8.2	5.5	4.0	347	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	347	
16.9	16.1	14.8	14.0	13.4	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.1	12.6	10.9	8.2	5.5	4.0	347	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Welded Pipe — Filler Metal Added (Cont'd)									
Austenitic (Cont'd)									
A 358	348	1 & 3	S34800	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	1.00
	348	2	S34800	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	0.90
	348	1 & 3	S34800	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	1.00
	348	2	S34800	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	0.90
A 358	...	1 & 3	S31254	20Cr–18Ni–6Mo	8	(1)(32)	94	44	1.00
	...	2	S31254	20Cr–18Ni–6Mo	8	(1)(32)	94	44	0.90
	...	1 & 3	S31254	20Cr–18Ni–6Mo	8	(1)(9)(32)	94	44	1.00
	...	2	S31254	20Cr–18Ni–6Mo	8	(1)(9)(32)	94	44	0.90
A 409	TP304	...	S30400	18Cr–8Ni	8	(1)(10)(29)	75	30	1.00
	TP304	...	S30400	18Cr–8Ni	8	(1)(10)(30)	75	30	0.90
	TP304	...	S30400	18Cr–8Ni	8	(1)(10)(31)	75	30	0.80
	TP304	...	S30400	18Cr–8Ni	8	(1)(9)(10)(29)	75	30	1.00
	TP304	...	S30400	18Cr–8Ni	8	(1)(9)(10)(30)	75	30	0.90
	TP304	...	S30400	18Cr–8Ni	8	(1)(9)(10)(31)	75	30	0.80
A 409	TP304L	...	S30403	18Cr–8Ni	8	(1)(29)	76	25	1.00
	TP304L	...	S30403	18Cr–8Ni	8	(1)(30)	76	25	0.90
	TP304L	...	S30403	18Cr–8Ni	8	(1)(31)	76	25	0.80
	TP304L	...	S30403	18Cr–8Ni	8	(1)(9)(29)	76	25	1.00
	TP304L	...	S30403	18Cr–8Ni	8	(1)(9)(30)	76	25	0.90
	TP304L	...	S30400	18Cr–8Ni	8	(1)(9)(31)	76	25	0.80
A 409	TP316	...	S31600	16Cr–12Ni–2Mo	8	(1)(10)(29)	75	30	1.00
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(1)(10)(30)	75	30	0.90
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(1)(10)(31)	75	30	0.80
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(1)(9)(10)(29)	75	30	1.00
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(1)(9)(10)(30)	75	30	0.90
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(1)(9)(10)(31)	75	30	0.80
A 409	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(29)	76	25	1.00
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(30)	76	25	0.90
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(31)	76	25	0.80
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)(29)	76	25	1.00
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)(30)	76	25	0.90
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)(31)	76	25	0.80

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Type or Grade	Spec. No.
Welded Pipe – Filler Metal Added (Cont'd)																			
Austenitic (Cont'd)																			
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	348	A 358
16.9	15.6	14.5	13.5	12.7	12.1	11.9	11.6	11.5	11.4	11.4	11.3	11.3	11.3	10.7	8.2	5.5	4.0	348	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	348	
16.9	16.1	14.8	14.0	13.4	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.1	12.6	10.9	8.2	5.5	4.0	348	
23.5	23.5	21.4	19.9	18.5	17.9	17.7	17.5	17.3	...	...	...	...	...	...	...	...	...	...	A 358
18.0	18.0	16.4	15.2	14.1	13.7	13.5	13.4	13.2	...	...	...	...	...	...	...	...	...	...	
23.5	23.5	22.4	21.3	20.5	20.1	19.9	19.9	19.8	...	...	...	...	...	...	...	...	...	...	
18.0	18.0	17.1	16.3	15.7	15.4	15.2	15.2	15.1	...	...	...	...	...	...	...	...	...	...	
18.8	16.7	15.0	13.8	12.9	12.1	12.0	11.8	11.5	11.2	11.0	10.9	10.6	10.4	10.1	9.8	7.7	6.1	TP304	A 409
16.9	15.0	13.5	12.4	11.6	10.9	10.8	10.6	10.4	10.1	9.9	9.8	9.5	9.4	9.1	8.8	6.9	5.5	TP304	
15.0	13.4	12.0	11.0	10.3	9.7	9.6	9.4	9.2	9.0	8.8	8.7	8.5	8.3	8.1	7.8	6.2	4.9	TP304	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	14.1	12.4	9.8	7.7	6.1	TP304	
16.9	16.0	14.9	14.6	14.3	14.3	14.3	14.3	14.0	13.7	13.4	13.2	13.0	12.7	11.2	8.8	6.9	5.5	TP304	
15.0	14.2	13.3	13.0	12.7	12.7	12.7	12.7	12.5	12.2	11.9	11.8	11.5	11.3	9.9	7.8	6.2	4.9	TP304	
16.7	14.3	12.8	11.7	10.9	10.3	10.1	10.0	9.8	9.7	...	...	...	...	...	...	...	...	TP304L	A 409
15.0	12.9	11.5	10.5	9.8	9.3	9.1	9.0	8.8	8.7	...	...	...	...	...	...	...	...	TP304L	
13.4	11.4	10.2	9.4	8.7	8.2	8.1	8.0	7.8	7.8	...	...	...	...	...	...	...	...	TP304L	
16.7	16.5	15.3	14.7	14.4	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	TP304L	
15.0	14.9	13.8	13.2	13.0	12.6	12.3	12.2	12.0	11.7	...	...	...	...	...	...	...	...	TP304L	
13.4	13.2	12.2	11.8	11.5	11.2	11.0	10.8	10.6	10.4	...	...	...	...	...	...	...	...	TP304L	
18.8	17.7	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.7	11.6	11.5	11.4	11.3	11.2	11.0	9.8	7.4	TP316	A 409
16.9	15.9	14.0	12.9	12.0	11.3	11.1	10.9	10.7	10.5	10.4	10.4	10.3	10.2	10.1	9.9	8.8	6.7	TP316	
15.0	14.2	12.5	11.4	10.6	10.1	9.8	9.7	9.5	9.4	9.3	9.2	9.1	9.0	9.0	8.8	7.8	5.9	TP316	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	12.4	9.8	7.4	TP316	
16.9	16.9	16.6	16.3	16.2	15.3	15.0	14.7	14.5	14.3	14.1	14.0	13.9	13.8	13.6	11.2	8.8	6.7	TP316	
15.0	15.0	14.7	14.5	14.4	13.6	13.4	13.0	12.9	12.7	12.6	12.5	12.3	12.2	12.1	9.9	7.8	5.9	TP316	
16.7	14.1	12.7	11.7	10.9	10.4	10.2	10.0	9.8	9.6	9.4	...	...	...	...	...	...	...	TP316L	A 409
15.0	12.7	11.4	10.5	9.8	9.4	9.2	9.0	8.8	8.6	8.5	...	...	...	...	...	...	...	TP316L	
13.4	11.3	10.2	9.4	8.7	8.3	8.2	8.0	7.8	7.7	7.5	...	...	...	...	...	...	...	TP316L	
16.7	16.7	16.0	15.6	14.8	14.0	13.8	13.5	13.2	13.0	12.7	...	...	...	...	...	...	...	TP316L	
15.0	15.0	14.4	14.0	13.3	12.6	12.4	12.2	11.9	11.7	11.4	...	...	...	...	...	...	...	TP316L	
13.4	13.4	12.8	12.5	11.8	11.2	11.0	10.8	10.6	10.4	10.2	...	...	...	...	...	...	...	TP316L	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Plate, Sheet, and Strip Austenitic									
A 240	304	...	S30400	18Cr–8Ni	8	(10)(11)	75	30	1.00
	304	...	S30400	18Cr–8Ni	8	(9)(10)(11)	75	30	1.00
	304L	...	S30403	18Cr–8Ni	8	(1)	70	25	1.00
	304L	...	S30403	18Cr–8Ni	8	(1)(9)	70	25	1.00
	304N	...	S30451	18Cr–8Ni–N	8	(1)(10)	80	35	1.00
	304N	...	S30451	18Cr–8Ni–N	8	(1)(9)(10)	80	35	1.00
A 240	309H	...	S30909	23Cr–12Ni	8	(9)(11)(27)	75	30	1.00
	309H	...	S30909	23Cr–12Ni	8	(11)(27)	75	30	1.00
	309S	...	S30908	23Cr–12Ni	8	(1)(10)	75	30	1.00
	309S	...	S30908	23Cr–12Ni	8	(1)(9)(10)	75	30	1.00
A 240	310H	...	S31009	25Cr–20Ni	8	(9)	75	30	1.00
	310H	...	S31009	25Cr–20Ni	8	...	75	30	1.00
	310S	...	S31008	25Cr–20Ni	8	(10)(11)(14)	75	30	1.00
	310S	...	S31008	25Cr–20Ni	8	(9)(10)(11)(14)	75	30	1.00
	310S	...	S31008	25Cr–20Ni	8	(10)(11)(15)	75	30	1.00
	310S	...	S31008	25Cr–20Ni	8	(9)(10)(11)(15)	75	30	1.00
A 240	316	...	S31600	16Cr–12Ni–2Mo	8	(10)(11)	75	30	1.00
	316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)(11)	75	30	1.00
	316L	...	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	1.00
	316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	1.00
	316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	1.00
	316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Type or Grade	Spec. No.
																		Plate, Sheet, and Strip Austenitic	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	304	A 240
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	304	
15.6	13.4	12.0	11.0	10.3	9.7	9.5	9.4	9.2	9.1	...	...	...	...	...	...	...	...	304L	
15.7	15.7	15.3	14.7	14.4	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	304L	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.7	11.5	11.3	11.0	10.8	10.5	10.3	9.7	7.7	6.0	304N	
20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.1	16.9	16.6	16.3	15.9	15.6	15.0	12.4	9.7	7.7	6.0	304N	
18.8	18.8	18.7	18.3	17.9	17.5	17.3	17.1	16.8	16.5	16.1	15.6	15.1	13.8	10.3	7.6	5.5	4.0	309H	A 240
18.8	17.6	16.1	15.1	14.1	13.9	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	10.3	7.6	5.5	4.0	309H	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.2	10.2	8.5	6.5	5.0	3.8	309S	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	10.5	8.5	6.5	5.0	3.8	309S	
18.8	18.4	17.6	17.4	17.4	17.4	17.4	17.4	17.2	17.0	16.7	16.3	15.9	13.8	10.3	7.6	5.5	4.0	310H	A 240
18.8	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	12.1	10.3	7.6	5.5	4.0	310H	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.4	10.8	9.8	8.5	7.3	6.0	310S	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	9.8	8.5	7.3	6.0	310S	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.1	9.9	7.1	5.0	3.6	2.5	310S	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	7.1	5.0	3.6	2.5	310S	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	316	A 240
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	316	
16.7	14.1	12.7	11.7	10.9	10.4	10.2	10.0	9.8	9.6	9.4	9.2	8.9	8.8	8.0	7.9	6.5	6.4	316L	
16.7	16.7	16.0	15.6	14.8	14.0	13.8	13.5	13.2	13.0	12.7	12.4	12.0	11.9	10.8	10.2	8.8	6.4	316L	
20.0	19.4	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	316N	
20.0	20.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1	17.8	17.4	15.8	12.4	9.8	7.4	316N	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Plate, Sheet, and Strip (Cont'd)									
Austenitic (Cont'd)									
A 240	317	...	S31700	18Cr–13Ni–3Mo	8	(1)(10)(11)	75	30	1.00
	317	...	S31700	18Cr–13Ni–3Mo	8	(1)(9)(10)(11)	75	30	1.00
	317L	...	S31703	18Cr–13Ni–3Mo	8	(1)	75	30	1.00
	317L	...	S31703	18Cr–13Ni–3Mo	8	(1)(9)	75	30	1.00
	321	...	S32100	18Cr–10Ni–Ti	8	(10)(11)	75	30	1.00
	321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)(11)	75	30	1.00
A 240	347	...	S34700	18Cr–10Ni–Cb	8	(10)(11)	75	30	1.00
	347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)(11)	75	30	1.00
	348	...	S34800	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	1.00
	348	...	S34800	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	1.00
A 240	XM15	...	S38100	18Cr–8Ni–2Si	8	(1)	75	30	1.00
	XM15	...	S38100	18Cr–8Ni–2Si	8	(1)(9)	75	30	1.00
	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(32)	94	44	1.00
	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(9)(32)	94	44	1.00
Ferritic/Martensitic									
A 240	405	...	S40500	12Cr–1Al	7	(3)	60	25	1.00
	410	...	S41000	13Cr	6	(1)	65	30	1.00
	410S	...	S41008	13Cr	7	(1)	60	30	1.00
	429	...	S42900	15Cr	6	(1)(3)	65	30	1.00
A 240	430	...	S43000	17Cr	7	(1)(3)	65	30	1.00
	XM27	...	S44627	26Cr–1Mo	10I	(1)(3)(32)	65	40	1.00
	XM33	...	S44626	27Cr–1Mo–Ti	10I	(2)(32)	68	45	1.00
Forgings									
Austenitic									
A 182	F44	...	S31254	20Cr–18Ni–6Mo	8	(1)(32)	94	44	1.00
	F44	...	S31254	20Cr–18Ni–6Mo	8	(1)(9)(32)	94	44	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Plate, Sheet, and Strip (Cont'd) Austenitic (Cont'd)	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	317	A 240
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	14.5	12.4	9.8	7.4	317	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	...	...	...	...	...	...	...	317L	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	...	...	...	...	...	...	...	317L	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	321	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	321	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	347	A 240
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	347	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	348	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	348	
18.8	15.6	14.0	12.9	12.1	11.4	11.2	11.0	10.8	10.5	10.3	10.1	9.9	9.7	...	...	...	...	XM15	A 240
18.8	17.7	16.6	16.1	15.9	15.9	15.9	15.9	15.5	15.1	14.9	14.6	14.3	13.7	...	...	...	...	XM15	
23.5	23.5	21.4	19.9	18.5	17.9	17.7	17.5	17.3	...	...	...	...	...	...	...	...	...	...	
23.5	23.5	22.4	21.3	20.5	20.1	19.9	19.9	19.8	...	...	...	...	...	...	...	...	...	...	
																		Ferritic/Martensitic	
15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	...	...	...	...	...	...	...	...	...	...	405	A 240
16.3	15.5	15.0	14.4	13.9	13.5	13.3	13.1	12.7	12.0	11.3	10.5	8.8	6.4	4.4	2.9	1.8	1.0	410	
15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	11.7	11.1	10.4	9.7	8.4	6.4	4.4	2.9	1.8	1.0	410S	
16.3	15.5	15.0	14.4	13.9	13.5	13.3	13.1	12.7	12.0	11.3	10.5	9.2	6.5	4.5	3.2	2.4	1.8	429	
16.3	15.5	15.0	14.4	13.9	13.5	13.3	13.1	12.7	12.0	11.3	10.5	9.2	6.5	4.5	3.2	2.4	1.8	430	A 240
16.2	16.2	15.9	15.9	15.9	15.9	15.9	...	...	...	...	...	...	...	...	...	...	...	XM27	
17.0	17.0	16.8	16.6	16.4	16.1	15.9	...	...	...	...	...	...	...	...	...	...	...	XM33	
																		Forgings Austenitic	
23.5	23.5	21.4	19.9	18.5	17.9	17.7	17.5	17.3	...	...	...	...	...	...	...	...	...	F44	A 182
23.5	23.5	22.4	21.3	20.5	20.1	19.9	19.9	19.8	...	...	...	...	...	...	...	...	...	F44	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Forgings (Cont'd) Austenitic (Cont'd)									
A 182	F304	...	S30400	18Cr–8Ni	8	(10)(12)	70	30	1.00
	F304	...	S30400	18Cr–8Ni	8	(9)(10)(12)	70	30	1.00
	F304	...	S30400	18Cr–8Ni	8	(10)	75	30	1.00
	F304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	1.00
A 182	F304H	...	S30409	18Cr–8Ni	8	(12)	70	30	1.00
	F304H	...	S30409	18Cr–8Ni	8	(9)(12)	70	30	1.00
	F304H	...	S30409	18Cr–8Ni	8	...	75	30	1.00
	F304H	...	S30409	18Cr–8Ni	8	(9)	75	30	1.00
A 182	F304L	...	S30403	18Cr–8Ni	8	(1)	65	25	1.00
	F304L	...	S30403	18Cr–8Ni	8	(1)(9)	65	25	1.00
	F304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	1.00
	F304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	1.00
A 182	F310	...	S31000	25Cr–20Ni	8	(1)(10)(14)	75	30	1.00
	F310	...	S31000	25Cr–20Ni	8	(1)(9)(10)(14)	75	30	1.00
	F310	...	S31000	25Cr–20Ni	8	(1)(10)(15)	75	30	1.00
	F310	...	S31000	25Cr–20Ni	8	(1)(9)(10)(15)	75	30	1.00
A 182	F316	...	S31600	16Cr–12Ni–2Mo	8	(10)(12)	70	30	1.00
	F316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)(12)	70	30	1.00
	F316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	1.00
	F316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	1.00
A 182	F316H	...	S31609	16Cr–12Ni–2Mo	8	(12)	70	30	1.00
	F316H	...	S31609	16Cr–12Ni–2Mo	8	(9)(12)	70	30	1.00
	F316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	1.00
	F316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	1.00
A 182	F316L	...	S31603	16Cr–12Ni–2Mo	8	(1)	65	25	1.00
	F316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)	65	25	1.00
	F316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	1.00
	F316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	1.00
A 182	F321	...	S32100	18Cr–10Ni–Ti	8	(12)	70	30	1.00
	F321	...	S32100	18Cr–10Ni–Ti	8	(9)(12)	70	30	1.00
	F321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	1.00
	F321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Forgings (Cont'd) Austenitic (Cont'd)	
17.5	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	F304	A 182
17.5	16.6	15.5	15.1	14.8	14.8	14.8	14.8	14.7	14.6	14.4	14.2	13.9	13.4	12.0	9.7	7.7	6.1	F304	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	F304	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	F304	
17.5	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	F304H	A 182
17.5	16.6	15.5	15.1	14.8	14.8	14.8	14.8	14.7	14.6	14.4	14.2	13.9	13.4	12.0	9.7	7.7	6.1	F304H	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	F304H	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	F304H	
15.7	13.4	12.0	11.0	10.3	9.7	9.5	9.4	9.2	9.1	...	...	...	...	...	...	...	...	F304L	A 182
15.5	15.4	14.2	13.6	13.4	13.3	13.2	13.1	13.0	12.9	...	...	...	...	...	...	...	...	F304L	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.8	11.6	11.3	11.1	10.8	10.6	10.3	9.8	7.7	6.1	F304N	
20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.2	16.9	16.7	16.3	15.9	15.6	15.0	12.4	9.8	7.7	6.1	F304N	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.4	10.8	9.8	8.5	7.3	6.0	F310	A 182
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	9.8	8.5	7.3	6.0	F310	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.1	9.9	7.1	5.0	3.6	2.5	F310	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	7.1	5.0	3.6	2.5	F310	
17.5	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	F316	A 182
17.5	17.5	17.1	16.8	16.8	16.8	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.0	14.1	12.4	9.8	7.4	F316	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	F316	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	F316	
17.5	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	F316H	A 182
17.5	17.5	17.1	16.8	16.8	16.8	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.0	14.1	12.4	9.8	7.4	F316H	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	F316H	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	F316H	
15.7	13.3	11.9	10.8	10.0	9.4	9.2	9.0	8.8	8.6	8.4	...	...	...	...	...	...	...	F316L	A 182
15.7	15.7	15.7	15.5	14.4	13.5	13.2	12.9	12.6	12.4	12.1	...	...	...	...	...	...	...	F316L	
17.0	16.5	15.1	14.0	13.1	12.4	12.1	11.8	11.6	11.3	11.1	10.9	10.7	10.5	10.4	9.9	8.3	6.3	F316N	
17.0	17.0	16.3	16.0	15.8	15.8	15.8	15.8	15.7	15.6	15.6	15.4	15.1	14.8	12.4	10.5	8.3	6.3	F316N	
17.5	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	F321	A 182
17.5	17.2	16.2	16.0	16.0	16.0	16.0	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	F321	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	F321	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	F321	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Forgings (Cont'd)									
Austenitic (Cont'd)									
A 182	F321H	...	S32109	18Cr–10Ni–Ti	8	(12)	70	30	1.00
	F321H	...	S32109	18Cr–10Ni–Ti	8	(9)(12)	70	30	1.00
	F321H	...	S32109	18Cr–10Ni–Ti	8	...	75	30	1.00
	F321H	...	S32109	18Cr–10Ni–Ti	8	(9)	75	30	1.00
A 182	F347	...	S34700	18Cr–10Ni–Cb	8	(12)	70	30	1.00
	F347	...	S34700	18Cr–10Ni–Cb	8	(9)(12)	70	30	1.00
	F347	...	S34700	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	F347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
A 182	F347H	...	S34709	18Cr–10Ni–Cb	8	(12)	70	30	1.00
	F347H	...	S34709	18Cr–10Ni–Cb	8	(9)(12)	70	30	1.00
	F347H	...	S34709	18Cr–10Ni–Cb	8	...	75	30	1.00
	F347H	...	S34709	18Cr–10Ni–Cb	8	(9)	75	30	1.00
A 182	F348	...	S34800	18Cr–10Ni–Cb	8	(12)	70	30	1.00
	F348	...	S34800	18Cr–10Ni–Cb	8	(9)(12)	70	30	1.00
	F348	...	S34800	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	F348	...	S34800	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
A 182	F348H	...	S34809	18Cr–10Ni–Cb	8	(12)	70	30	1.00
	F348H	...	S34809	18Cr–10Ni–Cb	8	(9)(12)	70	30	1.00
	F348H	...	S34809	18Cr–10Ni–Cb	8	...	75	30	1.00
	F348H	...	S34809	18Cr–10Ni–Cb	8	(9)	75	30	1.00
Ferritic/Martensitic									
A 182	FXM-27b	...	S44627	27Cr–1Mo	10I	(2)	60	35	1.00
A 336	FXM-27Cb	...	S44627	27Cr–1Mo	10I	(2)	60	35	1.00
Fittings (Seamless and Welded)									
Austenitic									
A 403	WP304	...	S30400	18Cr–8Ni	8	(1)(4)(7)(10)(11)	75	30	1.00
	WP304	...	S30400	18Cr–8Ni	8	(1)(4)(7)(9)(10)(11)	75	30	1.00
	WP304H	...	S30409	18Cr–8Ni	8	(1)(4)(7)(11)	75	30	1.00
	WP304H	...	S30409	18Cr–8Ni	8	(1)(4)(7)(9)(11)	75	30	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Forgings (Cont'd) Austenitic (Cont'd)	
17.5	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	F321H	A 182
17.5	17.2	16.2	16.0	16.0	16.0	16.0	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	F321H	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	F321H	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	F321H	
17.5	16.7	15.3	14.4	13.9	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	F347	A 182
17.5	16.7	15.3	14.4	13.9	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.6	13.2	12.0	9.1	6.1	4.4	F347	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	F347	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	F347	
17.5	16.7	15.3	14.4	13.9	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	F347H	A 182
17.5	16.7	15.3	14.4	13.9	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.6	13.5	13.2	12.5	10.5	7.9	F347H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.8	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	F347H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	F347H	
17.5	16.7	15.3	14.4	13.9	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	F348	A 182
17.5	16.7	15.3	14.4	13.9	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.6	13.2	12.0	9.1	6.1	4.4	F348	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	F348	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	F348	
17.5	16.7	15.3	14.4	13.9	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	F348H	A 182
17.5	16.7	15.3	14.4	13.9	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.6	13.5	13.2	12.5	10.5	7.9	F348H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.8	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	F348H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	F348H	
																		Ferritic/Martensitic	
15.0	15.0	14.6	14.2	14.2	14.2	14.2	...	...	...	...	...	...	...	...	...	...	...	FXM-27b	A 182
15.0	15.0	14.6	14.2	14.2	14.2	14.2	...	...	...	...	...	...	...	...	...	...	...	FXM 27Cb	A 336
																		Fittings (Seamless and Welded) Austenitic	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	WP304	A 403
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.5	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	WP304	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	WP304H	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.5	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	WP304H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Fittings (Seamless and Welded) (Cont'd)									
Austenitic (Cont'd)									
A 403	WP304L	...	S30403	18Cr-8Ni	8	(1)(7)(11)	70	25	1.00
	WP304L	...	S30403	18Cr-8Ni	8	(1)(7)(9)(11)	70	25	1.00
	WP304N	...	S30451	18Cr-8Ni-N	8	(1)(4)(7)(10)	80	35	1.00
	WP304N	...	S30451	18Cr-8Ni-N	8	(1)(4)(7)(9)(10)	80	35	1.00
A 403	WP309	...	S30900	23Cr-12Ni	8	(1)(7)(10)(11)	75	30	1.00
	WP309	...	S30900	23Cr-12Ni	8	(1)(7)(9)(10)(11)	75	30	1.00
	WP310	...	S31000	23Cr-20Ni	8	(1)(7)(10)(11)(14)	75	30	1.00
	WP310	...	S31000	23Cr-20Ni	8	(1)(7)(9)(10)(11)(14)	75	30	1.00
	WP310	...	S31000	23Cr-20Ni	8	(1)(7)(10)(11)(15)	75	30	1.00
	WP310	...	S31000	23Cr-20Ni	8	(1)(7)(9)(10)(11)(15)	75	30	1.00
A 403	WP316	...	S31600	16Cr-12Ni-2Mo	8	(4)(7)(10)(11)	75	30	1.00
	WP316	...	S31600	16Cr-12Ni-2Mo	8	(4)(7)(9)(10)(11)	75	30	1.00
	WP316H	...	S31609	16Cr-12Ni-2Mo	8	(4)(7)(11)	75	30	1.00
	WP316H	...	S31609	16Cr-12Ni-2Mo	8	(4)(7)(9)(11)	75	30	1.00
A 403	WP316L	...	S31603	16Cr-12Ni-2Mo	8	(1)(7)(11)	65	25	1.00
	WP316L	...	S31603	16Cr-12Ni-2Mo	8	(1)(7)(9)(11)	65	25	1.00
	WP316N	...	S31651	16Cr-12Ni-2Mo-N	8	(1)(7)(10)	80	35	1.00
	WP316N	...	S31651	16Cr-12Ni-2Mo-N	8	(1)(7)(9)(10)	80	35	1.00
A 403	WP317	...	S31700	18Cr-13Ni-3Mo	8	(1)(7)(10)(11)	75	30	1.00
	WP317	...	S31700	18Cr-13Ni-3Mo	8	(1)(7)(9)(10)(11)	75	30	1.00
	WP321	...	S32100	18Cr-10Ni-Ti	8	(4)(7)(10)(11)	75	30	1.00
	WP321	...	S32100	18Cr-10Ni-Ti	8	(4)(7)(9)(10)(11)	75	30	1.00
	WP321H	...	S32109	18Cr-10Ni-Ti	8	(4)(7)(11)	75	30	1.00
	WP321H	...	S32109	18Cr-10Ni-Ti	8	(4)(7)(9)(11)	75	30	1.00
A 403	WP347	...	S34700	18Cr-10Ni-Cb	8	(4)(7)(10)(11)	75	30	1.00
	WP347	...	S34700	18Cr-10Ni-Cb	8	(4)(7)(9)(10)(11)	75	30	1.00
	WP347H	...	S34709	18Cr-10Ni-Cb	8	(4)(7)(11)	75	30	1.00
	WP347H	...	S34709	18Cr-10Ni-Cb	8	(4)(7)(9)(11)	75	30	1.00
A 403	WP348	...	S34800	18Cr-10Ni-Cb	8	(4)(7)(10)(11)	75	30	1.00
	WP348	...	S34800	18Cr-10Ni-Cb	8	(4)(7)(9)(10)(11)	75	30	1.00
	WP348H	...	S34809	18Cr-10Ni-Cb	8	(4)(7)(11)	75	30	1.00
	WP348H	...	S34809	18Cr-10Ni-Cb	8	(4)(7)(9)(11)	75	30	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Fittings (Seamless and Welded) (Cont'd) Austenitic (Cont'd)	
15.7	13.4	12.0	11.0	10.3	9.7	9.5	9.4	9.2	9.1	...	...	...	...	...	...	...	...	WP304L	A 403
15.7	15.7	15.7	15.5	14.4	13.5	13.2	12.9	12.6	12.4	...	...	...	...	...	...	...	...	WP304L	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.7	11.5	11.3	11.1	10.8	10.5	10.3	9.7	7.7	6.0	WP304N	
20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.1	16.9	16.6	16.3	15.9	15.6	15.0	12.4	9.7	7.7	6.0	WP304N	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.2	10.2	8.5	6.5	5.0	3.8	WP309	A 403
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	10.5	8.5	6.5	5.0	3.8	WP309	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.4	10.8	9.8	8.5	7.3	6.0	WP310	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	9.8	8.5	7.3	6.0	WP310	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.1	9.9	7.1	5.0	3.6	2.5	WP310	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	7.1	5.0	3.6	2.5	WP310	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	WP316	A 403
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	14.5	12.4	9.8	7.4	WP316	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	WP316H	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	14.5	12.4	9.8	7.4	WP316H	
15.7	13.3	11.9	10.8	10.0	9.4	9.2	9.0	8.8	8.6	8.4	...	...	...	...	...	...	...	WP316L	A 403
15.7	15.7	15.7	15.5	14.4	13.5	13.2	12.9	12.6	12.4	12.1	...	...	...	...	...	...	...	WP316L	
20.0	19.4	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	WP316N	
20.0	10.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1	17.8	17.4	15.8	12.4	9.8	7.4	WP316N	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	WP317	A 403
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	14.5	12.4	9.8	7.4	WP317	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	WP321	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	WP321	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	WP321H	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	WP321H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	WP347	A 403
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	WP347	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.8	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	WP347H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	WP347H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	WP348	A 403
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	WP348	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.8	12.7	12.6	12.6	12.5	12.5	12.1	10.5	7.9	WP348H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	WP348H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Castings									
Austenitic									
A 351	CF3	...	J92500	18Cr–8Ni	8	(1)(5)(26)	70	30	0.80
	CF3	...	J92500	18Cr–8Ni	8	(1)(5)(9)(26)	70	30	0.80
	CF3A	...	J92500	18Cr–8Ni	8	(1)(5)(26)	77.5	35	0.80
	CF3A	...	J92500	18Cr–8Ni	8	(1)(5)(9)(26)	77.5	35	0.80
	CF3M	...	J92800	18Cr–12Ni–2Mo	8	(1)(5)(13)(26)	70	30	0.80
	CF3M	...	J92800	18Cr–12Ni–2Mo	8	(1)(5)(9)(13)(26)	70	30	0.80
A 351	CF8	...	J92600	18Cr–8Ni	8	(5)(10)(26)	70	30	0.80
	CF8	...	J92600	18Cr–8Ni	8	(5)(9)(10)(26)	70	30	0.80
	CF8C	...	J92710	18Cr–10Ni–Cb	8	(1)(5)(10)(26)	70	30	0.80
	CF8C	...	J92710	18Cr–10Ni–Cb	8	(1)(5)(9)(10)(26)	70	30	0.80
	CF8M	...	J92900	16Cr–12Ni–2Mo	8	(5)(13)(26)	70	30	0.80
	CF8M	...	J92900	16Cr–12Ni–2Mo	8	(5)(9)(13)(26)	70	30	0.80
A 351	CH8	...	J93400	25Cr–12Ni	8	(1)(5)(10)(26)	65	28	0.80
	CH8	...	J93400	25Cr–12Ni	8	(1)(5)(9)(10)(26)	65	28	0.80
	CH20	...	J93402	25Cr–12Ni	8	(1)(5)(10)(26)	70	30	0.80
	CH20	...	J93402	25Cr–12Ni	8	(1)(5)(9)(10)(26)	70	30	0.80
	CK20	...	J94202	25Cr–20Ni	8	(1)(5)(10)(26)	65	28	0.80
	CK20	...	J94202	25Cr–20Ni	8	(1)(5)(9)(10)(26)	65	28	0.80
Ferritic/Martensitic									
A 217	CA15	...	J91150	13Cr–½ Mo	6	(1)(3)(5)	90	65	0.80
Bolts, Nuts, and Studs									
Austenitic									
A 193	B8	1	S30400	18Cr–8Ni	...	(10)(11)(16)	75	30	...
	B8C	1	S34700	18Cr–10Ni–Cb	...	(10)(11)(16)	75	30	...
	B8M	1	S31600	16Cr–12Ni–2Mo	...	(10)(11)(16)	75	30	...
	B8T	1	S32100	18Cr–10Ni–Ti	...	(10)(11)(16)	75	30	...
A 193	B8	2	S30400	18Cr–8Ni	...	(16)(18)(20)	125	100	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(21)	115	80	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(22)	105	65	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(23)	100	50	...

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																			Castings Austenitic
14.0	12.5	11.2	10.3	9.7	9.1	9.0	8.8	8.6	8.4	...	...	...	...	...	...	...	...	CF3	A 351
14.0	13.3	12.2	12.1	11.8	11.8	11.8	11.8	11.8	11.7	...	...	...	...	...	...	...	...	CF3	
15.5	14.6	13.1	12.1	11.4	10.7	9.9	9.8	...	...	...	...	...	...	...	...	...	...	CF3A	
15.5	14.6	13.5	13.2	13.0	13.0	13.0	11.7	...	...	...	...	...	...	...	...	...	...	CF3A	
14.0	12.9	11.7	10.6	9.9	9.4	9.2	9.0	8.9	8.8	8.7	...	...	...	...	...	...	...	CF3M	
14.0	14.0	13.7	13.4	13.4	13.4	13.3	13.0	12.8	12.6	12.6	...	...	...	...	...	...	...	CF3M	
14.0	12.5	11.2	10.3	9.7	9.1	8.8	8.8	8.6	8.5	8.2	8.1	7.9	7.6	7.2	6.0	4.6	3.6	CF8	A 351
14.0	13.2	12.1	12.0	11.8	11.8	11.8	11.8	11.8	11.7	11.5	11.3	10.7	9.6	7.7	6.0	4.6	3.6	CF8	
14.0	13.3	12.2	11.5	11.1	10.7	10.5	10.3	10.2	10.2	10.1	10.1	10.0	9.5	9.0	8.4	6.4	4.0	CF8C	
14.0	13.3	12.2	11.5	11.1	11.0	11.0	11.0	11.0	11.0	11.0	11.0	10.8	10.6	9.6	8.4	6.4	4.0	CF8C	
14.0	12.9	11.7	10.6	9.9	9.4	9.2	9.0	8.9	8.8	8.7	8.6	8.6	8.5	8.1	7.5	6.4	4.8	CF8M	
14.0	14.0	13.7	13.4	13.4	13.4	13.3	13.0	12.8	12.6	12.6	12.4	12.3	11.9	9.6	7.5	6.4	4.8	CF8M	
13.0	11.9	11.4	11.0	10.6	10.0	9.8	9.5	9.4	9.1	8.9	8.7	8.6	7.9	6.8	5.2	4.0	3.0	CH8	A 351
13.0	11.9	11.4	11.0	10.8	10.6	10.6	10.5	10.4	10.4	10.2	10.0	9.4	8.4	6.8	5.2	4.0	3.0	CH8	
14.0	12.9	12.2	11.8	11.3	10.7	10.5	10.2	10.0	9.8	9.5	9.4	9.0	8.2	6.8	5.2	4.0	3.0	CH20	
14.0	12.9	12.2	11.8	11.6	11.4	11.4	11.3	11.2	11.1	11.0	10.6	10.0	8.4	6.8	5.2	4.0	3.0	CH20	
13.0	11.9	11.4	11.0	10.6	10.0	9.8	9.5	9.4	9.1	8.9	8.7	8.5	8.2	7.8	6.8	5.8	4.8	CK20	
13.0	11.9	11.4	11.0	10.8	10.6	10.6	10.5	10.4	10.4	10.2	10.0	9.5	8.8	7.8	6.8	5.8	4.8	CK20	
																			Ferritic/Martensitic
18.0	17.2	16.6	16.0	15.4	15.0	14.7	14.5	14.0	13.4	11.9	8.8	6.1	4.0	2.6	1.8	1.2	0.8	CA15	A 217
																			Bolts, Nuts, and Studs Austenitic
18.8	15.6	14.0	12.9	12.1	11.4	11.2	11.0	10.8	10.5	10.3	10.1	9.9	9.7	9.5	8.8	7.7	6.0	B8	A 193
18.8	17.2	16.0	15.0	14.0	13.4	13.1	12.9	12.8	12.7	12.6	12.6	12.5	12.5	11.9	9.1	6.1	4.4	B8C	
18.8	16.1	14.6	13.3	12.5	11.8	11.5	11.3	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	B8M	
18.8	15.9	14.1	12.9	12.0	11.3	11.1	10.9	10.8	10.7	10.6	10.6	10.5	10.4	9.2	6.9	5.0	3.6	B8T	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	A 193
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
16.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
12.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Bolts, Nuts, and Studs (Cont'd)									
Austenitic (Cont'd)									
A 193	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(20)	125	100	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(21)	115	80	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(22)	105	65	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(23)	100	50	...
A 193	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(20)	110	80	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(21)	100	80	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(22)	95	75	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(23)	90	65	...
A 193	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(20)	125	100	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(21)	115	80	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(22)	105	65	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(23)	100	50	...
A 194	8	...	S30400	18Cr–8Ni	...	(17)	...	...	...
	8C	...	S34700	18Cr–10Ni–Cb	...	(17)	...	...	...
A 194	8M	...	S31600	16Cr–12Ni–Mo	...	(17)	...	...	...
	8T	...	S32100	18Cr–10Ni–Ti	...	(17)	...	...	...
	8F	...	...	18Cr–8Ni–Fm	...	(17)	...	...	...
A 320	B8	1	S30400	18Cr–8Ni	...	(16)(18)	75	30	...
	B8	1	S30400	18Cr–8Ni	...	(16)(28)	75	30	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(23)	100	50	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(22)	105	65	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(21)	115	80	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(20)	125	100	...
A 320	B8C	1	S34700	18Cr–10Ni–Cb	...	(16)	75	30	...
	B8C	1	S34700	18Cr–10Ni–Cb	...	(16)(28)	75	30	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(23)	100	50	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(22)	105	65	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(21)	115	80	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(20)	125	100	...

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
–20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Bolts, Nuts, and Studs (Cont'd) Austenitic (Cont'd)	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	A 193
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
16.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
12.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	...	...	...	...	...	...	...	...	...	B8M	A 193
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	...	...	...	...	...	...	...	...	...	B8M	
18.8	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	...	...	...	...	...	...	...	...	...	B8M	
18.8	16.1	14.6	13.3	12.5	12.5	12.5	12.5	12.5	...	...	...	...	...	...	...	...	...	B8M	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	A 193
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
16.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
12.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8	A 194
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8C	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8M	A 194
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8T	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8F	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	A 320
18.8	16.7	15.0	13.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	A 320
18.8	17.9	16.4	15.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Bolts, Nuts, and Studs (Cont'd)									
Austenitic (Cont'd)									
A 320	B8M	1	S31600	16Cr–12Ni–2Mo	...	(16)	75	30	...
	B8M	1	S31600	16Cr–12Ni–2Mo	...	(16)(28)	75	30	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(23)	90	50	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(22)	95	65	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(21)	100	80	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(20)	110	95	...
A 320	B8T	1	S32100	18Cr–10Ni–Ti	...	(16)	75	30	...
	B8T	1	S32100	18Cr–10Ni–Ti	...	(16)(28)	75	30	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(23)	100	50	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(22)	105	65	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(21)	115	80	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(20)	125	100	...
A 453	660	A & B	S66286	15Cr–25Ni–Mo–Ti–V–B	...	(16)	130	85	...
A 479	TP309H	...	S30909	23Cr–12Ni	8	(9)	75	30	...
	TP309H	...	S30909	23Cr–12Ni	8	...	75	30	...
	TP310H	...	S31009	25Cr–20Ni	8	(9)	75	30	...
	TP310H	...	S31009	25Cr–20Ni	8	...	75	30	...
A 564	630	H-1100	S17400	17Cr–4Ni–3.5Cu–0.04P	...	(16)(24)	140	115	...
Ferritic/Martensitic									
A 193	B6	(410)	S41000	13Cr	...	(16)(19)	110	85	...
A 194	6	...	S41000	13Cr	...	(17)	...	...	...
Bar									
Austenitic									
A 479	TP304	...	S30400	18Cr–8Ni	8	(10)	75	30	1.00
	TP304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	...	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	(9)	75	30	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Bolts, Nuts, and Studs (Cont'd) Austenitic (Cont'd)	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	A 320
18.8	17.7	15.6	14.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
22.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	A 320
18.8	17.8	16.5	15.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	660	A 453
18.8	18.8	18.7	18.3	17.9	17.5	17.3	17.1	16.8	16.5	16.1	15.6	15.1	13.8	10.3	7.6	5.5	4.0	TP309H	A 479
18.8	17.6	16.1	15.1	14.1	13.8	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	10.3	7.6	5.5	4.0	TP309H	
18.8	18.4	17.6	17.4	17.4	17.4	17.4	17.4	17.2	17.0	16.7	16.3	15.9	13.8	10.3	7.6	5.5	4.0	TP310H	
18.8	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	12.1	10.3	7.6	5.5	4.0	TP310H	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	630	A 564
																		Ferritic/Martensitic	
21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	19.5	15.6	12.0	...	...	...	...	...	...	B6	A 193
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6	A 194
																		Bar Austenitic	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304	A 479
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304H	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Bar (Cont'd) Austenitic (Cont'd)									
A 479	TP304L	...	S30403	18Cr–8Ni	8	(25)	70	25	1.00
	TP304L	...	S30403	18Cr–8Ni	8	(9)(25)	70	25	1.00
	TP304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	1.00
	TP304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	1.00
A 479	TP310S	...	S31008	25Cr–20Ni	8	(10)(11)(15)	75	30	1.00
	TP310S	...	S31008	25Cr–20Ni	8	(10)(11)(14)	75	30	1.00
	TP310S	...	S31008	25Cr–20Ni	8	(9)(10)(11)	75	30	1.00
A 479	TP316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	1.00
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	1.00
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	1.00
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	1.00
A 479	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(25)	70	25	1.00
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(9)(25)	70	25	1.00
	TP316N	...	S31651	16Cr–12Ni–2Mo	8	(10)	80	35	1.00
	TP316N	...	S31651	16Cr–12Ni–2Mo	8	(9)(10)	80	35	1.00
A 479	TP321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	1.00
	TP321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	1.00
	TP321H	...	S32109	18Cr–10Ni–Ti	8	...	75	30	1.00
	TP321H	...	S32109	18Cr–10Ni–Ti	8	(9)	75	30	1.00
A 479	TP347	...	S34700	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	TP347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
	TP347H	...	S34709	18Cr–10Ni–Cb	8	...	75	30	1.00
	TP347H	...	S34709	18Cr–10Ni–Cb	8	(9)	75	30	1.00
A 479	TP348	...	S34800	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	TP348	...	S34800	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
	TP348H	...	S34809	18Cr–10Ni–Cb	8	...	75	30	1.00
	TP348H	...	S34809	18Cr–10Ni–Cb	8	(9)	75	30	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Bar (Cont'd) Austenitic (Cont'd)	
16.3	14.3	12.8	11.7	10.9	10.3	10.1	10.0	9.8	9.7	...	...	...	...	...	...	...	...	TP304L	A 479
16.7	16.5	15.3	14.7	14.4	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	TP304L	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.8	11.6	11.3	11.1	10.8	10.6	10.3	9.8	7.7	6.1	TP304N	
20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.2	16.9	16.7	16.3	15.9	15.6	15.0	12.4	9.8	7.7	6.1	TP304N	
18.8	16.9	15.8	14.9	14.1	13.4	13.0	12.7	12.5	12.1	11.9	11.6	11.1	9.8	...	...	...	...	TP310S	A 479
18.8	16.9	15.8	14.9	14.1	13.4	13.0	12.7	12.5	12.1	11.9	11.6	11.3	10.8	...	...	...	...	TP310S	
18.8	17.2	16.4	15.8	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.8	12.6	11.0	...	...	...	...	TP310S	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316	A 479
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316H	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316H	
16.7	14.1	12.7	11.7	10.9	10.4	10.2	10.0	9.8	9.6	9.4	...	...	...	...	...	...	...	TP316L	A 479
16.7	16.7	16.0	15.6	14.8	14.0	13.8	13.5	13.2	13.0	12.7	...	...	...	...	...	...	...	TP316L	
20.0	19.4	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	TP316N	
20.0	20.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1	17.8	17.4	15.8	12.4	9.8	7.4	TP316N	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	TP321	A 479
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	TP321	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	TP321H	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	TP321H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP347	A 479
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP347	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.8	12.8	12.7	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	TP347H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	TP347H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP348	A 479
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP348	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.8	12.8	12.7	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	TP348H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	TP348H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Bar (Cont'd) Ferritic/Martensitic									
A 479	TPXM-27	...	S44627	27Cr–1Mo	10I	(2)	65	40	1.00

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.
(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.
(c) The P-Numbers indicated in this Table are identical to those adopted by the ASME Boiler and Pressure Vessel Code. *Qualification of* welding procedures, welders, and welding operators is required and shall comply with the ASME Boiler and Pressure Vessel Code, Section IX, except as modified by para. 127.5.
(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."
(e) The materials listed in this Table shall not be used at design temperatures above those for which allowable stress values are given.
(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. *Weld joint efficiency* factors are shown in Table 102.4.3.
(g) Pressure-temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR USE ON BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) AND (B).
(2) Use of this material at temperatures above 650°F is not approved because of the possibility of temper embrittlement.
(3) This steel may be expected to develop embrittlement at room temperature after service at temperatures above 700°F. Consequently, its use at higher temperatures is not recommended unless due caution is observed.
(4) For fittings made from A 182 forgings over 5 in. in thickness, the allowable stress values tabulated shall be reduced by the ratio of 70 divided by 75.
(5) The material quality factors and allowable stress values for these materials may be increased in accordance with para. 102.4.6.
(6) Tensile strengths in parentheses are expected minimum values.
(7) See MSS SP-43 for requirements for lightweight stainless steel fittings. MSS SP-43 Schedule 5S fittings shall not be used for design temperatures above 400°F. MSS SP-43 Schedule 10S fittings shall not be used for design temperatures above 750°F.
(8) The material quality factor for centrifugally cast pipe (0.85) is based on all surfaces being machined after heat treatment. The surface finish, after machining, shall be 250 μin. arithmetic average deviation or smoother.
(9) Due to relatively low yield strength of these materials, these higher allowable stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. These stress values exceed 67% but do not exceed 90% of the yield strength at temperature. Use of these stress values may result in dimensional changes due to permanent strain. These values should not be used for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction.
(10) The allowable stress vlaues tabulated for temperatures over 1000°F apply only if the carbon content of the material is 0.04% or higher.
(11) The allowable stress values tabulated for temperatures over 1000°F apply only if the material is heat treated by heating to a *minimum* temperature of 1900°F and quenching in water or rapidly cooling by other means.
(12) These allowable stress values apply to forgings over 5 in. in thickness.

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TABLE A-3
STAINLESS STEELS (CONT'D)

01

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Bar (Cont'd) Ferritic/Martensitic	
16.2	16.2	15.9	15.9	15.9	15.9	15.9	...	...	...	...	...	...	...	...	...	...	...	TPXM-27	A 479

NOTES (CONT'D):

(13) The allowable stress values tabulated for temperatures over 800°F apply only if the carbon content of the material is 0.04% or higher.

(14) These allowable stress values shall be used only when the grain size of the material is ASTM No. 6 or coarser.

(15) These allowable stress values shall be used when the grain size of the material is finer than ASTM No. 6 or when the grain size has not been determined.

(16) These stress values are established from a consideration of strength only and will be satisfactory for average service. For bolted joints, where freedom from leakage over a long period of time without retightening is required, lower stress values may be necessary as determined from the relative flexibility of the flange and bolts and corresponding relaxation properties.

(17) This is a product specification. Allowable stress values are not necessary. Limitations on metal temperature for materials covered by this specification for use under B31.1 are:

Grade 6 and 8F	−20°F to 800°F
Grades 8, 8C, 8M, & 8T	−20°F to 1200°F

(18) The hardness of this material, under the thread roots, shall not exceed Rockwell C35. The hardness shall be measured on a flat area, at least $^1/_8$ in. across, prepared by removing thread. No more material than necessary shall be removed to prepare the flat area. Hardness measurements shall be made at the same frequency as tensile test.

(19) These allowable stress values apply to bolting materials 4 in. in diameter and smaller.

(20) These allowable stress values apply to bolting materials $^3/_4$ in. in diameter and smaller.

(21) These allowable stress values apply to bolting materials larger than $^3/_4$ in. but not larger than 1 in. in diameter.

(22) These allowable stress values apply to bolting materials larger than 1 in. but not larger than $1^1/_4$ in. in diameter.

(23) These allowable stress values apply to bolting materials larger than $1^1/_4$ in. but not larger than $1^1/_2$ in. in diameter.

(24) These allowable stress values apply to bolting materials 8 in. in diameter and smaller.

(25) Use of external pressure charts for material in the form of barstock is permitted for stiffening rings only.

(26) At the ferrite levels tabulated below, these materials will have significant reductions in Charpy V-notch toughness values at room temperature and below following service exposure at the indicated temperatures. This reduction indicates the potential for brittle fracture with high rate loading in the presence of sharp notches or cracks.

Ferrite Content	Service Temperature
5% and less	1100°F and above
10%	900°F and above
15%	800°F and above
20%	700°F and above
25%–30%	600°F and above
35%–40%	500°F and above

(27) This stress values at 1050°F and above shall be used only when the grain size is ASTM No. 6 or coarser.

(28) These allowable stress values apply to material that has been carbide solution treated.

(29) These allowable stress values apply for single or double butt welded pipe with radiography per para. 136.4.5.

(30) These allowable stress values apply for double butt welded pipe.

(31) These allowable stress values apply for single butt welded pipe.

(32) This material is one of the highest tensile strength materials approved for use in ASME pressure component applications and little fatigue data is available for it in the ASME database. Therefore, the designer shall consider this when calculating the allowable stress range for expansion stresses and provide appropriate design margins.

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TABLE A-4
NICKEL AND HIGH NICKEL ALLOYS

Spec. No.	UNS Alloy No.	Temper or Condition	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube								
B 161	N02200	Annealed	Ni	41	(1)(5)	55	15	1.00
	N02200	Annealed	Ni	41	(1)(6)	55	12	1.00
	N02200	Str. rel.	Ni	41	(1)	65	40	1.00
B 161	N02201	Annealed	Ni-LC	41	(1)(5)	50	12	1.00
	N02201	Annealed	Ni-LC	41	(1)(6)	50	10	1.00
	N02201	Str. Rel.	Ni-LC	41	(1)	60	30	1.00
B 163	N08800	Annealed	Ni-Cr-Fe	45	(1)(7)	75	30	1.00
	N08800	Annealed	Ni-Cr-Fe	45	(1)(2)(7)	75	30	1.00
	N08810	Annealed	Ni-Cr-Fe	45	(1)	65	25	1.00
	N08810	Annealed	Ni-Cr-Fe	45	(1)(2)	65	25	1.00
B 165	N04400	Annealed	Ni-Cu	42	(1)(5)	70	28	1.00
	N04400	Annealed	Ni-Cu	42	(1)(6)	70	25	1.00
	N04400	Str. rel.	Ni-Cu	42	(1)(2)(3)	85	35	1.00
B 167	N06600	H.F./Ann.	Ni-Cr-Fe	43	(1)(5)	80	30	1.00
	N06600	H.F./Ann.	Ni-Cr-Fe	43	(1)(2)(5)	75	30	1.00
	N06600	H.F./Ann.	Ni-Cr-Fe	43	(1)(6)	75	25	1.00
	N06600	H.F./Ann.	Ni-Cr-Fe	43	(1)(2)(6)	80	25	1.00
B 167	N06600	C.D./Ann.	Ni-Cr-Fe	43	(1)(5)	80	35	1.00
	N06600	C.D./Ann.	Ni-Cr-Fe	43	(1)(2)(5)	80	35	1.00
	N06600	C.D./Ann.	Ni-Cr-Fe	43	(1)(6)	80	30	1.00
	N06600	C.D./Ann.	Ni-Cr-Fe	43	(1)(2)(6)	80	30	1.00
B 407	N08800	C.D./Ann.	Ni-Cr-Fe	45	(7)	75	30	1.00
	N08800	C.D./Ann.	Ni-Cr-Fe	45	(2)(7)	75	30	1.00
	N08810	Annealed	Ni-Cr-Fe	45	(7)	65	25	1.00
	N08810	Annealed	Ni-Cr-Fe	45	(2)(7)	65	25	1.00
B 423	N08825	C.W./Ann.	Ni-Fe-Cr-Mo-Cu	45	(1)(7)	85	35	1.00
	N08825	C.W./Ann.	Ni-Fe-Cr-Mo-Cu	45	(1)(2)(7)	85	35	1.00
B 622	N06022	Sol. Ann.	Ni-Mo-Cr-LC	44	(1)(12)(13)	100	...	1.00
	N06022	Sol. Ann.	Ni-Mo-Cr-LC	44	(1)(2)(12)(13)	100	...	1.00
B 677	N08925	Annealed	Ni-Fe-Cr-Mo-Cu-LC	45	(1)	87	...	1.00
	N08926	Annealed	Ni-Fe-Cr-Mo-Cu-N-LC	...	(1)	94	...	1.00
	N08926	Annealed	Ni-Fe-Cr-Mo-Cu-N-LC	...	(1)(2)	94	...	1.00
B 690	N08367	Annealed	Ni-Fe-Cr-Mo	45	(1)(8)(13)	104	46	1.00
	N08367	Annealed	Ni-Fe-Cr-Mo	45	(1)(2)(8)(13)	104	46	1.00

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TABLE A-4
NICKEL AND HIGH NICKEL ALLOYS

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, ° F, Not Exceeding																			
–20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	UNS Alloy No.	Spec. No.
																		Seamless Pipe and Tube	
10.0	10.0	10.0	10.0	10.0	10.0	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 161
8.0	8.0	8.0	8.0	8.0	8.0	...	...	...	...	...	...	...	...	...	...	...	...	N02200	
16.3	16.3	16.3	16.3	16.0	15.4	...	...	...	...	...	...	...	...	...	...	...	...	N02200	
8.0	7.7	7.5	7.5	7.5	7.5	7.5	7.4	7.3	7.2	5.8	4.5	3.7	3.0	2.4	2.0	1.5	1.2	N02200	B 161
6.7	6.4	6.3	6.2	6.2	6.2	6.2	6.2	6.0	5.9	5.8	4.5	3.7	3.0	2.4	2.0	1.5	1.2	N02200	
15.0	15.0	15.0	15.8	14.7	14.2	...	...	...	...	...	...	...	...	...	...	...	...	N02200	
18.7	18.7	17.9	17.2	16.7	16.3	16.1	15.9	15.7	15.5	15.3	15.1	14.9	14.7	14.5	13.0	9.8	6.6	N08800	B 163
18.7	18.7	18.7	18.7	18.7	18.7	18.6	18.6	18.5	18.5	18.3	18.2	17.9	17.6	17.0	13.0	9.8	6.6	N08800	
16.2	15.4	14.5	13.5	12.9	12.2	11.9	11.7	11.4	11.1	10.9	10.7	10.5	10.3	10.1	10.0	9.3	7.4	N08810	
16.2	16.2	16.2	16.2	16.0	16.0	16.0	15.7	15.4	15.3	15.1	14.8	14.6	14.4	13.7	11.6	9.3	7.4	N08810	
17.5	16.4	15.4	14.8	14.7	14.7	14.7	14.7	14.6	14.2	11.0	8.0	...	...	...	...	...	...	N04400	B 165
16.6	14.6	13.6	13.2	13.1	13.1	13.1	13.1	13.0	12.7	11.0	8.0	...	...	...	...	...	...	N04400	
21.2	21.2	21.2	21.1	21.0	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	
20.0	19.1	18.2	17.5	16.9	16.1	16.0	15.6	15.5	15.3	15.0	14.9	10.6	7.0	4.5	3.0	2.2	2.0	N06600	B 167
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.6	16.0	10.6	7.0	4.5	3.0	2.2	2.0	N06600	
16.7	15.3	14.5	14.0	13.6	13.2	13.1	13.0	12.9	12.7	12.3	11.8	10.6	7.0	4.5	3.0	2.2	2.0	N06600	
16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.5	15.9	15.9	7.0	4.5	3.0	2.2	2.0	N06600	
20.0	20.0	20.0	20.0	20.0	20.0	19.8	19.6	19.4	19.1	18.7	16.0	10.6	7.0	4.5	3.0	2.2	2.0	N06600	B 167
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	16.0	10.6	7.0	4.5	3.0	2.2	2.0	N06600	
20.0	19.1	18.2	17.5	16.9	16.1	16.0	15.6	15.5	15.3	15.0	14.9	10.6	7.0	4.5	3.0	2.2	2.0	N06600	
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.6	16.0	10.6	7.0	4.5	3.0	2.2	2.0	N06600	
18.7	18.7	17.9	17.2	16.7	16.3	16.1	15.9	15.7	15.5	15.3	15.1	14.9	14.7	14.5	13.0	9.8	6.6	N08800	B 407
18.7	18.7	18.7	18.7	18.7	18.7	18.6	18.6	18.5	18.5	18.3	18.2	17.9	17.6	17.0	13.0	9.8	6.6	N08800	
16.2	15.4	14.5	13.5	12.9	12.2	11.9	11.7	11.4	11.1	10.9	10.7	10.5	10.3	10.1	10.0	9.3	7.4	N08810	
16.2	16.2	16.2	16.2	16.0	16.0	16.0	15.7	15.4	15.3	15.1	14.8	14.6	14.4	13.7	11.6	9.3	7.4	N08810	
21.2	21.2	20.4	19.2	18.3	17.8	17.6	17.3	17.2	17.1	...	...	...	...	...	...	...	...	N08825	B 423
21.2	21.2	21.2	21.2	21.2	21.2	21.1	21.0	20.9	20.8	...	...	...	...	...	...	...	...	N08825	
25.0	25.0	24.5	22.7	21.2	20.1	19.6	19.2	18.9	18.6	...	...	...	...	...	...	...	...	N06022	B 622
25.0	25.0	24.8	23.9	23.2	22.7	22.6	22.4	22.3	22.2	...	...	...	...	...	...	...	...	N06022	
21.7	21.7	20.9	19.6	18.3	17.3	16.9	16.9	16.9	16.9	...	...	...	...	...	...	...	...	N08925	B 677
23.5	23.5	21.3	19.9	18.7	17.9	17.7	17.6	17.5	...	...	...	...	...	...	...	...	...	N08926	
23.5	23.5	22.9	21.8	20.8	20.0	19.6	19.3	19.2	...	...	...	...	...	...	...	...	...	N08926	
26.0	26.0	24.2	22.7	20.9	19.9	19.3	19.0	18.7	18.4	...	...	...	...	...	...	...	...	N08367	B 690
26.2	26.0	24.6	23.5	22.9	22.3	22.1	21.9	21.8	21.7	...	...	...	...	...	...	...	...	N08367	

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TABLE A-4
NICKEL AND HIGH NICKEL ALLOYS (CONT'D)

Spec. No.	UNS Alloy No.	Temper or Condition	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube (Cont'd)								
B 729	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)	80	35	1.00
	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)(2)	80	35	1.00
Welded Pipe and Tube								
B 464	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)	80	35	0.85
	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)(2)	80	35	0.85
B 468	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)	80	35	0.85
	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)(2)	80	35	0.85
B 619	N06022	Sol. Ann.	Ni–Mo–Cr–LC	44	(1)(12)	100	...	0.85
	N06022	Sol. Ann.	Ni–Mo–Cr–LC	44	(1)(2)(12)	100	...	0.85
B 626	N06022	Sol. Ann.	Ni–Mo–Cr–LC	44	(1)(12)	100	...	0.85
	N06022	Sol. Ann.	Ni–Mo–Cr–LC	44	(1)(2)(12)	100	...	0.85
B 673	N08925	Annealed	Ni–Fe–Cr–Mo–Cu–LC	45	(1)	87	...	0.85
	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–LC	...	(1)	94	...	0.85
	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–LC	...	(1)(2)	94	...	0.85
B 674	N08925	Annealed	Ni–Fe–Cr–Mo–Cu–LC	45	(1)	87	...	0.85
	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–LC	...	(1)	94	...	0.85
	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–LC	...	(1)(2)	94	...	0.85
B 675	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(8)(13)	104	46	0.85
	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(2)(8)(13)	104	46	0.85
B 676	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(8)(13)	104	46	0.85
	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(2)(8)(13)	104	46	0.85
B 804	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(8)(13)	95	45	0.85
	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(2)(8)(13)	95	45	0.85
Plate, Sheet, and Strip								
B 168	N06600	Annealed	Ni–Cr–Fe	43	(1)	80	35	1.00
	N06600	Annealed	Ni–Cr–Fe	43	(1)(2)	80	35	1.00
	N06600	Hot rolled	Ni–Cr–Fe	43	(1)(4)	85	35	1.00
	N06600	Hot rolled	Ni–Cr–Fe	43	(1)(2)(4)	85	35	1.00
B 409	N08800	Annealed	Ni–Cr–Fe	45	(4)(7)	75	30	1.00
	N08800	Annealed	Ni–Cr–Fe	45	(2)(4)(7)	75	30	1.00
	N08810	Annealed	Ni–Cr–Fe	45	(4)(7)	65	25	1.00
	N08810	Annealed	Ni–Cr–Fe	45	(2)(4)(7)	65	25	1.00

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TABLE A-4
NICKEL AND HIGH NICKEL ALLOYS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, ° F, Not Exceeding																		UNS Alloy No.	Spec. No.
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Seamless Pipe and Tube (Cont'd)	
20.0	20.0	19.8	18.7	18.2	17.7	17.5	17.3	17.1	16.8	...	...	...	...	...	...	...	...	N08020	B 729
20.0	20.0	19.8	19.4	19.3	19.3	19.2	19.2	19.2	19.1	...	...	...	...	...	...	...	...	N08020	
																		Welded Pipe and Tube	
17.0	17.0	16.8	15.9	15.5	15.1	14.9	14.7	14.5	14.3	...	...	...	...	...	...	...	...	N08020	B 464
17.0	17.0	16.8	16.5	16.4	16.4	16.3	16.3	16.3	16.2	...	...	...	...	...	...	...	...	N08020	
17.0	17.0	16.8	15.9	15.5	15.1	14.9	14.7	14.5	14.3	...	...	...	...	...	...	...	...	N08020	B 468
17.0	17.0	16.8	16.5	16.4	16.4	16.3	16.3	16.3	16.2	...	...	...	...	...	...	...	...	N08020	
21.2	21.2	20.8	19.3	18.0	17.1	16.7	16.3	16.1	15.8	...	...	...	...	...	...	...	...	N06022	B 619
21.2	21.2	21.1	20.3	19.7	19.3	19.2	19.0	19.0	18.9	...	...	...	...	...	...	...	...	N06022	
21.2	21.2	20.8	19.3	18.0	17.1	16.7	16.3	16.1	15.8	...	...	...	...	...	...	...	...	N06022	B 626
21.2	21.2	21.1	20.3	19.7	19.3	19.2	19.0	19.0	18.9	...	...	...	...	...	...	...	...	N06022	
18.4	18.4	17.8	16.7	15.6	14.7	14.4	14.4	14.4	14.4	...	...	...	...	...	...	...	...	N08925	B 673
20.0	20.0	18.1	16.9	15.9	15.2	15.0	15.0	14.9	...	...	...	...	...	...	...	...	...	N08926	
20.0	20.0	19.5	18.5	17.7	17.0	16.7	16.4	16.3	...	...	...	...	...	...	...	...	...	N08926	
18.4	18.4	17.8	16.7	15.6	14.7	14.4	14.4	14.4	14.4	...	...	...	...	...	...	...	...	N08925	B674
20.0	20.0	18.1	16.9	15.9	15.2	15.0	15.0	14.9	...	...	...	...	...	...	...	...	...	N08926	
20.0	20.0	19.5	18.5	17.7	17.0	16.7	16.4	16.3	...	...	...	...	...	...	...	...	...	N08926	
22.1	22.1	20.6	19.3	17.8	16.9	16.4	16.2	15.9	15.6	...	...	...	...	...	...	...	...	N08367	B 675
22.1	22.1	20.9	20.0	19.5	19.0	18.8	18.6	18.5	18.4	...	...	...	...	...	...	...	...	N08367	
22.1	22.1	20.6	19.3	17.8	16.9	16.4	16.2	15.9	15.6	...	...	...	...	...	...	...	...	N08367	B 676
22.1	22.1	20.9	20.0	19.5	19.0	18.8	18.6	18.5	18.4	...	...	...	...	...	...	...	...	N08367	
20.2	20.2	19.1	18.2	17.3	16.6	16.1	15.8	15.6	15.3	...	...	...	...	...	...	...	...	N08367	B 804
20.2	20.2	19.1	18.2	17.8	17.3	17.2	17.0	16.9	16.8	...	...	...	...	...	...	...	...	N08367	
																		Plate, Sheet, and Strip	
20.0	20.0	20.0	20.0	20.0	20.0	19.8	19.6	19.4	19.1	18.7	16.0	10.6	7.0	4.5	3.0	2.2	2.0	N06600	B 168
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	16.0	10.6	7.0	4.5	3.0	2.2	2.0	N06600	
21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.1	21.0	20.4	20.2	19.6	19.3	14.5	10.3	7.2	5.8	5.5	N06600	
21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	14.5	10.3	7.2	5.8	5.5	N06600	
18.7	18.7	17.9	17.2	16.7	16.3	16.1	15.9	15.7	15.5	15.3	15.1	14.9	14.7	14.5	13.0	9.8	6.6	N08800	B 409
18.7	18.7	18.7	18.7	18.7	18.7	18.6	18.6	18.5	18.5	18.3	18.2	17.9	17.6	17.0	13.0	9.8	6.6	N08800	
16.2	15.4	14.5	13.5	12.9	12.2	11.9	11.7	11.4	11.1	10.9	10.7	10.5	10.3	10.1	10.0	9.3	7.4	N08810	
16.2	16.2	16.2	16.2	16.0	16.0	16.0	15.7	15.4	15.3	15.1	14.8	14.6	14.4	13.7	11.6	9.3	7.4	N08810	

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TABLE A-4
NICKEL AND HIGH NICKEL ALLOYS (CONT'D)

Spec. No.	UNS Alloy No.	Temper or Condition	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Plate, Sheet, and Strip (Cont'd)								
B 424	N08825	Annealed	Ni–Fe–Cr–Mo–Cu	45	(1)(7)	85	35	1.00
	N08825	Annealed	Ni–Fe–Cr–Mo–Cu	45	(1)(2)(7)	85	35	1.00
B 463	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)	80	35	1.00
	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)(12)	80	35	1.00
B 575	N06022	Sol. Ann.	Ni–Mo–Cr–LC	44	(1)(12)	100	...	1.00
	N06022	Sol. Ann.	Ni–Mo–Cr–LC	44	(1)(2)(12)	100	...	1.00
B 625	N08925	Annealed	Ni–Fe–Cr–Mo–Cu–LC	45	(1)	87	...	1.00
	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–LC	...	(1)	94	...	1.00
	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–LC	...	(1)(2)	94	...	1.00
B 688	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(7)(9)(13)	104	46	1.00
	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(2)(7)(9)(13)	104	46	1.00
	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(7)(10)(13)	100	45	1.00
	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(2)(7)(10)(13)	100	45	1.00
	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(7)(11)(13)	95	45	1.00
	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(2)(7)(11)(13)	95	45	1.00
Bars, Rods, Shapes, and Forgings								
B 408	N08800	Annealed	Ni–Cr–Fe	45	(7)	75	30	1.00
	N08800	Annealed	Ni–Cr–Fe	45	(2)(7)	75	30	1.00
	N08810	Annealed	Ni–Cr–Fe	45	(7)	65	25	1.00
	N08810	Annealed	Ni–Cr–Fe	45	(2)(7)	65	25	1.00
B 425	N08825	Annealed	Ni–Fe–Cr–Mo–Cu	45	(1)(7)	85	35	1.00
	N08825	Annealed	Ni–Fe–Cr–Mo–Cu	45	(1)(2)(7)	85	35	1.00
B 462	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)	80	35	1.00
	N08020	Annealed	Ni–Fe–Cr–Mo–Cu–Cb	45	(1)(2)	80	35	1.00
B 473	N08020	Annealed	Cr–Ni–Fe–Mo–Cu–Cb	45	(1)	80	35	1.00
	N08020	Annealed	Cr–Ni–Fe–Mo–Cu–Cb	45	(1)(2)	80	35	1.00
B 564	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(8)(13)	95	45	1.00
	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(2)(8)(13)	95	45	1.00
	N08800	Annealed	Ni–Cr–Fe	45	(1)	75	30	1.00
	N08800	Annealed	Ni–Cr–Fe	45	(1)(2)	75	30	1.00
	N08810	Annealed	Ni–Cr–Fe	45	(1)	65	25	1.00
	N08810	Annealed	Ni–Cr–Fe	45	(1)(2)	65	25	1.00
B 574	N06022	Sol. Ann.	Ni–Mo–Cr–LC	44	(1)(12)	100	...	1.00
	N06022	Sol. Ann.	Ni–Mo–Cr–LC	44	(1)(2)(12)	100	...	1.00

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TABLE A-4
NICKEL AND HIGH NICKEL ALLOYS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, ° F, Not Exceeding																		UNS Alloy No.	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Plate, Sheet, and Strip (Cont'd)	
21.2	21.2	20.4	19.2	18.3	17.8	17.6	17.3	17.2	17.1	...	...	...	...	...	...	...	...	N08825	B 424
21.2	21.2	21.2	21.2	21.2	21.2	21.1	21.0	20.9	20.8	...	...	...	...	...	...	...	...	N08825	
20.0	20.0	19.8	18.7	18.2	17.5	17.4	17.3	17.0	16.8	...	...	...	...	...	...	...	...	N08020	B 463
20.0	20.0	19.8	19.4	19.3	19.2	19.2	19.2	19.1	19.1	...	...	...	...	...	...	...	...	N08020	
25.0	25.0	24.5	22.7	21.2	20.1	19.6	19.2	18.9	18.6	...	...	...	...	...	...	...	...	N06022	B 575
25.0	25.0	24.8	23.9	23.2	22.7	22.6	22.4	22.3	22.2	...	...	...	...	...	...	...	...	N06022	
21.7	21.7	20.9	19.6	18.3	17.3	16.9	16.9	16.9	16.9	...	...	...	...	...	...	...	...	N08925	B 625
23.5	23.5	21.3	19.9	18.7	17.9	17.7	17.6	17.5	...	...	...	...	...	...	...	...	...	N08926	
23.5	23.5	22.9	21.8	20.8	20.0	19.6	19.3	19.2	...	...	...	...	...	...	...	...	...	N08926	
26.0	26.0	24.2	22.7	20.9	19.9	19.3	19.0	18.7	18.4	...	...	...	...	...	...	...	...	N08367	B 688
26.0	26.0	24.6	23.5	22.9	22.3	22.1	21.9	21.8	21.7	...	...	...	...	...	...	...	...	N08367	
25.0	25.0	23.6	22.2	20.4	19.5	18.9	18.6	18.3	18.0	...	...	...	...	...	...	...	...	N08367	
25.0	25.0	23.6	22.6	22.0	21.9	21.3	21.1	21.0	20.9	...	...	...	...	...	...	...	...	N08367	
23.8	23.8	22.5	21.4	20.4	19.5	18.9	18.6	18.3	18.0	...	...	...	...	...	...	...	...	N08367	
23.8	23.8	22.5	21.4	20.9	20.4	20.2	20.0	19.9	19.8	...	...	...	...	...	...	...	...	N08367	
																		Bars, Rods, Shapes, and Forgings	
18.7	18.7	17.9	17.2	16.7	16.3	16.1	15.9	15.7	15.5	15.3	15.1	14.9	14.7	14.5	13.0	9.8	6.6	N08800	B 408
18.7	18.7	18.7	18.7	18.7	18.7	18.6	18.6	18.5	18.5	18.3	18.2	17.9	17.6	17.0	13.0	9.8	6.6	N08800	
16.2	15.4	14.5	13.5	12.9	12.2	11.9	11.7	11.4	11.1	10.9	10.7	10.5	10.3	10.1	10.0	9.3	7.4	N08810	
16.2	16.2	16.2	16.2	16.0	16.0	16.0	15.7	15.4	15.3	15.1	14.8	14.6	14.4	13.7	11.6	9.3	7.4	N08810	
21.2	21.2	20.4	19.2	18.3	17.8	17.6	17.3	17.2	17.1	...	...	...	...	...	...	...	...	N08825	B 425
21.2	21.2	21.2	21.2	21.2	21.2	21.1	21.0	20.9	20.8	...	...	...	...	...	...	...	...	N08825	
20.0	20.0	19.8	18.7	18.2	17.7	17.5	17.3	17.1	16.8	...	...	...	...	...	...	...	...	N08020	B 462
20.0	20.0	19.8	19.4	19.3	19.3	19.2	19.2	19.2	19.1	...	...	...	...	...	...	...	...	N08020	
20.0	20.0	19.8	18.7	18.2	17.7	17.5	17.3	17.1	16.8	...	...	...	...	...	...	..	...	N08020	B 473
20.0	20.0	19.8	19.4	19.3	19.3	19.2	19.2	19.2	19.1	...	...	...	...	...	...	...	...	N08020	
23.8	23.8	22.5	21.4	20.4	19.5	18.9	18.6	18.3	18.0	...	...	...	...	...	...	...	...	N08367	B 564
23.8	23.8	22.5	21.4	20.9	20.4	20.2	20.0	19.9	19.8	...	...	...	...	...	...	...	...	N08367	
18.7	18.7	17.9	17.2	16.7	16.3	16.1	15.9	15.7	15.5	15.3	15.1	14.9	14.7	14.5	13.0	9.8	6.6	N08800	
18.7	18.7	18.7	18.7	18.7	18.7	18.6	18.6	18.5	18.5	18.3	18.2	17.9	17.6	17.0	13.0	9.8	6.6	N08800	
16.2	15.4	14.5	13.5	12.9	12.2	11.9	11.7	11.4	11.1	10.9	10.7	10.5	10.3	10.1	10.0	9.3	7.4	N08810	
16.2	16.2	16.2	16.2	16.0	16.0	16.0	15.7	15.4	15.3	15.1	14.8	14.6	14.4	13.7	11.6	9.3	7.4	N08810	
25.0	25.0	24.5	22.7	21.2	20.1	19.6	19.2	18.9	18.6	...	...	...	...	...	...	...	...	N06022	B 574
25.0	25.0	24.8	23.9	23.2	22.7	22.6	22.4	22.3	22.2	...	...	...	...	...	...	...	...	N06022	

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TABLE A-4
NICKEL AND HIGH NICKEL ALLOYS (CONT'D)

Spec. No.	UNS Alloy No.	Temper or Condition	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Bars, Rods, Shapes, and Forgings (Cont'd)								
B 649	N08925	Annealed	Ni–Fe–Cr–Mo–Cu–LC	45	(1)	87	...	0.85
	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–LC	...	(1)	94	...	1.00
	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–LC	...	(1)(2)	94	...	1.00
B 691	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(8)(13)	95	45	1.00
	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(2)(8)(13)	95	45	1.00
Seamless Fittings								
B 366	N06022	Sol. Ann.	Ni–Mo–Cr–LC	44	(1)(12)(13)	100	...	1.00
	N06022	Sol. Ann.	Ni–Mo–Cr–LC	44	(1)(2)(12)(13)	100	...	1.00
	N08020	Annealed	Cr–Ni–Fe–Mo–Cu–Cb	45	(1)	80	35	...
	N08020	Annealed	Cr–Ni–Fe–Mo–Cu–Cb	45	(1)(2)	80	35	...
	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(8)(13)	95	45	1.00
	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(2)(8)(13)	95	45	1.00
B 366	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–LC	...	(1)	94	...	1.00
	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–LC	...	(1)(2)	94	...	1.00
B 462	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(8)(13)	95	45	1.00
	N08367	Annealed	Ni–Fe–Cr–Mo	45	(1)(2)(8)(13)	95	45	1.00
Welded Fittings								
B 366	N06022	Sol. Ann.	Ni–Mo–Cr–LC	44	(1)(12)(13)	100	...	0.85
	N06022	Sol. Ann.	Ni–Mo–Cr–LC	44	(1)(2)(12)(13)	100	...	0.85
	N08020	Annealed	Cr–Ni–Fe–Mo–Cu–Cb	45	(1)	80	35	0.85
	N08020	Annealed	Cr–Ni–Fe–Mo–Cu–Cb	45	(1)(2)	80	35	0.85
B 366	N08925	Annealed	Ni–Fe–Cr–Mo–Cu–LC	45	(1)	87	...	0.85
	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–LC	...	(1)	94	...	0.85
	N08926	Annealed	Ni–Fe–Cr–Mo–Cu–N–LC	...	(1)(2)	94	...	0.85

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.

(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.

(c) The P-Numbers indicated in this Table are identical to those adopted by the ASME Boiler and Pressure Vessel Code. Qualification of welding procedures, welders, and welding operators is required and shall comply with the ASME Boiler and Pressure Vessel Code, Section IX, except as modified by para. 127.5.

(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."

(e) The materials listed in this table shall not be used at design temperatures above those for which allowable stress values are given.

(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. Weld joint efficiency factors are shown in Table 102.4.3.

(g) Pressure-temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.

(h) The y coefficient = 0.4 except where Note (7) applies [see Table 104.1.2(A)].

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TABLE A-4
NICKEL AND HIGH NICKEL ALLOYS (CONT'D)

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Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, ° F, Not Exceeding																		UNS Alloy No.	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
Bars, Rods, Shapes, and Forgings (Cont'd)																			
21.7	21.7	20.9	19.6	18.3	17.3	16.9	16.9	16.9	16.9	...	...	...	...	...	...	...	...	N08925	B 649
23.5	23.5	21.3	19.9	18.7	17.9	17.7	17.6	17.5	...	...	...	...	...	...	...	...	...	N08926	
23.5	23.5	22.9	21.8	20.8	20.0	19.6	19.3	19.2	...	...	...	...	...	...	...	...	...	N08926	
23.8	23.8	22.5	21.4	20.4	19.5	18.9	18.6	18.3	18.0	...	...	...	...	...	...	...	...	N08367	B 691
23.8	23.8	22.5	21.4	20.9	20.4	20.2	20.0	19.9	19.8	...	...	...	...	...	...	...	...	N08367	
Seamless Fittings																			
25.0	25.0	24.5	22.7	21.2	20.1	19.6	19.2	18.9	18.6	...	...	...	...	...	...	...	...	N06022	B 366
25.0	25.0	24.8	23.9	23.2	22.7	22.6	22.4	22.3	22.2	...	...	...	...	...	...	...	...	N06022	
20.0	20.0	19.8	18.7	18.2	17.5	17.4	17.3	17.0	16.8	...	...	...	...	...	...	...	...	N08020	
20.0	20.0	19.8	19.4	19.3	19.2	19.2	19.2	19.1	19.1	...	...	...	...	...	...	...	...	N08020	
23.8	23.8	22.5	21.4	20.4	19.5	18.9	18.6	18.3	18.0	...	...	...	...	...	...	...	...	N08367	
23.8	23.8	22.5	21.4	20.9	20.4	20.2	20.0	19.9	19.8	...	...	...	...	...	...	...	...	N08367	
23.5	23.5	21.3	19.9	18.7	17.9	17.7	17.6	17.5	...	...	...	...	...	...	...	...	...	N08926	B 366
23.5	23.5	22.9	21.8	20.8	20.0	19.6	19.3	19.2	...	...	...	...	...	...	...	...	...	N08926	
23.8	23.8	22.5	21.4	20.4	19.5	18.9	18.6	18.3	18.0	...	...	...	...	...	...	...	...	N08367	B 462
23.8	23.8	22.5	21.4	20.9	20.4	20.2	20.0	19.9	19.8	...	...	...	...	...	...	...	...	N08367	
Welded Fittings																			
21.2	21.2	20.8	19.3	18.0	17.1	16.7	16.3	16.1	15.8	...	...	...	...	...	...	...	...	N06022	B 366
21.2	21.2	21.1	20.3	19.7	19.3	19.2	19.0	19.0	18.9	...	...	...	...	...	...	...	...	N06022	
17.0	17.0	16.8	15.9	15.5	14.9	14.8	14.7	14.5	14.3	...	...	...	...	...	...	...	...	N08020	
17.0	17.0	16.8	16.5	16.4	16.4	16.3	16.3	16.3	16.2	...	...	...	...	...	...	...	...	N08020	
18.4	18.4	17.8	16.7	15.6	14.7	14.4	14.4	14.4	14.4	...	...	...	...	...	...	...	...	N08925	B 366
20.0	20.0	18.1	16.9	15.9	15.2	15.0	15.0	14.9	...	...	...	...	...	...	...	...	...	N08926	
20.0	20.0	19.5	18.5	17.7	17.0	16.7	16.4	16.3	...	...	...	...	...	...	...	...	...	N08926	

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR USE ON BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) AND (B).

(2) Due to the relatively low yield strengths of these materials, these higher allowable stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. These stress values exceed 67% but do not exceed 90% of the yield strength at temperature. Use of these values may result in dimensional changes due to permanent strain. These values should not be used for flanges of gasketed joints or other applications where slight amounts ofdistortion can cause leakage or malfunction.

(3) The maximum temperature is limited to 500°F because harder temper adversely affects design stress in the creep rupture temperature range.

(4) These values may be used for plate material only.

(5) These values apply to sizes NPS 5 and smaller.

(6) These values apply to sizes larger than NPS 5.

(7) See Table 104.1.2(A) for y coefficient value.

(8) Heat treatment after forming or welding is neither required nor prohibited. However, if heat treatment is applied, the solution annealing treatment shall consist of heating to a minimum temperature of 2025°F and then quenching in water or rapidly cooling by other means.

(9) These values apply to thickness less than $^3/_{16}$ in.

(10) These values apply to thickness from $^3/_{16}$ in. up to and including $^3/_4$ in.

(11) These values apply to thickness more than $^3/_4$ in.

(12) All filler metal, including consumable insert material, shall comply with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

(13) This material is one of the highest tensile strength materials approved for use in ASME pressure component applications and little fatigue data is available for it in the ASME database. Therefore, the designer shall consider this when calculating the allowable stress range for expansion stresses and provide appropriate design margins.

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TABLE A-5
CAST IRON

Spec. No.	Class	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Gray Cast Iron					
A 48	20	(1)(2)(3)(4)	20	...	...
	25	(1)(2)(3)(4)	25	...	...
	30	(1)(2)(3)(4)	30	...	...
	35	(1)(2)(3)(4)	35	...	...
	40	(1)(2)(3)(4)	40	...	...
	45	(1)(2)(3)(4)	45	...	...
	50	(1)(2)(3)(4)	50	...	...
	55	(1)(2)(3)(4)	55	...	...
	60	(1)(2)(3)(4)	60	...	...
A 126	A	(3)(4)(7)	21	...	...
	B	(3)(4)(7)	31	...	...
	C	(3)(4)(7)	41	...	...
A 278	20	(2)(4)(5)	20	...	...
	25	(2)(4)(5)	25	...	...
	30	(2)(4)(5)	30	...	...
	35	(2)(4)(5)	35	...	...
	40	(2)(4)(5)	40	...	...
	45	(2)(4)(5)	45	...	...
	50	(2)(4)(5)	50	...	...
	55	(2)(4)(5)	55	...	...
	60	(2)(4)(5)	60	...	...
Ductile Cast Iron					
A 395	...	(6)(8)	60	40	0.80
A 536	60-42-10	(1)(8)	60	42	0.80
	70-50-05	(1)(8)	70	50	0.80

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.

(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.

(c) Cast iron components shall not be welded during fabrication or assembly as part of the piping system.

(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."

(e) The materials listed in this Table shall not be used at design temperatures above those for which allowable stress values are given.

(f) The tabulated stress values for ductile cast iron materials are $S \times F$ (material quality factor). Material quality factors are not applicable to other types of cast iron.

(g) Pressure-temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.

(h) The y coefficient = 0.4 [see Table 104.1.2(A)].

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TABLE A-5
CAST IRON

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding							
–20 to 400	450	500	600	650	–20 to 650	Class	Spec. No.
							Gray Cast Iron
2.0	...	...	...	...	...	20	A 48
2.5	...	...	...	...	...	25	
3.0	...	...	...	...	...	30	
3.5	...	...	...	...	...	35	
4.0	...	...	...	...	...	40	
4.5	...	...	...	...	...	45	
5.0	...	...	...	...	...	50	
5.5	...	...	...	...	...	55	
6.0	...	...	...	...	...	60	
2.0	...	...	...	...	...	A	A 126
3.0	...	...	...	...	...	B	
4.0	...	...	...	...	...	C	
2.0	2.0	...	...	...	...	20	A 278
2.5	2.5	...	...	...	...	25	
3.0	3.0	...	...	...	...	30	
3.5	3.5	...	...	...	...	35	
...	...	...	...	...	4.0	40	
...	...	...	...	...	4.5	45	
...	...	...	...	...	5.0	50	
...	...	...	...	...	5.5	55	
...	...	...	...	...	6.0	60	
							Ductile Cast Iron
...	...	...	...	...	9.6	...	A 395
...	...	...	...	...	4.8	60-42-10	A 536
...	...	...	...	...	5.6	70-50-05	

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) AND (B).

(2) Material quality factors are not applicable to these materials.

(3) For saturated steam at 250 psi (406°F), the stress values given at 400°F may be used.

(4) For limitations on the use of this material, see para. 124.4.

(5) This material shall not be used where the design pressure exceeds 250 psig [1725 kPa(gage)] or where the design temperature exceeds 450°F (230°C).

(6) This material shall not be used for boiler external piping where the design pressure exceeds 350 psig [2415 kPa (gage)] or where the design temperature exceeds 450°F (230°C).

(7) Piping components conforming to either ASME B16.1 or ASME B16.4 may be used for boiler external piping, subject to all the requirements of the particular standard.

(8) For limitations on the use of this material, see para. 124.6.

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TABLE A-6
COPPER AND COPPER ALLOYS

Spec No.	UNS Alloy No.	Temper or Condition	Size or Thickness, in.	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube								
B 42	C10200, C12000, C12200	Annealed	...	31	(2)	30	9	1.00
	C10200, C12000, C12200	Drawn	1/8 to 2	31	(2)(4)	45	40	1.00
	C10200, C12000, C12200	Drawn	2 1/2 to 12	31	(2)(4)	36	30	1.00
B 43	C23000	Annealed	...	31	(2)	40	12	1.00
B 68	C10200, C12000, C12200	Annealed	...	31	(1)	30	9	1.00
B 75	C10200, C12000	Annealed	...	31	(2)	30	9	1.00
	C10200, C12000	Light Drawn	...	31	(2)(4)	36	30	1.00
	C10200, C12000	Hard Drawn	...	31	(2)(4)	45	40	1.00
B 75	C12200, C14200	Annealed	...	31	(2)	30	9	1.00
	C12200, C14200	Light Drawn	...	31	(2)(4)	36	30	1.00
	C12200, C14200	Hard Drawn	...	31	(2)(4)	45	40	1.00
B 88	C10200, C12000, C12200	Annealed	...	31	(1)	30	9	1.00
	C10200, C12000, C12200	Drawn	...	31	(1)(4)	36	30	1.00
B 111	C10200, C12000	Light Drawn	...	31	(1)(3)	36	30	1.00
	C10200, C12000	Hard Drawn	...	31	(1)(3)	45	40	1.00
	C12200, C14200	Light Drawn	...	31	(1)(3)	36	30	1.00
	C12200, C14200	Hard Drawn	...	31	(1)(3)	45	40	1.00
B 111	C23000	Annealed	...	32	(1)	40	12	1.00
	C28000	Annealed	...	32	(2)	50	20	1.00
	C44300, C44400, C44500	Annealed	...	32	(2)	45	15	1.00
	C60800	Annealed	...	35	(1)	50	19	1.00
B 111	C68700	Annealed	...	32	(1)	50	18	1.00
	C70400	Annealed	...	34	(1)	38	12	1.00
	C70400	Light Drawn	...	34	(1)(4)	40	30	1.00

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TABLE A-6
COPPER AND COPPER ALLOYS

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
−20 to 100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	UNS Alloy No.	Spec. No.
															Seamless Pipe and Tube	
6.0	5.1	4.8	4.8	4.7	4.0	3.0	...	...	...	...	...	...	...	...	C10200, C12000, C12200	B 42
11.3	11.3	11.3	11.3	11.0	10.3	4.3	...	...	...	...	...	...	...	...	C10200, C12000, C12200	
9.0	9.0	9.0	9.0	8.7	8.5	8.2	...	...	...	...	...	...	...	...	C10200, C12000, C12200	
8.0	8.0	8.0	8.0	8.0	7.0	5.0	2.0	...	...	...	...	...	...	...	C23000	B 43
6.0	6.0	5.9	5.8	5.0	3.8	2.5	...	...	...	...	...	...	...	...	C10200, C12000, C12200	B 68
6.0	5.1	4.8	4.8	4.7	4.0	3.0	...	...	...	...	...	...	...	...	C10200, C12000	B 75
9.0	9.0	9.0	9.0	8.7	8.5	8.2	...	...	...	...	...	...	...	...	C10200, C12000	
11.3	11.3	11.3	11.3	11.0	10.3	4.3	...	...	...	...	...	...	...	...	C10200, C12000	
6.0	5.1	4.8	4.8	4.7	4.0	3.0	...	...	...	...	...	...	...	...	C12200, C14200	B 75
9.0	9.0	9.0	9.0	8.7	8.5	8.2	...	...	...	...	...	...	...	...	C12200, C14200	
11.3	11.3	11.3	11.3	11.0	10.3	4.3	...	...	...	...	...	...	...	...	C12200, C14200	
6.0	5.1	4.8	4.8	4.7	4.0	3.0	...	...	...	...	...	...	...	...	C10200, C12000, C12200	B 88
9.0	9.0	9.0	9.0	8.7	8.5	8.2	...	...	...	...	...	...	...	...	C10200, C12000, C12200	
9.0	9.0	9.0	9.0	8.7	8.5	8.2	...	...	...	...	...	...	...	...	C10200, C12000	B 111
11.3	11.3	11.3	11.3	11.0	10.3	4.3	...	...	...	...	...	...	...	...	C10200, C12000	
9.0	9.0	9.0	9.0	8.7	8.5	8.2	...	...	...	...	...	...	...	...	C12200, C14200	
11.3	11.3	11.3	11.3	11.0	10.3	4.3	...	...	...	...	...	...	...	...	C12200, C14200	
8.0	8.0	8.0	8.0	8.0	7.0	5.0	2.0	...	...	...	...	...	...	...	C23000	B 111
12.5	12.5	12.5	12.5	12.5	10.8	5.3	...	...	...	...	...	...	...	...	C28000	
10.0	10.0	10.0	10.0	10.0	9.8	3.5	2.0	...	...	...	...	...	...	...	C44300, C44400, C44500	
12.5	12.4	12.2	11.9	11.6	10.0	6.0	4.0	2.0	...	...	...	...	...	...	C60800	
12.0	11.9	11.8	11.7	11.7	6.5	3.3	1.8	...	...	...	...	...	...	...	C68700	B 111
8.0	8.0	...	...	...	...	...	...	...	...	...	...	...	...	...	C70400	
10.0	10.0	...	...	...	...	...	...	...	...	...	...	...	...	...	C70400	

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TABLE A-6
COPPER AND COPPER ALLOYS (CONT'D)

Spec No.	UNS Alloy No.	Temper or Condition	Size or Thickness, in.	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube (Cont'd)								
B 111	C70600	Annealed	...	34	(2)	40	15	1.00
	C71000	Annealed	...	34	(2)	45	16	1.00
	C71500	Annealed	...	34	(2)	52	18	1.00
B 280	C12200	Annealed	...	31	(1)	30	9	1.00
	C12200	Drawn	...	31	(1)(4)	36	30	1.00
B 302	C12000, C12200	Drawn	...	32	(1)(3)	36	30	1.00
B 315	C61300, C61400	Annealed	...	35	(1)	65	28	1.00
B 466	C70600	Annealed	...	34	(1)	38	13	1.00
	C71500	Annealed	...	34	(1)	50	18	1.00
Welded Pipe and Tube								
B 467	C70600	Annealed	4½ & under	34	(1)	40	15	0.85
	C70600	Annealed	Over 4½	34	(1)	38	13	0.85
	C71500	Annealed	4½ & under	34	(1)	50	20	0.85
	C71500	Annealed	Over 4½	34	(1)	45	15	0.85
B 608	C61300, C61400	Annealed	4 to 48	35	(1)(6)	70	30	0.85
Plate								
B 402	C70600	Annealed	2½ & under	34	(1)	40	15	1.00
	C71500	Annealed	2½ & under	34	(1)	50	20	1.00
	C71500	Annealed	Over 2½ to 5	34	(1)	45	18	1.00
Rod and Bar								
B 151	C71500	Annealed	Over 1	34	(1)	45	18	1.00
Die Forgings (Hot Pressed)								
B 283	C37700	As forged	1½ & under	...	(1)(3)	50	18	1.00
	C37700	As forged	Over 1½	...	(1)(3)	46	15	1.00

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TABLE A-6
COPPER AND COPPER ALLOYS (CONT'D)

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Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
-20 to 100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	UNS Alloy No.	Spec. No.
															Seamless Pipe and Tube (Cont'd)	
10.0	9.7	9.5	9.3	9.0	8.7	8.5	8.2	8.0	7.0	6.0	...	...	...	...	C70600	B 111
10.7	10.6	10.5	10.4	10.3	10.1	9.9	9.6	9.3	8.9	8.4	7.7	7.0	...	...	C71000	
12.0	11.6	11.3	11.0	10.8	10.6	10.3	10.1	9.9	9.8	9.6	9.5	9.4	...	...	C71500	
6.0	5.1	4.8	4.8	4.7	4.0	3.0	...	...	...	...	...	...	...	...	C12200	B 280
9.0	9.0	9.0	9.0	8.7	8.5	8.2	...	...	...	...	...	...	...	...	C12200	
9.0	9.0	9.0	9.0	8.7	8.5	8.2	...	...	...	...	...	...	...	...	C12000, C12200	B 302
16.2	16.2	16.2	16.2	16.2	16.2	15.9	15.3	14.7	...	...	...	...	...	...	C61300, C61400	B 315
8.7	8.4	8.3	8.0	7.8	7.7	7.6	7.5	7.3	7.0	6.0	...	...	...	...	C70600	B 466
12.0	11.6	11.3	11.0	10.8	10.6	10.3	10.1	9.9	9.8	9.6	...	...	...	...	C71500	
															Welded Pipe and Tube	
8.5	8.2	8.1	7.9	7.6	7.4	7.2	7.1	6.3	5.7	4.3	...	...	...	...	C70600	B 467
7.4	7.1	7.1	6.8	6.6	6.5	6.5	6.4	6.2	5.7	4.3	...	...	...	...	C70600	
10.6	9.6	8.9	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	...	...	...	...	C71500	
8.5	8.2	8.0	7.8	7.7	7.5	7.3	7.1	7.0	6.9	6.8	...	...	...	...	C71500	
14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.6	13.2	...	...	...	...	...	...	C61300, C61400	B 608
															Plate	
10.1	9.7	9.5	9.3	9.0	8.7	8.5	8.2	8.0	7.0	6.0	...	...	...	...	C70600	B 402
12.5	11.3	10.5	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	C71500	
11.3	10.1	9.4	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	9.3	...	...	C71500	
															Rod and Bar	
11.3	10.8	10.5	10.2	9.9	9.7	9.5	9.4	9.3	9.2	9.1	...	...	...	...	C71500	B 151
															Die Forgings (Hot Pressed)	
12.0	11.3	10.9	...	...	...	...	...	...	...	...	...	...	...	...	C37700	B 283
10.0	9.5	9.1	...	...	...	...	...	...	...	...	...	...	...	...	C37700	

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TABLE A-6
COPPER AND COPPER ALLOYS (CONT'D)

Spec No.	UNS Alloy No.	Temper or Condition	Size or Thickness, in.	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Castings								
B 61	C92200	As cast	...	...	...	34	16	0.80
B 62	C83600	As cast	...	...	...	30	14	0.80
B 148	C95200	As cast	...	35	(1)	65	25	0.80
	C95400	As cast	...	35	(1)(5)	75	30	0.80
B 584	C92200	As cast	...	...		34	16	0.80
	C93700	As cast	...	...	(3)	30	12	0.80
	C97600	As cast	...	...	(3)	40	17	0.80
Bolts, Nuts, and Studs								
B 150	C61400	HR50	½ & under	...	(1)(3)	80	50	1.00
	C61400	HR50	Over ½ to 1	...	(1)(3)	75	35	1.00
	C61400	HR50	Over 2 to 3	...	(1)(3)	70	30	1.00

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.

(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.

(c) The P-Numbers listed in this Table are identical to those adopted by the ASME Boiler and Pressure Vessel Code, Qualification of welding procedures, welders, and welding operators is required and shall comply with the ASME Boiler and Pressure Vessel Code, Section IX, except as modified by para. 127.5.

(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."

(e) The materials listed in this Table shall not be used at design temperatures above those for which allowable stress values are given. However, for saturated steam at 250 psi (406°F), the allowable stress values given for 400°F may be used.

(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. Weld joint efficiency factors are shown in Table 102.4.3.

(g) Pressure-temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.

(h) For limitations on the use of copper and copper alloys for flammable liquids and gases, refer to paras. 122.7, 122.8, and 124.7.

(i) The y coefficient = 0.4 [see Table 104.1.2(A)].

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TABLE A-6
COPPER AND COPPER ALLOYS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
-20 to 100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	UNS Alloy No.	Spec. No.
																Castings
6.8	6.8	6.8	6.8	6.8	6.8	6.6	6.2	5.8	4.0	...	...	...	...	...	C92200	B 61
6.0	6.0	6.0	6.0	5.8	5.7	5.5	5.4	...	...	...	...	...	...	...	C83600	B 62
12.6	12.6	11.9	11.6	11.4	11.4	11.4	11.4	11.4	...	...	...	...	...	...	C95200	B 148
15.0	15.0	15.0	15.0	15.0	14.5	13.9	12.8	11.1	...	...	...	...	...	...	C95400	
6.8	6.8	6.8	6.8	6.8	6.8	6.6	6.2	5.8	4.0	...	...	...	...	...	C92200	B 584
6.0	6.0	5.8	5.4	5.3	5.2	5.1	...	...	...	...	...	...	...	...	C93700	
6.0	5.8	5.6	5.5	5.4	...	...	...	...	...	...	...	...	...	...	C97600	
																Bolts, Nuts, and Studs
10.0	9.9	9.9	9.8	9.8	9.7	9.6	9.5	9.5	...	...	...	...	...	...	C61400	B 150
8.7	8.7	8.6	8.6	8.5	8.5	8.4	8.3	8.2	...	...	...	...	...	...	C61400	
8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.5	...	...	...	...	...	...	C61400	

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR USE ON BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) and (B).

(2) This material may be used for Boiler External Piping provided that the nominal size does not exceed 3 in., and the design temperature does not exceed 406°F. This material shall not be used for blowoff piping. Where threaded brass or copper pipe is used for feed water piping, it shall have a wall thickness not less than that required for schedule 80 steel pipe of the same nominal size.

(3) Welding or brazing of this material is not permitted.

(4) When this material is used for welded or brazed construction, the allowable stress values used shall not exceed those given for the same material in the annealed condition.

(5) Castings which are welded or repair welded shall be heat treated at 1150°F–1200°F, followed by moving-air cooling. The required time at temperature is based on the cross section thicknesses as follows:

(a) $1\frac{1}{2}$ hr for the first inch, or fraction thereof;

(b) $\frac{1}{2}$ hr for each additional inch or fraction thereof.

(6) Welds must be made by an electric fusion welding process involving the addition of filler metal.

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TABLE A-7
ALUMINUM AND ALUMINUM ALLOYS

Spec No.	UNS Alloy No.	Temper	Size or Thickness, in.	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Drawn Seamless Tube								
B 210	A93003	O	0.010 to 0.500	21	(1)	14	5	1.00
	A93003	H14	0.010 to 0.500	21	(1)(3)	20	17	1.00
	Alclad A93003	O	0.010 to 0.500	21	(1)(4)	13	4.5	1.00
	Alclad A93003	H14	0.010 to 0.500	21	(1)(3)(4)	19	16	1.00
B 210	A95050	O	0.018 to 0.500	21	(1)	18	6	1.00
	Alclad A95050	O	0.018 to 0.500	21	(1)(13)(23)	17	...	1.00
	A96061	T4	0.025 to 0.500	23	(1)(6)	30	16	1.00
	A96061	T6	0.025 to 0.500	23	(1)(6)	42	35	1.00
	A96061	T4, T6 welded	0.025 to 0.500	23	(1)(7)	24	...	1.00
Seamless Pipe and Seamless Extruded Tube								
B 241	A93003	O	All	21	(1)	14	5	1.00
	A93003	H18	Less than 1.000	21	(1)(3)	27	24	1.00
	A93003	H112	Note (20)	21	(1)(3)(20)	14	5	1.00
	Alclad A93003	O	All	21	(1)(4)	13	4.5	1.00
	Alclad A93003	H112	All	21	(1)(3)(4)	13	4.5	1.00
B 241	A95083	O	Up thru 5.000	25	(1)(8)	39	16	1.00
	A95083	H112	Up thru 5.000	25	(1)(8)	39	16	1.00
	A95454	O	Up thru 5.000	22	(1)	31	12	1.00
	A95454	H112	Up thru 5.000	22	(1)	31	12	1.00
B 241	A96061	T4	All	23	(1)(6)(9)	26	16	1.00
	A96061	T6	Under 1 in. dia	23	(1)(2)(5)	42	35	1.00
	A96061	T6	All	23	(1)(6)(9)	38	35	1.00
	A96061	T4, T6 welded	All	23	(1)(7)(9)	24	...	1.00
	A96063	T6	Note (10)	23	(1)(6)(10)	30	25	1.00
	A96063	T5, T6 welded	Note (10)	23	(1)(7)(10)	17	...	1.00
Drawn Seamless Condenser and Heat Exchanger Tube								
B 234	A93003	H14	0.010 to 0.200	21	(1)(2)	20	17	1.00
	Alclad A93003	H14	0.010 to 0.200	21	(1)(2)(4)	19	16	1.00
	A95454	H34	0.010 to 0.200	22	(1)(2)	39	29	1.00

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TABLE A-7
ALUMINUM AND ALUMINUM ALLOYS

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding								
−20 to 100	150	200	250	300	350	400	UNS Alloy No.	Spec. No.
							Drawn Seamless Tube	
3.4	3.4	3.4	3.0	2.4	1.8	1.4	A93003	B 210
5.0	5.0	5.0	4.9	4.3	3.0	2.4	A93003	
3.0	3.0	3.0	2.7	2.2	1.6	1.3	Alclad A93003	
4.5	4.5	4.5	4.4	3.9	2.7	2.1	Alclad A93003	
4.0	4.0	4.0	4.0	4.0	2.8	1.4	A95050	B210
3.3	3.3	3.3	3.3	3.3	2.5	1.3	Alclad A95050	
7.5	7.5	7.5	7.4	6.9	6.3	4.5	A96061	
10.5	10.5	10.5	9.9	8.4	6.3	4.5	A96061	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	A96061	
							Seamless Pipe and Seamless Extruded Tube	
3.4	3.4	3.4	3.0	2.4	1.8	1.4	A93003	B 241
6.8	6.8	6.7	6.3	5.4	3.5	2.5	A93003	
3.4	3.4	3.4	3.0	2.4	1.8	1.4	A93003	
3.0	3.0	3.0	2.7	2.2	1.6	1.2	Alclad A93003	
3.0	3.0	3.0	2.7	2.2	1.6	1.2	Alclad A93003	
9.8	9.8	...	...	...	...	...	A95083	B 241
9.8	9.8	...	...	...	...	...	A95083	
7.8	7.8	7.8	7.4	5.5	4.1	3.0	A95454	
7.8	7.8	7.8	7.4	5.5	4.1	3.0	A95454	
6.5	6.5	6.5	6.4	6.0	5.8	4.5	A96061	B 241
10.5	10.5	10.5	9.9	8.4	6.3	4.5	A96061	
9.5	9.5	9.5	9.1	7.9	6.3	4.5	A96061	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	A96061	
7.5	7.5	7.4	6.8	5.0	3.4	2.0	A96063	
4.3	4.3	4.3	4.2	3.9	3.0	2.0	A96063	
							Drawn Seamless Condenser and Heat Exchanger Tube	
5.0	5.0	5.0	4.9	4.3	3.0	2.4	A93003	B 234
4.5	4.5	4.5	4.4	3.9	2.7	2.1	Alclad A93003	
9.8	9.8	9.8	7.5	5.5	4.1	3.0	A95454	

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TABLE A-7
ALUMINUM AND ALUMINUM ALLOYS (CONT'D)

Spec No.	UNS Alloy No.	Temper	Size or Thickness, in.	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Drawn Seamless Condenser and Heat Exchanger Tube (Cont'd)								
B 234	A96061	T4	0.025 to 0.200	23	(1)(6)	30	16	1.00
	A96061	T6	0.025 to 0.200	23	(1)(6)	42	35	1.00
	A96061	T4, T6 welded	0.025 to 0.200	23	(1)(7)	24	...	1.00
Arc-Welded Round Tube								
B 547	A93003	O	0.125 to 0.500	21	(1)(15)	14	5	1.00
	A93003	O	0.125 to 0.500	21	(1)(16)	14	5	0.85
	A93003	H112	0.250 to 0.400	21	(1)(14)(15)	17	10	1.00
	A93003	H112	0.250 to 0.400	21	(1)(14)(16)	17	10	0.85
B 547	Alclad A93003	O	0.125 to 0.499	21	(1)(4)(15)	13	4.5	1.00
	Alclad A93003	O	0.125 to 0.499	21	(1)(4)(16)	13	4.5	0.85
	Alclad A93003	H112	0.250 to 0.499	21	(1)(4)(14)(15)	16	9	1.00
	Alclad A93003	H112	0.250 to 0.499	21	(1)(4)(14)(16)	16	9	0.85
B 547	A95083	O	0.125 to 0.500	25	(1)(8)(15)	40	18	1.00
	A95083	O	0.125 to 0.500	25	(1)(8)(16)	40	18	0.85
B 547	A95454	O	0.125 to 0.500	22	(1)(15)	31	12	1.00
	A95454	O	0.125 to 0.500	22	(1)(16)	31	12	0.85
	A95454	H112	0.250 to 0.499	22	(1)(14)(15)	32	18	1.00
	A95454	H112	0.250 to 0.499	22	(1)(14)(16)	32	18	0.85
B 547	A96061	T4	0.125 to 0.249	23	(1)(7)(15)(17)	30	16	1.00
	A96061	T4	0.125 to 0.249	23	(1)(7)(16)(17)	30	16	0.85
	A96061	T451	0.250 to 0.500	23	(1)(7)(15)(17)	30	16	1.00
	A96061	T451	0.250 to 0.500	23	(1)(7)(16)(17)	30	16	0.85
B 547	A96061	T6	0.125 to 0.249	23	(1)(7)(15)(17)	42	35	1.00
	A96061	T6	0.125 to 0.249	23	(1)(7)(16)(17)	42	35	0.85
	A96061	T651	0.250 to 0.500	23	(1)(7)(15)(17)	42	35	1.00
	A96061	T651	0.250 to 0.500	23	(1)(7)(16)(17)	42	35	0.85

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TABLE A-7
ALUMINUM AND ALUMINUM ALLOYS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding								
–20 to 100	150	200	250	300	350	400	UNS Alloy No.	Spec. No.
							Drawn Seamless Condenser and Heat Exchanger Tube (Cont'd)	
7.5	7.5	7.5	7.4	6.9	6.3	4.5	A96061	B 234
10.5	10.5	10.5	9.9	8.4	6.3	4.5	A96061	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	A96061	
							Arc-Welded Round Tube	
3.4	3.4	3.4	3.0	2.4	1.8	1.4	A93003	B 547
2.9	2.9	2.9	2.6	2.0	1.5	1.2	A93003	
3.4	3.4	3.4	3.0	2.4	1.8	1.4	A93003	
2.9	2.9	2.9	2.6	2.0	1.5	1.2	A93003	
3.0	3.0	3.0	2.7	2.2	1.6	1.3	Alclad A93003	B 547
2.6	2.6	2.6	2.3	1.9	1.4	1.1	Alclad A93003	
3.0	3.0	3.0	2.7	2.2	1.6	1.3	Alclad A93003	
2.6	2.6	2.6	2.3	1.9	1.4	1.1	Alclad A93003	
10.0	10.0	...	...	...	...	...	A95083	B 547
8.5	8.5	...	...	...	...	...	A95083	
7.8	7.8	7.8	7.4	5.5	4.1	3.0	A95454	B 547
6.6	6.6	6.6	6.3	4.7	3.5	2.6	A95454	
7.8	7.8	7.8	7.4	5.5	4.1	3.0	A95454	
6.6	6.6	6.6	6.3	4.7	3.5	2.6	A95454	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	A96061	B 547
5.1	5.1	5.1	5.0	4.7	3.9	3.0	A96061	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	A96061	
5.1	5.1	5.1	5.0	4.7	3.9	3.0	A96061	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	A96061	B 547
5.1	5.1	5.1	5.0	4.7	3.9	3.0	A96061	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	A96061	
5.1	5.1	5.1	5.0	4.7	3.9	3.0	A96061	

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TABLE A-7
ALUMINUM AND ALUMINUM ALLOYS (CONT'D)

Spec No.	UNS Alloy No.	Temper	Size or Thickness, in.	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Sheet and Plate								
B 209	A93003	0	0.051 to 3.000	21	(1)	14	5	1.00
	A93003	H112	0.250 to 0.499	21	(1)(3)	17	10	1.00
	A93003	H112	0.500 to 2.000	21	(1)(3)	15	6	1.00
B 209	Alclad A93003	0	0.051 to 0.499	21	(1)(4)	13	4.5	1.00
	Alclad A93003	0	0.500 to 3.000	21	(1)(18)	14	5	1.00
	Alclad A93003	H112	0.250 to 0.499	21	(1)(3)(4)	16	9	1.00
	Alclad A93003	H112	0.500 to 2.000	21	(1)(3)(19)	15	6	1.00
B 209	A95083	0	0.051 to 1.500	25	(1)(8)	40	18	1.00
	A95454	0	0.051 to 3.000	22	(1)	31	12	1.00
	A95454	H112	0.250 to 0.499	22	(1)(3)	32	18	1.00
	A95454	H112	0.500 to 3.000	22	(1)(3)	31	12	1.00
B 209	A96061	T4	0.051 to 0.249	23	(1)(6)(9)	30	16	1.00
	A96061	T451	0.250 to 3.000	23	(1)(6)(9)	30	16	1.00
	A96061	T4 welded	0.051 to 0.249	23	(1)(7)(9)	24	...	1.00
	A96061	T451 welded	0.250 to 3.000	23	(1)(7)(9)	24	...	1.00
B 209	A96061	T6	0.051 to 0.249	23	(1)(6)(9)	42	35	1.00
	A96061	T651	0.250 to 4.000	23	(1)(6)(9)	42	35	1.00
	A96061	T651	4.001 to 6.000	23	(1)(6)(9)	40	35	1.00
	A96061	T6 welded	0.051 to 0.249	23	(1)(7)(9)	24	...	1.00
	A96061	T651 welded	0.250 to 6.000	23	(1)(7)(9)	24	...	1.00
Die and Hand Forgings								
B 247	A93003	H112	Up thru 4.000	21	(1)(11)	14	5	1.00
	A93003	H112 welded	Up thru 4.000	21	(1)(7)(11)	14	5	1.00
B 247	A95083	H111	Up thru 4.000	25	(1)(6)(8)	39	16	1.00
	A95083	H112	Up thru 4.000	25	(1)(6)(8)	39	16	1.00
	A95083	H111, H112 welded	Up thru 4.000	25	(1)(7)(8)	38	16	1.00
B 247	A96061	T6	Up thru 4.000	23	(1)(6)(11)	38	35	1.00
	A96061	T6	Up thru 4.000	23	(1)(6)(12)	37	33	1.00
	A96061	T6	4.001 to 8.000	23	(1)(6)(12)	35	32	1.00
	A96061	T6 welded	Up thru 8.000	23	(1)(7)	24	...	1.00

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TABLE A-7
ALUMINUM AND ALUMINUM ALLOYS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding								
-20 to 100	150	200	250	300	350	400	UNS Alloy No.	Spec. No.
								Sheet and Plate
3.4	3.4	3.4	3.0	2.4	1.8	1.4	A93003	B 209
4.3	4.3	4.3	4.0	3.6	3.0	2.4	A93003	
3.8	3.8	3.7	3.2	2.4	1.8	1.4	A93003	
3.0	3.0	3.0	2.7	2.2	1.6	1.3	Alclad A93003	B 209
3.0	3.0	3.0	2.7	2.2	1.6	1.3	Alclad A93003	
3.8	3.8	3.8	3.6	3.3	2.7	2.1	Alclad A93003	
3.4	3.4	3.4	2.9	2.2	1.6	1.3	Alclad A93003	
10.0	10.0	...	...	...	...	...	A95083	B 209
7.8	7.8	7.8	7.4	5.5	4.1	3.0	A95454	
8.0	8.0	8.0	8.0	5.5	4.1	3.0	A95454	
7.8	7.8	7.8	7.4	5.5	4.1	3.0	A95454	
7.5	7.5	7.5	7.4	6.9	6.3	4.5	A96061	B 209
7.5	7.5	7.5	7.4	6.9	6.3	4.5	A96061	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	A96061	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	A96061	
10.5	10.5	10.5	9.9	8.4	6.3	4.5	A96061	B 209
10.5	10.5	10.5	9.9	8.4	6.3	4.5	A96061	
10.0	10.0	10.0	9.6	8.2	6.3	4.4	A96061	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	A96061	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	A96061	
								Die and Hand Forgings
3.4	3.4	3.4	3.0	2.4	1.8	1.4	A93003	B 247
3.4	3.4	3.4	3.0	2.4	1.8	1.4	A93003	
9.8	9.8	...	...	...	...	...	A95083	B 247
9.8	9.8	...	...	...	...	...	A95083	
9.5	9.5	...	...	...	...	...	A95083	
9.5	9.5	9.5	9.1	7.9	6.3	4.5	A96061	B 247
9.3	9.3	9.3	8.8	7.7	6.3	4.5	A96061	
8.8	8.8	8.8	8.4	7.4	6.1	4.5	A96061	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	A96061	

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TABLE A-7
ALUMINUM AND ALUMINUM ALLOYS (CONT'D)

Spec No.	UNS Alloy No.	Temper	Size or Thickness, in.	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Rods, Bars, and Shapes								
B 221	A91060	-0	All	21	(1)(21)(22)	8.5	2.5	1.00
		-H112	All	21	(1)(3)(21)(22)	8.5	2.5	1.00
B 221	A91100	-0	All	21	(1)(21)(22)	11	3	1.00
		-H112	All	21	(1)(3)(21)(22)	11	3	1.00
B 221	A93003	-0	All	21	(1)(21)(22)	14	5	1.00
		-H112	All	21	(1)(3)(21)(22)	14	5	1.00
B 221	A92024	-T3	Up thru 0.249	...	(1)(2)(9)(21)(22)	57	42	1.00
			0.250–0.749	...	(1)(2)(9)(21)(22)	60	44	1.00
			0.750–1.499	...	(1)(2)(9)(21)(22)	65	46	1.00
			1.500 and over	...	(1)(2)(9)(21)(22)	68	48	1.00
B 221	A95083	-0	Up thru 5.000	25	(1)(8)(21)(22)	39	16	1.00
		-H111	Up thru 5.000	25	(1)(3)(8)(21)(22)	40	24	1.00
		-H112	Up thru 5.000	25	(1)(3)(8)(21)(22)	39	16	1.00
B 221	A95086	-H112	Up thru 5.000	25	(1)(2)(8)(21)(22)	35	14	1.00
B 221	A95154	-0	All	22	(1)(8)(21)(22)	30	11	1.00
		-H112	All	22	(1)(3)(8)(21)(22)	30	11	1.00
B 221	A95454	-0	Up thru 5.000	22	(1)(21)(22)	31	12	1.00
		-H111	Up thru 5.000	22	(1)(3)(21)(22)	33	19	1.00
		-H112	Up thru 5.000	22	(1)(3)(21)(22)	31	12	1.00
B 221	A95456	-0	Up thru 5.000	25	(1)(8)(21)(22)	41	19	1.00
		-H111	Up thru 5.000	25	(1)(3)(8)(21)(22)	42	26	1.00
		-H112	Up thru 5.000	25	(1)(3)(8)(21)(22)	41	19	1.00
B 221	A96061	-T4	All	23	(1)(2)(9)(21)(22)	26	16	1.00
		-T6	All	23	(1)(2)(9)(21)(22)	38	35	1.00
		-T4 Wld.	All	23	(1)(7)(9)(21)(22)	24	...	1.00
		-T6 Wld.	All	23	(1)(7)(9)(21)(22)	24	...	1.00

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TABLE A-7
ALUMINUM AND ALUMINUM ALLOYS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding								
-20 to 100	150	200	250	300	350	400	UNS Alloy No.	Spec. No.
								Rods, Bars, and Shapes
1.7	1.7	1.6	1.5	1.3	1.1	0.80	A91060	B 221
1.7	1.7	1.6	1.5	1.3	1.1	0.80		
2.0	2.0	2.0	2.0	1.8	1.4	1.0	A91100	B 221
2.0	2.0	2.0	2.0	1.8	1.4	1.0		
3.4	3.4	3.4	3.0	2.4	1.8	1.4	A93003	B 221
3.4	3.4	3.4	3.0	2.4	1.8	1.4		
14.3	14.3	14.3	12.6	9.5	6.0	4.2	A92024	B 221
15.0	15.0	15.0	13.2	10.0	6.3	4.4		
16.3	16.3	16.3	14.3	10.8	6.8	4.7		
17.0	17.0	17.0	15.0	11.3	7.1	5.0		
9.8	9.8	...	...	...	...	...	A95083	B 221
10.0	10.0	...	...	...	...	...		
9.8	9.8	...	...	...	...	...		
8.8	8.8	...	...	...	...	...	A95086	B 221
7.5	7.5	...	...	...	...	...	A95154	B 221
7.5	7.5	...	...	...	...	...		
7.8	7.8	7.8	7.4	5.5	4.1	3.0	A95454	B 221
8.3	8.3	8.3	7.5	5.5	4.1	3.0		
7.8	7.8	7.8	7.4	5.5	4.1	3.0		
10.3	10.3	...	...	...	...	...	A95456	B 221
10.5	10.5	...	...	...	...	...		
10.3	10.3	...	...	...	...	...		
6.5	6.5	6.5	6.4	6.0	5.8	4.5	A96061	B 221
9.5	9.5	9.5	9.1	7.9	6.3	4.5		
6.0	6.0	6.0	5.9	5.5	4.6	3.5		
6.0	6.0	6.0	5.9	5.5	4.6	3.5		

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TABLE A-7
ALUMINUM AND ALUMINUM ALLOYS (CONT'D)

Spec No.	UNS Alloy No.	Temper	Size or Thickness, in.	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Rods, Bars, and Shapes (Cont'd)								
B 221	A96063	-T1	Up thru 0.500	23	(1)(2)(21)(22)	17	9	1.00
			0.501–1.000	23	(1)(2)(21)(22)	16	8	1.00
		-T5	Up thru 0.500	23	(1)(2)(21)(22)	22	16	1.00
			0.501–1.000	23	(1)(2)(21)(22)	21	15	1.00
		-T6	Up thru 1.000	23	(1)(2)(21)(22)	30	25	1.00
		-T5, -T6 Wld.	Up thru 1.000	23	(1)(7)(21)(22)	17	...	1.00
Castings								
B 26	A24430	F	...	...	(1)(2)	17	6	0.80
	A03560	T6	...	...	(1)(2)	30	20	0.80
	A03560	T71	...	...	(1)(2)	25	18	0.80

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.

(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.

(c) The P-Numbers listed in this Table are identical to those adopted by the ASME Boiler and Pressure Vessel Code. Qualification of welding procedures, welders, and welding operators is required and shall comply with the ASME Boiler and Pressure Vessel Code, Section IX, except as modified by para. 127.5.

(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."

(e) The materials listed in this Table shall not be used at design temperatures above those for which allowable stress values are given.

(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. Weld joint efficiency factors are shown in Table 102.4.3.

(g) Pressure-temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.

(h) Aluminum and aluminum alloys shall not be used for flammable fluids within the boiler plant structure (see para. 122.7).

(i) The y coefficient = 0.4 [see Table 104.1.2(A)].

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR USE ON BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) and (B).

(2) These allowable stress values are not applicable when either welding or thermal cutting is employed.

(3) These allowable stress values are not applicable when either welding or thermal cutting is employed. In such cases, the corresponding stress values for the O temper shall be used.

(4) These allowable stress values are 90% of those for the corresponding core material.

(5) These allowable stress values apply only to seamless pipe smaller than NPS 1 which is extruded and then drawn.

(6) These allowable stress values are not applicable when either welding or thermal cutting is employed. In such cases, the corresponding stress values for the welded condition shall be used.

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TABLE A-7
ALUMINUM AND ALUMINUM ALLOYS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding								
–20 to 100	150	200	250	300	350	400	UNS Alloy No.	Spec. No.
							Rods, Bars, and Shapes (Cont'd)	
4.3	4.3	4.3	4.2	4.2	3.4	2.0	A96063	B 221
4.0	4.0	4.0	4.0	4.0	3.4	2.0		
5.5	5.5	5.4	5.1	4.6	3.4	2.0		
5.3	5.3	5.1	4.9	4.3	3.4	2.0		
7.5	7.5	7.4	6.8	5.0	3.4	2.0		
4.3	4.3	4.3	4.2	3.9	3.0	2.0		
								Castings
3.2	3.2	3.2	3.0	2.8	2.5	2.2	A24430	B 26
6.0	6.0	6.0	5.0	...	...	...	A03560	
5.0	5.0	5.0	4.9	4.3	3.3	1.9	A03560	

NOTES (CONT'D):

(7) The strength of a reduced-section tensile specimen is required to qualify welding procedures. Refer to the ASME Boiler and Pressure Vessel Code, Section IX, QW-150.

(8) Refer to the ASME Boiler and Pressure Vessel Code, Section VIII, Part UNF, NF-13(b) regarding stress corrosion.

(9) For stress relieved tempers (T351, T3510, T3511,T451, T4510, T4511,T651, T6510, and T6511) stress values for the material in the basic temper shall be used.

(10) These allowable stress values apply to all thicknesses of and sizes of seamless pipe. They also apply to seamless extruded tube in thicknesses up to and including 1.000 in.

(11) These allowable stress values are for die forgings.

(12) These allowable stress values are for hand forgings.

(13) For temperatures up to 300°F, these allowable stress values are 83% of those for the corresponding core material. At temperatures of 350°F and 400°F, these allowable stress values are 90% of those for the corresponding core material.

(14) These allowable stress values are for the tempers listed in the welded condition and are identical to those for the O temper.

(15) These allowable stress values are based on 100% radiography of the longitudinal weld in accordance with ASTM B 547, para. 11.

(16) These allowable stress values are based on spot radiography of the longitudinal weld in accordance with ASTM B 547, para. 11.

(17) These allowable stress values are for the heat treated tempers listed in the welded condition.

(18) The tension test specimen from plate which is not less than 0.500 in. thick is machined from the core and does not include the cladding alloy. Therefore, the allowable stress values for thicknesses less than 0.500 in. shall be used.

(19) The tension test specimen from plate which is not less than 0.500 in thick is machined from the core and does not include the cladding alloy. Therefore, these allowable stress values are 90% of those for the core material of the same thickness.

(20) The allowable stress values for seamless pipe in sizes NPS 1 and larger are as follows:

100 °F	3.5 ksi
150 °F	3.5 ksi
200 °F	3.4 ksi

(21) Stress values in restricted shear such as dowel bolts, or similar construction in which the shearing member is so restricted that the section under consideration would fail without reduction of areas shall be 0.80 times the values in the above Table.

(22) Stress values in bearing shall be 1.60 times the values in the above Table.

(23) ASTM B 210 does not include this alloy/grade of material.

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TABLE A-8
TEMPERATURES 1200°F AND ABOVE

Spec. No.	Type or Grade	UNS Alloy No.	Temper	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi
Seamless Pipe and Tube								
A 213	TP304H	S30409	...	18Cr–8Ni	8	...	75	30
	TP310H	S31009	...	25Cr–20Ni	8	(2)(4)	75	30
	TP316H	S31609	...	16Cr–12Ni–2Mo	8	...	75	30
A 213	TP321H	S32109	...	18Cr–10Ni–Ti	8	...	75	30
	TP347H	S34709	...	18Cr–10Ni–Cb	8	...	75	30
	TP348H	S34809	...	18Cr–10Ni–Cb	8	...	75	30
A 312	TP304H	S30409	...	18Cr–8Ni	8	...	75	30
	TP310H	S31009	...	25Cr–20Ni	8	(2)(4)	75	30
	TP316H	S31609	...	16Cr–12Ni–2Mo	8	...	75	30
A 312	TP321H	S32109	...	18Cr–10Ni-Ti	8	...	75	30
	TP347H	S34709	...	18Cr–10Ni–Cb	8	...	75	30
	TP348H	S34809	...	18Cr–10Ni–Cb	8	...	75	30
A 376	TP304H	S30409	...	18Cr–8Ni	8	...	75	30
	TP316H	S31609	...	16Cr–12Ni–2Mo	8	...	75	30
	TP321H	S32109	...	18Cr–10Ni–Ti	8	...	75	30
	TP347H	S34709	...	18Cr–10Ni–Cb	8	...	75	30
A 430	FP304H	S30409	...	18Cr–8Ni	8	...	70	30
	FP316H	S31609	...	16Cr–12Ni–2Mo	8	...	70	30
	FP321H	S32109	...	18Cr–10Ni–Ti	8	...	70	30
	FP347H	S34709	...	18Cr–10Ni–Cb	8	...	70	30
B 163	...	N08800	Annealed	Ni–Cr–Fe	45	(1)	75	30
	...	N08810	Annealed	Ni–Cr–Fe	45	(1)	65	25
B 407	...	N08800	C.D./Ann.	Ni–Cr–Fe	45	...	75	30
	...	N08810	Annealed	Ni–Cr–Fe	45	...	65	25
Welded Pipe and Tube — Without Filler Metal								
A 249	TP304H	S30409	...	18Cr–8Ni	8	...	75	35
	TP310H	S31009	...	25Cr–20Ni	8	(1)(2)(4)	75	35
	TP316H	S31609	...	16Cr–12Ni–2Mo	8	...	75	35

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TABLE A-8
TEMPERATURES 1200°F AND ABOVE

E or *F*	Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding							Type or Grade	Spec. No.
	1200	1250	1300	1350	1400	1450	1500		
								Seamless Pipe and Tube	
1.00	6.1	4.7	3.7	2.9	2.3	1.8	1.4	TP304H	A 213
1.00	4.0	3.0	2.2	1.7	1.3	0.97	0.75	TP310H	
1.00	7.4	5.5	4.1	3.1	2.3	1.7	1.3	TP316H	
1.00	5.4	4.1	3.2	2.5	1.9	1.5	1.1	TP321H	A 213
1.00	7.9	5.9	4.4	3.2	2.5	1.8	1.3	TP347H	
1.00	7.9	5.9	4.4	3.2	2.5	1.8	1.3	TP348H	
1.00	6.1	4.7	3.7	2.9	2.3	1.8	1.4	TP304H	A 312
1.00	4.0	3.0	2.2	1.7	1.3	0.97	0.75	TP310H	
1.00	7.4	5.5	4.1	3.1	2.3	1.7	1.3	TP316H	
1.00	5.4	4.1	3.2	2.5	1.9	1.5	1.1	TP321H	A 312
1.00	7.9	5.9	4.4	3.2	2.5	1.8	1.3	TP347H	
1.00	7.9	5.9	4.4	3.2	2.5	1.8	1.3	TP348H	
1.00	6.1	4.7	3.7	2.9	2.3	1.8	1.4	TP304	A 376
1.00	7.4	5.5	4.1	3.1	2.3	1.7	1.3	TP316H	
1.00	5.4	4.1	3.2	2.5	1.9	1.5	1.1	TP321H	
1.00	7.9	5.9	4.4	3.2	2.5	1.8	1.3	TP347H	
1.00	6.1	4.7	3.7	2.9	2.3	1.8	1.4	FP304H	A 430
1.00	7.4	5.5	4.1	3.1	2.3	1.7	1.3	FP316H	
1.00	5.4	4.1	3.2	2.5	1.9	1.5	1.1	FP321H	
1.00	7.9	5.9	4.4	3.2	2.5	1.8	1.3	FP347H	
1.00	6.6	4.2	2.0	1.6	1.1	1.0	0.80	N08800	B 163
1.00	7.4	5.9	4.7	3.8	3.0	2.4	1.9	N08810	
1.00	6.6	4.2	2.0	1.6	1.1	1.0	0.80	N08800	B 407
1.00	7.4	5.9	4.7	3.8	3.0	2.4	1.9	N08810	
								Welded Pipe and Tube — Without Filler Metal	
0.85	5.2	4.0	3.2	2.5	2.0	1.6	1.2	TP304H	A 249
0.85	3.4	2.6	1.9	1.4	1.1	0.82	0.64	TP310H	
0.85	6.3	4.7	3.5	2.6	1.9	1.5	1.1	TP316H	

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TABLE A-8
TEMPERATURES 1200°F AND ABOVE (CONT'D)

Spec. No.	Type or Grade	UNS Alloy No.	Temper	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi
Welded Pipe and Tube — Without Filler Metal (Cont'd)								
A 249	TP321H	S32109	...	18Cr–10Ni–Ti	8	...	75	35
	TP347H	S34709	...	18Cr–10Ni–Cb	8	...	75	35
	TP348H	S34809	...	18Cr–10Ni–Cb	8	...	75	35
A 312	TP304H	S30409	...	18Cr–8Ni	8	...	75	30
	TP310H	S31009	...	25Cr–20Ni	8	(2)(4)	75	30
	TP316H	S31609	...	16Cr–12Ni–2Mo	8	...	75	30
A 312	TP321H	S32109	...	18Cr–10Ni–Ti	8	...	75	30
	TP347H	S32709	...	18Cr–10Ni–Cb	8	...	75	30
Plate								
A 240	304	S30400	...	18Cr–8Ni	8	(2)(3)	75	30
	310S	S31008	...	25Cr–20Ni	8	(2)(3)(4)	75	30
	316	S31600	...	16Cr–12Ni–2Mo	8	(2)(3)	75	30
	316L	S31603	...	16Cr–12Ni–2Mo	8	(1)	70	25
A 240	321	S32100	...	18Cr–10Ni–Ti	8	(2)(3)	75	30
	347	S34700	...	18Cr–10Ni–Cb	8	(2)(3)	75	30
	348	S34800	...	18Cr–10Ni–Cb	8	(1)(2)(3)	75	30
B 409	...	N08800	Annealed	Ni–Cr–Fe	45	(3)	75	30
	...	N08810	Annealed	Ni–Cr–Fe	45	(3)	65	25
Bars, Rods, and Shapes								
B 408	...	N08800	Annealed	Ni–Cr–Fe	45	...	75	30
	...	N08810	Annealed	Ni–Cr–Fe	45	...	65	25
Forgings								
A 182	F304H	S30409	...	18Cr–8Ni	8	...	75	30
	F310H	S31009	...	25Cr–20Ni	8	(1)(2)(4)	75	30
	F316H	S31609	...	16Cr–12Ni–2Mo	8	...	75	30
A 182	F321H	S32109	...	18Cr–10Ni–Ti	8	...	75	30
	F347H	S34709	...	18Cr–10Ni–Cb	8	...	75	30
	F348H	S34809	...	18Cr–10Ni–Cb	8	...	75	30

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TABLE A-8
TEMPERATURES 1200°F AND ABOVE (CONT'D)

E or F	Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding							Type or Grade	Spec. No.
	1200	1250	1300	1350	1400	1450	1500		
								Welded Pipe and Tube — Without Filler Metal (Cont'd)	
0.85	4.6	3.5	2.7	2.1	1.6	1.3	1.0	TP321H	A 249
0.85	6.7	5.0	3.7	2.7	2.1	1.6	1.1	TP347H	
0.85	6.7	5.0	3.7	2.7	2.1	1.6	1.1	TP348H	
0.85	5.2	4.0	3.2	2.5	2.0	1.6	1.2	TP304H	A 312
0.85	3.4	2.6	1.9	1.4	1.1	0.82	0.64	TP310H	
0.85	6.3	4.7	3.5	2.6	1.9	1.5	1.1	TP316H	
0.85	4.6	3.5	2.7	2.1	1.6	1.3	1.0	TP321H	A 312
0.85	6.7	5.0	3.7	2.7	2.1	1.6	1.1	TP347H	
									Plate
1.00	6.1	4.7	3.7	2.9	2.3	1.8	1.4	304	A 240
1.00	2.5	1.5	0.80	0.50	0.40	0.30	0.20	310S	
1.00	7.4	5.5	4.1	3.1	2.3	1.7	1.3	316	
1.00	6.4	4.7	3.5	2.5	1.8	1.3	1.0	316L	
1.00	3.6	2.6	1.7	1.1	0.80	0.50	0.30	321	A 240
1.00	4.4	3.3	2.2	1.5	1.2	0.90	0.80	347	
1.00	4.4	3.3	2.2	1.5	1.2	0.90	0.80	348	
1.00	6.6	4.2	2.0	1.6	1.1	1.0	0.80	N08800	B 409
1.00	7.4	5.9	4.7	3.8	3.0	2.4	1.9	N08810	
									Bars, Rods, and Shapes
1.00	6.6	4.2	2.0	1.6	1.1	1.0	0.80	N08800	B 408
1.00	7.4	5.9	4.7	3.8	3.0	2.4	1.9	N08810	
									Forgings
1.00	6.1	4.7	3.7	2.9	2.3	1.8	1.4	F304H	A 182
1.00	4.0	3.0	2.2	1.7	1.3	0.97	0.75	F310H	
1.00	7.4	5.5	4.1	3.1	2.3	1.7	1.3	F316H	
1.00	5.4	4.1	3.2	2.5	1.9	1.5	1.1	F321H	A 182
1.00	7.9	5.9	4.4	3.2	2.5	1.8	1.3	F347H	
1.00	7.9	5.9	4.4	3.2	2.5	1.8	1.3	F348H	

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TABLE A-8
TEMPERATURES 1200°F AND ABOVE (CONT'D)

Spec. No.	Type or Grade	UNS Alloy No.	Temper	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi
Forgings (Cont'd)								
B 564	...	N08800	Annealed	Ni–Cr–Fe	45	...	75	30
	...	N08810	Annealed	Ni–Cr–Fe	45	...	65	25
Fittings (Seamless and Welded)								
A 403	WP304H	S30409	...	18Cr–8Ni	8	(1)	75	30
	WP316H	S31609	...	16Cr–12Ni–2Mo	8	(1)	75	30
	WP321H	S32109	...	18Cr–10Ni–Ti	8	(1)	75	30
	WP347H	S34709	...	18Cr–10Ni–Cb	8	(1)	75	30
	WP348H	S34809	...	18Cr–10Ni–Cb	8	(1)	75	30

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.

(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.

(c) The P-Numbers listed in this Table are identical to those adopted by the ASME Boiler and Pressure Vessel Code. Qualification of welding procedures, welders, and welding operators is required and shall comply with the ASME Boiler and Pressure Vessel Code, Section IX, except as modified by para. 127.5.

(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."

(e) The materials listed in this Table shall not be used at design temperatures above those for which allowable stress values are given.

(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. Weld joint efficiency factors are shown in Table 102.4.3.

(g) Pressure-temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.

(h) All the materials listed are classified as austenitic [see Table 104.1.2(A)].

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TABLE A-8
TEMPERATURES 1200°F AND ABOVE (CONT'D)

E or F	Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding							Type or Grade	Spec. No.
	1200	1250	1300	1350	1400	1450	1500		
									Forgings (Cont'd)
1.00	6.6	4.2	2.0	1.6	1.1	1.0	0.80	N08800	B 564
1.00	7.4	5.9	4.7	3.8	3.0	2.4	1.9	N08810	
									Fittings (Seamless and Welded)
1.00	6.1	4.7	3.7	2.9	2.3	1.8	1.4	WP304H	A 403
1.00	7.4	5.5	4.1	3.1	2.3	1.7	1.3	WP316H	
1.00	5.4	4.1	3.2	2.5	1.9	1.5	1.1	WP321H	
1.00	7.9	5.9	4.4	3.2	2.5	1.8	1.3	WP347H	
1.00	7.9	5.9	4.4	3.2	2.5	1.8	1.3	WP348H	

NOTES:
(1) THIS MATERIAL IS NOT ACCEPTABLE FOR USE ON BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) and (B).
(2) These allowable stress values shall be used only if the carbon content of the material is 0.04% or higher.
(3) These allowable stress values tabulated shall be used only if the material is heat treated by heating to a minimum temperature of 1900°F and quenching in water or rapidly cooling by other means.
(4) These allowable stress values shall be used only when the grain size of the material is ASTM No. 6 or coarser.

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TABLE A-9
TITANIUM AND TITANIUM ALLOYS

Spec No.	Grade	Condition	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Seamless Pipe and Tube								
B 337	1	Annealed	Ti	51	(1)	35	25	1.00
	2	Annealed	Ti	51	(1)	50	40	1.00
	3	Annealed	Ti	52	(1)	65	55	1.00
	7	Annealed	Ti–Pd	51	(1)	50	40	1.00
	12	Annealed	Ti–Mo–Ni	52	(1)	70	50	1.00
B 338	1	Annealed	Ti	51	(1)	35	25	1.00
	2	Annealed	Ti	51	(1)	50	40	1.00
	3	Annealed	Ti	52	(1)	65	55	1.00
	7	Annealed	Ti–Pd	51	(1)	50	40	1.00
	12	Annealed	Ti–Mo–Ni	52	(1)	70	50	1.00
Welded Pipe and Tube								
B 337	1	Annealed	Ti	51	(1)(2)	35	25	0.85
	2	Annealed	Ti	51	(1)(2)	50	40	0.85
	3	Annealed	Ti	52	(1)(2)	65	55	0.85
	7	Annealed	Ti–Pd	51	(1)(2)	50	40	0.85
	12	Annealed	Ti–Mo–Ni	52	(1)(2)	70	50	0.85
B 338	1	Annealed	Ti	51	(1)(2)	35	25	0.85
	2	Annealed	Ti	51	(1)(2)	50	40	0.85
	3	Annealed	Ti	52	(1)(2)	65	55	0.85
	7	Annealed	Ti–Pd	51	(1)(2)	50	40	0.85
	12	Annealed	Ti–Mo–Ni	52	(1)(2)	70	50	0.85
Plate, Sheet, and Strip								
B 265	1	Annealed	Ti	51	(1)	35	25	1.00
	2	Annealed	Ti	51	(1)	50	40	1.00
	3	Annealed	Ti	52	(1)	65	55	1.00
	7	Annealed	Ti–Pd	51	(1)	50	40	1.00
	12	Annealed	Ti–Mo–Ni	52	(1)	70	50	1.00

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TABLE A-9
TITANIUM AND TITANIUM ALLOYS

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
−20 to 100	150	200	250	300	350	400	450	500	550	600	Grade	Spec. No.
											Seamless Pipe and Tube	
8.8	8.1	7.3	6.5	5.8	5.2	4.8	4.5	4.1	3.6	3.1	1	B 337
12.5	12.0	10.9	9.9	9.0	8.4	7.7	7.2	6.6	6.2	5.7	2	
16.3	15.6	14.3	13.0	11.7	10.4	9.3	8.3	7.5	6.7	6.0	3	
12.5	12.0	10.9	9.9	9.0	8.4	7.7	7.2	6.6	6.2	5.7	7	
17.5	17.5	16.4	15.2	14.2	13.3	12.5	11.9	11.4	11.1	10.8	12	
8.8	8.1	7.3	6.5	5.8	5.2	4.8	4.5	4.1	3.6	3.1	1	B 338
12.5	12.0	10.9	9.9	9.0	8.4	7.7	7.2	6.6	6.2	5.7	2	
16.3	15.6	14.3	13.0	11.7	10.4	9.3	8.3	7.5	6.7	6.0	3	
12.5	12.0	10.9	9.9	9.0	8.4	7.7	7.2	6.6	6.2	5.7	7	
17.5	17.5	16.4	15.2	14.2	13.3	12.5	11.9	11.4	11.1	10.8	12	
											Welded Pipe and Tube	
7.5	6.9	6.2	5.5	4.9	4.4	4.1	3.8	3.5	3.1	2.6	1	B 337
10.6	10.2	9.3	8.4	7.7	7.1	6.5	6.1	5.6	5.3	4.8	2	
13.8	13.3	12.1	11.1	10.0	8.8	7.9	7.1	6.4	5.7	5.1	3	
10.6	10.2	9.3	8.4	7.7	7.1	6.5	6.1	5.6	5.3	4.8	7	
14.9	14.9	13.9	12.9	12.1	11.3	10.6	10.1	9.7	9.4	9.2	12	
7.5	6.9	6.2	5.5	4.9	4.4	4.1	3.8	3.5	3.1	2.6	1	B 338
10.6	10.2	9.3	8.4	7.7	7.1	6.5	6.1	5.6	5.3	4.8	2	
13.8	13.3	12.1	11.1	10.0	8.8	7.9	7.1	6.4	5.7	5.1	3	
10.6	10.2	9.3	8.4	7.7	7.1	6.5	6.1	5.6	5.3	4.8	7	
14.9	14.9	13.9	12.9	12.1	11.3	10.6	10.1	9.7	9.4	9.2	12	
											Plate, Sheet, and Strip	
8.8	8.1	7.3	6.5	5.8	5.2	4.8	4.5	4.1	3.6	3.1	1	B 265
12.5	12.0	10.9	9.9	9.0	8.4	7.7	7.2	6.6	6.2	5.7	2	
16.3	15.6	14.3	13.0	11.7	10.4	9.3	8.3	7.5	6.7	6.0	3	
12.5	12.0	10.9	9.9	9.0	8.4	7.7	7.2	6.6	6.2	5.7	7	
17.5	17.5	16.4	15.2	14.2	13.3	12.5	11.9	11.4	11.1	10.8	12	

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TABLE A-9
TITANIUM AND TITANIUM ALLOYS (CONT'D)

Spec No.	Grade	Condition	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Forgings								
B 381	F1	Annealed	Ti	51	(1)	35	25	1.00
	F2	Annealed	Ti	51	(1)	50	40	1.00
	F3	Annealed	Ti	52	(1)	65	55	1.00
	F7	Annealed	Ti–Pd	51	(1)	50	40	1.00
	F12	Annealed	Ti–Mo–Ni	52	(1)	70	50	1.00
Bars and Billets								
B 348	1	Annealed	Ti	51	(1)	35	25	1.00
	2	Annealed	Ti	51	(1)	50	40	1.00
	3	Annealed	Ti	52	(1)	65	55	1.00
	7	Annealed	Ti–Pd	51	(1)	50	40	1.00
	12	Annealed	Ti–Mo–Ni	52	(1)	70	50	1.00
Castings								
B 367	C-2	As-cast	Ti	50	(1)(3)	50	40	0.80

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.

(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.

(c) The P-Numbers listed in this Table are identical to those adopted by the ASME Boiler and Pressure Vessel Code. Qualification of welding procedures, welders, and welding operators is required and shall comply with the ASME Boiler and Pressure Vessel Code, Section IX, except as modified by para. 127.5.

(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."

(e) The materials listed in this Table shall not be used at design temperatures above those for which allowable stress values are given.

(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. Weld joint efficiency factors are shown in Table 102.4.3.

(g) Pressure-temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.

(h) The y coefficient = 0.4 [see Table 104.1.2(A)].

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TABLE A-9
TITANIUM AND TITANIUM ALLOYS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
−20 to 100	150	200	250	300	350	400	450	500	550	600	Grade	Spec. No.
												Forgings
8.8	8.1	7.3	6.5	5.8	5.2	4.8	4.5	4.1	3.6	3.1	F1	B 381
12.5	12.0	10.9	9.9	9.0	8.4	7.7	7.2	6.6	6.2	5.7	F2	
16.3	15.6	14.3	13.0	11.7	10.4	9.3	8.3	7.5	6.7	6.0	F3	
12.5	12.0	10.9	9.9	9.0	8.4	7.7	7.2	6.6	6.2	5.7	F7	
17.5	17.5	16.4	15.2	14.2	13.3	12.5	11.9	11.4	11.1	10.8	F12	
												Bars and Billets
8.8	8.1	7.3	6.5	5.8	5.2	4.8	4.5	4.1	3.6	3.1	1	B 348
12.5	12.0	10.9	9.9	9.0	8.4	7.7	7.2	6.6	6.2	5.7	2	
16.3	15.6	14.3	13.0	11.7	10.4	9.3	8.3	7.5	6.7	6.0	3	
12.5	12.0	10.9	9.9	9.0	8.4	7.7	7.2	6.6	6.2	5.7	7	
17.5	17.5	16.4	15.2	14.2	13.3	12.5	11.9	11.4	11.1	10.8	12	
												Castings
10.0	9.1	8.2	7.4	7.0	6.2	...	...	...	...	...	C-2	B 367

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR USE ON BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) and (B).

(2) Filler metal shall not be used in the manufacture of welded pipe or tubing.

(3) Welding of this material is not permitted.

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APPENDIX B

Begins on Next Page

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01

TABLE B-1
THERMAL EXPANSION DATA

A = Mean Coefficient of Thermal Expansion, 10^{-6} in./in./°F

B = Linear Thermal Expansion, in./100 ft

} in Going From 70°F to Indicated Temperature [Note (1)]

Material	Coefficient	Temperature Range 70°F to																
		−325	−150	−50	70	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Group 1 carbon and low alloy steels [Note (2)]	*A*	5.5	5.9	6.2	6.4	6.7	6.9	7.1	7.3	7.4	7.6	7.8	7.9	8.1	8.2	8.3	8.4	8.4
	B	−2.6	−1.6	−0.9	0	1.0	1.9	2.8	3.7	4.7	5.7	6.8	7.9	9.0	10.1	11.3	12.4	14.7
Group 2 low alloy steels [Note (3)]	*A*	6.0	6.5	6.7	7.0	7.3	7.4	7.6	7.7	7.8	7.9	8.1	8.1	8.2	8.3	8.4	8.4	8.5
	B	−2.9	−1.7	−1.0	0	1.1	2.1	3.0	4.0	5.0	6.0	7.1	8.1	9.2	10.3	11.4	12.4	14.8
5Cr–1Mo steels	*A*	5.6	6.0	6.2	6.4	6.7	6.9	7.0	7.1	7.2	7.3	7.3	7.4	7.5	7.6	7.6	7.7	7.8
	B	−2.7	−1.6	−0.9	0	1.1	1.9	2.8	3.6	4.6	5.5	6.4	7.4	8.4	9.4	10.4	11.4	12.4
9Cr–1Mo steels	*A*	5.0	5.4	5.6	5.8	6.0	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.2
	B	−2.4	−1.4	−0.8	0	0.9	1.7	2.5	3.3	4.1	5.0	5.9	6.8	7.7	8.7	9.6	10.6	11.6
Straight chromium stainless steels																		
12Cr to 13Cr steels	*A*	5.1	5.5	5.7	5.9	6.2	6.3	6.4	6.5	6.5	6.6	6.7	6.7	6.8	6.8	6.9	6.9	7.0
	B	−2.4	−1.5	−0.8	0	1.0	1.7	2.5	3.3	4.2	5.0	5.8	6.7	7.6	8.4	9.3	10.2	10.6
15Cr to 17Cr steels	*A*	4.5	4.9	5.1	5.3	5.5	5.7	5.8	5.9	6.0	6.1	6.1	6.2	6.3	6.4	6.4	6.5	6.6
	B	−2.1	−1.3	−0.7	0	0.9	1.6	2.3	3.0	3.8	4.6	5.3	6.2	7.0	7.9	8.7	9.6	10.0
27Cr steels	*A*	4.3	4.7	4.9	5.0	5.2	5.2	5.3	5.4	5.4	5.5	5.6	5.7	5.7	5.8	5.9	5.9	6.0
	B	−2.0	−1.2	−0.7	0	0.8	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.4	7.2	7.9	8.8	9.6
Austenitic stainless steels (304, 305, 316, 317, 321, 347, 348 19-9DL, XM-15, etc.)	*A*	7.5	8.0	8.2	8.5	8.9	9.2	9.5	9.7	9.8	10.0	10.1	10.2	10.3	10.5	10.6	10.7	10.8
	B	−3.6	−2.1	−1.2	0	1.4	2.5	3.7	5.0	6.3	7.5	8.8	10.2	11.5	12.9	14.3	15.7	17.2
Other austenitic stainless steels (309, 310, 315, XM-19, etc.)	*A*	7.1	7.6	7.8	8.2	8.5	8.8	8.9	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.1
	B	−3.4	−2.0	−1.1	0	1.3	2.4	3.5	4.7	5.8	7.0	8.2	9.5	10.7	12.0	13.3	14.7	16.0
Gray cast iron	*A*	...	...	...	...	5.8	5.9	6.1	6.3	6.5	6.7	6.8	7.0	7.2	...	...	...	...
	B	...	...	...	0	0.9	1.6	2.4	3.2	4.1	5.0	6.0	7.0	8.0	...	...	...	...
Ductile cast iron		...	4.9	5.3	5.7	6.0	6.3	6.5	6.9	7.0	7.1	7.3	7.4	7.5	...	...	...	...
	B	...	−1.3	−0.8	0	0.9	1.7	2.6	3.5	4.4	5.4	6.4	7.4	8.4	...	...	...	...

(continued)

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TABLE B-1
THERMAL EXPANSION DATA (CONT'D)

A = Mean Coefficient of Thermal Expansion, 10^{-6} in./in./°F
B = Linear Thermal Expansion, in./100 ft
} in Going From 70°F to Indicated Temperature [Note (1)]

Material	Coefficient	Temperature Range 70°F to																
		−325	−150	−50	70	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
Monel (67Ni–30Cu) N04400	*A*	5.8	6.8	7.2	7.7	8.1	8.3	8.5	8.7	8.8	8.9	8.9	9.0	9.1	9.1	9.2	9.2	9.3
	B	−2.7	−1.8	−1.0	0	1.3	2.3	3.4	4.5	5.6	6.7	7.8	8.9	10.1	11.3	12.4	13.6	14.8
Nickel alloys N02200 and N02201	*A*	5.6	6.4	6.7	7.0	7.3	7.5	7.7	7.9	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9
	B	−2.7	−1.7	−1.0	0	1.2	2.1	3.1	4.1	5.1	6.2	7.2	8.4	9.5	10.6	11.8	13.0	14.2
Nickel alloy N06600	*A*	5.5	6.1	6.4	6.8	7.1	7.3	7.5	7.6	7.8	7.9	8.1	8.2	8.3	8.4	8.6	8.7	8.9
	B	−2.6	−1.6	−0.9	0	1.1	2.0	3.0	3.9	5.0	6.0	7.1	8.1	9.3	10.4	11.6	12.9	14.2
Nickel alloys N08800 and N08810	*A*	5.9	6.9	7.4	7.9	8.3	8.6	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8
	B	−2.8	−1.7	−1.1	0	1.3	2.4	3.5	4.6	5.7	6.9	8.1	9.3	10.5	11.7	13.0	14.3	15.7
Nickel alloy N08825	*A*	...	...	7.2	7.5	7.7	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	...	...	...	...
	B	...	...	−1.0	0	1.2	2.2	3.2	4.2	5.2	6.3	7.4	8.5	9.6	...	...	...	...
Copper alloys C1XXXX series	*A*	7.7	8.7	9.0	9.3	9.6	9.7	9.8	9.9	10.0	...	...	...	...	...	...	...	...
	B	−3.7	−2.3	−1.3	0	1.5	2.7	3.9	5.1	6.1	...	...	...	...	...	...	...	...
Bronze alloys	*A*	8.4	8.8	9.2	9.6	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	...	...
	B	−4.0	−2.3	−1.3	0	1.6	2.8	4.1	5.3	6.6	8.0	9.3	10.7	12.1	13.5	14.9	...	...
Brass alloys	*A*	8.2	8.5	9.0	9.3	9.8	10.0	10.2	10.5	10.7	10.9	11.2	11.4	11.6	11.9	12.1	...	...
	B	−3.9	−2.2	−1.3	0	1.5	2.8	4.1	5.4	6.8	8.3	9.8	11.4	13.0	14.7	16.4	...	...
Copper–nickel (70Cu–30Ni)	*A*	6.7	7.4	7.8	8.2	8.5	8.7	8.9	9.1	9.2	9.3	...	...	...	...	...	...	...
	B	−3.2	−2.0	−1.1	0	1.3	2.4	3.5	4.7	5.9	7.0	...	...	...	...	...	...	...
Aluminum alloys	*A*	9.9	10.9	11.6	12.3	13.0	13.3	13.6	13.9	14.2	...	...	...	...	...	...	...	...
	B	−4.7	−2.9	−1.7	0	2.0	3.7	5.4	7.2	9.0	...	...	...	...	...	...	...	...
Titanium alloys (Grades 1, 2, 3, 7, and 12)	*A*	...	...	4.5	4.6	4.7	4.8	4.8	4.9	4.9	5.0	5.1	...	...	...	...	...	...
	B	...	...	−0.6	0	0.7	1.3	1.9	2.5	3.1	3.8	4.4	...	...	...	...	...	...

(continued)

01 TABLE B-1 (CONT'D)

NOTES:
(1) These data are for information and it is not to be implied that materials are suitable for all the temperature ranges shown.
(2) Group 1 alloys (by nominal composition):

Carbon steels
(C, C–Si, C–Mn, and C–Mn–Si)
C–½Mo
½Cr–⅕Mo–V
½Cr–¼Mo–Si
½Cr–½Mo
½Cr–½Ni–¼Mo
¾Cr–½Ni–Cu
¾Cr–¾Ni–Cu–Al
1Cr–⅕Mo
1Cr–⅕Mo–Si
1Cr–½Mo
1Cr–½Mo–V
1¼Cr–½Mo
1¼Cr–½Mo–Si
1¾Cr–½Mo–Cu
2Cr–½Mo
2¼Cr–1Mo
3Cr–1Mo
½Ni–½Mo–V
½Ni–½Cr–¼Mo–V
¾Ni–½Mo–Cr–V
¾Ni–½Mo–⅓Cr–v
¾Ni–½Cu–Mo
¾Ni–½Cr–½Mo–V
¾Ni–1Mo–¾Cr
1Ni–½Cr–½Mo
1¼Ni–1Cr–½Mo
1¾Ni–¾Cr–¼Mo
2Ni–¾Cr–¼Mo
2Ni–¾Cr–⅓Mo
2½Ni
3½Ni
3½Ni–1¾Cr–½Mo–V

(3) Group 2 alloys (by nominal composition):

M–V
Mn–¾Mo
Mn–½Mo
Mn–½Mo–¼Ni
Mn–½Mo–½Ni
Mn–½Mo–¾Ni

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TABLE B-1 (SI)
THERMAL EXPANSION DATA

A = Mean Coefficient of Thermal Expansion, 10^{-6} mm/mm/°C
B = Linear Thermal Expansion, mm/m
} in Going From 20°C to Indicated Temperature [Note (1)]

Material	Coef-ficient	Temperature Range 20°C to													
		−200	−100	−50	20	50	75	100	125	150	175	200	225	250	275
Group 1 carbon and low Alloy steels [Note (2)]	*A*	9.9	10.7	11.1	11.6	11.8	11.9	12.1	12.2	12.4	12.5	12.7	12.8	13.0	13.2
	B	−2.2	−1.3	−0.8	0	0.4	0.7	1.0	1.3	1.6	1.9	2.3	2.6	3.0	3.4
Group 2 low alloy steels [Note (3)]	*A*	10.8	11.7	12.0	12.5	12.7	12.9	13.1	13.3	13.4	13.5	13.6	13.7	13.8	13.9
	B	−2.4	−1.4	−0.8	0	0.4	0.7	1.0	1.4	1.7	2.1	2.5	2.8	3.2	3.6
5Cr–1Mo steels	*A*	10.1	10.8	11.2	11.6	11.8	12.0	12.1	12.2	12.4	12.5	12.6	12.6	12.7	12.7
	B	−2.2	−1.3	−0.8	0	0.4	0.7	1.0	1.3	1.6	1.9	2.3	2.6	2.9	3.3
9Cr–1Mo steels	*A*	9.0	9.8	10.1	10.4	10.6	10.7	10.8	10.9	11.1	11.2	11.3	11.4	11.5	11.6
	B	−2.0	−1.2	−0.7	0	0.3	0.6	0.9	1.1	1.4	1.7	2.0	2.3	2.6	3.0
Straight chromium stainless steels															
12Cr to 13Cr steels	*A*	9.1	9.9	10.2	10.7	10.8	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.7
	B	−2.0	−1.2	−0.7	0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0
15Cr to 17Cr steels	*A*	8.1	8.8	9.1	9.6	9.7	9.8	9.9	10.0	10.2	10.3	10.3	10.4	10.5	10.6
	B	−1.8	−1.1	−0.6	0	0.3	0.5	0.8	1.1	1.3	1.6	1.9	2.1	2.4	2.7
27Cr steels	*A*	7.7	8.5	8.7	9.0	9.1	9.2	9.3	9.4	9.4	9.5	9.5	9.6	9.7	9.7
	B	−1.7	−1.0	−0.6	0	0.3	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.2	2.5
Austenitic stainless steels (304, (305, 316, 317, 321, 347, 348 19-9DL XM-15, etc.)	*A*	13.5	14.3	14.7	15.3	15.6	15.9	16.1	16.4	16.6	16.8	17.0	17.2	17.3	17.5
	B	−3.0	−1.7	−1.0	0	0.5	0.9	1.3	1.7	2.2	2.6	3.1	3.5	4.0	4.5
Other austenitic stainless steels (309, 310, 315, XM-19, etc.)	*A*	12.8	13.6	14.1	14.7	14.9	15.1	15.4	15.6	15.8	16.0	16.1	16.2	16.3	16.4
	B	−2.8	−1.6	−1.0	0	0.4	0.8	1.2	1.6	2.1	2.5	2.9	3.3	3.8	4.2
Gray cast iron	*A*	...	...	...	9.8	10.1	10.2	10.4	10.5	10.7	10.8	11.0	11.1	11.2	11.4
	B	...	...	...	0	0.3	0.6	0.8	1.1	1.4	1.7	2.0	2.3	2.6	2.9
Ductile cast iron	*A*	...	8.8	9.5	10.3	10.6	10.8	10.9	11.1	11.3	11.4	11.7	12.0	12.2	12.3
	B	...	−1.1	−0.7	0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.5	2.8	3.1
Monel (67Ni–30Cu) N04400	*A*	10.4	12.2	13.0	13.8	14.1	14.4	14.7	14.9	15.0	15.2	15.3	15.4	15.6	15.7
	B	−2.3	−1.5	−0.9	0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
Nickel alloys N02200 and N02201	*A*	10.1	11.5	12.0	12.7	12.9	13.1	13.3	13.5	13.6	13.8	13.9	14.0	14.2	14.3
	B	−2.2	−1.4	−0.8	0	0.4	0.7	1.1	1.4	1.8	2.1	2.5	2.9	3.3	3.6
Nickel alloy N06600	*A*	9.9	10.8	11.5	12.2	12.5	12.7	12.8	13.1	13.2	13.3	13.5	13.6	13.7	13.8
	B	−2.2	−1.3	−0.8	0	0.4	0.7	1.0	1.4	1.7	2.1	½2.4	2.8	3.2	3.5
Nickel alloys N08800 and N08810	*A*	10.6	12.5	13.3	14.3	14.6	14.9	15.1	15.3	15.5	15.7	15.8	15.9	16.0	16.1
	B	−2.3	−1.5	−0.9	0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.3	3.7	4.1
Nickel alloy N08825	*A*	...	...	12.9	13.5	13.6	13.8	13.9	14.0	14.1	14.2	14.4	14.4	14.5	14.6
	B	...	...	−0.9	0	0.4	0.8	1.1	1.5	1.8	2.2	2.6	3.0	3.3	3.7

(continued)

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TABLE B-1 (SI)
THERMAL EXPANSION DATA

01

A = Mean Coefficient of Thermal Expansion, 10^{-6} mm/mm/°C
B = Linear Thermal Expansion, mm/m
} in Going From 20°C to Indicated Temperature [Note (1)]

Temperature Range 20°C to																				
300	325	350	375	400	425	450	475	500	525	550	575	600	625	650	675	700	725	750	775	800
13.3	13.5	13.6	13.7	13.8	13.9	14.1	14.2	14.3	14.4	14.6	14.7	14.8	14.9	15.0	15.0	15.1	15.1	15.2	...	...
3.7	4.1	4.5	4.9	5.2	5.6	6.1	6.5	6.9	7.3	7.7	8.1	8.6	9.0	9.4	9.8	10.2	10.7	11.1	...	...
14.0	14.1	14.2	14.3	14.4	14.5	14.6	14.6	14.7	14.8	14.8	14.9	14.9	15.0	15.1	15.1	15.2	...	...	...	...
3.9	4.3	4.7	5.1	5.5	5.9	6.3	6.7	7.1	7.5	7.9	8.3	8.7	9.1	9.5	9.9	10.3	...	...	...	...
12.8	12.9	13.0	13.1	13.1	13.2	13.2	13.3	13.4	13.5	13.5	13.6	13.6	13.7	13.8	13.8	13.9	...	...	...	...
3.6	3.9	4.3	4.6	5.0	5.3	5.7	6.1	6.4	6.8	7.2	7.5	7.9	8.3	8.7	9.1	9.4	...	...	...	...
11.7	11.8	11.8	11.9	12.0	12.1	12.2	12.2	12.3	12.4	12.5	12.6	12.6	12.7	12.8	12.8	12.9	...	...	...	...
3.3	3.6	3.9	4.2	4.6	4.9	5.2	5.6	5.9	6.3	6.6	7.0	7.3	7.7	8.1	8.4	8.8	...	...	...	...
11.7	11.8	11.8	11.9	11.9	12.0	12.1	12.1	12.2	12.2	12.2	12.3	12.3	12.4	12.4	12.4	12.5	...	...	...	...
3.3	3.6	3.9	4.2	4.5	4.9	5.2	5.5	5.8	6.2	6.5	6.8	7.2	7.5	7.8	8.1	8.5	...	...	...	...
10.7	10.8	10.8	10.9	11.0	11.0	11.1	11.2	11.3	11.3	11.4	11.4	11.5	11.6	11.6	11.7	11.7	...	...	...	...
3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.7	6.0	6.3	6.7	7.0	7.3	7.6	8.0	...	...	...	...
9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.6	10.6	10.7	...	...	...	...
2.7	3.0	3.3	3.5	3.8	4.1	4.3	4.6	4.9	5.2	5.5	5.8	6.1	6.4	6.7	7.0	7.3	...	...	...	...
17.6	17.7	17.9	18.0	18.1	18.2	18.3	18.3	18.5	18.5	18.6	18.7	18.8	18.9	19.0	19.1	19.2	...	...	...	...
4.9	5.4	5.9	6.4	6.9	7.4	7.8	8.3	8.9	9.4	9.9	10.4	10.9	11.4	12.0	12.5	13.0	...	...	...	...
16.5	16.5	16.7	16.7	16.8	16.9	17.0	17.1	17.2	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	...	...	...	...
4.6	5.0	5.5	5.9	6.4	6.8	7.3	7.8	8.2	8.7	9.2	9.7	10.1	10.6	11.1	11.6	12.2	...	...	...	...
11.5	11.7	11.8	12.0	12.1	12.3	12.4	12.6	12.7	12.9	13.0	...	...	...	...	...	...	...	...	...	...
3.2	3.6	3.9	4.2	4.6	5.0	5.3	5.7	6.1	6.5	6.9	...	...	...	...	...	...	...	...	...	...
12.5	12.7	12.7	12.9	13.0	13.1	13.1	13.2	13.3	13.5	13.6	...	...	...	...	...	...	...	...	...	...
3.5	3.9	4.2	4.6	4.9	5.3	5.7	6.0	6.4	6.8	7.2	...	...	...	...	...	...	...	...	...	...
15.8	15.9	16.0	16.0	16.1	16.1	16.2	16.2	16.2	16.3	16.3	16.3	16.4	16.4	16.5	16.5	16.5	16.6	16.6	16.7	16.7
4.4	4.9	5.3	5.7	6.1	6.5	7.0	7.4	7.8	8.2	8.6	9.1	9.5	9.9	10.4	10.8	11.2	11.7	12.1	12.6	13.0
14.4	14.5	14.6	14.7	14.8	14.9	15.0	15.0	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.8	15.9	16.0	16.1	16.2
4.0	4.4	4.8	5.2	5.6	6.0	6.4	6.8	7.3	7.7	8.1	8.5	9.0	9.4	9.9	10.3	10.8	11.2	11.7	12.2	12.6
13.9	14.0	14.1	14.2	14.4	14.5	14.6	14.7	14.8	14.9	15.0	15.0	15.2	15.3	15.4	15.6	15.7	15.8	15.9	16.1	16.2
3.9	4.3	4.7	5.1	5.5	5.9	6.3	6.7	7.1	7.5	7.9	8.4	8.8	9.3	9.7	10.2	10.6	11.1	11.6	12.1	12.7
16.2	16.3	16.3	16.4	16.5	16.6	16.7	16.7	16.8	16.9	17.0	17.1	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9
4.5	5.0	5.4	5.8	6.3	6.7	7.2	7.6	8.1	8.5	9.0	9.5	9.9	10.4	10.9	11.4	11.9	12.4	12.9	13.4	14.0
14.7	14.8	14.9	15.0	15.1	15.1	15.2	15.3	15.4	15.5	15.6	...	...	...	...	...	...	...	...	...	...
4.1	4.5	4.9	5.3	5.7	6.1	6.5	7.0	7.4	7.8	8.3	...	...	...	...	...	...	...	...	...	...

(continued)

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TABLE B-1 (SI)
THERMAL EXPANSION DATA (CONT'D)

A = Mean Coefficient of Thermal Expansion, 10^{-6} mm/mm/°C
B = Linear Thermal Expansion, mm/m
} in Going From 20°C to Indicated Temperature [Note (1)]

Material	Coef-ficient	Temperature Range 20°C to													
		−200	−100	−50	20	50	75	100	125	150	175	200	225	250	275
Copper alloys C1XXXX series	*A*	13.9	15.7	16.2	16.8	17.0	17.1	17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0
	B	−3.1	−1.9	−1.1	0	0.5	0.9	1.4	1.8	2.3	2.7	3.2	3.7	4.1	4.6
Bronze alloys	*A*	15.1	15.8	16.4	17.2	17.6	17.9	18.1	18.2	18.3	18.3	18.4	18.5	18.5	18.6
	B	−3.3	−1.9	−1.1	0	0.5	1.0	1.4	1.9	2.4	2.8	3.3	3.8	4.3	4.8
Brass alloys	*A*	14.7	15.4	16.0	16.8	17.2	17.4	17.6	17.8	18.0	18.2	18.4	18.6	18.8	19.0
	B	−3.2	−1.9	−1.1	0	0.5	1.0	1.4	1.9	2.3	2.8	3.3	3.8	4.3	4.8
Copper–nickel (70Cu–30Ni)	*A*	11.9	13.4	14.0	14.7	14.9	15.2	15.4	15.5	15.7	15.9	16.1	16.2	16.3	16.4
	B	−2.6	−1.6	−1.0	0	0.4	0.8	1.2	1.6	2.0	2.5	2.9	3.3	3.7	4.2
Aluminum alloys	*A*	18.0	19.7	20.8	22.1	22.6	23.0	23.4	23.7	23.9	24.2	24.5	24.7	24.9	25.2
	B	−4.0	−2.4	−1.5	0	0.7	1.3	1.9	2.5	3.1	3.7	4.4	5.1	5.7	6.4
Titanium alloys (Grades 1, 2, 3, 7, and 12)	*A*	...	...	8.2	8.3	8.4	8.4	8.5	8.5	8.6	8.6	8.6	8.7	8.7	8.8
	B	...	...	−0.6	0	0.3	0.5	0.7	0.9	1.1	1.3	1.6	1.8	2.0	2.2

NOTES:
(1) These data are for information and it is not to be implied that materials are suitable for all the temperature ranges shown.
(2) Group 1 alloys (by nominal composition):

Carbon steels
(C, C–Si, C–Mn, and C–Mn–Si)
C–½Mo
½Cr–½Mo–V
½Cr–¼Mo–Si
½Cr–½Mo
½Cr–½Ni–¼Mo
¾Cr–½Ni–Cu
¾Cr–¾Ni–Cu–Al
1Cr–½Mo
1Cr–½Mo–Si
1Cr–½Mo
1Cr–½Mo–V
1¼Cr–½Mo
1¼Cr–½Mo–Si
1¾Cr–½Mo–Cu
2Cr–½Mo
2¼Cr–1Mo
3Cr–1Mo
½Ni–½Mo–V
½Ni–½Cr–¼Mo–V
¾Ni–½Mo–Cr–V
¾Ni–½Mo–⅓Cr–V
¾Ni–½Cu–Mo
¾Ni–½Cr–½Mo–V
¾Ni–1Mo–¾Cr
1Ni–½Cr–½Mo
1¼Ni–1Cr–½Mo
1¾Ni–¾Cr–¼Mo
2Ni–¾Cr–¼Mo
2Ni–¾Cr–⅓Mo
2½Ni
3½Ni
3½Ni–1¾Cr–½Mo–V

(3) Group 2 alloys (by nominal composition):

M–V
Mn–¼Mo
Mn–½Mo
Mn–½Mo–¼Ni
Mn–½Mo–½Ni
Mn–½Mo–¾Ni

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TABLE B-1 (SI)
THERMAL EXPANSION DATA (CONT'D)

01

A = Mean Coefficient of Thermal Expansion, 10^{-6} mm/mm/°C
B = Linear Thermal Expansion, mm/m
} in Going From 20°C to Indicated Temperature [Note (1)]

Temperature Range 20°C to																				
300	325	350	375	400	425	450	475	500	525	550	575	600	625	650	675	700	725	750	775	800
18.0	18.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5.1	5.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
18.7	18.8	18.9	19.0	19.0	19.1	19.2	19.3	19.4	19.4	19.5	19.6	19.7	19.7	19.8	...	...	...	...	...	...
5.2	5.7	6.2	6.7	7.2	7.7	8.3	8.8	9.3	9.8	10.3	10.9	11.4	11.9	12.5	...	...	...	...	...	...
19.2	19.3	19.5	19.7	19.9	20.1	20.3	20.5	20.7	20.8	21.0	21.2	21.4	21.6	21.8	...	...	...	...	...	...
5.4	5.9	6.4	7.0	7.6	8.1	8.7	9.3	9.9	10.5	11.1	11.8	12.4	13.1	13.7	...	...	...	...	...	...
16.5	16.5	16.6	16.6	16.7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4.6	5.0	5.5	5.9	6.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
25.5	25.7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7.1	7.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8.8	8.9	8.9	9.0	9.0	9.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2.5	2.7	2.9	3.2	3.4	3.7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

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APPENDIX C

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TABLE C-1
MODULI OF ELASTICITY FOR FERROUS MATERIAL

Material	E = Modulus of Elasticity, psi (Multiply Tabulated Values by 10^6) [Note (1)]															
	Temperature, °F															
	-100	70	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
Carbon steels with carbon content 0.30% or less	30.2	29.5	28.8	28.3	27.7	27.3	26.7	25.5	24.2	22.4	20.4	18.0	...	...	...	...
Carbon steels with carbon content above 0.30%	30.0	29.3	28.6	28.1	27.5	27.1	26.5	25.3	24.0	22.3	20.2	17.9	15.4	...	...	...
Carbon-moly steels	29.9	29.2	28.5	28.0	27.4	27.0	26.4	25.3	23.9	22.2	20.1	17.8	15.3	...	...	...
Nickel steels	28.5	27.8	27.1	26.7	26.1	25.7	25.2	24.6	23.9	23.2	22.4	21.5	20.4	19.2	17.7	...
Chromium steels:																
½Cr through 2Cr	30.4	29.7	29.0	28.5	27.9	27.5	26.9	26.3	25.5	24.8	23.9	23.0	21.8	20.5	18.9	...
2¼Cr through 3Cr	31.4	30.6	29.8	29.4	28.8	28.3	27.7	27.1	26.3	25.6	24.6	23.7	22.5	21.1	19.4	...
5Cr through 9Cr	31.7	30.9	30.1	29.7	29.0	28.6	28.0	27.3	26.1	24.7	22.7	20.4	18.2	15.5	12.7	...
Austenitic stainless steels:																
Type 304—18Cr–8Ni Type 310—25Cr–20Ni Type 316—16Cr–12Ni–2Mo Type 321—18Cr–10Ni–Ti Type 347—18Cr–10Ni–Cb Type 309—23Cr–12Ni	29.1	28.3	27.6	27.0	26.5	25.8	25.3	24.8	24.1	23.5	22.8	22.1	21.2	20.2	19.2	18.1
Straight chromium stainless steels (12Cr, 17Cr, 27Cr)	30.1	29.2	28.5	27.9	27.3	26.7	26.1	25.6	24.7	23.2	21.5	19.1	16.6	...	...	...
Gray cast iron	...	13.4	13.2	12.9	12.6	12.2	11.7	11.0	10.2	...	...	...	...	...	...	...

NOTE:
(1) These data are for information and it is not to be implied that materials are suitable for all the temperature ranges shown.

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TABLE C-1 (SI)
MODULI OF ELASTICITY FOR FERROUS MATERIAL

Material	E = Modulus of Elasticity, GPa [Note (1)] Temperature, °C																	
	−75	20	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800
Carbon steels with carbon content 0.30% or less	208	203	201	198	195	191	189	185	179	172	162	150	136	122	107	...	...	...
Carbon steels with carbon content above 0.30%	207	202	200	197	194	190	188	184	178	171	161	149	135	121	106	...	...	...
Carbon-moly steels	206	201	199	196	193	189	187	183	177	170	160	149	135	121	106	...	...	...
Nickel steels	196	192	190	187	184	180	178	174	169	162	153	141	128	115	101	...	...	...
Chromium steels:																		
½Cr through 2Cr	210	205	204	201	197	193	190	186	181	176	170	160	148	133	...	...	...	...
2¼Cr through 3Cr	216	211	210	207	203	199	195	191	187	182	175	165	153	137	...	...	...	...
5Cr through 9Cr	219	213	212	209	205	201	197	193	189	185	181	176	171	164	156	147	138	...
Austenitic stainless steels: Type 304—18Cr–8Ni; Type 310—25Cr–20Ni; Type 316—16Cr–12Ni–2Mo; Type 321—18Cr–10Ni–Ti; Type 347—18Cr–10Ni–Cb; Type 309—23Cr–12Ni	201	195	194	192	188	184	180	176	172	168	164	160	156	152	146	140	134	127
Straight chromium stainless steels (12Cr, 17Cr, 27Cr)	208	201	200	198	194	190	186	181	178	174	167	156	144	130	113	...	...	...
Gray cast iron	...	92	92	91	89	87	85	82	78	73	67	...	...	...	...	...	...	...

NOTE:
(1) These data are for information and it is not to be implied that materials are suitable for all the temperature ranges shown.

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TABLE C-2
MODULI OF ELASTICITY FOR NONFERROUS MATERIAL

01

Materials	E = Modulus of Elasticity, psi (Multiply Tabulated Values by 10^6) [Note (1)]												
	Temperature, °F												
	-100	70	200	300	400	500	600	700	800	900	1000	1100	1200
High Nickel Alloys													
N02200 (200) N02201 (201)	30.9	30.0	29.3	28.8	28.5	28.1	27.8	27.3	26.7	26.1	25.5	25.1	24.5
N04400 (400)	26.8	26.0	25.4	25.0	24.7	24.3	24.1	23.7	23.1	22.6	22.1	21.7	21.2
N06002 (X)	29.4	28.5	27.8	27.4	27.1	26.6	26.4	25.9	25.4	24.8	24.2	23.7	23.2
N06600 (600)	31.9	31.0	30.2	29.9	29.5	29.0	28.7	28.2	27.6	27.0	26.4	25.9	25.3
N06625 (625)	30.9	30.0	29.3	28.8	28.5	28.1	27.8	27.3	26.7	26.1	25.5	25.1	24.5
N08800 (800) (2) N08810 (800H) (2)	29.4	28.5	27.8	27.4	27.1	26.6	26.4	25.9	25.4	24.8	24.2	23.8	23.2
N10001 (B)	32.0	31.1	30.3	29.9	29.5	29.1	28.8	28.3	27.7	27.1	26.4	26.0	25.3
N06007 (G)	28.6	27.8	27.1	26.7	26.4	26.0	25.7	25.3	24.7	24.2	23.6	23.2	22.7
N06455 (C-4)	30.6	29.8	29.1	28.6	28.3	27.9	27.6	27.1	26.5	25.9	25.3	24.9	24.3
N08320 (20 Mod)	28.6	27.8	27.1	26.7	26.4	26.0	25.7	25.3	24.7	24.2	23.6	23.2	22.7
N10276 (C276)	30.6	29.8	29.1	28.6	28.3	27.9	27.6	27.1	26.5	25.9	25.3	24.9	24.3
N10665 (B-2)	32.3	31.4	30.6	30.1	29.8	29.3	29.0	28.6	27.9	27.3	26.7	26.2	25.6
Aluminum and Aluminum Alloys													
A24430 (B443) A91060 (1060) A91100 (1100) A93003 (3003) A93004 (3034) A96061 (6061) A96063 (6063)	10.5	10.0	9.6	9.2	8.7	8.1	...	...	...	...	...	...	...
A95052 (5052) A95154 (5154) A95454 (5454) A95652 (5652)	10.7	10.2	9.7	9.4	8.9	8.3	...	...	...	...	...	...	...
A03560 (356) A95083 (5083) A95086 (5086) A95456 (5456)	10.8	10.3	9.8	9.5	9.0	8.3	...	...	...	...	...	...	...
Copper and Copper Alloys													
C83600 C92200	14.4	14.0	13.7	13.4	13.2	12.9	12.5	12.0	...	...	...	...	...
C46400 C65500 C95200 C95400	15.4	15.0	14.6	14.4	14.1	13.8	13.4	12.8	...	...	...	...	...

(continued)

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TABLE C-2
MODULI OF ELASTICITY FOR NONFERROUS MATERIAL (CONT'D)

Materials	E = Modulus of Elasticity, psi (Multiply Tabulated Values by 10^6 [Note (1)] Temperature, °F												
	−100	70	200	300	400	500	600	700	800	900	1000	1100	1200
Copper and Copper Alloys (Cont'd)													
C11000	16.5	16.0	15.6	15.4	15.0	14.7	14.2	13.7	...	...	...	...	...
C10200 C12000 C12200 C12500 C14200 C23000 C61400	17.5	17.0	16.6	16.3	16.0	15.6	15.1	14.5	...	...	...	...	...
C70600	18.5	18.0	17.6	17.3	16.9	16.6	16.0	15.4	...	...	...	...	...
C97600	19.6	19.0	18.5	18.2	17.9	17.5	16.9	16.2	...	...	...	...	...
C71000	20.6	20.0	19.5	19.2	18.8	18.4	17.8	17.1	...	...	...	...	...
C71500	22.7	22.0	21.5	21.1	20.7	20.2	19.6	18.8	...	...	...	...	...
Unalloyed Titanium													
Grades 1, 2, 3, 7, and 12	...	15.5	15.0	14.6	14.0	13.3	12.6	11.9	11.2	...	...	...	...

NOTES:
(1) These data are for information and it is not to be implied that materials are suitable for all the temperature ranges shown.
(2) For N08800 and N08810, use the following E values above 1200°F: at 1300°F, E = 22.7; at 1400°F, E = 21.9; at 1500°F, E = 21.2 × 10^6 psi.

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TABLE C-2 (SI)
MODULI OF ELASTICITY FOR NONFERROUS MATERIAL

01

Materials	E = Modulus of Elasticity, GPa [Note (1)] Temperature, °C																	
	−75	20	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800
High Nickel Alloys																		
N02200 (200) N02201 (201)	214	207	205	202	199	197	194	191	189	186	183	180	176	172	169	164	161	156
N04400 (400)	185	179	178	175	173	170	168	166	164	161	158	156	153	149	146	142	139	135
N06002 (X)	203	197	195	192	189	187	184	182	179	177	174	171	167	163	160	156	153	148
N06600 (600)	221	214	212	209	206	203	200	198	195	192	189	186	182	178	174	170	166	161
N06625 (625)	214	207	205	202	199	197	194	191	189	186	183	180	176	172	169	164	161	156
N08800 (800) N08810 (800H)	203	197	195	192	189	187	184	182	179	177	174	171	167	163	160	156	153	148
N10001 (B)	222	214	213	210	207	204	201	198	196	193	190	186	182	178	175	170	167	161
N06007 (G)	198	192	190	187	185	182	180	177	175	172	169	167	163	159	156	152	149	144
N06455 (C-4)	212	205	204	201	198	195	193	190	188	185	182	179	175	171	167	163	160	155
N08320 (20Mod)	198	192	190	187	185	182	180	177	175	172	169	167	163	159	156	152	149	144
N10276 (C-276)	212	205	204	201	198	195	193	190	188	185	182	179	175	171	167	163	160	155
N10665 (B-2)	224	217	215	212	209	206	203	200	198	195	191	188	184	180	176	172	168	163
Aluminum and Aluminum Alloys																		
A24430 (B443) A91060 (1060) A91100 (1100) A93003 (3003) A93004 (3034) A96061 (6061) A96063 (6063)	72	69	68	66	63	61	57	52	46	...	...	...	...	...	...	...	...	...
A95052 (5052) A95154 (5154) A95454 (5454) A95652 (5652)	74	70	69	67	65	62	58	53	47	...	...	...	...	...	...	...	...	...
A03560 (356) A95083 (5083) A95086 (5086) A95456 (5456)	74	71	70	68	65	62	58	54	47	...	...	...	...	...	...	...	...	...
Copper and Copper Alloys																		
C83600 C92200	99	97	96	94	93	91	89	87	84	81	...	...	...	...	...	...	...	...
C46400 C65500 C95200 C95400	107	103	102	101	99	98	96	93	90	86	...	...	...	...	...	...	...	...

(continued)

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TABLE C-2 (SI)
MODULI OF ELASTICITY FOR NONFERROUS MATERIAL (CONT'D)

	E = Modulus of Elasticity, GPa [Note (1)]																	
	Temperature, °C																	
Materials	−75	20	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800
Copper and Copper Alloys (Cont'd)																		
C11000	114	110	109	108	106	104	102	99	96	92	...	...	...	...	...	...	...	...
C10200 C12000 C12200 C12500 C14200 C23000 C61400	121	117	116	115	113	111	108	106	102	98	...	...	...	...	...	...	...	...
C70600 C97600 C71000 C71500	128	124	123	121	119	117	115	112	108	104	...	...	...	...	...	...	...	...
Unalloyed Titanium																		
Grades 1, 2, 3, 7, and 12	...	107	106	103	100	97	92	88	84	79	75	71	...	...	...	...	...	...

NOTE:
(1) These data are for information and it is not to be implied that materials are suitable for all the temperature ranges shown.

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APPENDIX D

Begins on Next Page

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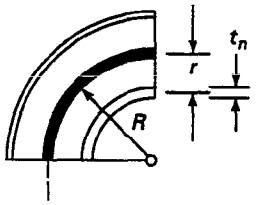
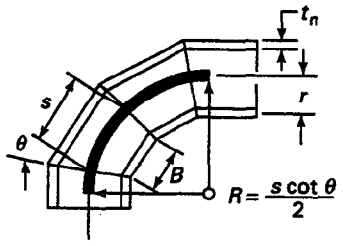
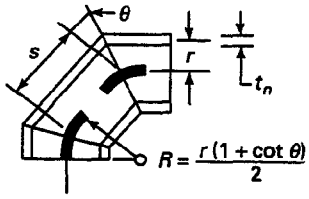
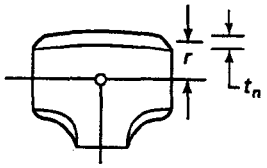
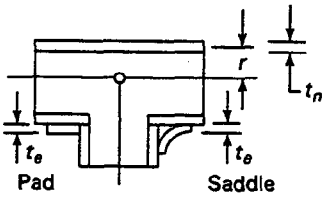
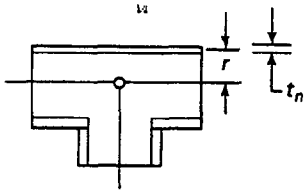
TABLE D-1
FLEXIBILITY AND STRESS INTENSIFICATION FACTORS

Description	Flexibility Characteristic h	Flexibility Factor k	Stress Intensification Factor i	Sketch
Welding elbow or pipe bend [Notes (1), (2), (3), (9), (13)]	$\frac{t_n R}{r^2}$	$\frac{1.65}{h}$	$\frac{0.9}{h^{2/3}}$	
Closely spaced miter bend [Notes (1), (2), (3), (13)] $s < r(1 + \tan\theta)$ $B \geq 6\ t_n$ $\theta \leq 22\frac{1}{2}$ deg.	$\frac{s t_n \cot\theta}{2r^2}$	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	
Widely spaced miter bend [Notes (1), (2), (4), (13)] $s \geq r(1 + \tan\theta)$ $\theta \leq 22\frac{1}{2}$ deg.	$\frac{t_n (1 + \cot\theta)}{2r}$	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	
Welding tee per ASME B16.9 [Notes (1), (2), (10)]	$\frac{4.4 t_n}{r}$	1	$\frac{0.9}{h^{2/3}}$	
Reinforced fabricated tee [Notes (1), (2), (5), (10)]	$\frac{\left(t_n + \frac{t_e}{2}\right)^{5/2}}{r(t_n)^{3/2}}$	1	$\frac{0.9}{h^{2/3}}$	
Unreinforced fabricated tee [Notes (1), (2), (10)]	$\frac{t_n}{r}$	1	$\frac{0.9}{h^{2/3}}$	

(continued)

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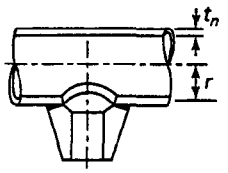
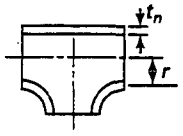
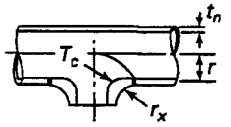
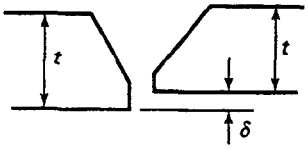
TABLE D-1
FLEXIBILITY AND STRESS INTENSIFICATION FACTORS (CONT'D)

Description	Flexibility Characteristic h	Flexibility Factor k	Stress Intensification Factor i	Sketch
Branch welded-on fitting (integrally reinforced) per MSS SP-97 [Notes (1), (2)]	$\frac{3.3t_n}{r}$	1	$\frac{0.9}{h^{2/3}}$	
Extruded outlet meeting the requirements of para. 104.3.1(G) [Notes (1), (2)]	$\frac{t_n}{r}$	1	$\frac{0.9}{h^{2/3}}$	
Welded-in contour insert with $r_x \geq D_{ob}/8$ $T_c \geq 1.5\ t_n$ [Notes (1), (2)]	$4.4\frac{t_n}{r}$	1	$\frac{0.9}{h^{2/3}}$	

Description	Flexibility Factor k	Stress Intensification Factor i	Sketch
Branch connection [Notes (1), (6)]	1	For checking branch end $1.5\left(\frac{R_m}{t_{nh}}\right)^{2/3}\left(\frac{r'_m}{R_m}\right)^{1/2}\left(\frac{t_{nb}}{t_{nh}}\right)\left(\frac{r'_m}{r_p}\right)$	See Fig. D-1
Butt weld [Note (1)] $t \geq 0.237$ in., $\delta_{max} \leq 1/16$ in., and $\delta_{avg}/t \leq 0.13$	1	1.0 [Note (12)]	
Butt weld [Note (1)] $t \geq 0.237$ in., $\delta_{max} \leq 1/8$ in., and δ_{avg}/t = any value	1	1.9 max. or $[0.9 + 2.7(\delta_{avg}/t)]$, but not less than 1.0 [Note (12)]	
Butt weld [Note (1)] $t \geq 0.237$ in., $\delta_{max} \leq 1/16$ in., and $\delta_{avg}/t \leq 0.33$	1		
Fillet welds	1	2.1; or 1.3 for fillet welds as defined in Note (11)	See Figs. 127.4.4(A), 127.4.4(B), and 127.4.4(C)

(continued)

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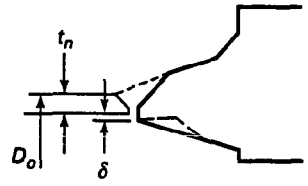
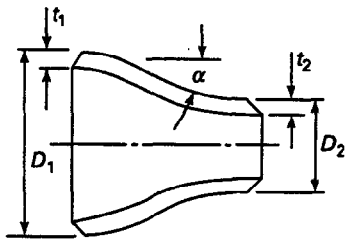
TABLE D-1
FLEXIBILITY AND STRESS INTENSIFICATION FACTORS (CONT'D)

Description	Flexibility Factor k	Stress Intensification Factor i	Sketch
Tapered transition per para. 127.4.2(B) and ASME B16.25 [Note (1)]	1	1.9 max. or $1.3 + 0.0036\frac{D_o}{t_n} + 3.6\frac{\delta}{t_n}$	
Concentric reducer per ASME B16.9 [Note (7)]	1	2.0 max. or $0.5 + 0.01\alpha\left(\frac{D_2}{t_2}\right)^{1/2}$	
Threaded pipe joint, or threaded flange	1	2.3	...
Corrugated straight pipe, or corrugated or creased bend [Note (8)]	5	2.5	...

NOTES:

(1) The following nomenclature applies to Table D-1:

B = length of miter segment at crotch, in. (mm)
D_o = outside diameter, in.
D_{ob} = outside diameter of branch, in. (mm)
R = bend radius of elbow or pipe bend, in. (mm)
r = mean radius of pipe, in. (mm) (matching pipe for tees)
r_x = external crotch radius of welded-in contour inserts, in. (mm)
s = miter spacing at center line, in. (mm)
T_c = crotch thickness of welded-in contour inserts, in. (mm)
t_n = nominal wall thickness of pipe, in. (mm) (matching pipe for tees)
t_r = reinforcement pad or saddle thickness, in. (mm)
α = reducer cone angle, deg.
δ = mismatch, in. (mm)
θ = one-half angle between adjacent miter axes, deg.

(2) The flexibility factors k and stress intensification factors i in Table D-1 apply to bending in any plane for fittings and shall in no case be taken less than unity. Both factors apply over the effective arc length (shown by heavy center lines in the sketches) for curved and miter elbows, and to the intersection point for tees. The values of k and i can be read directly from Chart D-1 by entering with the characteristic h computed from the formulas given.

(3) Where flanges are attached to one or both ends, the values of k and i in Table D-1 shall be multiplied by the factor c given below, which can be read directly from Chart D-2, entering with the computed h: one end flanged, $c = h^{1/6}$; both ends flanged, $c = h^{1/3}$.

(4) Also includes single miter joints.

(5) When $t_e > 1.5t_n$, $h = 4.05t_n/r$.

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TABLE D-1 (CONT'D)

NOTES (CONT'D):

(6) The equation applies only if the following conditions are met.
- (a) The reinforcement area requirements of para. 104.3 are met.
- (b) The axis of the branch pipe is normal to the surface of run pipe wall.
- (c) For branch connections in a pipe, the arc distance measured between the centers of adjacent branches along the surface of the run pipe is not less than three times the sum of their inside radii in the longitudinal direction or is not less than two times the sum of their radii along the circumference of the run pipe.
- (d) The inside corner radius r_1 (see Fig. D-1) is between 10% and 50% of t_{nh}.
- (e) The outer radius r_2 (see Fig. D-1) is not less than the larger of $T_b/2$, $(T_b + y)/2$ [shown in Fig. D-1 sketch (c)], or $t_{nh}/2$.
- (f) The outer radius r_3 (see Fig. D-1) is not less than the larger of:
  - (1) $0.002\theta d_o$;
  - (2) $2(\sin\theta)^3$ times the offset for the configurations shown in Fig. D-1 sketches (a) and (b).
- (g) $R_m/t_{nh} \le 50$ and $rt_m/R_m \le 0.5$.

(7) The equation applies only if the following conditions are met:
- (a) Cone angle α does not exceed 60 deg., and the reducer is concentric.
- (b) The larger of D_1/t_1 and D_2/t_2 does not exceed 100.
- (c) The wall thickness is not less than t_1 throughout the body of the reducer, except in and immediately adjacent to the cylindrical portion on the small end, where the thickness shall not be less than t_2.

(8) Factors shown apply to bending; flexibility factor for torsion equals 0.9.

(9) The designer is cautioned that cast butt welding elbows may have considerably heavier walls than those of the pipe with which they are used. Large errors may be introduced unless the effect of these greater thicknesses is considered.

(10) The stress intensification factors in the Table were obtained from tests on full size outlet connections. For less than full size outlets, the full size values should be used until more applicable values are developed.

(11) A stress intensification factor of 1.3 may be used for socket weld fitting if toe weld blends smoothly with no undercut in pipe wall as shown in the concave, unequal leg fillet weld of Fig. 127.4.4(A).

(12) The stress intensification factors apply to girth butt welds between two items for which the wall thicknesses are between $0.875t$ and $1.10t$ for an axial distance of $\sqrt{D_o t}$. D_o and t are nominal outside diameter and nominal wall thickness, respectively. δ_{avg} is the average mismatch or offset.

(13) In large diameter thin-wall elbows and bends, pressure can significantly affect magnitudes of k and i. Values from the table may be corrected by dividing k by

$$\left[1 + 6\left(\frac{P}{E_c}\right)\left(\frac{r}{t_n}\right)^{7/3}\left(\frac{R}{r}\right)^{1/3}\right]$$

and dividing i by

$$\left[1 + 3.25\left(\frac{P}{E_c}\right)\left(\frac{r}{t_n}\right)^{5/2}\left(\frac{R}{r}\right)^{2/3}\right]$$

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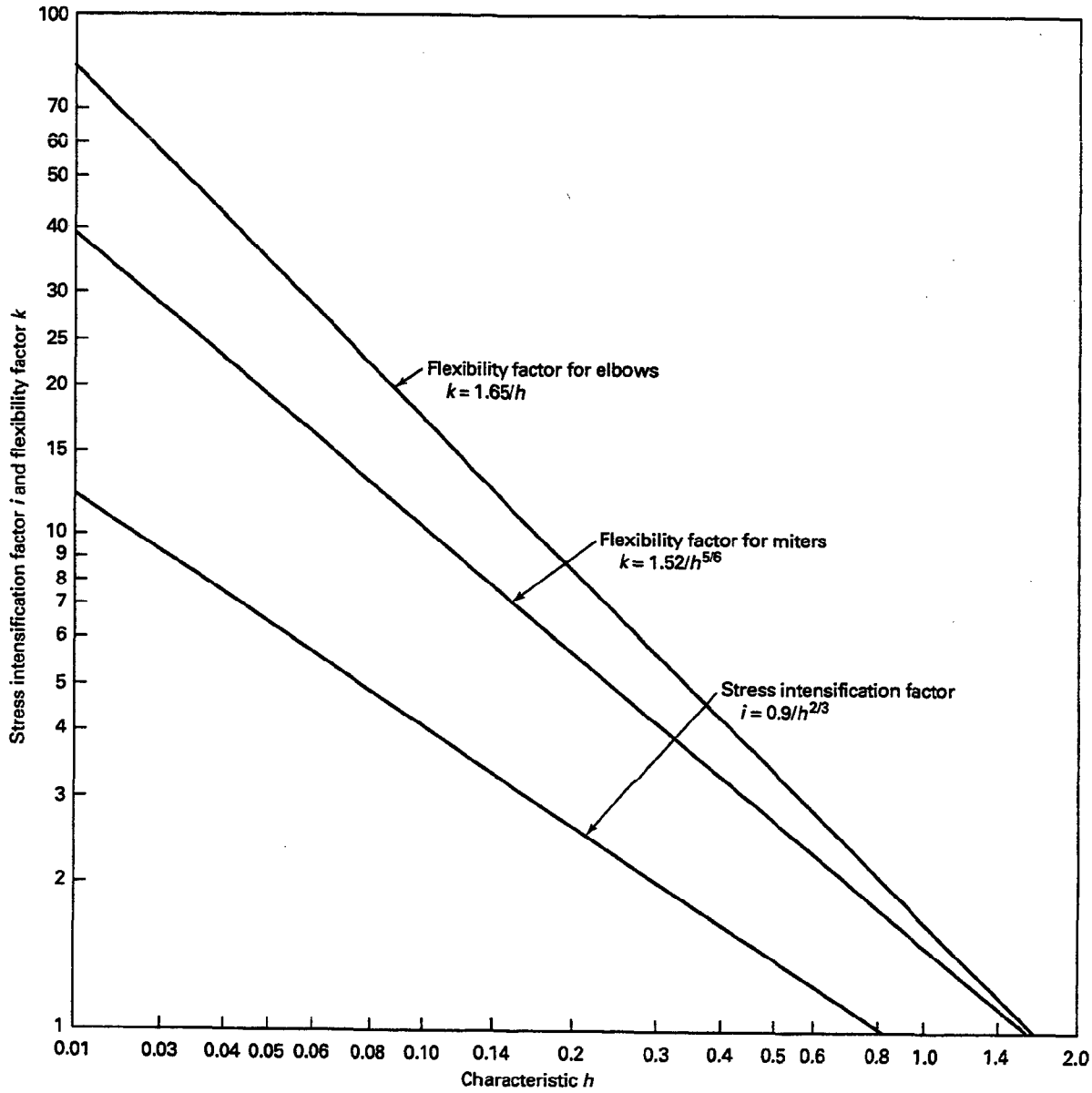

CHART D-1 FLEXIBILITY FACTOR *k* AND STRESS INTENSIFICATION FACTOR *i*

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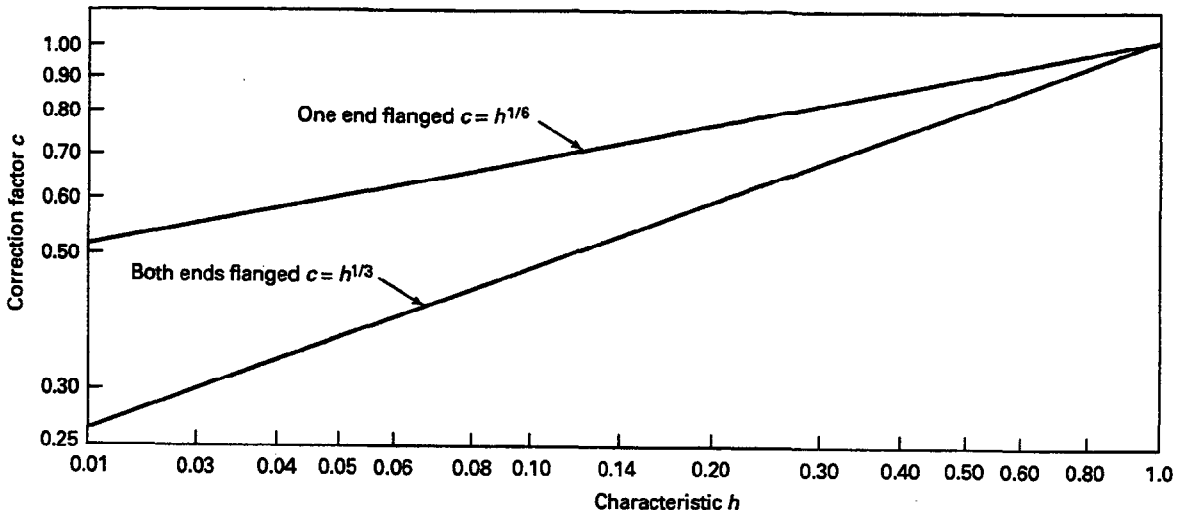

CHART D-2 CORRECTION FACTOR c

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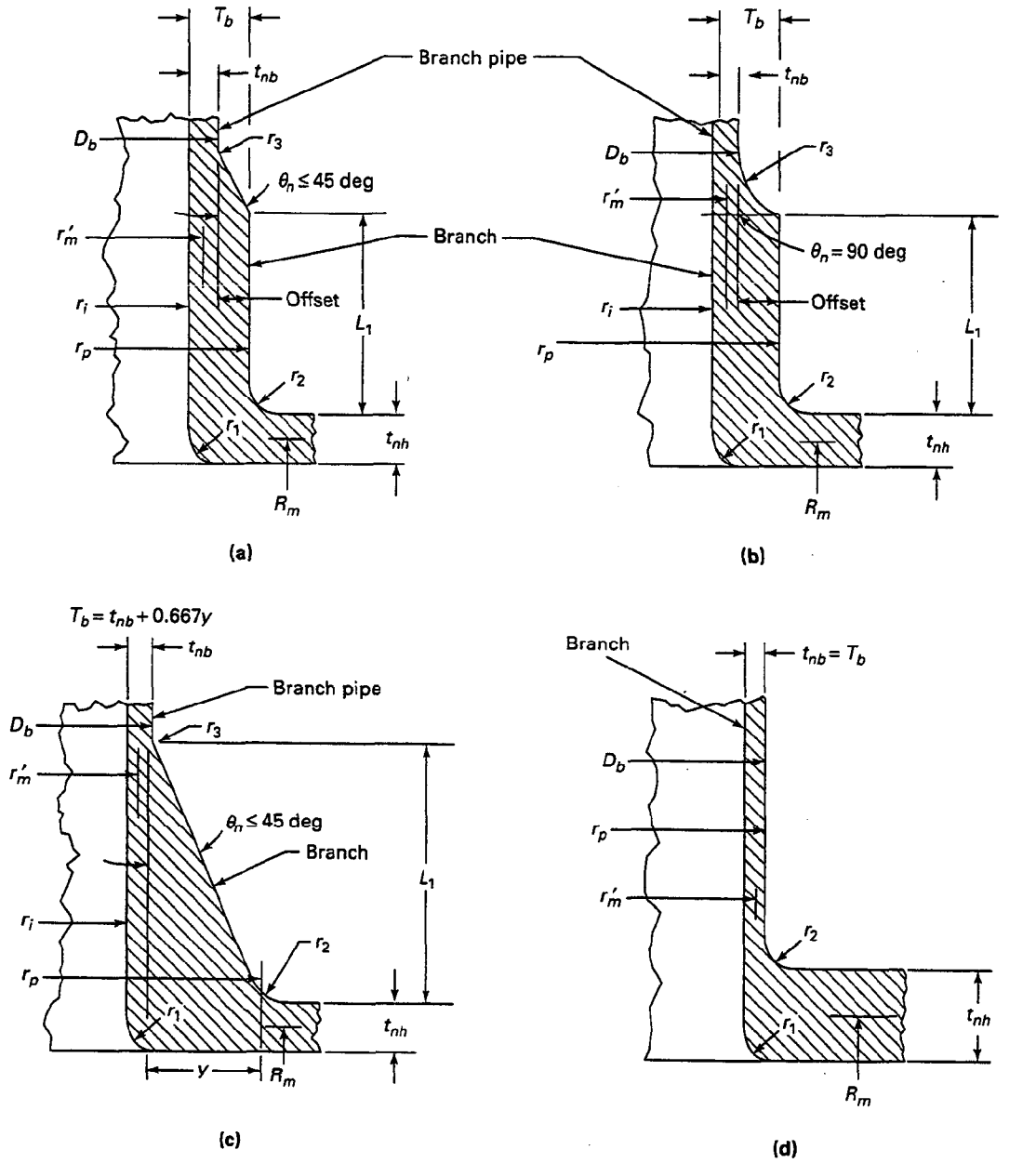

D_b = outside diameter of branch pipe, in. (mm)
L_1 = height of nozzle, in. (mm)
R_m = mean radius of run pipe, in. (mm)
T_b = effective thickness of branch reinforcement, in. (mm)
r_1 = inside radius of branch, in. (mm)
r'_m = mean radius of branch pipe, in. (mm)

r_1, r_2, r_3 = transition radii of branch reinforcement, in. (mm)
r_p = outside radius of branch reinforcement, in. (mm)
t_{nb} = nominal thickness of branch pipes, in. (mm)
t_{nh} = nominal thickness of run pipe, in. (mm)
θ_n = transition angle of branch reinforcement, deg

FIG. D-1 BRANCH CONNECTION DIMENSIONS

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APPENDIX F
REFERENCED STANDARDS[1]
ASME B31.1-2001, POWER PIPING

Specific editions of standards incorporated in this Code by reference are shown in this issue of Appendix F. It is not practical to refer to a specific edition of each standard throughout the Code text, but instead, the specific edition reference dates are shown here. Appendix F will be revised at intervals as needed and issued. The names and addresses of the sponsoring organizations are also shown in this issue.

American National Standards

B1.20.3-1976 (R81)
B16.18-1984 (R94)
B18.2.1-1981 (R92)
B18.2.4.6M-1979 (R90)
B18.22M-1981
B18.22.1-1965 (R81)
Z223.1-1996

ASTM Specifications [Note (2)]

A 36-89
A 47-84 (R89)
A 48-83
A 53-90A

A 105-87a
A 106-90
A 125-81
A 126-84
A 134-89a
A 135-89a
A 139-89b
A 178-90
A 179-90
A 181-87
A 182-90
A 192-90
A 193-90
A 194-88a
A 197-87
A 199-89

A 210-90
A 211-75 (R85)
A 213-90
A 214-90
A 216-89
A 217-89

ASTM Specifications [Note (2)] (Cont'd)

A 226-90
A 229-83
A 234-90a
A 240-89b
A 242-89
A 249-90
A 254-90
A 268-90a
A 276-89a
A 278-85
A 283-87
A 285-82 (R87)
A 299-82 (R87)

A 307-90
A 312-89a
A 320-90
A 322-90
A 333-88a
A 335-89a
A 350-89a
A 351-89b
A 354-90
A 358-88a
A 369-89
A 376-88
A 377-89
A 387-90
A 389-89
A 395-88

A 403-89
A 409-95a
A 420-90a
A 426-89
A 430-88
A 437-88

ASTM Specifications [Note (2)] (Cont'd)

A 449-93
A 450-89
A 451-80 (R85)
A 452-88
A 453-88a
A 479-89

A 515-82 (R87)
A 516-86
A 530-89
A 564-89
A 575-86a
A 576-90
A 587-89a

A 671-85
A 672-89a
A 691-85a

A 714-89a

B 26-88
B 32-89
B 42-89
B 43-88
B 61-86
B 62-86
B 68-86
B 75-86
B 88-88a

B 108-87
B 111-88
B 148-90a
B 150-86
B 151-94

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REFERENCED STANDARDS (CONT'D)

ASTM Specifications [Note (2)] (Cont'd)

B 161-87
B 163-89
B 165-87
B 167-90
B 168-90

B 209-89
B 210-88
B 221-88
B 234-88
B 241-88
B 247-88
B 251-88
B 265-89
B 280-86
B 283-89

B 302-87
B 315-86
B 337-83
B 338-83
B 348-83
B 361-88
B 366-93
B 367-83
B 381-83

B 402-86
B 407-88
B 408-87
B 409-87
B 423-90
B 424-87
B 425-90
B 462-89
B 463-84
B 464-89
B 466-86
B 467-88
B 468-89
B 473-87

B 547-88
B 564-88
B 584-98A

B 608-88
B 625-93
B 649-93
B 673-91
B 674-91
B 677-91

B 729-87

ASTM Standard Test Methods

D 323-99

E 125-63 (R85)
E 186-91
E 280-93
E 446-91

MSS Standard Practices

SP-6-96
SP-9-97
SP-25-98
SP-42-90
SP-43-91
SP-45-98
SP-51-91
SP-53-95
SP-54-95
SP-55-96
SP-58-93
SP-61-92
SP-67-95
SP-69-96
SP-75-98
SP-79-92
SP-80-97
SP-89-98
SP-93-87
SP-94-92
SP-97-95
SP-105-96

AWS Specifications

A3.0-94
QC1-88

API Specifications

5L, 38th Edition, 1990

ASME Codes and Standards

Boiler and Pressure Vessel Code, 1992 Edition, including Addenda
B1.1-1989
B1.13M-1995
B1.20.1-1983 (R92)
(ANSI/ASME B1.20.1)
B16.1-1989
(ASME/ANSI B16.1)
B16.3-1992
B16.4-1992

ASME Codes and Standards (Cont'd)

B16.5-1988
(ASME/ANSI B16.5)
B16.9-1993
B16.10-1992
B16.11-1991
B16.14-1991
B16.15-1985 (R94)
(ANSI/ASME B16.15)
B16.20-1993
B16.21-1992
B16.24-1991
B16.25-1992
B16.28-1994
B16.34-1996
B16.42-1987
(ASME/ANSI B16.42)
B16.47-1990
B16.48-1997
B18.2.2-1987 (R93)
(ASME/ANSI B18.2.2)
B18.2.3.5M-1979 (R95)
B18.2.3.6M-1979 (R95)
B18.21.1-1994
B31.3-1996
B31.4-1992
B31.8-1995
B36.10M-1996
B36.19M-1985 (R94)
(ANSI/ASME B36.19M)
TDP-1-1985

ASNT Specifications

CP-189-95
SNT-TC-1A (1992)

AWWA and ANSI/AWWA Standards

C-110/A21.10-87
C-111/A21.11-90
C-115/A21.15-88
C-150/A21.50-91
C-151/A21.51-91

C-200-91
C-207-86
C-208-89

C-300-89
C-301-84
C-302-87

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REFERENCED STANDARDS (CONT'D)

AWWA and ANSI/AWWA Standards (Cont'd)	National Fire Codes	PFI Standard
C-400-86	NFPA 8503-92	ES-16-94
C-500-86	NFPA 1963-93	
C-504-87		
C-600-87		
C-606-87		

NOTES:
(1) The issue date shown immediately following the hyphen after the number of the standard (e.g., B1.1-1989, A 36-89, SP-6-90) is the effective date of issue (edition) of the standard. B18.2.2-1987 (R93) designates specification reaffirmed without change in 1993.
(2) For boiler external piping material application, see para. 123.2.2.

Specifications and standards of the following organizations, appear in this Appendix:

ANSI American National Standards Institute
11 W 42nd Street
New York, NY 10036
Phone: 212 642-4900

API American Petroleum Institute
1220 L Street, NW
Washington, DC 20005
Phone: 202 682-8000

ASME The American Society of Mechanical Engineers
Three Park Avenue
New York, NY 10016-5990

ASME Order Department
22 Law Drive
Box 2300
Fairfield, NJ 07007-2300
Phone: 201 882-1167
800-THE-ASME (US & Canada)
Fax: 201 882-1717, 5155

ASNT American Society of Nondestructive Testing
1711 Arlingate Lane
PO Box 28518
Columbus, OH 43228-0518
Phone: 614 274-6003

ASTM American Society for Testing and Materials
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959
Phone: 610 832-9585
Fax: 610 832-9555

AWS American Welding Society
550 NW LeJeune Road
PO Box 351040
Miami, FL 33135
Phone: 305 443-9353

AWWA American Water Works Association
6666 W. Quincy Avenue
Denver, CO 80235
Phone: 303 794-7711

MSS Manufacturers Standardization Society of the Valve and Fittings Industry, Inc.
127 Park Street, NE
Vienna, VA 22180
Phone: 703 281-6613

NFPA National Fire Protection Association
1 Batterymarch Park
PO Box 9101
Quincy, MA 02269-9101
Phone: 617 770-3000
Fax: 617 770-0700

PFI Pipe Fabrication Institute
PO Box 173
Springdale, PA 15144
Phone: 412 274-4722

PPI Plastic Pipe Institute
1275 K Street, NW
Suite 400
Washington, DC 20005
Phone: 202 371-5200
Fax: 202 371-1022

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APPENDIX G
NOMENCLATURE

This Appendix is a compliation of the nomenclature used within this Code. Included are the term definitions and units that can be uniformly applied. These terms are also defined at a convenient location within the Code. When used elsewhere within the Code, definitions given here shall be understood to apply.

Symbol	Definition	Units		References	
		US	SI	Paragraph	Table/Fig./App.
A	Corrosion, erosion, and mechanical allowances (including threading, grooving)	in.	mm	104.1.2(A)[Eqs.(3), (3A), (4), (4A)] 104.4.1(B) 104.5.2(B) 104.5.3(A) 104.3.1	...
Area available for reinforcement:					
A_1	in run pipe	in.^{2}	mm^2	104.3.1(D.2)	104.3.1(D) 104.3.1(G)
A_2	in branch pipe	in.^{2}	mm^2	104.3.1(D.2)	104.3.1(D) 104.3.1(G)
A_3	by deposited metal beyond outside diameter of run and branch and for fillet weld attachments of rings, pads, and saddles	in.^{2}	mm^2	104.3.1(d.2)	104.3.1(D)
A_4	by reinforcing ring, pad, or integral reinforcement	in.^{2}	mm^2	104.3.1(D.2)	104.3.1(D) 104.3.1(G)
A_5	in saddle on right angle connection	in.^{2}	mm^2	104.3.1(D.2)	104.3.1(D)
A_7	Required reinforcement area	in.^{2}	mm^2	104.3.1(D.2)	104.3.1(D) 104.3.1(G)
b	Subscript referring to branch	...	...	104.3.1(D.2)	104.3.1(D)
c	Flanged elbow correction factor	...	...	...	Table D-1 Chart D-2
C	Cold-spring factor	...	...	119.10.1[Eqs. (9), (10)]	...
C_x	Size of fillet weld for socket welding components other than flanges	in.	mm	...	127.4.4(C)
d	Inside diameter of pipe	in.	mm	104.1.2(A)[Eqs. (3A), (4A)]	...
d_1	Inside center line longitudinal direction of the finished branch opening in the run of the pipe	in.	mm	...	104.3.1(D)
d_2	Half-width of reinforcement zone	in.	mm	104.3.1(D.2)	104.3.1(D)
d_5	Diameter of finished opening	in.	mm	104.4.1(C)	...
d_6	Inside or pitch diameter of gasket	in.	mm	104.5.3(A)	...
d_b	Corroded internal diameter of branch pipe	in.	mm	104.3.1(G.4)	104.3.1(G)

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NOMENCLATURE (CONT'D)

Symbol	Definition	Units		References	
		US	SI	Paragraph	Table/Fig./App.
d_c	Corroded internal diameter of extruded outlet	in.	mm	104.3.1(G.4)	104.3.1(G)
d_n	Nominal inside diameter of pipe	in.	mm	102.3.2(D)	...
d_r	Corroded internal diameter of run	in.	mm	104.3.1(G.4)	104.3.1(G)
D	Nominal pipe size	in.	mm	119.7.1(A.3)	...
D_n	Nominal outside diameter of pipe	in.	mm	102.3.2(D)	...
D_o	Outside diameter of pipe	in.	mm	102.3.2(D) 104.1.2(A)[Eqs. (3), (4)] 104.3.1(D.2) 104.8.1[Eqs. (11a), (11b)] 104.8.2[Eqs. (12a), (12b)]	App. D
D_{ob}	Outside diameter of branch	in.	mm	...	App. D
E	Weld joint efficiency factor	...	...	104.1.2(A)[Eqs (3), (3A), (4), (4A)] 104.4.1(B)	102.4.3 App. A Notes to Tables A-1 thru A-4 and A-7
E	Young's modulus of elasticity (used with subscripts)	psi	MPa	119.6.2 119.6.4 119.10.1[Eqs. (9), (10)]	App. C
F	Casting quality factor	...	...	104.1.2(A)	App. A Notes to Tables A-1 thru A-7
f	Stress range reduction factor	...	...	102.3.2(C) 104.8.3[Eqs. (13a), (13b)]	102.3.2(C)
h	Subscript referring to run or header	...	...	104.3.1(D.2)	104.3.1(D)
h	Flexibility characteristic, to compute i, k	...	...	...	App. D
h_o	Height of extruded lip	in.	mm	104.3.1(G.4)	104.3.1(G)
i	Stress intensification factor	...	...	104.8.1[Eqs. (11a), (11b)] 104.8.2[Eqs. (12a), (12b)] 104.8.3[Eqs. (13a), (13b)]	App. D
k	Factor for Occasional Loads	...	...	104.8.2[Eqs. (12a), (12b)]	...
k	Flexibility factor	...	...	...	App. D

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NOMENCLATURE (CONT'D)

Symbol	Definition	Units		References	
		US	SI	Paragraph	Table/Fig./App.
L	Developed length of line axis	ft	m	119.7.1(a.3)	...
L_4	Altitude of reinforcing zone outside run pipe	in.	mm	104.3.1(D.2)	104.3.1(D)
L_8	Altitude of reinforcing zone for extruded outlet	in.	mm	104.3.1(G.4)	104.3.1(G)
M	Moment of bending or torsional force (used with subscripts to define applications as shown in referenced paragraphs)	in.-lb, ft-lb	N-mm	104.8.1[Eqs. (11a), (11b)] 104.8.2[Eqs. (12a), (12b)] 104.8.3[Eqs. (13a), (13b)] 104.8.4	104.8.4
MAWP	Maximum Allowable Working Pressure	psi	kPa	100.2	...
MSOP	Maximum sustained operating pressure	psi	kPa	101.2.2 102.2.3 122.1.1(B) 122.1.2(A)	...
N	Equivalent full temperature cycles	...	...	102.3.2(C)[Eq. (2)]	102.3.2(C)
N_n	Number of cycles of lesser temperature change, n = 1, 2, ...	...	...	102.3.2(C)[Eq. (2)]	...
N_E	Number of cycles of full temperature change	...	...	102.3.2(C)[Eq. (2)]	...
NPS	Nominal pipe size	in.	...	General	...
P	Internal design gage pressure of pipe, component	psi	kPa	101.2.2 102.3.2(D) 104.1.2(A)[Eqs. (3), (3A), (4), (4A)] 104.4.1(B) 104.5.1(A) 104.5.2(B) 104.5.3(A)[Eq. (7)] 104.8.1[Eqs. (11a), (11b)] 122.1.2(A) 122.1.3(A) 122.1.4(B) 122.1.6(B)	...
r	ratio of partial T to maximum T (used with subscripts)	...	...	102.3.2(C)[Eq. (2)]	...
r	Mean radius of pipe using nominal wall t_n	in.	mm	104.3.3	App. D
r_1	Half width of reinforcement zone	in.	mm	104.3.1(G.4)	104.3.1(G)
r_b	Branch mean cross-sectional radius	in.	mm	104.8.4	...
r_o	Radius of curvature of external curved portion	in.	mm	104.3.1(G.4)	104.3.1(G)
r_x	External crotch radius of welded-in contour inserts	in.	mm	...	App. D
R	Reaction moment in fexibility analysis (used with subscripts)	in.-lb, ft-lb	N-mm	119.10.1[Eqs. (9), (10)]	...

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NOMENCLATURE (CONT'D)

Symbol	Definition	Units		References	
		US	SI	Paragraph	Table/Fig./App.
R	Center line radius of elbow or bend, and effective "radius" of miter bends	in.	mm	104.3.3(C.3.1)	App. D
s	Miter spacing pipe center line	in.	mm	104.3.3(C.3.1)	App. D
S	Basic material allowable stress	psi	MPa	102.3.1(A) 121.1.2(A) 122.1.3(A)	App. A Notes to Tables A-1 thru A-7
S_a	Bolt design stress at atmospheric temperature	psi	kPa	104.5.1(A)	...
S_b	Bolt design stress at design temperature	psi	kPa	104.5.1(A)	...
S_c	Basic material allowable stress at minimum (cold) temperature	psi	MPa	102.3.2(C)[Eq. (1)]	...
S_f	Allowable stress for flange material or pipe	psi	kPa	104.5.1(A)	...
S_h	Basic material allowable stress at maximum (hot) temperature	psi	MPa	102.3.2(C) 102.3.2(D) 104.8.1[Eq. (11a)] 104.8.2[Eqs. (12a), (12b)] 119.10.1	...
S_{lp}	Longitudinal pressure stress	psi	MPa	102.3.2(D) 104.8	...
S_A	Allowable stress range for expansion stress	psi	MPa	102.3.2(C)[Eq. (1)] 104.8.3[Eqs. (13a), (13b)]	...
S_E	Computed thermal expansion stress range	psi	MPa	104.8.3[Eqs. (13a), (13b)] 119.10.1[Eq. (10)]	...
SE	Allowable stress (including weld joint efficiency factor)	psi	MPa	102.3.1(A) 104.1.2(A)[Eqs. (3), (3A), (4), (4A)] 104.4.1(B) 104.5.2(B)[Eq. (6)] 104.5.3(A)[Eq. (7)]	App. A
SF	Allowable stress (including casting quality factor)	psi	MPa	104.1.2(A)	...
S_L	Longitudinal stress due to pressure, weight, and other sustained loads	psi	kPa	102.3.2(D) 104.8.1[Eqs. (11A), (11B)]	...
t	Pressure design thickness pipe, components (used with subscripts)	in.	mm	104.1.2(A)[Eqs. (3), (3A), (4), (4A)] 104.3.1(D.2) 104.3.1(G.4) 104.3.3(C.3.1)	

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NOMENCLATURE (CONT'D)

Symbol	Definition	Units		References	
		US	SI	Paragraph	Table/Fig./App.
				104.3.3(C.3.2) 104.4.1(B) 104.5.2(B) 104.5.3(A)[Eq. (7)] 104.8.1 104.8.4(C) 127.4.8(B) 132.4.2(E)	104.3.1(G) 104.5.3 127.4.8(D)
t_b	Required thickness of branch pipe	in.	mm	104.3.1(G.4)	104.3.1(G)
t_c	Throat thickness of cover fillet weld, branch conn.	in.	mm	127.4.8(B) 132.4.2(E)	127.4.8(D)
t_e	Effective branch wall thickness	in.	mm	104.8.4(C)	...
t_h	Required thickness of header or run	in.	mm	104.3.1(G)	104.3.1(D) 104.3.1(G)
t_m	Minimum required thickness of component, including allowances (c) for mechanical joining, corrosion, etc. (used with subscripts), viz., t_{mb} = minimum thickness of branch t_{mh} = minimum thickness of header	in.	mm	104.1.2(A)[Eqs. (3), (3A), (4), (4A)] 104.3.1(D.2) 104.3.1(G) 104.3.1(G.4) 104.3.3(C.3.1) 104.3.3(C.3.2) 104.4.1(B) 104.5.2(B)[Eq. (6)] 104.5.3(A)	127.4.2 104.3.1(D) 104.3.1(G)
t_n	Nominal wall thickness of component (used with subscripts), viz., t_{nb} = nominal wall thickness of branch t_{nh} = nominal wall thickness of header t_{nr} = nominal thickness of reinforcement	in.	mm	102.3.2(D) 104.3.3 104.8.1 104.8.4 127.4.8(B) 132.4.2(E)	127.4.4(B), (C) 127.4.8(D) App. D
t_p	Pressure design thickness	in.	mm	104.5.3(A)[Eq. (7)]	...
t_r	Thickness of reinforcing pad or saddle	in.	mm	104.3.1(D.2) 127.4.8(B)	104.3.1(D) 127.4.8(D) Table D
t_s	Wall thickness of segment or miter	in.	mm	104.3.3(C.3)	App. D
t_w	Weld thickness	in.	mm	104.3.1(C.2)	127.4.8(F)
T	Pipe wall thickness (measured or minimum, in accordance with purchase specification used with or without subscripts), viz., T_b = thickness of branch T_h = thickness of header, etc	in.	mm	104.3.1(D.2) 104.3.1(G.4)	104.3.1(D) 104.3.1(G) App. D
T_c	Crotch thickness of welded-in contour inserts	in.	mm	...	App. D

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NOMENCLATURE (CONT'D)

Symbol	Definition	Units		References	
		US	SI	Paragraph	Table/Fig./App.
T_o	Corroded finished thickness extruded outlet	in.	mm	104.3.1(G.4)	104.3.1(G)
U	Anchor distance (length of straight line joining anchors)	ft	m	119.7.1(A.3)	...
$x_{min.}$	Size of fillet weld for slip-on and socket welding flanges or socket wall for socket welds	in.	mm	...	127.4.4(B)
y	A coefficient having values given in Table 104.1.2(A)	...	...	104.1.2[Eqs. (3), (3A), (4), (4A)]	104.1.2(A)
Y	Resultant of movement to be absorbed by pipelines	...	...	119.7.1(A.3)	...
Z	Section modulus of pipe	$in.^3$	mm^3	104.8.1[Eqs. (11a), (11b)] 104.8.2[Eqs. (12a), (12b)] 104.8.3[Eqs. (13a), (13b)]	104.8.4(C)
α	Angle between axes of branch and run	deg	deg	104.3.1(D.2)	104.3.1(D)
α	Reducer cone angle	deg	deg	...	Table D-1
β	Length of segment at crotch	in.	mm	...	App. D
δ	Mismatch or offset	in.	mm	127.3.1(C)	App. D
ΔT	Range of temperature change	°F	°C	102.3.2(C)	...
θ	Angle of miter cut	deg	deg	104.3.3	App. D
$\geq$	Equal to or greater than	...	...	...	...
$\leq$	Equal to or less than	...	...	...	...

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APPENDIX H
PREPARATION OF TECHNICAL INQUIRIES

H-1 INTRODUCTION

The ASME B31 Committee, Code for Pressure Piping, will consider written requests for interpretations and revisions of the Code rules, and develop new rules if dictated by technical development. The Committee's activities in this regard are limited strictly to interpretations of the rules or to the consideration of revisions to the present rules on the basis of new data or technology. The Introduction to this Code states "It is the owner's responsibility to determine which Code Section is applicable to a piping installation." The Committee will not respond to inquiries requesting assignment of a Code Section to a piping installation. As a matter of published policy, ASME does not approve, certify, rate, or endorse any item, construction, proprietary device, or activity, and, accordingly, inquiries requiring such consideration will be returned. Moreover, ASME does not act as a consultant on specific engineering problems or on the general application or understanding of the Code rules. If, based on the inquiry information submitted, it is the opinion of the Committee that the inquirer should seek professional assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

Inquiries that do not provide the information needed for the Committee's full understanding will be returned.

H-2 REQUIREMENTS

Inquiries shall be limited strictly to interpretations of the rules or to the consideration of revisions to the present rules on the basis of new data or technology. Inquiries shall meet the following requirements:

(a) Scope. Involve a single rule or closely related rules in the scope of the Code. An inquiry letter concerning unrelated subjects will be returned.

(b) Background. State the purpose of the inquiry, which may be either to obtain an interpretation of Code rules, or to propose consideration of a revision to the present rules. Provide concisely the information needed for the Committee's understanding of the inquiry, being sure to include reference to the applicable Code Section, Edition, Addenda, paragraphs, figures, and tables. If sketches are provided, they shall be limited to the scope of the inquiry.

(c) Inquiry Structure

(1) Proposed Question(s). The inquiry shall be stated in a condensed and precise question format, omitting superfluous background information, and, where appropriate, composed in such a way that "yes" or "no" (perhaps with provisos) would be an acceptable reply. The inquiry statement should be technically and editorially correct.

(2) Proposed Reply(ies). Provide a proposed reply stating what it is believed that the Code requires. If in the inquirer's opinion, a revision to the Code is needed, recommended wording shall be provided in addition to information justifying the change.

H-3 SUBMITTAL

Inquiries should be submitted in typewritten form; however, legible handwritten inquiries will be considered. They shall include the name and mailing address of the inquirer, and be mailed to the following address:

Secretary
ASME B31 Committee
Three Park Avenue
New York, NY 10016-5990

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APPENDIX J
QUALITY CONTROL REQUIREMENTS FOR BOILER EXTERNAL PIPING (BEP)

FOREWORD

This Appendix contains the quality control requirements for boiler external piping. The following is that portion of Appendix A-300 Quality Control System of the ASME Boiler and Pressure Vessel Code, Section I, which is applicable to BEP.

J-1.0 QUALITY CONTROL SYSTEM

J-1.1 General

J-1.1.1 Quality Control System. The Manufacturer or assembler shall have and maintain a quality control system which will establish that all Code requirements, including material, design, fabrication, examination (by the Manufacturer), and inspection of boilers and boiler parts (by the Authorized Inspector), will be met. Provided that Code requirements are suitably identified, the system may include provisions for satisfying any requirements by the Manufacturer or user which exceed minimum Code requirements and may include provisions for quality control of non-Code work. In such systems, the Manufacturer may make changes in parts of the system which do not affect the Code requirements without securing acceptance by the Authorized Inspector. Before implementation, revisions to quality control systems of Manufacturers and assemblers of safety and safety relief valves shall have been found acceptable to an ASME designee if such revisions affect Code requirements.

The system that the Manufacturer or assembler uses to meet the requirements of this Section must be one suitable for his own circumstances. The necessary scope and detail of the system shall depend on the complexity of the work performed and on the size and complexity of the Manufacturer's (or assembler's) organization. A written description of the system the Manufacturer or assembler will use to produce a Code item shall be available for review. Depending upon the circumstances, the description may be brief or voluminous.

The written description may contain information of proprietary nature relating to the Manufacturer's (or assembler's) processes. Therefore, the Code does not require any distribution of this information, except for the Authorized Inspector or ASME designee.

It is intended that information learned about the system in connection with evaluation will be treated as confidential and that all loaned descriptions will be returned to the Manufacturer upon completion of the evaluation.

J-1.2 Outline of Features to Be Included in the Written Description of the Quality Control System

The following is a guide to some of the features which should be covered in the written description of the quality control system and which is equally applicable to both shop and field work.

J-1.2.1 Authority and Responsibility. The authority and responsibility of those in charge of the quality control system shall be clearly established. Persons performing quality control functions shall have sufficient and well-defined responsibility, the authority, and the organizational freedom to identify quality control problems and to initiate, recommend, and provide solutions.

J-1.2.2 Organization. An organization chart showing the relationship between management and engineering, purchasing, manufacturing, field assembling, inspection, and quality control is required to reflect the actual organization. The purpose of this chart is to identify and associate the various organizational groups with the particular function for which they are responsible. The Code does not intend to encroach on the Manufacturer's right to establish, and from time to time to alter, whatever form of organization the Manufacturer considers appropriate for its Code work.

J-1.2.3 Drawings, Design Calculations, and Specification Control. The Manufacturer's or assembler's quality control system shall provide procedures which will assure that the latest applicable drawings, design

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calculations, specifications, and instructions, required by the Code, as well as authorized changes, are used for manufacture, assembly, examination, inspection, and testing.

J-1.2.4 Material Control. The Manufacturer or assembler shall include a system of receiving control which will insure that the material received is properly identified and has documentation, including required material certifications or material test reports, to satisfy Code requirements as ordered. The material control system shall insure that only the intended material is used in Code construction.

J-1.2.5 Examination and Inspection Program. The Manufacturer's quality control system shall describe the fabrication operations, including examinations, sufficiently to permit the Authorized Inspector to determine at what stages specific inspections are to be performed.

J-1.2.6 Correction of Nonconformities. There shall be a system agreed upon with the Authorized Inspector for correction of nonconformities. A nonconformity is any condition which does not comply with the applicable rules of this Section. Nonconformities must be corrected or eliminated in some way before the completed component can be considered to comply with this Section.

J-1.2.7 Welding. The quality control system shall include provisions for indicating that welding conforms to requirements of Section IX as supplemented by this Section.

J-1.2.8 Nondestructive Examination. The quality control system shall include provisions for identifying nondestructive examination procedures the Manufacturer will apply to conform with requirements of this Section.

J-1.2.9 Heat Treatment. The quality control system shall provide controls to assure that heat treatments as required by the rules of this Section are applied. Means shall be indicated by which the Authorized Inspector can satisfy himself that these Code heat treatment requirements are met. This may be by review of furnace time – temperature records or by other methods as appropriate.

J-1.2.10 Calibration of Measurement and Test Equipment. The Manufacturer or assembler shall have a system for the calibration of examination, measuring, and test equipment used in fulfillment of requirements of this Section.

J-1.2.11 Records Retention. The Manufacturer or assembler shall have a system for the maintenance of radiographs and Manufacturers' Data Reports as required by this Section.

J-1.2.12 Sample Forms. The forms used in the quality control system and any detailed procedures for their use shall be available for review. The written description shall make necessary references to these forms.

J-1.2.13 Inspection of Boilers and Boiler Parts

J-1.2.13.1 Inspection of boilers and boiler parts shall be by the Authorized Inspector described in PG-91.

J-1.2.13.2 The written description of the quality control system shall include reference to the Authorized Inspector.

J-1.2.13.2.1 The Manufacturer (or assembler) shall make available to the Authorized Inspector at the Manufacturer's plant (or construction site) a current copy of the written description or the applicable quality control system.

J-1.2.13.2.2 The Manufacturer's quality control system shall provide for the Authorized Inspector at the Manufacturer's plant to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the Inspector to perform his duties in accordance with this Section. The Manufacturer may provide such access either to his own files of such documents or by providing copies to the Inspector.

J-1.2.14 Inspection of Safety and Safety Relief Valves

J-1.2.14.1 Inspection of safety and safety relief valves shall be by designated representative of the ASME, as described in PG-73.3.

J-1.2.14.2 The written description of the quality control system shall include reference to the ASME designee.

J-1.2.14.2.1 The valve Manufacturer (or assembler) shall make available to the ASME designee at the Manufacturer's plant a current copy of the written description of the applicable quality control system.

J-1.2.14.2.2 The valve Manufacturer's (or assembler's) quality control system shall provide for the ASME designee to have access to all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and any other documents as necessary for the designee to perform his duties in accordance with this Section. The Manufacturer may provide such access either to his own files of such documents or by providing copies to the designee.

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NONMANDATORY APPENDIX II[1]
RULES FOR THE DESIGN OF SAFETY VALVE INSTALLATIONS

FOREWORD

ASME B31.1 contains rules governing the design, fabrication, materials, erection, and examination of power piping systems. Experience over the years has demonstrated that these rules may be reasonably applied to safety valve installations. Nevertheless, instances have occurred wherein the design of safety valve installations may not have properly and fully applied the ASME B31.1 rules. Accordingly, this nonmandatory Appendix to ASME B31.1 has been prepared to illustrate and clarify the application of ASME B31.1 rules to safety valve installations. To this end, Appendix II presents the designer with design guidelines and alternative design methods.

II-1.0 SCOPE AND DEFINITION

II-1.1 Scope

The scope of Appendix II is confined to the design of the safety valve installations as defined in para. 1.2 of this Appendix. The loads acting at the safety valve station will affect the bending moments and stresses in the complete piping system, out to its anchors and/or extremities, and it is the designer's responsibility to consider these loads. Appendix II, however, deals primarily with the safety valve installation, and not the complete piping system.

The design of the safety valve installation requires that careful attention be paid to:

(1) all loads acting on the system;

(2) the forces and bending moments in the piping and piping components resulting from the loads;

(3) the loading and stress criteria; and

(4) general design practices.

All components in the safety valve installation must be given consideration, including the complete piping system, the connection to the main header, the safety valve, valve and pipe flanges, the downstream discharge or vent piping, and the system supports. The scope of this Appendix is intended to cover all loads on all components. It is assumed that the safety valve complies with the requirements of American National Standards prescribed by ASME B31.1 for structural integrity.

This Appendix has application to either safety, relief, or safety-relief valve installations. For convenience, however, the overpressure protection device is generally referred to as a safety valve. The loads associated with relief or safety-relief valve operation may differ significantly from those of safety valve operation, but otherwise the rules contained herein are equally applicable to each type of valve installation. See para. II-1.2 for definition.

This Appendix provides analytic and nomenclature definition figures to assist the designer, and is not intended to provide actual design layout (drains, drip pans, suspension, air gaps, flanges, weld ends, and other design details are not shown). Sample problems have been provided at the end of the text to assist the designer in application of the rules in this Appendix.

II-1.2 Definitions (Valve Descriptions Follow the Definitions Given in Section I of the ASME Boiler and Pressure Vessel Code)

Safety Valve: an automatic pressure relieving device actuated by the static pressure upstream of the valve and characterized by full opening pop action. It is used for gas or vapor service.

Relief Valve: an automatic pressure relieving device actuated by the static pressure upstream of the valve which opens further with the increase in pressure over the opening pressure. It is used primarily for liquid service.

Safety Relief Valve: an automatic pressure actuated relieving device suitable for use either as a safety valve or relief valve, depending on application.

Power-Actuated Pressure Relieving Valve: a relieving device whose movements to open or close are fully controlled by a source of power (electricity, air, steam,

[1] Nonmandatory Appendices are identified by a Roman numeral; mandatory Appendices are identified by a letter. Therefore, Roman numeral I is not used in order to avoid confusion with the letter I.

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or hydraulic). The valve may discharge to atmosphere or to a container at lower pressure. The discharge capacity may be affected by the downstream conditions, and such effects shall be taken into account. If the power-actuated pressure relieving valves are also positioned in response to other control signals, the control impulse to prevent overpressure shall be responsive only to pressure and shall override any other control function.

Open Discharge Installation: an installation where the fluid is discharged directly to the atmosphere or to a vent pipe that is uncoupled from the safety valve. Figure II-1-2(A) shows a typical open discharge installation with an elbow installed at the valve discharge to direct the flow into a vent pipe. The values for l and m on Fig. II-1-2(A) are upper limits for which the rules for open discharge systems may be used. l shall be limited to a value less than or equal to $4D_o$; m shall be limited to a value less than or equal to $6D_o$ where D_o is the outside diameter of the discharge pipe. Open discharge systems which do not conform to these limits shall be evaluated by the designer for the applicability of these rules.

Closed Discharge Installation: an installation where the effluent is carried to a distant spot by a discharge pipe which is connected directly to the safety valve. Figure II-1-2(B) shows a typical closed discharge system.

Safety Valve Installation: the safety valve installation is defined as that portion of the system shown on Figs. II-1-2(A) and II-1-2(B). It includes the run pipe, branch connection, the inlet pipe, the valve, the discharge piping, and the vent pipe. Also included are the components used to support the system for all static and dynamic loads.

II-2.0 LOADS

II-2.1 Thermal Expansion

Loads acting on the components in the safety valve installation and the displacements at various points due to thermal expansion of the piping shall be determined by analyzing the complete piping system out to its anchors, in accordance with procedures in para. 119.

II-2.1.1 Installations with Open Discharge. For safety valve installations with open discharge, there will be no thermal expansion loads acting on the discharge elbow, the valve, or the valve inlet other than that from restraint to thermal expansion as described below. Restraint to thermal expansion can sometimes occur due to drain lines, or when structural supports are provided to carry the reaction forces associated with safety valve lift. Examples of such structural supports are shown in Fig. II-6-1 sketch (b). When such restraints exist, the thermal expansion loads and stresses shall be calculated and effects evaluated.

II-2.1.2 Installations with Closed Discharge. Loads due to thermal expansion and back pressure of a safety valve installation with a closed discharge can be high enough to cause malfunction of the valve, excessive leakage of the valve or flange, or overstress of other components. The loads due to thermal expansion shall be evaluated for all significant temperature combinations, including the cases where the discharge piping is hot following safety valve operation.

II-2.2 Pressure

Pressure loads acting on the safety valve installation are important from two main considerations. The first consideration is that the pressure acting on the walls of the safety valve installation can cause membrane stresses which could result in rupture of the pressure retaining parts. The second consideration is that the pressure effects associated with discharge can cause high loads acting on the system which create bending moments throughout the piping system. These pressure effects are covered in para. II-2.3.

All parts of the safety valve installation must be designed to withstand the design pressures without exceeding the Code allowable stresses. The branch connection, the inlet pipe, and the inlet flanges shall be designed for the same design pressure as that of the run pipe. The design pressure of the discharge system will depend on the safety valve rating and on the configuration of the discharge piping. The open discharge installation and the closed discharge installation present somewhat different problems in the determination of design pressures, and these problems are discussed in the paragraphs below.

II-2.2.1 Design Pressure and Velocity for Open Discharge Installation Discharge Elbows and Vent Pipes. There are several methods available to the designer for determining the design pressure and velocity in the discharge elbow and vent pipe. It is the responsibility of the designer to assure himself that the method used yields conservative results. A method for determining the design pressures and velocities in the discharge elbow and vent pipe for open discharge

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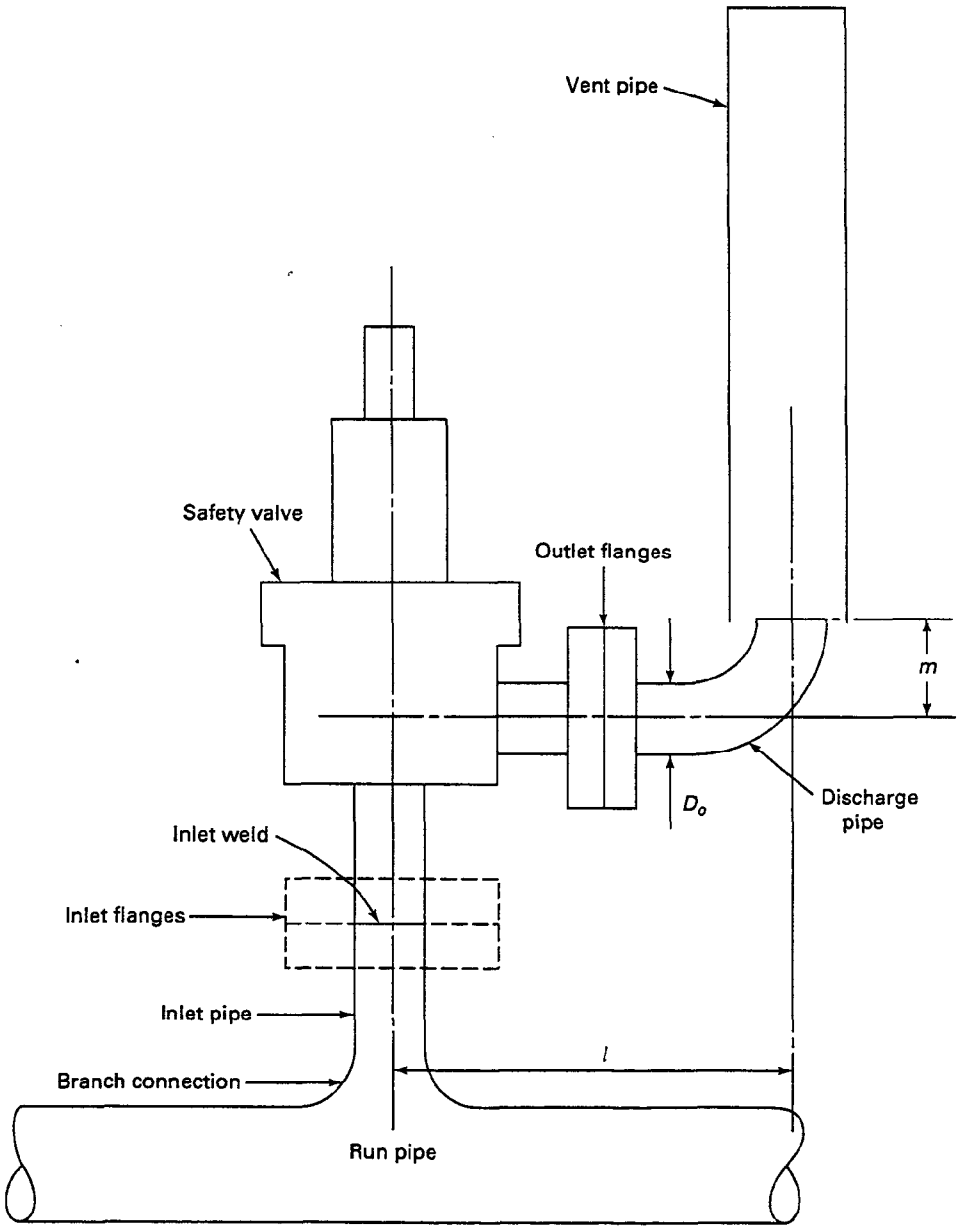

FIG. II-1-2(A) SAFETY VALVE INSTALLATION (OPEN DISCHARGE SYSTEM)

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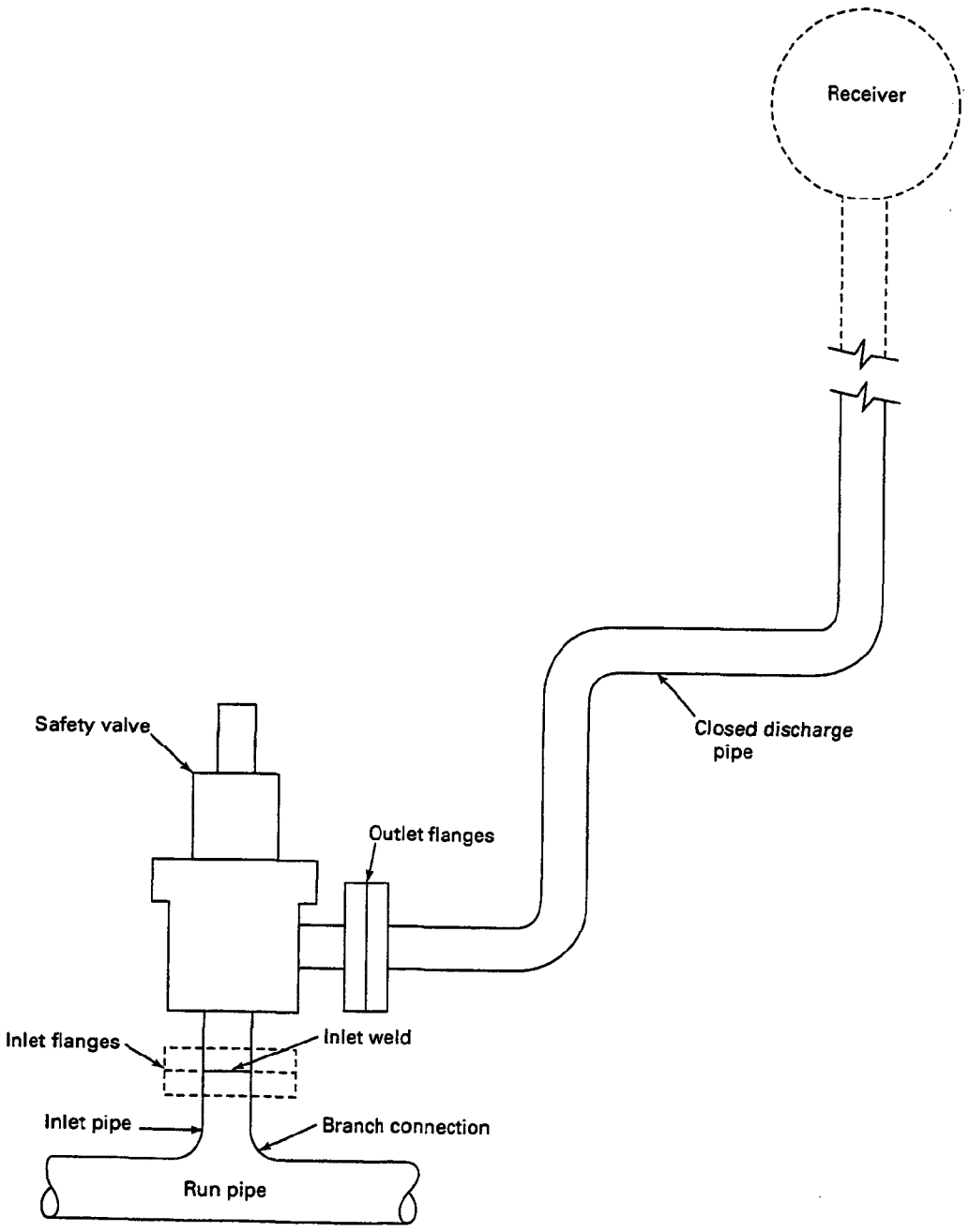

FIG. II-1-2(B) SAFETY VALVE INSTALLATION (CLOSED DISCHARGE SYSTEM)

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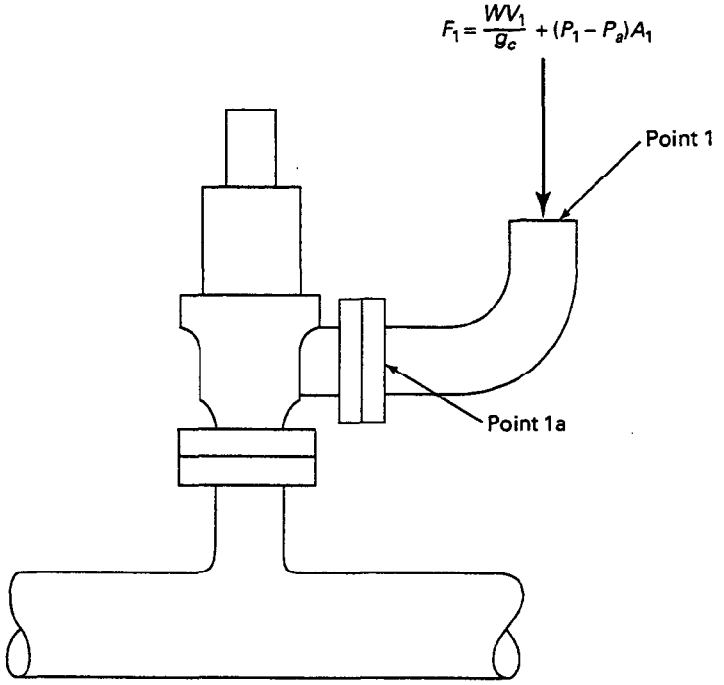

FIG. II-2-1

installation is shown below and illustrated in the sample problem.

First, calculate the design pressure and velocity for the discharge elbow.

(1) Determine the pressure P_1 that exists at the discharge elbow outlet (Fig. II-2-1).

$$P_1 = \frac{W}{A_1}\frac{(b-1)}{b}\sqrt{\frac{2(h_o - a)J}{g_c(2b-1)}}$$

(2) Determine the velocity V_1 that exists at the discharge elbow outlet (Fig. II-2-1).

$$V_1 = \sqrt{\frac{2g_cJ(h_o - a)}{(2b-1)}}$$

where

W = actual mass flow rate, lbm/sec
A_1 = discharge elbow area, in.^{2}
h_o = stagnation enthalpy at the safety valve inlet, Btu/lbm
J = 778.16 ft-lbf/Btu
g_c = gravitational constant = 32.2 lbm-ft/lbf-sec^2
P_1 = pressure, psia (lbf/in.^{2}, absolute)
V_1 = ft/sec

TABLE II-2.2.1

Steam Condition	*a*, Btu/lbm	*b*
Wet steam, < 90% quality	291	11
Saturated steam, ≥ 90% quality, 15 psia ≤ P_1 ≤ 1000 psia	823	4.33
Superheated steam, ≥ 90% quality, 1000 psia < P_1 ≤ 2000 psia[1]	831	4.33

NOTE:
(1) This method may be used as an approximation for pressures > 2000 psi, but an alternate method should be used for verification.

Common values of a and b are listed in Table II-2.2.1.

(3) Determine the safety valve outlet pressure P_{1a} at the inlet to the discharge elbow (Fig. II-2-1).

(3.1) Determine the length to diameter ratio (dimensionless) for the pipe sections in the discharge elbow (L/D).

$$L/D = \frac{L_{max.}}{D}$$

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(3.2) Determine a Darcy-Weisbach friction factor f to be used. (For steam, a value of 0.013 can be used as a good estimate since f will vary slightly in turbulent pipe flow.)

(3.3) Determine a specific heat ratio (for superheated steam, $k = 1.3$ can be used as an estimate — for saturated steam, $k = 1.1$).

(3.4) Calculate:

$$f\left(\frac{L_{max.}}{D}\right)$$

(3.5) Enter Chart II-1 with value of

$$f\left(\frac{L_{max.}}{D}\right)$$

and determine P/P^*.

(3.6) $P_{1a} = P_1\ (P/P^*)$

(3.7) P_{1a} is the maximum operating pressure of the discharge elbow.

Secondly, determine the design pressure and velocity for the vent pipe.

(1) Determine the pressure P_3 that exists at the vent pipe outlet (Fig. II-2-2).

$$P_3 = P_1\left(\frac{A_1}{A_3}\right)$$

(2) Determine the velocity V_3 that exists at the vent pipe outlet (Fig. II-2-2).

$$V_3 = V_1$$

(3) Repeat Steps (3.1) to (3.7) in the calculation of the discharge elbow maximum operating pressure to determine the maximum operating pressure of the vent pipe.

(4) Determine the velocity V_2 and pressure P_2 that exists at the inlet to the vent pipe (Fig. II-2-2).

(4.1) Enter Chart II-1[2] with value of

$$f\left(\frac{L_{max.}}{D}\right)$$

from Step (3.4) and determine value of V/V^* and P/P^*.

(4.2) Calculate V_2

$$V_2 = V_3\ (V/V^*)$$

(4.3) P_2, $P_2 = P_3\ (P/P^*)$. This is the highest pressure the vent stack will see and should be used in calculating vent pipe blow back (see para. II-2.3.1.2).

II-2.2.2 Pressure for Closed Discharge Installations. The pressures in a closed discharge pipe during steady state flow may be determined by the methods described in para. II-2.2.1. However, when a safety valve discharge is connected to a relatively long run of pipe and is suddenly opened, there is a period of transient flow until the steady state discharge condition is reached. During this transient period, the pressure and flow will not be uniform. When the safety valve is initially opened, the discharge pipe may be filled with air. If the safety valve is on a steam system, the steam discharge from the valve must purge the air from the pipe before steady state steam flow is established and, as the pressure builds up at the valve outlet flange and waves start to travel down the discharge pipe, the pressure wave initially emanating from the valve will steepen as it propagates, and it may steepen into a shock wave before it reaches the exit. Because of this, it is recommended that the design pressure of the closed discharge pipe be greater than the steady state operating pressure by a factor of at least 2.

II-2.3 Reaction Forces From Valve Discharge

It is the responsibility of the piping system designer to determine the reaction forces associated with valve discharge. These forces can create bending moments at various points in the piping system so high as to cause catastrophic failure of the pressure boundary parts. Since the magnitude of the forces may differ substantially, depending on the type of discharge system, each system type is discussed in the paragraphs below.

II-2.3.1 Reaction Forces With Open Discharge Systems

II-2.3.1.1 Discharge Elbow. The reaction force F due to steady state flow following the opening of the safety valve includes both momentum and pressure effects. The reaction force applied is shown in Fig. II-2-1, and may be computed by the following equation.

[2] Chart II-1 may be extended to other values of f (L_{max}/D) by use of the Keenan and Kaye Gas Tables for Fanno lines. The Darcy-Weisbach friction factor is used in Chart II-1, whereas the Gas Tables use the Fanning factor which is one-fourth the value of the Darcy-Weisbach factor.

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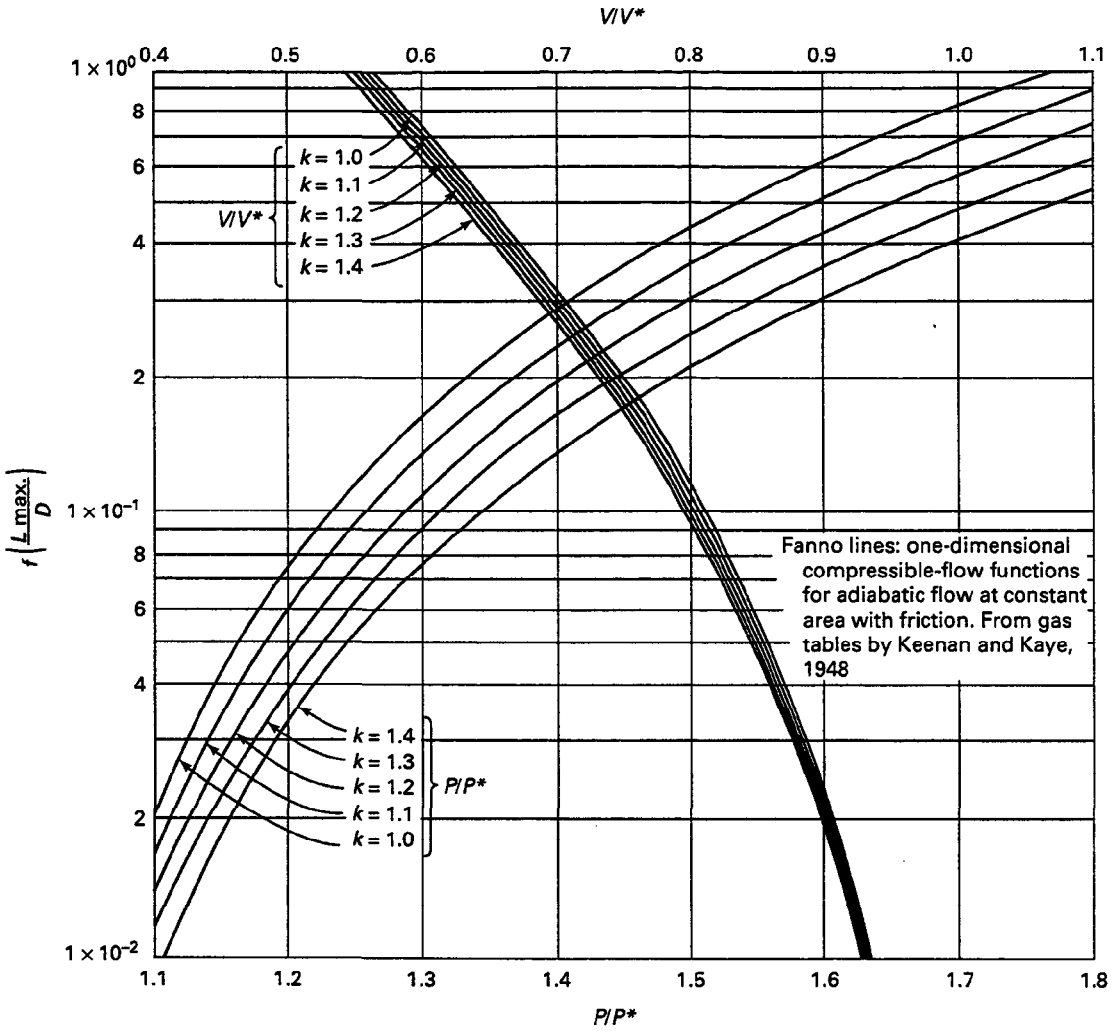

CHART II-1

$$F_1 = \frac{W}{g_c} V_1 + (P_1 - P_a) A_1$$

where

F_1 = reaction force, lbf at Point 1
W = mass flow rate, (relieving capacity stamped on the valve × 1.11), lbm/sec
g_c = gravitational constant
= 32.2 lbm-ft/lbf-sec^2
V_1 = exit velocity at Point 1, ft/sec
P_1 = static pressure at Point 1, psia
A_1 = exit flow area at Point 1, in.^{2}
P_a = atmospheric pressure, psia

To insure consideration of the effects of the suddenly applied load F, a dynamic load factor DLF should be applied (see para. II-3.5.1.3).

The methods for calculating the velocities and pressures at the exit point of the discharge elbow are the same as those discussed in para. II-2.2 of this Appendix.

II-2.3.1.2 Vent Pipe. Figure II-2-2 shows the external forces resulting from a safety valve discharge, which act on the vent pipe. The methods for calculating F_2 and F_3 are the same as those previously described. The vent pipe anchor and restraint system must be capable of taking the moments caused by these two forces, and also be capable of sustaining the unbalanced forces in the vertical and horizontal directions.

A bevel of the vent pipe will result in a flow that is not vertical. The equations shown are based on vertical flow. To take account for the effect of a bevel at the exit, the exit force will act at an angle ϕ, with

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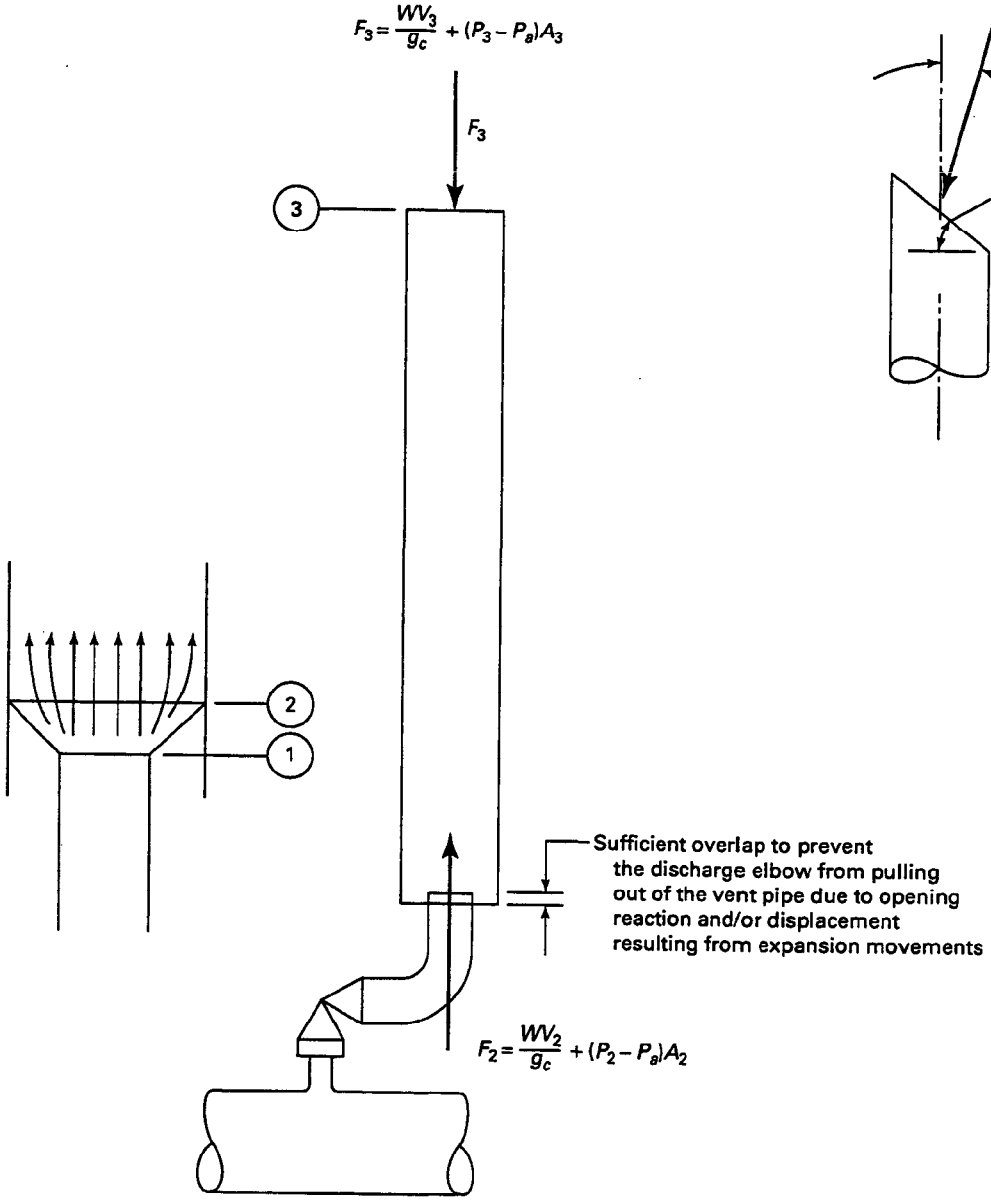

FIG. II-2-2

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the axis of the vent pipe discharge which is a function of the bevel angle θ. The beveled top of the vent deflects the jet approximately 30 deg off the vertical for a 60 deg bevel, and this will introduce a horizontal component force on the vent pipe systems.

The terms in the equations shown on Fig. II-2-2 are the same as those defined in para. II-2.3.1. above.

The vent pipe must be sized so that no steam is blown back at the vent line entrance. The criteria which may be used as a guide to prevent this condition are listed below.

$$\frac{W(V_1 - V_2)}{g_c} > (P_2 - P_a)A_2 - (P_1 - P_a)A_1$$

P_a = standard atmospheric pressure, psia
W = mass flow rate, lbm/sec
V = velocity, ft/sec
P_1, P_2 = local absolute pressure, psia
A = area, in.^{2}
g_c = gravitational constant
= 32.2 lbm-ft/lbf-sec^2

The inequality states that the momentum at Point 1 has to be greater than the momentum at Point 2 in order that air is educted into the vent pipe. If the momentum at Point 1 equalled the momentum at Point 2, no air would be educted into the vent pipe. If the momentum at Point 1 was less than the momentum at Point 2, steam would "blow back" from the vent pipe.

The educting effect of the vent pipe is especially important for indoor installation of safety valves. The steam being vented from the upper body during safety valve operation will be removed from the area through the vent pipe. For that reason, the fluid momentum at 1 should exceed the fluid momentum at 2, not just be equal.

If this inequality is satisfied, "blow back" will not occur. The pressures and velocities are those calculated in para. II-2.2.1.

II-2.3.2 Reaction Forces with Closed Discharge Systems. When safety valves discharge a closed piping system, the forces acting on the piping system under steady state flow will be self-equilibrated, and do not create significant bending moments on the piping system. The large steady state force will act only at the point of discharge, and the magnitude of this force may be determined as described for open discharge systems.

Relief valves discharging into an enclosed piping system create momentary unbalanced forces which act on the piping system during the first few milliseconds following relief valve lift. The pressure waves traveling through the piping system following the rapid opening of the safety valve will cause bending moments in the safety valve discharge piping and throughout the remainder of the piping system. In such a case, the designer must compute the magnitude of the loads, and perform appropriate evaluation of their effects.

II-2.4 Other Mechanical Loads

Other design mechanical loads that must be considered by the piping designer include the following:

II-2.4.1 Interaction loads on the pipe run when more than one valve opens.

II-2.4.2 Loads due to earthquake and/or piping system vibration (see para. II-3.4).

II-3.0 BENDING MOMENT COMPUTATIONS

II-3.1 General

One of the most important considerations related to the mechanical design and analysis of safety valve installation is the identification and calculation of the moments at critical points in the installation. If the bending moments are not properly calculated, it will not be possible to meet the loading and stress criteria contained in ASME B31.1. As a minimum, the following loads, previously discussed in para. II-2.0 of this Appendix, should be considered in determining these moments:

(1) thermal expansion
(2) dead weight
(3) earthquake
(4) reaction force from valve discharge
(5) other mechanical loads

The analysis of the safety valve installation should include all critical sections, such as intersection points, elbows, transition sections, etc., and any related piping, vessels, and their supports which may interact with the safety valve installation. It is often most appropriate to model the safety valve installation and its related piping as a lumped mass system joined by straight or curved elements.

II-3.2 Thermal Expansion Analysis

There are many standard and acceptable methods for determination of moments due to thermal expansion of the piping installation. The thermal expansion analysis must comply with the requirements in para. 119. The

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safety valve installation often presents a special problem in that there may be a variety of operational modes to consider where each mode represents a different combination of temperatures in various sections of the piping system. The design condition shall be selected so that none of the operational modes represents a condition that gives thermal expansion bending moments greater than the design condition.

The design of the safety valve installation should consider the differential thermal growth and expansion loads, as well as the local effects of reinforcing and supports. The design should also consider the differential thermal growth and expansion loads existing after any combination of safety valves (one valve to all valves) operates, raising the temperature of the discharge piping.

II-3.3 Dead Weight Analysis

The methods used for determination of bending moments due to dead weight in a safety valve installation are not different from the methods used in any other piping installation. If the support system meets the requirements in para. 121, the bending moments due to dead weight may be assumed to be $1500Z$ (in.-lb) where Z is the section modulus (in.^{3}) of the pipe or fitting being considered. However, bending moments due to dead weight are easily determined and should always be calculated in systems where stresses exceed 90% of the allowable stress limits in meeting the requirements of Eqs. (11) and (12) of para. 104.8.

II-3.4 Earthquake Analysis

Seismic loads must be known in order to calculate bending moments at critical points in the safety valve installation. If a design specification exists, it should stipulate if the piping system must be designed for earthquake. If so, it should specify the magnitude of the earthquake, the plant conditions under which the earthquake is assumed to occur, and the type earthquake analysis to be used (equivalent static or dynamic). If a design specification does not exist, it is the responsibility of the designer to determine what consideration must be given to earthquake analysis. It is beyond the scope of this Appendix to provide rules for calculating moments due to earthquake. The literature contains satisfactory references for determining moments by use of static seismic coefficients and how to perform more sophisticated dynamic analyses of the piping system using inputs in such form as time histories of displacement, velocity, and acceleration or response spectra where displacement, velocity, or acceleration is presented as a function of frequency.

Two types of seismic bending moments occur. One type is due to inertia effects and the other type is due to seismic motions of pipe anchors and other attachments. As will be shown later, the moments due to inertia effects must be considered in Eq. (12), para. 104.8, in the kS_h category. Moments due to seismic motions of the attachments may be combined with thermal expansion stress and considered in Eq. (13), para. 104.8 in the S_A category. For this reason, it may sometimes be justified for the designer to consider the moments separately; otherwise both sets of moments would have to be included in the kS_h category.

II-3.5 Analysis for Reaction Forces due to Valve Discharge

II-3.5.1 Open Discharge Systems

II-3.5.1.1 The moments due to valve reaction forces may be calculated by simply multiplying the force, calculated as described in para. II-2.3.1.1, times the distance from the point in the piping system being analyzed, times a suitable dynamic load factor. In no case shall the reaction moment used in para. II-4.2 at the branch connection below the valve be taken at less than the product of

$$(DLF)\ (F_1)\ (D)$$

where

F_1 = force calculated per para. II-2.3.1.1
D = nominal O.D. of inlet pipe
DLF = dynamic load factor (see para. II-3.5.1.3)

Reaction force and resultant moment effects on the header, supports, and nozzles for each valve or combination of valves blowing shall be considered.

II-3.5.1.2 Multiple Valve Arrangements. Reaction force and moment effects on the run pipe, header, supports, vessel, and connecting nozzles for each valve blowing, and when appropriate, for combinations of valves blowing should be considered. In multiple valve arrangements, each valve will open at a different time, and since all valves may not be required to open during an overpressure transient, several possible combinations of forces can exist. It may be desirable to vary the direction of discharge of several safety valves on the same header to reduce the maximum possible forces when all valves are blowing.

II-3.5.1.3 Dynamic Amplification of Reaction Forces. In a piping system acted upon by time varying loads, the internal forces and moments are generally greater than those produced under static application of

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the load. This amplification is often expressed as the dynamic load factor *DLF* and is defined as the maximum ratio of the dynamic deflection at any time to the deflection which would have resulted from the static application of the load. For structures having essentially one degree-of-freedom and a single load application, the *DLF* value will range between one and two depending on the time-history of the applied load and the natural frequency of the structure. If the run pipe is rigidly supported, the safety valve installation can be idealized as a one degree-of-freedom system and the time-history of the applied loads can often be assumed to be a single ramp function between the no-load and steady state condition. In this case the *DLF* may be determined in the following manner.

(1) Calculate the safety valve installation period T using the following equation and Fig. II-3-1.

$$T = 0.1846 \sqrt{\frac{Wh^3}{EI}}$$

where

T = safety valve installation period, sec
W = weight of safety valve, installation piping, flanges, attachments, etc., lb
h = distance from run pipe to center line of outlet piping, in.
E = Young's modulus of inlet pipe, lb/in.^{2}, at design temperature
I = moment of inertia of inlet pipe, in.^{4}

(2) Calculate ratio of safety valve opening time to installation period (t_o/T) where t_o is the time the safety valve takes to go from fully closed to fully open, sec, and T is determined in (1) above.

(3) Enter Fig. II-3-2 with the ratio of safety valve opening time to installation period and read the *DLF* from the ordinate. The *DLF* shall never be taken less than 1.1.

If a less conservative *DLF* is used, the *DLF* shall be determined by calculation or test.

II-3.5.1.4 Valve Cycling. Often, safety valves are full lift, pop-type valves, and are essentially full-flow devices, with no capability for flow modulation. In actual pressure transients, the steam flow required to prevent overpressure is a varying quantity, from zero to the full rated capacity of the safety valves. As a result, the valves may be required to open and close a number of times during the transient. Since each opening and closing produces a reaction force, consideration should be given to the effects of multiple valve operations on the piping system, including supports.

II-3.5.1.5 Time-History Analysis. The reaction force effects are dynamic in nature. A time-history dynamic solution, incorporating a multidegree of freedom lumped mass model solved for the transient hydraulic forces is considered to be more accurate than the form of analysis presented in this Appendix.

II-3.5.2 Closed Discharge Systems. Closed discharge systems do not easily lend themselves to simplified analysis techniques. The discussions on pressure in para. II-2.2.2 and on forces in para. II-2.3.2 indicate that a time-history analysis of the piping system may be required to achieve realistic values of moments.

II-3.5.3 Water Seals. To reduce the problem of steam or gas leakage through the safety valve seats, the valve inlet piping may be shaped to form a water seal below each valve seat. If the valves are required to open to prevent overpressure, the water from the seal is discharged ahead of the steam as the valve disk lifts. The subsequent flow of water and steam through the discharge piping produces a significant pressure and momentum transient. Each straight run of discharge piping experiences a resulting force cycle as the water mass moves from one end of the run to the other.

For most plants which employ water seals, only the first cycle of each occurrence has a force transient based on water in the seal. The remaining cycles of each occurrence would be based on steam occupying the seal piping, and the transient forces would be reduced in magnitude.

II-4.0 LOADING CRITERIA AND STRESS COMPUTATION

II-4.1

All critical points in the safety valve installation shall meet the following loading criteria.

$$S_{lp} + S_{SL} \le S_h \quad (1)$$

$$S_{lp} + S_{SL} + S_{OL} \le kS_h \quad (2)$$

$$S_{lp} + S_{SL} + S_E \le S_A + S_h \quad (3)$$

where

S_{lp} = longitudinal pressure stress
S_{SL} = bending stresses due to sustained loads, such as dead weight

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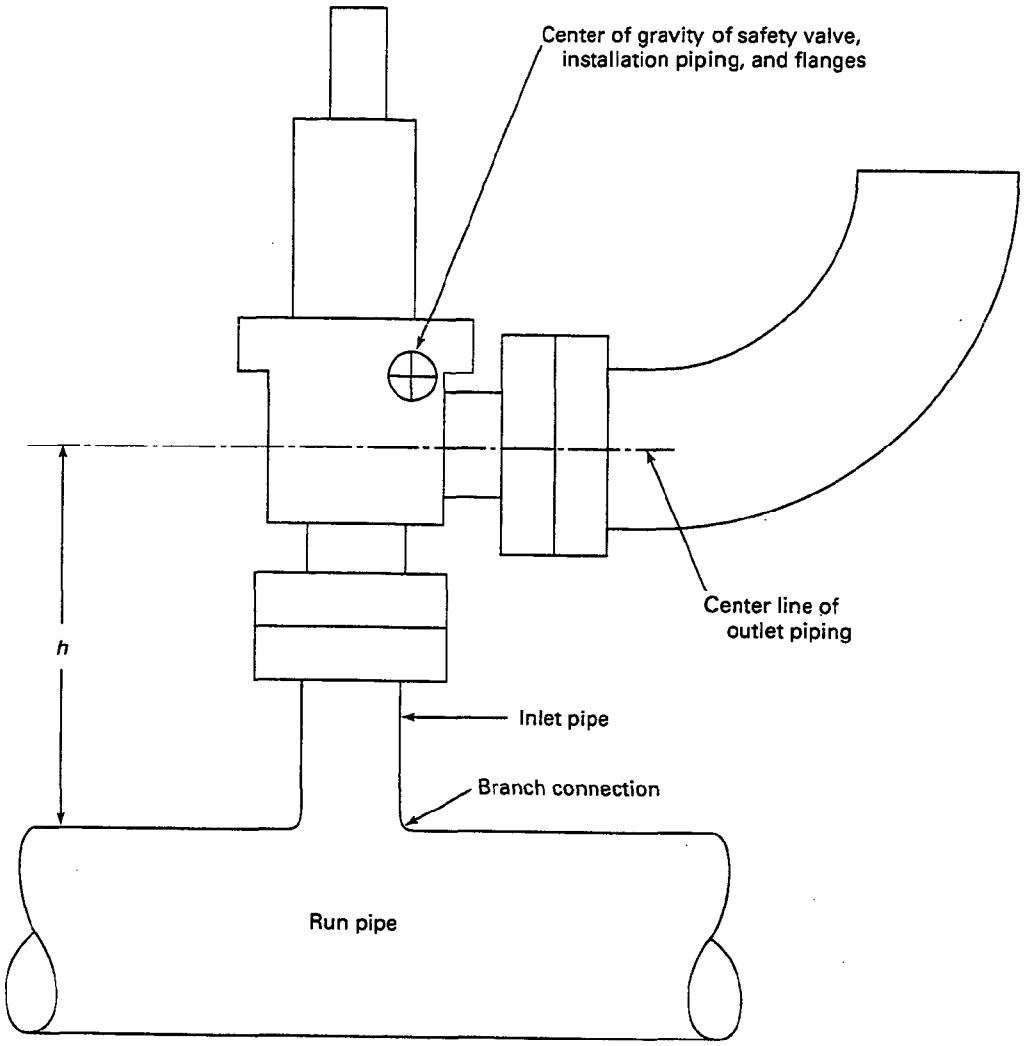

FIG. II-3-1 SAFETY VALVE INSTALLATION (OPEN DISCHARGE SYSTEM)

S_{OL} = bending stresses due to occasional loads, such as earthquake, reaction from safety valve discharge and impact loads

S_E = bending stresses due to thermal expansion

S_h, k, and S_A are as defined in ASME B31.1

The three loading criteria defined above are represented by Eqs. (11) and (12) in para. 104.8.

II-4.2 Stress Calculations

II-4.2.1 Pressure Stresses. The Code does not require determination of the pressure stresses that could cause failure of the pressure containing membrane. Instead, the Code provides rules to insure that sufficient wall thickness is provided to prevent failures due to pressure. It is not necessary to repeat these rules in this Appendix; however, some of the more important are listed below for reference.

(1) All pipe (plus other components) must satisfy the minimum required wall thickness of Eq. (3) of para. 104.1.2. In addition, wall thickness must be adequate to satisfy Eqs. (11) and (12) in para. 104.8. These two equations may govern determination of wall thickness in low pressure systems.

(2) No minimum wall thickness calculations are needed for components purchased to approved standards in Table 126.1.

(3) Pipe bends must meet the requirements of (1) above *after* bending.

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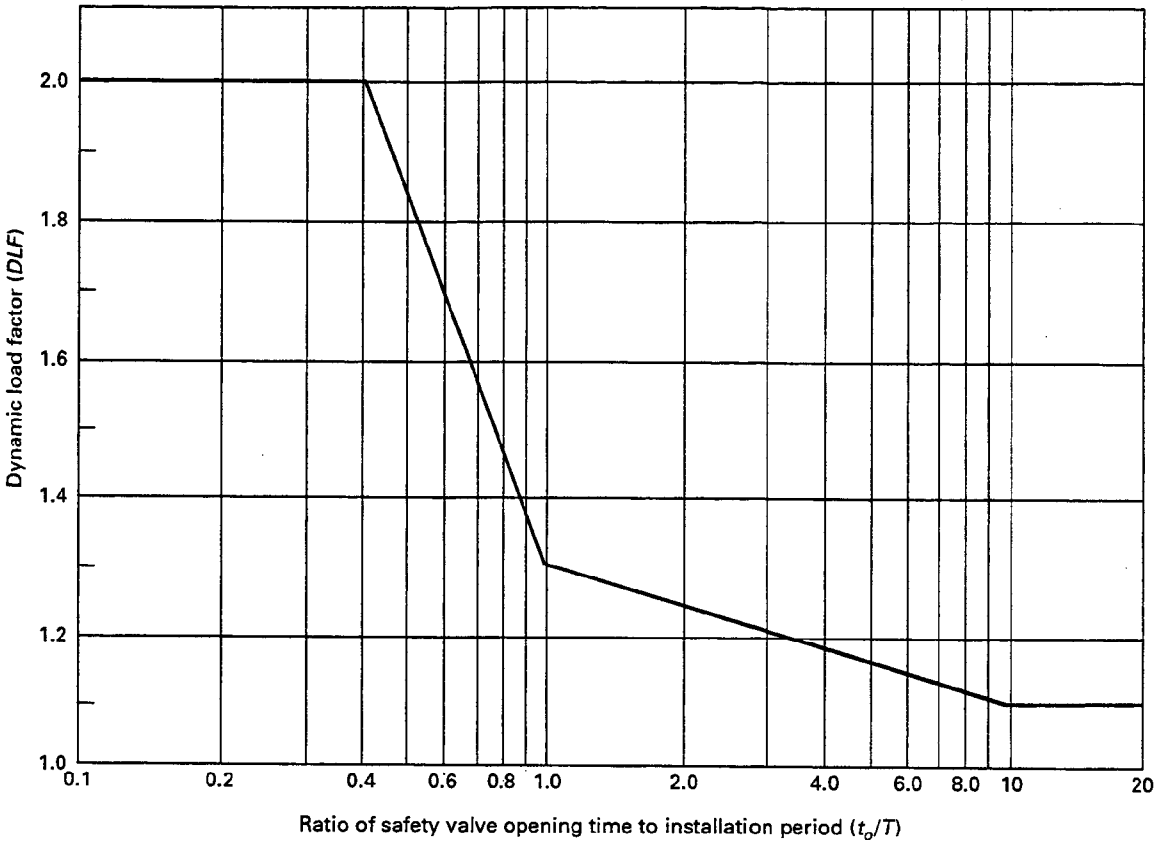

GENERAL NOTE: This figure is based on curves from *Introduction to Structural Dynamics,* J. M. Biggs, McGraw-Hill Book Co., 1964.

FIG. II-3-2 DYNAMIC LOAD FACTORS FOR OPEN DISCHARGE SYSTEM
This Figure Is Based on Curves From *Introduction to Structural Dynamics,* J. M. Biggs, McGraw-Hill Book Co., 1964

(4) Branch connections which do not meet the requirements of (2) above must meet the area replacement requirements of para. 104.3.

II-4.2.2 Pressure Plus Bending Stresses. In order to guard against membrane failures (catastrophic), prevent fatigue (leak) failures, and to assure shakedown, the equations in para. 104.8 must be satisfied. These equations apply to all components in the safety valve installation and will not be repeated here. However, some additional explanation of these equations in regard to the very critical points upstream of the safety valve are in the paragraphs below.

II-4.2.2.1 Additive Stresses at Branch Connection. For purposes of Eqs. (11), (12), and (13) in para. 104.8 the section modulus and moments for application to branch connections, such as safety valve inlet pipes, are:

(1) For branch connections the Z should be the effective section modulus for the branch as defined in para. 104.8.

Thus,

$$Z = Z_b = \pi r_b^2 t_s \text{ (effective section modulus)}$$

where

r_b = mean branch cross-sectional radius, in.
t_s = lesser of t_r and it_b where
t_r = nominal thickness of run pipe
i = the branch connection stress intensification factor

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t_b = nominal thickness of branch pipe

(2) Moment terms shall be defined as follows:

$$M_B = \sqrt{M_{x3}^2 + M_{y3}^2 + M_{z3}^2}$$

where M_B, M_{x3}, M_{y3}, and M_{z3} are defined in para. 104.8.

(3) Where the D_o/t_n of the branch connection differs from the D_o/t_n header or run, the larger of the two D_o/t_n values should be used in the first term of Eqs. (11) and (12) where D_o and t_n are defined in paras. 104.1 and 104.8, respectively.

II-4.2.2.2 Additive Stresses in Inlet Pipe. Equations (11), (12), and (13) in para. 104.8 may be applied to the inlet pipe in the same manner as described above for the branch connection, except that the values for D_o/t_n and Z should be for the inlet pipe and the stress intensification factor used will be different. It should be noted that the values D_o, t_n, and Z should be taken from a point on the inlet pipe such that D_o/t_n will have a maximum and Z a minimum value for the inlet pipe.

II-4.2.3 Analysis of Flange. It is important that the moments from the various loading conditions described in para. II-4.2.2 do not overload the flanges on the safety valve inlet and outlet. One method of doing this is to convert the moments into an equivalent pressure that is then added to the internal pressure. The sum of these two pressures P_{FD} would be acceptable if either of the following criteria are met.

(1) P_{FD} does not exceed the ASME B16.5 flange rating.

(2) S_H, S_R, and S_T should be less than the yield stress at design temperature, where S_H, S_R, and S_T are as defined in 2-7 of ASME Section VIII, Division 1 with these exceptions.

(A) P_{FD} should be used in the ASME Section VIII, Division 1 equations instead of the design pressure.

(B) S_H should include the longitudinal pressure stress at the flange hub.

II-4.2.4 Analysis of Valve. The allowable forces and moments which the piping system may place on the safety valves must be determined from the valve manufacturer. In some cases, the valve flanges are limiting rather than the valve body.

II-5.0 DESIGN CONSIDERATIONS

II-5.1 General

The design of safety valve installations shall be in accordance with para. 104 except that consideration be given to the rules provided in the following subparagraphs. These rules are particularly concerned with that portion of the piping system attached to and between the safety valve and the run pipe, header, or vessel which the valve services and includes the branch connection to the run pipe, header, or vessel.

II-5.2 Geometry

II-5.2.1 Locations of Safety Valve Installations. Safety valve installations should be located at least eight pipe diameters (based on I.D.) downstream from any bend in a high velocity steam line to help prevent sonic vibrations. This distance should be increased if the direction of the change of the steam flow is from vertical upwards to horizontal in such a manner as to increase density of the flow in the area directly beneath the station nozzles. Similarly, safety valve installation should not be located closer than eight pipe diameters (based on I.D.) either upstream or downstream from fittings.

II-5.2.2 Spacing of Safety Valve Installation. Spacing of safety valve installations must meet the requirements in Note (6)(c), Appendix D, Table D-1.

II-5.3 Types of Valves and Installations

II-5.3.1 Installations With Single Outlet Valves. Locate unsupported valves as close to the run pipe or header as is physically possible to minimize reaction moment effects.

Orientation of valve outlet should preferably be parallel to the longitudinal axis of the run pipe or header.

Angular discharge elbows oriented to minimize the reaction force moment shall have a straight pipe of at least one pipe diameter provided on the end of the elbow to assure that the reaction force is developed at the desired angle. Cut the discharge pipe square with the center line. Fabrication tolerances, realistic field erection tolerances, and reaction force angle tolerances must be considered when evaluating the magnitude of the reaction moment.

The length of unsupported discharge piping between the valve outlet and the first outlet elbow [Fig. II-1-2(A), distance *l*] should be as short as practical to minimize reaction moment effects.

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II-5.3.2 Installations with Double Outlet Valves. Double outlet valves with symmetrical tail-pipes and vent stacks will eliminate the bending moment in the nozzle and the run pipe or header providing there is equal and steady flow from each outlet. If equal flow cannot be guaranteed, the bending moment due to the unbalanced flow must be considered. Thrust loads must also be considered.

II-5.3.3 Multiple Installations. The effects of the discharge of multiple safety valves on the same header shall be such as to tend to balance one another for all modes of operation.

II-5.4 Installation Branch Connections

Standard branch connections shall as a minimum meet the requirements of para. 104.3. It should be noted that branch connections on headers frequently do not have sufficient reinforcement when used as a connection for a safety valve. It may be necessary to provide additional reinforcing (weld deposit buildup) or special headers that will satisfactorily withstand the reaction moments applied.

Material used for the branch connection and its reinforcement shall be the same or of higher strength than that of the run pipe or header.

It is strongly recommended that branch connections intersect the run pipe or header normal to the surface of the run pipe or header at $\alpha = 90$ deg, where α is defined as the angle between the longitudinal axis of the branch connection and the normal surface of the run pipe or header. Branch connections that intersect the run pipe or headers at angles,

$$90 \text{ deg} > \alpha \geq 45 \text{ deg}$$

should be avoided. Branch connections should not in any case intersect the run pipe or header at angles,

$$\alpha < 45 \text{ deg}$$

II-5.5 Water in Installation Piping

II-5.5.1 Drainage of Discharge Piping. Drains shall be provided so that condensed leakage, rain, or other water sources will not collect on the discharge side of the valve and adversely affect the reaction force. Safety valves are generally provided with drain plugs that can be used for a drain connection. Discharge piping shall be sloped and provided with adequate drains if low points are unavoidable in the layout.

II-5.5.2 Water Seals. Where water seals are used ahead of the safety valve, the total water volume in the seals shall be minimized. To minimize forces due to slug flow or water seal excursion, the number of changes of direction and the lengths of straight runs of installation piping shall be limited. The use of short radius elbows is also discouraged; the pressure differential across the cross section is a function of the elbow radius.

II-5.6 Discharge Stacks

If telescopic or uncoupled discharge stacks, or equivalent arrangements, are used then care should be taken to insure that forces on the stack are not transmitted to the valve discharge elbow. Stack clearances shall be checked for interference from thermal expansion, earthquake displacements, etc. Discharge stacks shall be supported adequately for the forces resulting from valve discharge so that the stack is not deflected, allowing steam to escape in the vicinity of the valve. In addition, the deflection of the safety valve discharge nozzle (elbow) and the associated piping system when subjected to the reaction force of the blowing valve shall be calculated. This deflection shall be considered in the design of the discharge stacks slip-joint to assure that the discharge nozzle remains in the stack, preventing steam from escaping in the vicinity of the valve.

To prevent blowback of discharging steam from inlet end of vent stack, consider the use of an antiblowback device that still permits thermal movements of header.

II-5.7 Support Design

Supports provided for safety valves and the associated piping require analysis to determine their role in restraint as well as support. These analyses shall consider at least the following effects:

(A) differential thermal expansion of the associated piping, headers, and vessels;

(B) dynamic response characteristics of the support in relation to the equipment being supported and the structure to which it is attached, during seismic events and valve operation. Maximum relative motions of various portions of the building and structures to which supports are attached resulting from seismic excitation must be considered in selecting, locating, and analyzing support systems.

(C) capability of the support to provide or not provide torsional rigidity, per the support design requirements.

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II-5.7.1 Pipe Supports. Where necessary, it is recommended that the support near the valve discharge be connected to the run pipe, header, or vessel rather than to adjacent structures in order to minimize differential thermal expansion and seismic interactions.

Each straight leg of discharge piping should have a support to take the force along that leg. If the support is not on the leg itself, it should be as near as possible on an adjacent leg.

When a large portion of the system lies in a plane, the piping if possible should be supported normal to that plane even though static calculations do not identify a direct force requiring restraint in that direction. Dynamic analyses of these systems have shown that out-of-plane motions can occur.

II-5.7.2 Snubbers. Snubbers are often used to provide a support or a stop against a rapidly applied load, such as the reaction force of a blowing valve or the pressure-momentum transient in a closed piping system. Since snubbers generally displace a small distance before becoming rigid, the displacement must be considered in the analysis. In addition, if the load is applied to the snubber for a relatively long time, the snubber performance characteristics shall be reviewed to assure that the snubber will not permit motion during the time period of interest, or the additional displacement must be considered in the analysis. The snubber performance shall also be reviewed for response to repetitive load applications caused by the safety valve cycling open and closed several times during a pressure transient.

II-5.8 Silencer Installation

Silencers are occasionally installed on safety valve discharges to dissipate the noise generated by the sonic velocity attained by the fluid flowing through the valve.

Silencers must be properly sized to avoid excessive backpressure on the safety valve causing improper valve action or reducing relieving capacity.

Safety valve discharge piping, silencers, and vent stacks shall be properly supported to avoid excessive loading on the valve discharge flange.

II-6.0 SAMPLE DESIGNS

Examples of various safety valve installations that a designer may encounter in practice are presented in Figs. II-1-2(A) and II-6-1.

II-7.0 SAMPLE PROBLEM (SEE FIGS. II-7-1 AND II-7-2)

II-7.1 Procedure

(1) Determine pressure and velocity at discharge elbow exit.

(2) Calculate maximum operating pressure for discharge exit.

(3) Calculate reaction force at discharge elbow exit.

(4) Calculate bending moments of Points (1) and (2) from reaction force and seismic motion.

(5) Determine stress intensification factors at Points (1) and (2).

(6) Calculate predicted stresses at Points (1) and (2) and compare with allowable stress.

(7) Calculate maximum operating pressure for vent pipe.

(8) Check for blowback.

(9) Calculate forces and moments on vent pipe.

(1) Pressure and Velocity at Discharge Elbow Exit (Para. II-2.2.1)

$$P_1 = \frac{W}{A_1}\frac{(b-1)}{b}\sqrt{\frac{2(h_o - a)J}{g_c(2b-1)}}$$

$$V_1 = \sqrt{\frac{2g_c J(h_o - a)}{(2b-1)}}$$

W = flow rate
= 116.38 lbm/sec
A_1 = 50.03 in.^{2}
h_o = stagnation enthalpy for steam at 925 psia, 1000°F
= 1507.3 Btu/lbm
a = 823 Btu/lbm for $15 \le P_1 \le 1000$ psia and $h_o \le 1600$ Btu/lbm
b = 4.33 for $15 \le P_1 \le 1000$ psia and $h_o \le 1600$ Btu/lbm
J = 778 ft-lbf/Btu
g_c = 32.2 lbm-ft/lbf-sec^2
P_1 = 118 psia
V_1 = 2116 ft/sec

(2) Discharge Elbow Maximum Operating Pressure

L/D for 8 in. Class 150 ASME weld neck flange

$$= \frac{4 \text{ in.}}{7.981 \text{ in.}} = 0.5$$

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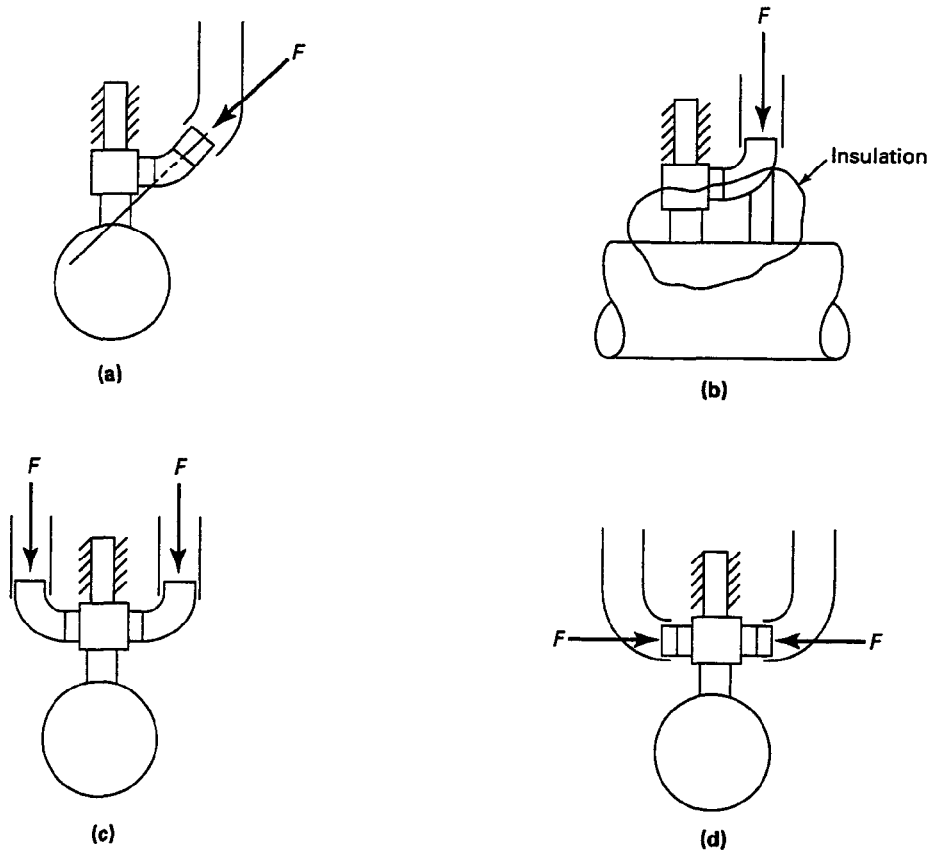

F = reaction force

FIG. II-6-1

L/D for 8 in. SCH 40 short radius elbow = 30

L/D for 12 in. of 8 in. SCH 40 pipe

$$= \frac{12 \text{ in.}}{7.981 \text{ in.}} = 1.5$$

$$\Sigma\left(\frac{L}{D}\right) = \left(\frac{L_{max.}}{D}\right) = 32.0$$

$$f = 0.013$$

$$k = 1.3$$

$$f\left(\frac{L_{max.}}{D}\right) = 0.416$$

From Chart II-1, $P/P^* = 1.647$.

$$P_{1a} = P_1 (P/P^*) = 194 \text{ psia}$$

(3) Reaction Force at Discharge Elbow Exit. Reaction force,

$$F_1 = \frac{WV_1}{g_c} + (P_1 - P_a) A_1$$

$W = 116.38$ lbm/sec
$V_1 = 2116$ ft/sec
$g_c = 32.2$ lbm-ft/lbf-sec^2
$P_1 = 118$ psia
$A_1 = 50.03$ in.^{2}
$P_a = 15$ psia

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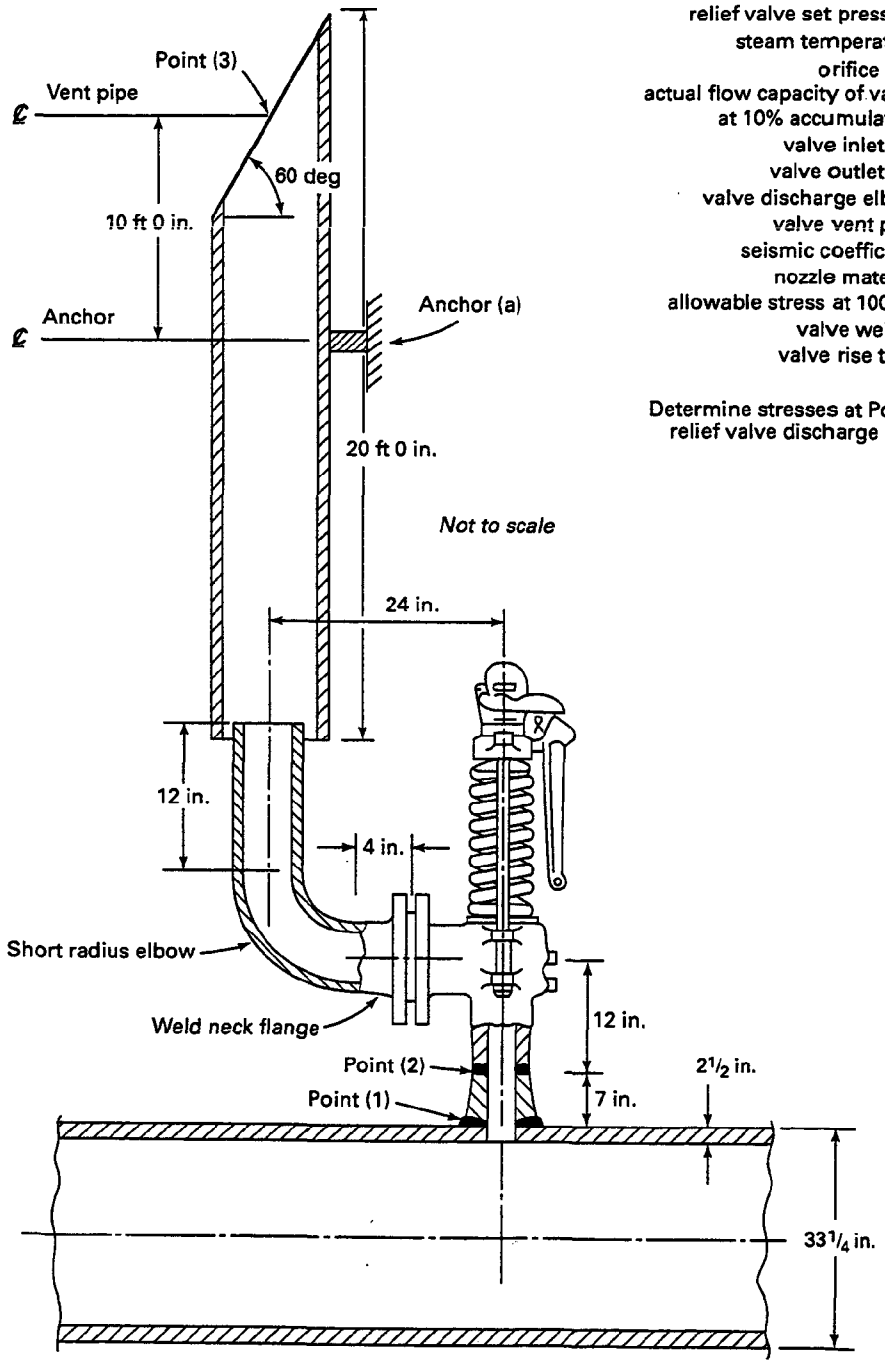

relief valve set pressure = 910 psig
steam temperature = 1000°F
orifice size = 11.05 in.^{2} (Q orifice)
actual flow capacity of valve
at 10% accumulation = 418,950 lbm/hr
valve inlet I.D. = 6 in.
valve outlet I.D. = 8 in.
valve discharge elbow = 8 in. SCH 40
valve vent pipe = 12 in. SCH 30
seismic coefficient = 1.5*g*
nozzle material = ASTM A 335 P22 2¼Cr–1Mo
allowable stress at 1000°F = 7800 psi
valve weight = 800 lb
valve rise time = 0.040 sec

Determine stresses at Points (1) and (2) due to seismic and relief valve discharge loads only.

FIG. II-7-1

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$$i = 1.5 \left(\frac{R_m}{T_r}\right)^{2/3} \left(\frac{r'_m}{R_m}\right)^{1/2} \left(\frac{T'_b}{T_r}\right) \left(\frac{r'_m}{r_p}\right)$$

R_m, T_r, r'_m, T'_b, and r_p are shown in sketch below:

$$i_{(1)} = 1.5 \left(\frac{15.375}{2.5}\right)^{2/3} \left(\frac{4.25}{15.375}\right)^{1/2} \left(\frac{2.5}{2.5}\right) \left(\frac{4.25}{5.5}\right)$$

$$i_{(1)} = 2.05$$

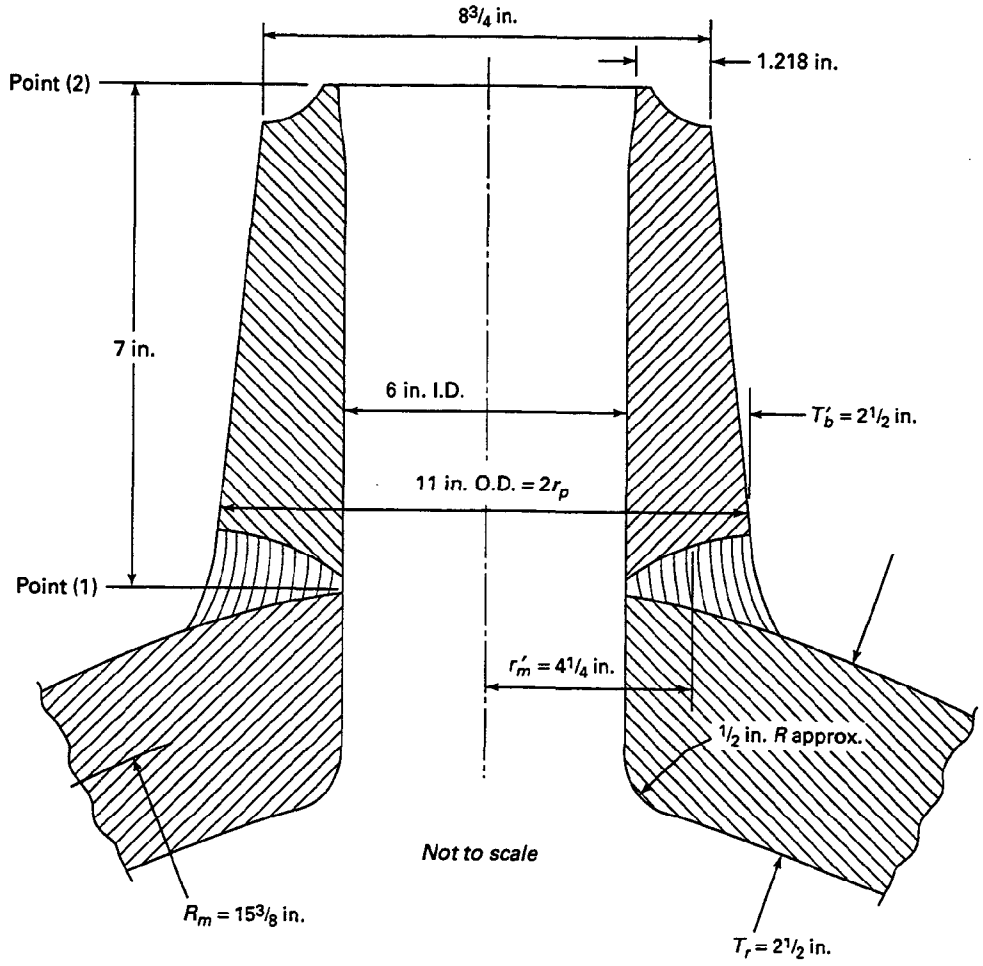

FIG. II-7-2

$$(P_1 - P_a) = 118 - 15$$
$$= 103 \text{ psig}$$
$$WV_1/g_c = 7648 \text{ lbf}$$
$$(P_1 - P_a)\, A_1 = 5153 \text{ lbf}$$
$$F_1 = 12{,}801 \text{ lbf}$$

(4) Bending Moments at Points (1) and (2)

(A) Bending Moment at Points (1) and (2) due to Reaction at Point (1):

$$M_{1(1)} = M_{1(2)}$$
$$= F_1 \times L \times DLF$$
$$L = \text{moment arm}$$
$$= 24 \text{ in.}$$

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DLF = dynamic load factor

To determine DLF, first determine the safety valve installation period T:

$$T = 0.1846 \sqrt{\frac{Wh^3}{EI}}$$

where

W = weight of valve
= 800 lb
h = distance from run pipe to center line of outlet piping
= 19 in.
E = Young's modulus of inlet pipe at design temperature
= 23×10^6 psi
I = moment of inertia of inlet pipe
= $\frac{\pi}{64}(D_o^4 - D_i^4)$
Use average O.D. and I.D. to determine I.
D_o = 9.875 in. avg.; D_i = 6 in. avg.
= 403.2 in.^{4}
T = 0.00449 sec

For a valve rise time of 0.040 sec = t_o, the ratio t_o/T is 8.9. From Fig. II-3-2, DLF = 1.11.

Using F_1 = 12,801 lbf, L = 24 in., and DLF = 1.11.

$$M_{1(1)} = M_{1(2)} = 341{,}018 \text{ in.-lb}$$

(B) Bending Moments at Points (1) and (2) due to Seismic Loading

Seismic force,

$$F_S = \text{mass} \times \text{acceleration}$$

$$= \left[\frac{800 \text{ lbm}}{32.2 \text{ lbm-ft/lbf-sec}^2}\right] \times 1.5(32.2 \text{ ft/sec}^2)$$

$$= 1200 \text{ lbf}$$

Moment arm for Point (1) = 19 in.

$$M_{S(1)} = 1200 \text{ lbf (19 in.)} = 22{,}800 \text{ in.-lb}$$

Moment arm for Point (2) = 12 in.

$$M_{S(2)} = 1200 \text{ lbf (12 in.)} = 14{,}400 \text{ in.-lb}$$

(C) Combined Bending Moments at Points (1) and (2)

$$M_{(1)} = M_{1(1)} + M_{S(1)} = 363{,}819 \text{ in.-lb}$$

$$M_{(2)} = M_{1(2)} + M_{S(2)} = 355{,}419 \text{ in.-lb}$$

(5) Stress Intensification Factors at Points (1) and (2)

(A) At Point (1), Branch Connection

$$i_{(1)} = 2.05$$

(B) Stress Intensification Factors at Point (2), Buttweld

$$i_{(2)} = 1.0$$

(6) Predicted Stresses at Points (1) and (2)

(A) Predicted Stresses at Point (1), Branch Connection

$$\text{Predicted stress} = \frac{PD_o}{4t_n}$$

$$\frac{D_o}{t_n} \text{ for run pipe} = \frac{33.25 \text{ in.}}{2.5 \text{ in.}} = 13.3$$

$$\frac{D_o}{t_n} \text{ for branch pipe} = \frac{11 \text{ in.}}{2.5 \text{ in.}} = 4.4$$

Use larger value with P = 910 psig.

$$\text{Pressure stress}_{(1)} = 3030 \text{ psi}$$

$$\text{Flexure stress}_{(1)} = \frac{0.75i\,M_{(1)}}{Z_{(1)}}$$

$$Z_{(1)} = \pi r_b^2 t_s$$

t_S = lesser of t_r or $(i)\,t_b$

t_R = 2.5 in.; $(i)\,t_b$ = (2.05) 2.5 in.

t_S = 2.5 in.

r_b = 4.25 in.

$Z_{(1)}$ = 142 in.^{3}

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$$i_{(1)} = 2.05;\ M_{(1)} = 363{,}819 \text{ in.-lb}$$

$$\text{Flexure stress}_{(1)} = 3939 \text{ psi}$$

$$\text{Combined stress}_{(1)} = \text{pressure stress}_{(1)} + \text{flexure stress}_{(1)} = 6969 \text{ psi}$$

(B) Predicted Stresses at Point (2), Buttweld

$$\text{Pressure stress} = \frac{P\,D_o}{4\,t_n}$$

$$P = 910 \text{ psig}$$

$$D_o = 8.75 \text{ in.}$$

$$t_n = 1.218 \text{ in.}$$

$$\text{Pressure stress}_{(2)} = 1635 \text{ psi}$$

$$\text{Flexure stress}_{(2)} = \frac{0.75\,i\,M_{(2)}}{Z_{(2)}}$$

$$Z_{(2)} = \frac{\pi}{32}\,\frac{D_o^4 - D_i^4}{D_o}$$

$$D_o = 8.75 \text{ in.}$$

$$D_i = 6 \text{ in.}$$

$$Z_{(2)} = 51.1 \text{ in.}^3$$

$$i_{(2)} = 1.0$$

$$M_{(2)} = 355{,}419 \text{ in.-lb}$$

$$\text{Flexure stress}_{(2)} = 6955 \text{ psi}$$

(Note that $0.75i$ is set equal to 1.0 whenever $0.75i$ is less than 1.0, as in this case.)

$$\text{Combined stress}_{(2)} = \text{pressure stress}_{(2)} + \text{flexure stress}_{(2)} = 8590 \text{ psi}$$

(C) Comparison of Predicted Stress with Allowable Stress. Allowable stress of nozzle material at 1000°F is

$$S_h = 7800 \text{ psi}$$

$$k = 1.2$$

$$kS_h = 9360 \text{ psi}$$

$$\text{Combined stress}_{(1)} = 6969 \text{ psi}$$

$$\text{Combined stress}_{(2)} = 8590 \text{ psi}$$

(7) Calculate the Maximum Operating Pressure for Vent Pipe

$$P_3 = P_1\left(\frac{A_1}{A_3}\right) = 118 \text{ psia}\left(\frac{50.03 \text{ in.}^2}{114.80 \text{ in.}^2}\right)$$

$$= 51.4 \text{ psia}$$

L/D for 20 ft 0 in. of 12 in. SCH 30 pipe = 19.85.

$$\Sigma(L/D) = \left(\frac{L_{\max.}}{D}\right) = 19.85$$

$$f = 0.013$$

$$k = 1.3$$

$$f\left(\frac{L_{\max.}}{D}\right) = 0.258$$

From Chart II-1, $P/P^* = 1.506$.

$$P_2 = P_3\,(P/P^*) = 77.4 \text{ psia}$$

(8) Check for Blowback From Vent Pipe. Calculate the velocity V_2 that exists at the inlet to the vent pipe (para. II-2.2.1.4).

$$f\left(\frac{L_{\max.}}{D}\right) = 0.258 \text{ from Step (7)}$$

$$V_3 = V_1 = 2116 \text{ ft/sec}$$

From Chart II-1, $V/V^* = 0.7120$.

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$$V_2 = V_3 (V/V^*) = 1507 \text{ ft/sec}$$

Check the inequality from para. II-2.3.1.2.

$$\frac{W (V_1 - V_2)}{g_c} > (P_2 - P_a) A_2 - (P_1 - P_a) A_1$$

$$\frac{116.38 (2116 - 1507)}{32.2} > (77.4 - 14.7)(114.8) - (118 - 14.7)(50.03)$$

$$2201 > 2030$$

The inequality has been satisfied but the designer may require a design margin that would make 14 in. SCH 30 more acceptable. If a larger vent pipe is chosen, then the vent pipe analysis would have to be repeated for the 14 in. SCH 30 pipe.

(9) Calculate Forces and Moments on Vent Pipe Anchor (a)

$$F_2 = \frac{WV_2}{g_c} + (P_2 - P_a) A_2$$

$$= \frac{(116.38)(1507)}{32.2} + (77.4 - 14.7)(114.8)$$

$$= 5447 + 7198.0 = 12{,}645 \text{ lbf}$$

$$F_3 = \frac{(116.38)(2116)}{32.2} + (51.4 - 14.7)(114.8)$$

$$= 7648 + 4213 = 11{,}861 \text{ lbf}$$

Assume a 30 deg jet deflection angle for vent pipe outlet.

Vertical component of F_3

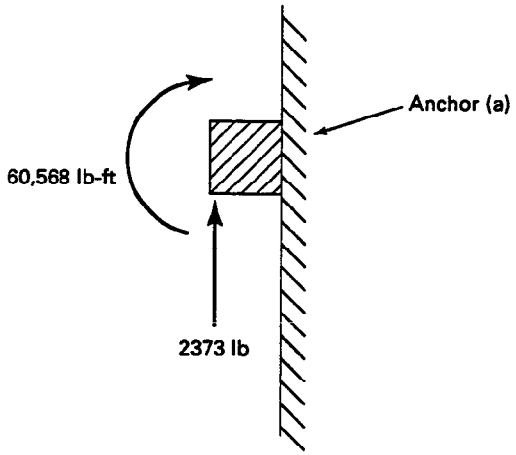

FIG. II-7-3

$$F_{3V} = F_3 \cos 30 \text{ deg} = 10{,}272 \text{ lbf}$$

Horizontal component of F_3

$$F_{3H} = F_3 \sin 30 \text{ deg} = 5931 \text{ lbf}$$

Net imbalance on the vent pipe in the vertical direction is

$$F_2 - F_{3V} = 2373 \text{ lbf}$$

Moment on vent pipe anchor

$$\Sigma M = (F_2 - F_{3V}) \frac{D_o}{2} + F_{3H} \times [\text{distance from (a) to point 3}]$$

$$= (2373)\left(\frac{1.06}{2}\right) + (5931)(10.0)$$

$$= 60{,}568 \text{ ft-lb}$$

The vent pipe anchor would then be designed for the loads shown in Fig. II-7-3 for safety valve operation.

Conclusion

Branch connection stresses at Points (1) and (2) due to seismic and relief valve discharge are within 1.2 S_h. Blowback will not occur with the 12 in. standard weight vent pipe. The vent pipe anchor loads have been identified.

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NONMANDATORY APPENDIX III[1]
RULES FOR NONMETALLIC PIPING

FOREWORD

ASME B31.1 contains rules governing the design, fabrication, materials, erection, and examination of power piping systems. Experience in the application of nonmetallic materials for piping systems has shown that a number of considerations exist for the use of these materials that are not addressed in the current body of the Code. In order to address these, the requirements and recommendations for the use of nonmetallic piping (except in paras. 105.3, 108.4, 116, and 118) have been separately assembled in this nonmandatory Appendix.

III-1.0 SCOPE AND DEFINITION

III-1.1 General

III-1.1.1 This Appendix provides minimum requirements for the design, materials, fabrication, erection, testing, examination, and inspection of nonmetallic piping within the jurisdiction of the ASME B31.1 Power Piping Code. All references to the Code or to Code paragraphs in this Appendix are to the Section B31.1 Power Piping Code. In this Appendix, nonmetallic piping shall be limited to plastic and elastomerbased piping materials, with or without fabric or fibrous material added for pressure reinforcement.

III-1.1.2 Standards and specifications incorporated in this Appendix are listed in Table III-4.1.1. The effective date of these documents shall correspond to the date of this Appendix.

III-1.1.3 The provisions in Chapters I through VI and in Appendices A through F are requirements of this Appendix only when specifically referenced herein.

[1] Nonmandatory Appendices are identified by a Roman numeral; mandatory Appendices are identified by a letter. Therefore, Roman numeral I is not used in order to avoid confusion with the letter I.

III-1.2 Scope

III-1.2.1 All applicable requirements of para. 100.1 and the limitations of para. 105.3 shall be met in addition to those in this Appendix.

III-1.2.2 Use of this Appendix is limited to:

(A) water service;

(B) nonflammable and nontoxic liquid, dry material, and slurry systems;

(C) reinforced thermosetting resin pipe in buried flammable and combustible liquid service systems [refer to para. 122.7.3(F)]; and

(D) polyethylene pipe in buried flammable and combustible liquid and gas service. Refer to paras. 122.7.3(F) and 122.8.1(G).

III-1.2.3 Nonmetallic piping systems shall not be installed in a confined space where toxic gases could be produced and accumulate, either from combustion of the piping materials or from exposure to flame or elevated temperatures from fire.

III-1.3 Definitions and Abbreviations

III-1.3.1 Terms and definitions relating to plastic and other nonmetallic piping materials shall be in accordance with ASTM D 883. The following terms and definitions are in addition to those provided in the ASTM standard.

adhesive: a material designed to join two other component materials together by surface attachment (bonding)

adhesive joint: a bonded joint made using an adhesive on the surfaces to be joined

bonder: one who performs a manual or semiautomatic bonding operation

bonding operator: one who operates a machine or automatic bonding equipment

bonding procedure: the detailed methods and practices involved in the production of a bonded joint

Bonding Procedure Specification (BPS): the document that lists the parameters to be used in the construction

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of bonded joints in accordance with the requirements of this Code

butt-and-wrapped joint: a joint made by applying plies of reinforcement saturated with resin to the surfaces to be joined

chopped roving: a collection of noncontinuous glass strands gathered without mechanical twist. Each strand is made up of glass filaments bonded together with a finish or size for application by chopper gun

chopped strand mat: a collection of randomly oriented glass fiber strands, chopped or swirled together with a binder in the form of a blanket

continuous roving: a collection of continuous glass strands wound into a cylindrical package without mechanical twist

curing agent: a reactive material which when combined with a resin material reacts or polymerizes (cross-links) with the resin; also referred to as a hardener

diluent: a reactive modifying material, usually liquid, which reduces the concentration of a resin material to facilitate handling characteristics and improve wetting

fire retardant resin: a specially compounded material combined with a resin material designed to reduce or eliminate the tendency to burn

flexibilizer: a modifying liquid material added to a resinous mixture designed to allow the finished component the ability to be flexed or less rigid and more prone to bending

grout: a heavily filled paste material used to fill crevices and transitions between piping components

heat fusion joint: a joint made by heating the surfaces to be joined and pressing them together so they fuse and become essentially one piece

hot gas welded joint: a joint made by simultaneously heating a filler material and the surfaces to be joined with a stream of hot air or hot inert gas until the materials soften, after which the surfaces to be joined are pressed together and welded with the molten filler material

liner: a coating or layer of material constructed as, applied to, or inserted within the inside surface of a piping component intended to protect the structure from chemical attack, to inhibit erosion, or to prevent leakage under strain

seal weld: the addition of material external to a joint by welding or bonding for the purpose of enhancing leak tightness

solvent cement joint: a joint using a solvent cement to soften the surfaces to be joined, after which the joining surfaces are pressed together and become essentially one piece as the solvent evaporates

stiffness factor: the measurement of a pipe's ability to resist deflection as determined in accordance with ASTM D 2412

thixatropic agent: a material added to resin to impart high static shear strength (viscosity) and low dynamic shear strength

ultraviolet absorber: a material which when combined in a resin mixture will selectively absorb ultraviolet radiation

woven roving: a heavy glass fiber fabric reinforcing material made by the weaving of glass fiber roving

III-1.3.2 Abbreviations used in this Appendix denote materials and terms as follows:

Abbreviation	Term
ABS[2]	Acrylonitrile-butadiene-styrene
AP	Polyacetal
CP	Chlorinated polyether
CPVC[2]	Chlorinated poly (vinyl chloride)
DS	Design stress
FEP[2]	Perfluoro (ethylene propylene)
HDB	Hydrostatic design basis
HDS	Hydrostatic design stress
PA[2]	Polyamide (nylon)
PB	Polybutylene
PE[2]	Polyethylene
PFA	Poly (perfluoroalkoxy)
POP	Poly (phenylene oxide)
PP[2]	Polypropylene
PPS	Polyphenylene
PR	Pressure rated
PTFE[2]	Polytetrafluoroethylene
PVC[2]	Poly (vinyl chloride)
PVDC	Poly (vinylidene chloride)
PVDF	Poly(vinylidene fluoride)
RTR	Reinforced thermosetting resin
SDR	Standard dimensional ratio

[2] Abbreviations in accordance with ASTM D 1600.

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III-2.0 DESIGN

III-2.1 Conditions and Criteria

III-2.1.1 General

(A) The Design Conditions of para. 101 shall apply for the design of nonmetallic piping systems.

(B) The design of nonmetallic piping systems must ensure the adequacy of material and its manufacture, considering at least the following:

(B.1) tensile, compressive, flexural, shear strength, and modulus of elasticity at design temperature (long-term and short-term);

(B.2) creep characteristics for the service conditions;

(B.3) design stress and its basis;

(B.4) coefficient of thermal expansion;

(B.5) ductility and plasticity;

(B.6) impact and thermal shock properties;

(B.7) temperature limits for the service;

(B.8) transition temperatures: melting and vaporization;

(B.9) toxicity of the material or of the gases produced by its combustion or exposure to elevated temperatures;

(B.10) porosity and permeability;

(B.11) test methods;

(B.12) methods of making joints and their efficiency;

(B.13) deterioration in the service environment;

(B.14) the effects on unprotected piping from external heat sources (particularly solar radiation).

III-2.1.2 Pressure-Temperature Ratings for Components

(A) Components having specific pressure-temperature ratings have been established in the standards listed in Table III-4.1.1. Other components may be used in accordance with para. III-2.1.2(B).

(A.1) Except as qualified in paras. III-2.1.3, the ratings of Tables III-4.2.1, III-4.2.2, and III-4.2.3 are the limiting values for allowable stresses at temperature in this Appendix.

(A.2) The application of pressures exceeding the pressure-temperature ratings of valves is not permitted. Valves shall be selected for operation within the limits defined in para III-2.1.2(C)

(B) Components Not Having Specific Ratings

(B.1) Pipe and other piping components for which allowable stresses have been developed in accordance with para. III-2.1.3, but which do not have specific pressure-temperature ratings, shall be rated by the rules for pressure design in para. III-2.2 within the range of temperatures for which stresses are listed in Tables III-4.2.1, III-4.2.2, and III-4.2.3.

(B.2) Custom-molded pipe and other piping components that do not have allowable stresses or pressure-temperature ratings shall be qualified for pressure design as required in para. III-2.2.9.

(C) Allowances for Pressure and Temperature Variations. Allowances for variations of pressure, or temperature, or both, above design conditions are not permitted. The most severe conditions of coincident pressure and temperature shall be used to determine the design conditions.

(D) Considerations for Local Conditions. Where two services that operate at different pressure-temperature conditions are connected, the valve segregating the two services shall be rated for the most severe service conditions. Other requirements of para. 102.2.5 must be considered where applicable.

III-2.1.3 Allowable Stresses and Other Stress Limits

(A) General. Tables III-4.2.1, III-4.2.2, and III-4.2.3 list recommended maximum allowable stresses in the form of hydrostatic design stresses (HDS), allowable design stresses (DS), and the hydrostatic design basis (HDB), which may be used in design calculations except where modified by other provisions of this Appendix. The use of hydrostatic design stresses for calculations other than pressure design has not been established. The basis for determining allowable stresses and pressures is outlined in para. III-2.1.3(B). The allowable stresses are grouped by materials and listed for stated temperatures. Where sufficient data have been provided, straight-line interpolation between temperatures is permissible. The materials listed are available from one or more manufacturers and may be obtained with maximum allowable stresses varying from those listed in Tables III-4.2.1, III-4.2.2, and III-4.2.3. These materials and values are acceptable for use where they have been established in accordance with (B) below and para. III-2.2.9.

(B) Basis for Allowable Stresses for Internal Pressure

(B.1) Thermoplastics. A method of determining hydrostatic design stress (HDS) and pressure rating (PR) is described in ASTM D 2837. Hydrostatic design stresses are provided in Table III-4.2.1 for those materials and temperatures for which sufficient data have been compiled to substantiate a determination of stress. Data on these materials at other temperatures, and on other materials, are being developed. Pending publication of additional data, the limitations in para. III-2.1.2(B) shall be observed.

(B.2) Reinforced Thermosetting Resin (Laminated). For laminated piping components, the design stresses

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(DS) are listed in Table III-4.2.2. These typically are based on one-tenth of the minimum tensile strengths specified in Table 1 of ASTM C 582.

(B.3) Reinforced Thermosetting Resin (Filament Wound and Centrifugally Cast). For filament wound and centrifugally cast piping components, hydrostatic design basis (HDB) values are listed in Table III-4.2.3. These values may be obtained by procedures in ASTM D 2992. HDS may be obtained by multiplying the HDB by a service (design) factor[3] selected for the application, in accordance with procedures described in ASTM D 2992, within the following limits.

(B.3.1) When using the cyclic HDB from Table III-4.2.3, the service (design) factor shall not exceed 1.0.

(B.3.2) When using the static HDB from Table III-4.2.3, the service (design) factor shall not exceed 0.5.

III-2.1.4 Limits of Calculated Stresses due to Sustained Loads

(A) Internal Pressure Stresses. The limits for stress due to internal pressure are provided in para. III-2.2.2.

(B) External Pressure Stresses. Stresses due to uniform external pressures shall be considered safe when the wall thickness of the component, and means of stiffening, have been established in accordance with para. III-2.2.9.

(C) External Loading Stresses. Design of reinforced thermosetting resin (RTR) and thermoplastic piping under external loading shall be based on the results of the parallel plate loading test in ASTM D 2412. The allowable deflection for RTR and thermoplastic pipe shall be 5% of the pipe diameter. Where other nonmetallic piping is intended for use under conditions of external loading, it shall be subject to a crushing or three-edge bearing test, in accordance with ASTM C 14 or C 301, and the allowable load shall be 25% of the minimum value obtained.

III-2.1.5 Limits of Calculated Stresses due to Occasional Loads

(A) Operation. The total stress produced by pressure, live and dead loads, and by occasional loads, such as wind or earthquake, shall not exceed the considerations and recommendations in para. III-2.5. Wind and earthquake forces need not be considered as acting concurrently.

(B) Test. Stresses due to test conditions are not subject to the limitations in (A) above. It is not necessary to consider other occasional loads, such as wind and earthquake, as occurring concurrently with test loads.

III-2.1.6 Allowances

(A) Erosion, Corrosion, Threading, and Grooving. In determining the minimum required thickness of a piping component, allowances shall be included for erosion and for thread depth or groove depth.

(B) Mechanical Strength. When necessary, pipe wall thicknesses shall be increased to prevent overstress, damage, collapse, or buckling due to superimposed loads from supports, ice formation, backfill, or other causes. Where increasing thickness will cause excessive local stress, or is otherwise impractical, the required strength may be obtained through the use of additional supports, braces, or other means without an increased wall thickness. Particular consideration should be given to the mechanical strength of a small branch connected to large piping or to equipment.

III-2.2 Pressure Design of Piping Components

III-2.2.1 Criteria for Pressure Design. The design of piping components shall consider the effects of pressure and temperature in accordance with para. III-2.1.2, and provide for allowances in accordance with para. III-2.1.6. In addition, the design shall be checked for adequacy of mechanical strength under other applicable loadings as required in paras. III-2.1.4 and III-2.1.5.

(A) The required minimum wall thickness of straight sections of pipe t_m shall be determined in accordance with Eq. (1).

$$t_m = t + c \quad (1)$$

where

t_m = minimum required thickness, in.

t = pressure design thickness, in., as calculated in para. III-2.2.2 for internal pressure, or in accordance with para. III-2.2.3 for external pressure

c = the sum of the mechanical allowances (thread or groove depth), plus erosion and/or corrosion allowance, and the manufacturer's minus tolerance for product wall thickness, in. For threaded components, the nominal thread depth shall apply. For machined surfaces or grooves where a tolerance is not specified, the tolerance shall be assumed to be 0.02 in., in addition to the specified depth of the thread or groove.

[3] The service (design) factor should be selected by the designer after evaluating fully the service conditions and the engineering properties of the specific material under consideration. Aside from the limits in paras. III-2.1.3.(B.3.1) and (B.3.2), it is not the intent of the Code to specify service (design) factors.

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III-2.2.2 Straight Pipe Under Internal Pressure

(A) The internal pressure design thickness t shall not be less than that calculated by the following equations.

(A.1) Thermoplastic Pipe

$$t = \frac{D}{2S_a/P + 1} \quad (2)$$

(A.2) Reinforced Thermosetting Resin (Laminated)

$$t = \frac{D}{2S_b/P + 1} \quad (3)$$

(A.3) Reinforced Thermosetting Resin (Filament Wound and Centrifugally Cast)

$$t = \frac{D}{2S_cF/P + 1} \quad (4)$$

where

D = outside diameter of pipe, in.
F = service design factor in accordance with para. III-2.1.3(B.3)
P = internal design gage pressure, psi
S_a = hydrostatic design stress from Table III-4.2.1
S_b = design stress from Table III-4.2.2
S_c = hydrostatic design basis from Table III-4.2.3

(B) The internal pressure design thickness t in (A.1) and (A.2) above shall not include any thickness of pipe wall reinforced with less than 30% (by weight) of reinforcing fibers, or added liner thickness.

III-2.2.3 Straight Pipe Under External Pressure

(A) Thermoplastic Pipe. The external pressure design thickness t shall be qualified as required by para. III-2.2.9

(B) Reinforced Thermosetting Resin Pipe

(B.1) Above Ground. For determining design pressure thickness for straight pipe under external pressure, the procedures outlined in ASTM D 2924 shall be followed. A safety factor of at least 4 shall be used.

(B.2) Below Ground. For determining design pressure thickness for straight pipe under external pressure in a buried condition, the procedures outlined in AWWA C-950, Appendix A, Sections A-2.5 and A-2.6 shall be followed.

(C) Metallic Pipe Lined With Nonmetals

(C.1) The external pressure design thickness for the base (outer) material shall be determined in accordance with para. 104.1.3.

(C.2) The external pressure design thickness t for the lining material shall be qualified as required by para. III-2.2.9.

III-2.2.4 Curved and Mitered Segments of Pipe

(A) Pipe Bends. The minimum required thickness t_m of a pipe bend after bending shall be determined as for straight pipe in accordance with para. III-2.2.1.

(B) Elbows. Manufactured elbows not in accordance with para. III-2.1.2 shall meet the requirements of para. III-2.2.9.

(C) Mitered Bends. Mitered bend sections shall meet the requirements of para. III-2.2.9.

III-2.2.5 Branch Connections

(A) General. A pipe having a branch connection is weakened by the opening that must be made in it, and unless the wall thickness of the pipe is sufficiently in excess of that required to sustain the pressure, it is necessary to provide added reinforcement. The amount of reinforcement required shall be in accordance with the requirements of para. III-2.2.9 except as provided in (B) and (C) below.

(B) Branch Connections Using Fittings. A branch connection shall be considered to have adequate strength to sustain the internal and external pressure which will be applied to it if a fitting (a tee, lateral, or cross) is utilized in accordance with para. III-2.1.2(A).

(C) Additional Considerations. The requirements of (A) and (B) above are designed to assure satisfactory performance of a branch connection subjected only to internal or external pressure. The designer shall also consider the following:

(C.1) external forces and moments which may be applied to a branch connection by thermal expansion and contraction, by dead and live loads, by vibration or pulsating pressure, or by movement of piping terminals, supports, and anchors;

(C.2) adequate flexibility shall be provided in branch piping to accommodate movements of the run piping;

(C.3) ribs, gussets, or clamps may be used for pressure-strengthening a branch connection in lieu of the reinforcement required by (A) above if the adequacy of the design is established in accordance with para. III-2.2.9.

III-2.2.6 Closures. Closures in piping systems, such as those provided for temporary or future lateral or end-point branches, shall be made using fittings, flanges, or parts in accordance with paras. III-2.2.7 and III-2.2.9.

III-2.2.7 Pressure Design of Flanges

(A) General

(A.1) Nonmetallic flanges that are rated in accordance with published ASTM standards listed in Table III-4.1.1 shall be considered suitable for use within the limitations specified in this Appendix. Alternatively,

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flanges shall be in accordance with para. 103, or may be designed in conformance with the requirements of para. III-2.2.7 or III-2.2.9.

(A.2) Flanges for use with ring type gaskets may be designed in accordance with Section VIII, Division 1, Appendix 2 of the ASME Boiler and Pressure Vessel Code, except that the allowable stresses for nonmetallic components shall govern. All nomenclature shall be as defined in the ASME Code except the following:

P = design gage pressure
S_a = bolt design stress at atmospheric temperature. (Bolt design stresses shall not exceed those in Appendix A.)
S_b = bolt design stress at design temperature. (Bolt design stresses shall not exceed those in Appendix A.)
S_f = allowable stress for flange material from Para. III-4.2

(A.3) The flange design rules in (A.2) above are not applicable for designs employing full-face gaskets that extend beyond the bolts or where flanges are in solid contact beyond the bolts. The forces and reactions in such a joint differ from those joints employing ring type gaskets, and the flanges should be designed in accordance with Section VIII, Division 1, Appendix Y of the ASME Boiler and Pressure Vessel Code. (Note that the plastic flange sealing surface may be more irregular than the sealing surface of a steel flange. For this reason, thicker and softer gaskets may be required for plastic flanges.)

(B) Blind Flanges. Blind flanges shall be in accordance with para. 103, or alternatively, may be designed in accordance with para. 104.5.2, except that the allowable stress for nonmetallic components shall be taken from the data in para. III-4.2. Otherwise, the design of blind flanges shall meet the requirements of para. III-2.2.9.

III-2.2.8 Reducers. Reducers not in compliance with para. 103 shall meet the requirements of para. III-2.2.9.

III-2.2.9 Design of Other Components

(A) Listed Components. Other pressure-retaining components manufactured in accordance with standards listed in Table III-4.1.1 may be utilized in accordance with para. III-2.1.2.

(B) Unlisted Components and Products. For pressure-retaining components and piping products not in accordance with the standards and specifications in Table III-4.1.1, and for proprietary components and joints for which the rules in paras. III-2.2.1 through III-2.2.8 do not apply, pressure design shall be based on calculations consistent with the design criteria of the Code. This must be substantiated by one or more of the following, with consideration given to applicable dynamic effects, such as vibration and cyclic operation, the effects of thermal expansion or contraction, and the load effects of impact and thermal shock:

(B.1) extensive successful service experience under comparable design conditions with similarly proportioned components or piping elements made of the same or like material;

(B.2) performance tests under design conditions, including applicable dynamic and creep effects, continued for a time period sufficient to determine the acceptability of the component or piping element for its design life;

(B.3) for either (B.1) or (B.2) above, reasonable interpolations between sizes and pressure classes and reasonable analogies among related materials are permitted.

III-2.3 Selection of Piping Components

III-2.3.1 General. Nonmetallic pipe, tubing, fittings, and miscellaneous items conforming to the standards and specifications listed in Table III-4.1.1 shall be used within the limitations of para. III-4.0 of this Appendix.

III-2.4 Selection of Piping Joints

III-2.4.1 General. Joints shall be suitable for the pressure-temperature design conditions and shall be selected giving consideration to joint tightness and mechanical strength under those conditions (including external loadings), the materials of construction, the nature of the fluid service, and the limitations of paras. III-2.4.2 through III-2.4.7.

III-2.4.2 Bonded Joints

(A) General Limitations. Unless limited elsewhere in para. III-2.4.2, joints made by bonding in accordance with para. III-5.1, and examined in accordance with para. III-6.2, may be used within other limitations on materials and piping components in this Appendix.

(B) Specific Limitations

(B.1) Fillet Joints. Fillet bonded joints may be used in hot gas welded joints, only, if in conformance with the requirements of para. III-5.1.3(A).

(B.2) Butt-and-Wrapped Joints. Butt-and-wrapped joints in RTR piping shall be made with sufficient strength to withstand pressure and external loadings.

III-2.4.3 Flanged Joints

(A) General Limitations. Unless limited elsewhere in

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para. III-2.4.3, flanged joints may be used, considering the requirements for materials in para. III-3.0, and for piping components in para. III-2.3, within the following limitations.

(A.1) Joints With Flanges of Different Ratings. Where flanges of different ratings are bolted together, the rating of the joint shall be that of the lower rated flange. Bolting torque shall be limited so that excessive loads will not be imposed on the lower rated flange in obtaining a tight joint.

(A.2) Metallic to Nonmetallic Flanged Joints. Where metallic and nonmetallic flanges are to be joined, both should be flat-faced. Full-faced gaskets are preferred. If full-faced gaskets are not used, bolting torque shall be limited so that the nonmetallic flange is not overloaded.

III-2.4.4 Expanded or Rolled Joints. Expanded or rolled joints are not permitted in nonmetallic piping systems.

III-2.4.5 Threaded Joints

(A) General Limitations

(A.1) Threaded joints may be used within the requirements for materials in para. III-3.0, and on piping components in para. III-2.3, within the following limitations.

(A.2) Threaded joints shall be avoided in any service where severe erosion or cyclic loading may occur, unless the joint has been specifically designed for these conditions.

(A.3) Where threaded joints are designed to be seal welded, thread sealing compound shall not be used.

(A.4) Layout of piping should minimize reaction loads on threaded joints, giving special consideration to stresses due to thermal expansion and the operation of valves.

(A.5) Metallic-to-nonmetallic and dissimilar nonmetallic threaded joints are not permitted in piping $2\frac{1}{2}$ in. NPS, and larger.

(A.6) Threaded joints are not permitted at design temperatures above 150°F.

(B) Specific Limitations

(B.1) Thermoplastic Resin Piping. Threaded joints in thermoplastic piping shall conform to the following requirements.

(B.1.1) The pipe wall shall be at least Schedule 80 thickness.

(B.1.2) Pipe threads shall conform to ASME B1.20.1 NPT. Threaded fittings shall be compatible with that standard.

(B.1.3) A suitable thread lubricant and sealant shall be specified.

(B.1.4) Threaded piping joints are not permitted in polyolefin materials[4] because of creep characteristics that must be considered.

(B.2) Thermosetting Resin Piping. Threaded joints in thermosetting resin piping shall conform to the following requirements.

(B.2.1) Threads shall be factory cut or molded on pipe ends and in matching fittings, with allowance for thread depth in accordance with para. III-2.2.1(A).

(B.2.2) Threading of plain ends of piping is not permitted except where such male threads are limited to the function of forming a mechanical lock with matching female threads during bonding.

(B.2.3) Factory cut or molded threaded nipples, couplings, or adapters bonded to plain end components, may be used where necessary to provide connections to threaded metallic piping.

III-2.4.6 Caulked Joints. In liquid service, bell and spigot and other caulked joints shall be used within the pressure-temperature limitations of the joints and the components. Provisions shall be made to prevent disengagement of the joints at bends and dead ends and to support lateral reactions produced by branch connections or other causes.

III-2.4.7 Proprietary Joints. Metal coupling, mechanical, gland and other proprietary joints may be used within the limitations on materials in para. III-3.0, on components in para. III-2.3, and the following.

(A) Adequate provisions shall be made to prevent the separation of joints under internal pressure, temperature and external loads.

(B) Prior to acceptance for use, a prototype joint shall be subjected to performance tests to determine the safety of the joint under test conditions simulating all expected fluid service conditions.

III-2.5 Expansion and Flexibility

III-2.5.1 General Concepts

(A) Elastic Behavior. The concept of piping strain imposed by the restraint of thermal expansion or contraction, and by external movements, applies in principle to nonmetals. Nevertheless, the assumption that stresses can be predicted from these strains in a nonmetallic piping system, based on the linear elastic characteristics of the material, is generally not valid. The variation in elastic characteristics between otherwise similar material types, between source manufacturers, and between batch

[4] The polyolefin group of materials includes polyethylene, polypropylene, and polybutylene.

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lots of the same source material, can at times be significant. If a method of flexibility analysis that assumes elastic behavior is used, the designer must be able to demonstrate its validity for the system and must establish conservative limits for the computed stresses.

(B) Overstrained Behavior. Stresses cannot be considered proportional to displacement strains in nonmetallic piping systems where an excessive level of strain may be produced in a localized area of the system, and in which elastic behavior of the piping material is uncertain. (See unbalanced systems in para. 119.3 of the Code.) Overstrain must be minimized by effective system routing in order to avoid the necessity of a requirement for special joints or expansion devices for accommodating excessive displacements.

(C) Progressive Failure. In thermoplastics and some thermosetting resins, displacement strains are not likely to produce immediate failure of piping but may produce unacceptable distortion. Thermoplastics, particularly, are prone to progressive deformation that may occur upon repeated thermal cycling or under prolonged exposure to elevated temperature.

(D) Brittle Failure. In brittle thermosetting resins, the materials are essentially rigid in behavior and may readily develop high-displacement stresses, to the point of sudden breakage or fracture, under moderate levels of strain.

III-2.5.2 Properties for Flexibility Analysis

(A) Thermal Expansion Data. Table III-4.3.1 of this Appendix lists coefficients of thermal expansion for several nonmetallic materials. More precise values in some instances may be obtained from the manufacturers of these materials. If these values are to be used in stress analysis, the thermal displacements shall be determined as indicated in para. 119.

(B) Modulus of Elasticity. Table III-4.3.2 lists representative data on the tensile modulus of elasticity E for several nonmetals. More precise values in some instances may be obtained from the materials manufacturer. (Note that the modulus may vary with the geometrical orientation of a test sample for filler-reinforced, filament-wound, or impregnated nonmetallic materials.) For materials and temperatures not listed, refer to an authoritative source, such as publications of the National Bureau of Standards.

(C) Poisson's Ratio. For nonmetals, Poisson's ratio will vary widely, depending upon materials and temperature. For that reason formulas used in linear elastic stress analysis can be used only if the manufacturer has test data to substantiate the use of a specific Poisson's ratio for that application.

(D) Dimensions. The nominal thickness and outside diameters of pipe and fittings shall be used in flexibility calculations.

III-2.5.3 Analysis

(A) Formal stress analysis is not required for systems that:

(A.1) are duplicates, or replacements without significant change, of successfully operating installations; or

(A.2) can readily be judged adequate by comparison with previously analyzed systems; or

(A.3) are routed with a conservative margin of inherent flexibility, or employ joining methods or expansion joint devices, or a combination of these methods, in accordance with applicable manufacturer's instruction.

(B) A substantiating stress analysis is required for a system not meeting the above criteria. The designer may demonstrate that adequate flexibility exists by employing a simplified, approximate, or comprehensive stress analysis, using a method that can be shown to be valid for the specific case. If essentially elastic behavior can be demonstrated for a piping system [see para. III-2.5.1(A)], the methods outlined in para. 119 may be applicable.

(C) Special attention shall be given to movement (displacement or rotation) of the piping with respect to supports and points of close clearance. Movements of a run at the junction of a small branch shall be considered in determining the need for flexibility in the branch.

III-2.5.4 Flexibility

(A) Piping systems shall have sufficient flexibility to prevent the effects of thermal expansion or contraction, the movement of pipe supports or terminal points, or pressure elongation from causing:

(A.1) failure of piping or supports from overstrain or fatigue;

(A.2) leakage at joints; or

(A.3) unacceptable stresses or distortion in the piping or in connected equipment.

(B) Where nonmetallic piping and components are used, piping systems must be designed and routed so that flexural stresses resulting from displacements due to expansion, contraction and other causes are minimized. This concept requires special attention for supports and restraints, the terminal connections, and for the techniques outlined in para. 119.5.1. Further infor-

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mation on the design of thermoplastic piping can be found in PPI Technical Report TR-21.

III-2.6 Design of Pipe Supporting Elements

III-2.6.1 General. In addition to the other applicable requirements of paras. 120 and 121, supports, guides, and anchors shall be selected and applied to comply with the requirements of para. III-2.5, and the following.

(A) Support or restraint loads shall be transmitted to piping attachment or bearing points in a manner that will preclude pipe wall deformation or damage. Padding or other isolation material should be installed in support or restraint clearance spaces for added protection.

(B) Valves and in-line components shall be independently supported to prevent the imposition of high load effects on the piping or adjacent supports.

(C) Nonmetallic piping should be guarded where such systems are exposed to casual damage from traffic or other work activities.

(D) A manufacturer's recommendations for support shall be considered.

III-2.6.2 Thermoplastic and RTR Piping. Supports shall be spaced to avoid excessive displacement at design temperature and within the design life of the piping system. Decreases in the modulus of elasticity, with increasing temperature, and creep of the material, with time, shall be considered where applicable. The coefficient of thermal expansion of most plastic materials is high and must be considered in the design and location of supports and restraints.

III-2.7 Burial of RTR Pipe

III-2.7.1 Design. The design procedures of ANSI/AWWA C-950, Appendix A shall apply. A minimum pipe stiffness shall meet the requirements in Table 6 of ANSI/AWWA C-950. The minimum stiffness ($F/\Delta y$) shall be determined at 5% deflection using the apparatus and procedures of ASTM D 2412.

III-2.7.2 Installation. The pipe manufacturer's recommendations shall be equal to or more stringent than those described in ASTM D 3839 for RTR pipe or ASTM D 2774 for thermoplastic pipe. The manufacturer's recommendations should be followed.

III-3.0 MATERIALS

III-3.1 General Requirements

Paragraph III-3.0 provides limitations and qualifications for materials based on their inherent properties. The use of these materials in piping may also be subject to requirements and limitations in other parts of the Code.

III-3.2 Materials and Specifications

III-3.2.1 Listed Materials. Listed materials used in pressure containing piping shall have basic allowable stresses and other design limits as covered in para. III-2.1.

III-3.2.2 Unlisted Materials. Unlisted materials used in pressure containing piping shall have basic allowable stresses and other design limits determined in accordance with para. III-2.1, or on a more conservative basis.

III-3.2.3 Unknown Materials. Materials of an unknown specification or standard shall not be used.

III-3.2.4 Reclaimed Materials. Reclaimed piping components may be used provided they are properly identified as conforming to a listed specification and otherwise meet the requirements of this Appendix. Sufficient cleaning and examination shall be performed to determine that the components are acceptable for the intended service, considering at least the following:

(A.1) minimum available wall thickness;

(A.2) extent of any imperfections;

(A.3) possible loss of strength;

(A.4) chemical absorption.

III-3.3 Temperature Limitations

The designer shall determine that materials which meet other requirements of this Appendix are suitable for the fluid service throughout the operating temperature range of the systems in which the materials will be used.

III-3.3.1 Upper Temperature Limitations

(A) The maximum design temperature for a listed material shall not exceed maximum temperatures listed in Tables III-4.2.1, III-4.2.2, or III-4.2.3, as applicable, except as provided in para. III-2.1.3(A).

(B) An unlisted material acceptable under para. III-3.2.2 shall have upper temperature limits established in accordance with para. III-2.1.2.

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III-3.3.2 Lower Temperature Limitations

(A) The minimum design temperature for a listed material shall not be lower than the minimum temperatures listed in Tables III-4.2.1 and III-4.2.2, as applicable, except as provided in para. III-2.1.3(A).

(B) An unlisted material acceptable under para. III-3.2.2 shall have lower temperature limits established in accordance with the manufacturer's recommendation but in no case less than –20°F.

III-3.4 Fluid Service Limitations

III-3.4.1 General Limitations. The use of nonmetallic piping materials and components, under the scope of this Appendix, shall be limited to those services and conditions stated in para. III-1.2.2. In addition:

(A) nonmetallic materials shall not be used under severe cyclic conditions unless it can be demonstrated that the materials are suitable for the intended service in accordance with para. III-2.2.9;

(B) these materials shall be appropriately protected against transient or operating temperatures and pressures beyond design limits, and shall be adequately protected against mechanical damage;

(C) limitations on the use or application of materials in this Appendix apply to pressure containing parts. They do not apply to the use of materials for supports, linings, gaskets, or packing.

III-3.4.2 Specific Material Limitations

(A) Thermoplastics shall be installed and protected against elevated temperatures.

(B) Thermosetting and fiber-reinforced thermosetting resins shall be limited to the services stated in para. III-1.2.3 and shall be installed and protected against mechanical damage, vibration, and excessive cyclic strain in service.

III-3.4.3 Miscellaneous Materials: Joining and Auxiliary Materials. When selecting materials, such as cements, solvents, packing, and O-rings for making or sealing joints, the designer shall consider their suitability for the fluid service.

III-3.5 Piping Component Requirements

III-3.5.1 Dimensions of Piping Components

(A) Listed Piping Components. Dimensions of listed piping components, including tolerances, shall conform to the applicable piping component specification or standard listed in Table III-4.1.1.

(B) Unlisted Piping Components. Dimensions of unlisted piping components, including tolerances, shall conform to those of comparable listed piping components insofar as practical. In all cases, dimensions shall be such as to provide strength and performance equivalent to listed piping components and shall meet the requirements of para. III-2.2.9.

(C) Threads. Dimensions of piping connection threads not covered by a governing component specification or standard shall conform to para. III-2.4.5.

III-4.0 SPECIFICATIONS AND STANDARD DATA

III-4.1 Material Specifications and Standards

III-4.1.1 Standard Piping Components. Dimensions of standard piping components shall comply with the standards and specifications listed in Table III-4.1.1, in accordance with the requirements of para. III-2.1.2(A). Abbreviations used in this Appendix and in Table III-4.1.1 are listed in para. III-1.3.2.

III-4.1.2 Nonstandard Piping Components. Where nonstandard piping components are designed in accordance with para. III-2.2, adherence to dimensional standards of ANSI and ASME is strongly recommended where practical.

III-4.1.3 Reference Documents

(A) The documents listed in Table III-4.1.1 may contain references to codes, standards, or specifications not listed in the Table. Such unlisted codes, standards, or specifications are to be used only in the context of the listed documents in which they appear.

(B) Where documents listed in Table III-4.1.1 contain design rules that are in conflict with this Appendix, the design rules of this Appendix shall govern.

(C) The fabrication, assembly, examination, inspection, and testing requirements of Parts 5 and 6 of this Appendix apply to the construction of piping systems. These requirements are not applicable to the manufacture of material or components listed in Table III-4.1.1, unless specifically stated.

III-4.2 Stress and Temperature Limits

Tables III-4.2.1, III-4.2.2, and III-4.2.3 provide listings of the stress and recommended temperature limits for the following, in accordance with paras. III-2.1.3(A) and (B).

III-4.2.1 Thermoplastic Piping Components. Table III-4.2.1 provides hydrostatic design stresses (HDS) and recommended temperature limits for thermoplastic piping components.

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TABLE III-4.1.1
NONMETALLIC MATERIAL AND PRODUCT STANDARDS

Standard or Specification	Designation[1,2]
Nonmetallic Fittings	
Threaded Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Sch 80	ASTM D 2464-90
Poly(Vinyl Chloride) PVC Plastic Pipe Fittings, Schedule 40	ASTM D 2466-90a
Socket-Type Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80	ASTM D 2467-90
Acrylonitrile-Butadiene-Styrene ABS Plastic Pipe Fittings, Schedule 40	ASTM D 2468-89
Thermoplastic Gas Pressure Pipe, Tubing, and Fittings	ASTM D 2513-90b
Reinforced Epoxy Resin Gas Pressure Pipe and Fittings	ASTM D 2517 (R1987)
Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe	ASTM D 2609-90
Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing	ASTM D 2683-90
Chlorinated Poly(Vinyl Chloride) CPVC Plastic Hot and Cold Water Distribution Systems	ASTM D 2846-90
Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing	ASTM D 3261-90
Polybutylene (PB) Plastic Hot-Cold-Water Distribution Systems	ASTM D 3309-89a
Reinforced Thermosetting Resin (RTR) Flanges	ASTM D 4024-87
Threaded Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80	ASTM F 437-89a
Socket-Type Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40	ASTM F 438-89a
Socket-Type Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80	ASTM F 439-89
Nonmetallic Pipe and Tube Products	
Polyethylene Line Pipe	API 15LE (1987)
Thermoplastic Line Pipe (PVC and CPVC)	API 15LP (1987)
Low Pressure Fiberglass Line Pipe	API 15LR (1986)
Concrete Sewer, Storm Drain, and Culvert Pipe	ASTM C 14-82
Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, Sch 40 and 80	ASTM D 1527-77 (1989)
Poly(Vinyl Chloride) (PVC) Plastic Pipe, Sch 40, 80 and 120	ASTM D 1785-89
Polyethylene (PE) Plastic Pipe, Schedule 40	ASTM D 2104-89
Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter	ASTM D 2239-89
Poly(Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)	ASTM D 2241-89
Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR)	ASTM D2282-89
Machine-Made Reinforced Thermosetting-Resin Pipe	ASTM D 2310-80 (1986)
Polyethylene (PE) Plastic Pipe, Sch 40 and 80, Based on Outside Diameter	ASTM D 2447-89
Thermoplastic Gas Pressure Pipe, Tubing, and Fittings	ASTM D 2513-86A
Reinforced Epoxy Resin Gas Pressure Pipe and Fittings	ASTM D 2517 (R1987)
Polybutylene (PB) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter	ASTM D 2662-89
Polybutylene (PB) Plastic Tubing	ASTM D 2666-89
Joints for IPS PVC Pipe Using Solvent Cement	ASTM D 2672-89
Polyethylene (PE) Plastic Tubing	ASTM D 2737-89
Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution System	ASTM D 2846-90
Filament-Wound "Fiberglass" (Glass-Fiber Reinforced Thermosetting-Resin) Pipe	ASTM D 2996-88
Centrifugally Cast Reinforced Thermosetting Resin Pipe	ASTM D 2997-90
Polybutylene (PB) Plastic Pipe (SDR-PR) Based on Outside Diameter	ASTM D 3000-89
Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Controlled Outside Diameter	ASTM D 3035-89a
PB Plastic Hot-Water Distribution Systems	ASTM D 3309-89a
Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80	ASTM F 441-89
Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe, (SDR-PR)	ASTM F 442-87
PVC Pressure Pipe, 4-inch through 12-inch, for Water	*AWWA C 900
AWWA Standarda for Glass-Fiber-Reinforced Thermosetting-Resin Pressure Pipe	*AWWA C 950-88
Miscellaneous	
Standard Methods of Testing Vitrified Clay Pipe	ASTM C 301-87
Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion Resistant Equipment	ASTM C 582-87
Standard Definitions of Terms Relating to Plastics	ASTM D 297-81

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TABLE III-4.1.1 (CONT'D)
NONMETALLIC MATERIAL AND PRODUCT STANDARDS (CONT'D)

Standard or Specification	Designation[1,2]
Miscellaneous (Cont'd)	
Standard Abbreviations of Terms Relating to Plastics	ASTM D 1600-90
Threads 60° (Stub) for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe	*ASTM D 1694-91
Solvent Cements for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings	ASTM D 2235-88
External Loading Properties of Plastic Pipe by Parallel-Plate Loading	ASTM D 2412-87
Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Pipe and Fittings	ASTM D 2564-88
Heat-Joining Polyolefin Pipe and Fitting	ASTM D 2657-90
Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials	ASTM D 2837-90
Making Solvent-Cemented Joints With Poly (Vinyl Chloride) (PVC) Pipe and Fittings	ASTM D 2855-90
Standard Test Method For External Pressure Resistance of Reinforced Thermosetting Resin Pipe	ASTM D 2924-86
Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings	*ASTM D 2992-87
Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals	ASTM D 3139-89
Underground Installation of "Fiberglass" (Glass-Fiber Reinforced Thermosetting Resin) Pipe	ASTM D 3839-89
Design and Construction of Nonmetallic Enveloped Gaskets for Corrosive Service	ASTM F 336-87
Solvent Cements for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe and Fittings	ASTM F 493-89
Plastic Pipe Institute (PPI) Technical Report Thermal Expansion and Contraction of Plastic Pipe	PPI TR21-88

NOTES:
(1) An asterisk (*) preceding the designation indicates that the standard has been approved as an American National Standard by the American National Standards Institute.
(2) Numbers in parentheses are reapproval dates.

III-4.2.2 Laminated Reinforced Thermosetting Resin Piping Components. Table III-4.2.2 provides design stresses (DS) and recommended temperature limits for laminated reinforced thermosetting resin piping components.

III-4.2.3 Machine-Made Reinforced Thermosetting Resin Pipe. Table III-4.2.3 provides hydrostatic design bases (HDB) at a temperature level of 73°F for machine-made reinforced thermosetting resin pipe.

III-4.2.4 Notes for Tables III-4.2.1, III-4.2.2, and III-4.2.3. Notations may be identified in the body of Tables 4.2.1, 4.2.2, and 4.2.3 relative to the information, as applicable, in Notes (1) through (10) that follow Table III-4.2.3.

III-4.3 Standard Data

The following data are available and are acceptable for design purposes at the present time. It should be noted for all properties that individual compounds may vary from the values shown. Manufacturers should be consulted for specific values that may be applicable for their products.

III-4.3.1 See Table III-4.3.1 Thermal Expansion Coefficients, Nonmetals.

III-4.3.2 See Table III-4.3.2 Modulus of Elasticity, Nonmetals.

III-5.0 FABRICATION, ASSEMBLY, AND ERECTION

III-5.1 Bonding Plastic Joints

III-5.1.1 General

(A) Bonded joints which conform to para. III-5.0 may be used in accordance with para. III-2.4.2.

(B) Production joints shall be made only in accordance with a written Bonding Procedure Specification (BPS) that has been qualified in accordance with para. III-5.1.2.

(C) Production joints shall be made only by qualified bonders or bonding operators who have satisfactorily passed a performance qualification test that has been performed in accordance with a written BPS in accordance with para. III-5.1.2.

(D) Qualification in one BPS does not qualify a

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TABLE III-4.2.1
HYDROSTATIC DESIGN STRESSES (HDS) AND RECOMMENDED TEMPERATURE LIMITS FOR THERMOPLASTIC PIPING COMPONENTS

ASTM Spec. No.	Material	Recommended Temperature Limits[1,2,3] Minimum,[4] °F	Recommended Temperature Limits[1,2,3] Maximum,[5] °F	Hydrostatic Design Stress at 73°F,[6] ksi	Hydrostatic Design Stress at 100°F, ksi	Hydrostatic Design Stress at 180°F, ksi
D 1527, D 2282, D 2513	ABS1210	0	180	1.0	0.8	...
	ABS1316	0	160	1.6	1.25	...
	ABS2112	0	180	1.25	1.0	...
...	AP	0	170	...	...	...
...	CP	0	210	0.8	...	...
D 2846, F 441, F 442	CPVC4120	0	200	2.0	1.6	0.5
...	PA	−20	180	...	...	...
D 2513, D 2662, D 2666, D 3000, D 3309	PB2110	0	210	1.0	0.8	0.5
D 2104, D 2239, D 2447, D 2513, D 2737, D 3035	PE2306	−30	140	0.63	0.4	...
	PE3306	−30	140	0.63	0.5	...
	PE3406	−30	140	0.63	0.5	0.25
	PE3408	−30	140	0.80	...	...
...	POP2125	30	210	...	...	...
...	PP	30	210	...	...	...
D 1785, D 2241, D 2513, D 2672	PVC1120	0	140	2.0	1.6	...
	PVC1220	0	150	2.0	1.6	...
	PVC2110	0	130	1.0	0.8	...
	PVC2112	0	130	1.25	1.0	...
	PVC2116	0	150	1.6	1.25	...
	PVC2120	0	150	2.0	1.6	...
...	PVDC	40	160	...	...	...
...	PVDF	0	275	...	...	...

Notes for this Table follow below Table III-4.2.3

bonder or bonding operator for any other bonding procedure.

(E) Bonding materials which have deteriorated by exposure to air or prolonged storage or which will not spread smoothly shall not be used.

(F) Longitudinal joints are not within the scope of para. III-5.1.

(G) Joint Identification. Each qualified bonder and bonding operator shall be assigned an identification symbol. Unless otherwise specified in the engineering design, each pressure containing bond or adjacent area shall be stenciled or otherwise suitably marked with the identification symbol of the bonder or bonding operator. Identification stamping shall not be used and

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TABLE III-4.2.2
DESIGN STRESSES (DS) AND RECOMMENDED TEMPERATURE LIMITS FOR LAMINATED REINFORCED THERMOSETTING RESIN PIPING COMPONENTS

ASTM Spec. No.	Type	Resin	Reinforcing	Recommended Temperature Limits[3] Minimum, °F	Maximum, °F	Thickness, in.	Design Stress,[7] ksi
C 582	I	Polyester	Glass fiber	−20	180	1/8–3/16	0.9
						1/4	1.2
						5/16	1.35
						3/8 & up	1.5
...	...	Furan	Carbon	−20	180	...	...
...	...	Furan	Glass fiber	−20	180	...	...
C 582	II	Epoxy	Glass fiber	−20	180	1/8–3/16	0.9
						1/4	1.2
						5/16	1.35
						3/8 & up	1.5

Notes for this Table follow below Table III-4.2.3

any marking paint or ink shall not be detrimental to the piping material. In lieu of marking the bond, appropriate records shall be filed.

III-5.1.2 Qualification

(A) Qualification of the BPS to be used, and of the performance of bonders and bonding operators, is required. Bonding Procedure Specifications shall specify, for both the bonding operation and qualification testing requirements, all required materials, including material storage requirements; the fixtures and tools required, including the care of tools; and the temperature requirements for all operations, including the methods required for temperature measurement.

(B) Bonding Responsibility. An employer of bonding personnel is responsible for the bonding done by members of his organization and, except as provided in (C) below, shall conduct the required performance qualification tests to qualify the bonding procedure specifications and the bonders or bonding operators.

(C) Qualification by Others

(C.1) Bonding Procedure Specification (BPS). The piping system erector shall be responsible for qualifying a BPS that personnel of his organization will use. Subject to the specific approval of the designer, a BPS qualified by others may be used if the following conditions apply.

(C.1.1) The designer accepts that the proposed qualified BPS has been prepared and executed by a responsible recognized organization with expertise in the field of bonding.

(C.1.2) The designer accepts both the BPS and Procedure Qualification Record (PQR) by signature as his own.

(C.1.3) The piping erector has at least one bonder, currently employed, who has satisfactorily passed a performance qualification test using the proposed qualified BPS.

(C.2) Bonding Performance Qualification. A piping erector shall not accept a performance qualification test made by a bonder or bonding operator for another piping erector without the designer's specific approval. If approval is given, acceptance is limited to performance qualification tests on piping using the same or an equivalent BPS. The piping erector accepting such performance qualification tests shall obtain a copy of the PQR from the previous erector, showing the name of the piping erector by whom bonders or bonding operators were qualified, the dates of such qualification, and the date the bonder or bonding operator last assembled pressure piping under the previous performance qualification.

(D) Qualification tests for the bonding procedure and operator performance shall comply with the requirements of the BPS and the following.

(D.1) A test assembly shall be fabricated in accordance with the bonding procedure specification. The test assembly shall consist of at least one pipe-to-pipe joint and one pipe-to-fitting joint. The size of the pipe used for the test assembly shall be as follows.

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TABLE III-4.2.3
HYDROSTATIC DESIGN BASIS (HDB) FOR MACHINE-MADE REINFORCED THERMOSETTING RESIN PIPE

ASTM Spec. No. and Type	Grade	Class	Material Designation ASTM D 2310	HDB Stress[8] at 73°F[9,10] Cyclic,[11] ksi	HDB Stress[8] at 73°F[9,10] Static,[12] ksi
D 2517 filament wound	Glass fiber reinforced epoxy resin	No liner	RTRP-11AD	5.0	...
			RTRP-11AW	...	16.0
D 2996 filament wound	Glass fiber reinforced epoxy resin	No liner	RTRP-11AD	5.0	...
			RTRP-11AW	...	16.0
		Epoxy resin liner, reinforced	RTRP-11FE	6.3	...
			RTRP-11FD	5.0	...
	Glass fiber reinforced polyester resin	Polyester resin liner, reinforced	RTRP-12EC	4.0	...
			RTRP-12ED	5.0	...
			RTRP-12EU	...	12.5
		No liner	RTRP-12AD	5.0	...
			RTRP-12AU	...	12.5
D 2997 centrifugally cast	Glass fiber reinforced polyester resin	Polyester resin liner, nonreinforced	RTRP-22BT	...	10.0
			RTRP-22BU	...	12.5
		Epoxy resin liner, nonreinforced	RTRP-21CT	...	10.0
			RTRP-21CU	...	12.5

NOTES TO TABLES III-4.2.1, III-4.2.2, AND III-4.2.3:
(1) These recommended limits are for low pressure applications with water and other fluids that do not significantly affect the properties of the thermoplastic material. In conservative practice, the upper temperature limits may be reduced at higher pressures depending on the required service and expected life. Lower temperature limits are affected more by the environment, safeguarding, and installation conditions than by strength.
(2) Because of low thermal conductivity, temperature gradients through the piping component wall may be substantial. Tabulated limits apply where more than half the wall thickness is at or below the stated temperature.
(3) These recommended limits apply only to listed materials. Manufacturers should be consulted for temperature limits on specific types and kinds of materials not listed.
(4) Minimum for installation.
(5) Maximum for operation.
(6) Use these hydrostatic design stress values at all lower temperatures.
(7) The design stress (DS) values apply only in the temperature range of −20°F through 180°F.
(8) A service (design) factor must be applied to these HDB values to obtain the HDS.
(9) These HDB values apply only at 73°F.
(10) Recommended temperature limits for these materials are shown in Table III-4.2.2.
(11) When using the cyclic design basis, the service factor shall not exceed 1.0.
(12) When using the static design basis, the service factor shall not exceed 0.5.

(D.1.1) When the largest size to be joined (within the BPS) is 4 in. NPS or smaller, the test assembly shall be the same NPS as the largest size to be joined.

(D.1.2) When the largest size to be joined within the BPS is greater than 4 in. NPS, the test assembly shall be made of piping components either 4 in. NPS or a minimum of 25% of the NPS of the largest piping component to be joined, whichever is larger.

(D.2) The test assembly shall be subjected to one of the following qualification test operations.

(D.2.1) When the test assembly has been cured, it shall be subjected to a hydrostatic pressure test of the

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TABLE III-4.3.1
THERMAL EXPANSION COEFFICIENTS, NONMETALS

Material Description	Mean Coefficients[1] in./in., °F	Range, °F
Thermoplastics		
Acetal AP2012	2	...
Acrylonitrile-butadiene-styrene		
ABS 1208	60	...
ABS 1210	55	45–55
ABS 1316	52	...
ABS 2112	60	...
Chlorinated poly (vinyl chloride)		
CPVC 4120	30	...
Polybutylene PB 2110	72	...
Polyether, chlorinated	45	...
Polyethylene		
PE 2306	90	70–100
PE 3306	90	70–120
PE 3406	90	70–120
PE 3408	90	70–120
Polyphenylene POP 2125	30	...
Polypropylene		
PP1110	48	33–67
PP1208	43	...
PP2105	40	...
Poly (vinyl chloride)		
PVC1120	30	23–373
PVC1220	35	34–40
PVC2110	50	...
PVC2112	45	...
PVC2116	40	37–45
PVC2120	30	...
Vinylidine fluoride	85	...
Vinylidine/vinyl chloride	100	...
Reinforced Thermosetting Resins		
Glass-epoxy, centrifugally cast	9–13	...
Glass-polyester, centrifugally cast	9–15	...
Glass-polyester, filament-wound	9–11	...
Glass-polyester, hand lay-up	12–15	...
Glass-epoxy, filament-wound	9–13	...
Other Nonmetallic Materials		
Hard rubber (Buna N)	40	...

NOTE:
(1) Divide table values by 10^6.

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TABLE III-4.3.2
MODULUS OF ELASTICITY, NONMETALS

Material Description	E,[1] ksi (73.4°F)
Thermoplastics	
Acetal	410
ABS, Type 1210	300
ABS, Type 1316	340*
PVC, Type 1120	410
PVC, Type 1220	410
PVC, Type 2110	340*
PVC, Type 2116	360
Chlorinated PVC	420*
Chlorinated Polyether	160*
PE, Type 2306	120
PE, Type 3306	130
PE, Type 3406	130
PE, Type 3408	130
Polypropylene	120*
Polypropylene (vinylidene/chloride)	100*
Poly(vinylidene fluoride)	194*
Poly(tetrafluoroethylene)	57*
Poly(fluorinated ethylenepropylene)	67*
Poly(perfluoroalkoxy)	100*
Thermosetting Resins, Axially Reinforced	
Epoxy-glass, centrifugally cast	1200–1900
Epoxy-glass, filament-wound	1100–2000
Polyester-glass, centrifugally cast	1200–1900
Polyester-glass, filament-wound	1100–2000
Polyester-glass, hand lay-up	800–1000
Other	
Hard rubber (Buna N)	300

NOTE:
(1) The modulus of elasticity values for thermosetting resin pipe are given in the longitudinal direction; different values may apply in the circumferential or hoop direction. The modulus of elasticity values for thermoplastic resin pipe are temperature-dependent and stress-time related. Values noted with an asterisk (*) have not been confirmed by industry-accepted standards. In all cases for materials listed in this Table, manufacturers may be consulted for specific product information.

maximum of either 150 psig or 1.5 times an equivalent allowable pressure which shall be calculated using the least nominal wall thickness and outside diameter of the pipe in the test assembly. This pressure shall be determined using the equation in para. III-2.2.2(A) for the test material. The test shall be conducted so that the joint is loaded in both the circumferential and longitudinal directions. Joints shall not leak or separate when tested.

(D.2.2) When a test assembly is joined by heat fusion, the fusion joints may be tested by cutting a minimum of three coupons containing the joint and bending the strips using a procedure which shall be defined in the BPS. As a minimum requirement, the test strips shall not break when bent a minimum of 90 deg, at ambient temperature, over an inside bend radius of 1.5 times the nominal diameter of the tested pipe.

(E) Performance Requalification

(E.1) Renewal of a bonding performance qualification is required when:

(E.1.1) a bonder or bonding operator has not used

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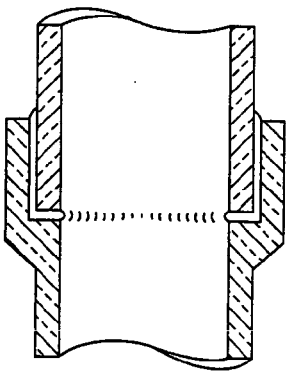

FIG. III-5.1.3(A)

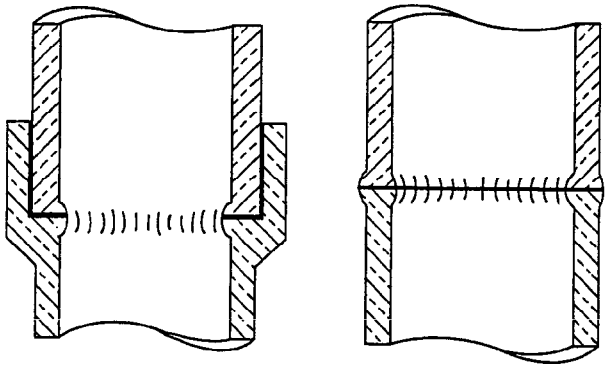

FIG. III-5.1.3(B)

the specific bonding process for a period of time greater than 6 months, or a specific maximum period of time otherwise permitted in the BPS for the work;

(E.1.2) there is a specific reason to question a bonder or bonding operator's ability to make bonds that meet the BPS.

(E.2) Renewal of a bonding performance qualification for a specific bonding process may be made in only a single test assembly.

(F) Qualification Records. An erector using bonders, or bonder operators, shall maintain a record of the procedures used and of operators employed by him who are qualified in these procedures.

III-5.1.3 Thermoplastic Joints

(A) Solvent-Cemented Joints

(A.1) Preparation. PVC and CPVC surfaces to be cemented shall be cleaned by wiping with a clean cloth moistened with acetone or methylethyl ketone. Cleaning for ABS shall conform to ASTM D 2235. Cuts shall be free of burrs and circumferential cuts shall be as square as those obtained by the use of a saw with a miter box or a square-end sawing vise. A slight interference fit between the pipe and a fitting socket is preferred, and the diametral clearance between a pipe and the entrance of a mating socket shall not exceed 0.04 in. This fit shall be checked before solvent cementing.

(A.2) Procedure. Joints shall be made in accordance with a qualified BPS. ASTM D 2855 provides a suitable basis for such a procedure. Solvent cements for PVC, CPVC, and ABS shall conform to ASTM D 2564, D 2846, and D 2235, respectively. Cement shall be applied to both joint surfaces. The amount of cement shall be sufficient to produce a small continuous fillet of cement at the outer limits of the joints. See Fig. III-5.1.3(A)

(A.3) Branch Connections. For branch connections not using a tee, a manufactured full reinforcement saddle with an integral branch socket shall be solvent cemented to the run pipe over its entire contact surface.

(A.4) Limitations on Imperfections. Imperfections exceeding the following limitations are considered defects and shall be repaired and reexamined in accordance with para. III-5.1.5:

(A.4.A) protrusion of dried cement exceeding 50% of pipe wall thickness into the bore of the pipe; or

(A.4.B) unfilled or unbonded areas in a joint as indicated by the lack or interruption of the continuous fillet noted in (A.2) above.

(B) Heat Fusion Joints

(B.1) Preparation. Surfaces to be heat fused together shall be cleaned of any foreign material. Cuts shall be free of burrs, and circumferential cuts shall be as square as those obtained by the use of a saw with a miter box or a square-end sawing vise.

(B.2) Procedure. Joints shall be made in accordance with a qualified BPS. The general procedures in ASTM D 2657, Technique I-Socket Fusion, II-Butt Fusion, and III-Saddle Fusion provide a suitable basis for such a procedure. Both surfaces to be joined shall be uniformly heated to produce a continuous homogeneous bond between them. This will produce a small continuous fillet of fused material at the outer limits of the joints. See Fig. III-5.1.3(B).

(B.3) Branch Connections. Branch connections shall be made only with the use of molded fittings in sizes that are commercially available.

(B.4) Limitations on Imperfections. Imperfections exceeding the following limitations are considered defects and shall be repaired and reexamined in accordance with para. III-5.1.5:

(B.4.A) protrusion of fused material exceeding 25% of the pipe wall thickness into the bore of the pipe; or

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01 *(B.4.B)* unfilled or unbonded areas in a joint as indicated by the lack or interruption of the continuous fillet noted in (B.2) above.

III-5.1.4 Thermosetting Resin Joints

(A) Preparation. Cutting of pipe and preparation of bonding surfaces shall be done, as recommended by the manufacturer, without chipping or cracking of the cut ends; particularly, the inner surface of centrifugally cast pipe. Pipe may be preheated, if necessary, to comply with the above requirements. Cuts shall be free of burrs, and circumferential cuts shall be as square as required by the purchaser's specifications or the recommendations of the manufacturer, whichever requires the closer squareness. For branch connections, holes in the run pipe may be made with a hole saw. Mold release agent and any other material which may interfere with adhesion shall be removed from surfaces to be bonded.

(B) Joining Procedures

(B.1) Socket and Spigot Joints. Joints shall be made in accordance with a qualified BPS based on the manufacturer's recommended procedure. Application of adhesive to the surfaces to be joined, and assembly of those surfaces shall produce a continuous bond between them. Cut ends of the pipe and edges of the laminate fabric shall be sealed to prevent fluid penetration of the pipe wall or the laminate material.

(B.2) Butt-and-Wrap Joints. Joints shall be made in accordance with a qualified BPS. The general procedures in ASTM C 582 Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion Resistant Equipment provide a suitable basis for the development of such a procedure. Application of plies of reinforcement, saturated with catalyzed resin, to the surfaces to be joined shall produce a continuous structure with the surfaces. Cut ends shall be sealed as required in (B.1) above.

(C) Branch Connections. Branch connections shall be made using a manufactured tee fitting or a full reinforcement saddle having suitable provisions for joining as in (B) above. The cut edges of any hole in the run pipe shall be sealed with adhesive at the time the saddle is bonded to the run pipe.

(D) Limitations on Imperfections. Imperfections exceeding the following limitations are considered defects and shall be repaired and reexamined in accordance with para. III-5.1.5:

(D.1) protrusion of adhesive exceeding 25% of pipe wall thickness into the bore at the bottom of a socket, or inside a branch connection; or

(D.2) unfilled or unbonded areas in the joint.

III-5.1.5 Repair of Defects. Defective material, joints and other workmanship in piping which fail to meet the requirements of paras. III-3.0 and III-5.0, and of the engineering design, shall be repaired or replaced. Limitations on imperfections, and the method and extent of the required examination of repairs and replacements, shall be the same as for the original work.

III-5.2 Bending

III-5.2.1 Pipe Bending. Flattening of a bend is defined as the difference between the maximum and minimum outside diameters, at any cross section, expressed as a percentage of the nominal outside diameter. Flattening shall not exceed 8% for pipe exposed to internal pressure. For pipe under external pressure, flattening shall not exceed 3%. The thickness after bending shall not be less than that required in para. III-2.2.4(A).

III-5.2.2 Bending Methods. Pipe may be bent by any suitable hot or cold method permissible by radii limitations and material characteristics of the pipe being bent. Hot bending shall be done within a temperature range consistent with material characteristics, end-use requirements, and the pipe manufacturer's recommendations.

III-5.3 Component Forming

Piping components may be formed by any suitable hot or cold method permissible by the characteristics of the material being formed. Forming shall be done within a temperature range consistent with the material characteristics, end-use requirements, and the component manufacturer's recommendations. The thickness after forming shall not be less than that required by the engineering design.

III-5.4 Assembly and Erection

III-5.4.1 General. The assembly and erection of nonmetallic piping systems shall comply with the requirements of para. 135 of the Code and para. III-5.0 of this Appendix. In addition:

(A) when assembling nonmetallic flanges, flat washers shall be used under all bolt heads and nuts. The specified maximum bolt torque shall not be exceeded.

(B) full circumference wrenches shall be used to tighten threaded pipe joints. Tools and other devices used to hold or apply forces to the pipe shall be such that pipe surfaces are not scored or deeply scratched. For thermosetting resin piping, threads shall be coated

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with sufficient adhesive to cover the threads and completely fill the clearance between the pipe and fittings.

III-6.0 EXAMINATION, INSPECTION, AND TESTING

III-6.1 General

The general requirements of Chapter VI with regard to visual examination and leak testing are basically applicable to nonmetallic piping systems.

III-6.2 Examination and Inspection

III-6.2.1 Visual Examination

(A) Visual examination is observation of the portion of components, joints, and other piping elements that are or can be exposed to view before, during, or after manufacture, fabrication, assembly, erection, inspection, or testing.

(B) Visual examination shall be performed in accordance with Article 9, Section V of the ASME Boiler and Pressure Vessel Code.

III-6.2.2 Examination Required

(A) Piping shall be examined at least to the extent required herein, or to any greater extent specified in the engineering design.

(A.1) Visually examine at least 5% of fabrication. For bonds (joints) each bonder or bonding operator's work shall be represented and shall include each type of bond for each bonder or bonding operator.

(A.2) Visually examine 100% of fabrication for bonds, other than circumferential bonds, and other than those in components made to material specifications recognized in this Code.

(A.3) Perform a random visual examination of the assembly of threaded, bolted, and other joints to satisfy the inspector that these conform to the requirements of para. III-5.4.1

(A.4) Perform a random visual examination during erection of piping, including checking of alignment and supports.

(A.5) Examine erected piping for evidence of damage that would require repair or replacement and for other deviations from the design.

(B) The inspector shall be assured, by examination of certifications, records, or other evidence that the materials and components are of the specified grades and that they have received the required examination and testing.

III-6.2.3 Extent of Required Examination. When visual examination reveals a defect requiring repair:

(A) two additional examinations of the same type shall be made of the same kind of item (if of a bond, others by the same bonder or bonding operator); and

(B) if the additional items examined as required by (A) above are acceptable, the item requiring repair shall be replaced or repaired and reexamined to meet the requirements of the Code, and all items represented by this additional examination shall be accepted; or

(C) if either of the items examined as required by (A) above reveals a defect, two additional items shall be examined; and

(D) if the additional items examined as required by (C) above are acceptable, the items requiring repair shall be replaced or repaired and reexamined to meet the requirements of the Code, and all items represented by this additional examination shall be accepted; or

(E) if either of the additional items examined as required by (C) above reveals a defect, all comparable items shall be replaced or they shall be fully examined, and all items requiring repair shall be repaired and reexamined to meet the requirements of the Code.

III-6.3 Pressure Tests

Leak tests, when specified shall be performed in accordance with para. 137.

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NONMANDATORY APPENDIX IV[1]
CORROSION CONTROL FOR ASME B31.1 POWER PIPING SYSTEMS

FOREWORD

Present Code rules apply to the design, materials, fabrication, erection, tests, and inspection of new piping systems normally termed "new construction."

This nonmandatory Appendix contains guidelines that are applicable to existing operating piping systems contained in the scope of ASME B31.1, as well as "new construction."

Minimum requirements for corrosion control of power piping systems are outlined herein. It is recognized that many sound, although perhaps diverse, corrosion control programs exist. The philosophy used has been to establish minimum requirements. Users are encouraged to augment these guidelines to suit their particular needs and to offer constructive criticism to the Committee on this Appendix.

IV-1.0 GENERAL

IV-1.1

External and internal corrosion should be prevented or controlled consistent with design requirements and the environment in which the system is located.

IV-1.2

Application of corrosion control requires a significant amount of competent judgment. NACE[2] RP-01-69, Recommended Practice-Control of External Corrosion on Underground or Submerged Metallic Piping Systems, and RP-01-75, Recommended Practice-Control of Internal Corrosion in Steam Pipelines and Piping Systems, provide a guide for establishing the minimum requirements for control of corrosion of underground or submerged metallic piping systems. In addition, ASME B31G, Manual for Determining the Remaining Strength of Corroded Pipelines [3] may provide additional guidance.

IV-1.3

The following minimum requirements and procedures should be provided for protection of all piping systems containing hazardous liquids or gases and other piping as specified by the owner against internal, external, and atmospheric corrosion.

IV-2.0 EXTERNAL CORROSION CONTROL FOR BURIED OR SUBMERGED PIPELINES

IV-2.1 General

IV-2.1.1 Means to prevent or mitigate external corrosion of buried or submerged piping systems should be considered in the initial design, unless it can be demonstrated by tests, investigations, or experience in the area of installation that a detrimental corrosive environment does not exist.

IV-2.1.2 A means for control of external corrosion of buried or submerged pipe and components may be accomplished through application of an effective protective coating or wrapping. This method of corrosion control can be supplemented with cathodic protection such as sacrificial anodes, rectifier-ground bed units, and suitable drainage bonds in stray current areas. Materials should be selected with due regard to the type of supplemental corrosion protection employed.

IV-2.2 Protective Coating

IV-2.2.1 Protective coatings applied for the purpose of external corrosion should:

(A) be applied on a properly prepared surface;

(B) mitigate corrosion;

(C) have sufficient adhesion to the metal surface and be free of voids so as to effectively resist underfilm migration of moisture;

(D) be sufficiently ductile to resist cracking;

(E) have sufficient strength to resist damage due to handling and soil stress;

[1] Nonmandatory Appendices are identified by a Roman numeral; mandatory Appendices are identified by a letter. Therefore, Roman numeral I is not used in order to avoid confusion with the letter I.

[2] NACE: National Association of Corrosion Engineers, P.O. Box 1499, Houston, Texas 77001

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(F) be impact resistant.

IV-2.2.2 Coatings should have low moisture absorption characteristics and provide high electrical resistance. Properly compounded concrete coatings may be used.

IV-2.2.3 Pipe coatings should be inspected visually with a holiday detector and thickness gage prior to backfilling the excavation. Any bare spots, thin areas, holidays, or other damage to the coating should be repaired and reexamined prior to backfilling.

IV-2.2.4 Precautions should be taken to minimize pipe coating damage during installation if coated pipe is installed by boring, driving, or similar method.

IV-2.2.5 Pipe coatings should be protected from damage resulting from adverse ditch conditions or damage from supporting blocks. Only fine grain backfill is permitted in contact with the coating. This fine grain layer should be continuous and of sufficient thickness to prevent coating damage from larger articles in the backfill.

IV-2.2.6 The backfilling operation should be carefully controlled to prevent damage to pipe coatings.

IV-2.3 Cathodic Protection System

IV-2.3.1 Unless it can be demonstrated by investigation, tests, or experience that cathodic protection is not needed, a cathodic protection system should be installed for all new buried carbon steel, alloy, ductile iron, cast iron, aluminum or other metallic piping.

IV-2.3.2 All cathodic protection systems should comply with one or more of the criteria contained in Section 6 of the latest issue of the NACE Standard RP-01-69.

IV-2.3.3 Cathodic protection current should be controlled so as to prevent damage to the protective coating, pipe, or components.

IV-2.4 Electrical Isolation

IV-2.4.1 Buried or submerged coated and uncoated piping systems should be electrically isolated at all interconnections with neighboring systems except where arrangements are made for mutual cathodic protection or where underground metallic structures are electrically interconnected and cathodically protected as a unit. Electrical isolation of dissimilar metals, i.e., steel pipe connected to aluminum tanks, should be provided.

IV-2.4.2 Grounding of all piping systems, where required, should be in accordance with IEEE[3] Standard 142 or acceptable alternate standards.

IV-2.4.3 The electrical continuity of all buried or submerged metallic piping systems is recommended for proper station grounding, and to facilitate the installation of cathodic protection. Continuity across all mechanical joints should be achieved by electrical bonding.

IV-2.4.4 Where piping systems are located in near electrical transmission tower footings, ground cables, ground rods, or in other areas where fault currents or unusual risk of lightning may be anticipated, piping should be provided with protection against damage which may result from fault currents or lightning. Protective measures should also be taken at insulating devices where used.

IV-2.4.5 If a pipe culvert or sleeve is used, the encased pipe should be independently supported outside each end of the sleeve and electrically insulated throughout the length of the section.

IV-2.5 Electrical Interference

IV-2.5.1 The possibility of external corrosion induced by stray electrical currents in the earth is recognized. These stray currents are generated by sources independent of the piping system, and are more predominant in highly industrialized areas, mining regions, and locales containing high voltage, direct current, electrical power ground beds. Neighbor company pipeline cathodic protection systems are also a common source of stray earth currents.

IV-2.5.2 The protection of the piping system against stray current induced corrosion should be provided by metallic bonds, increased electrical cathodic protection, supplemental protective coatings, or insulating flanges.

IV-2.5.3 Each cathodic protection system provided for the plant piping should be designed and installed so as to minimize any adverse effects on adjacent underground metallic structures.

IV-3.0 INTERNAL CORROSION CONTROL

IV-3.1

Internal corrosion might occur during operation. A liquid or gas which will corrode the internal surfaces of piping should not be transported unless its corrosive

[3] IEEE: Institute of Electrical and Electronics Engineers, 445 Hose Lane, P.O. Box 1331, Piscataway, NJ 08855

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effects have been investigated. The piping material and any lining should be selected to be compatible with the flowing fluid to minimize corrosion, in accordance with NACE Standard RP-01-75.

IV-3.2 Inhibitors

If inhibitors are used to control internal corrosion, sufficient coupon samples or other types of monitoring techniques should be utilized to determine adequately the effectiveness of the inhibitors.

IV-3.3 Linings

If linings are used to prevent corrosion, they should meet the quality specifications established by the design engineer. They should be inspected in accordance with industry recommended practices. All base material and weld metal surfaces should be covered with the lining to at least the thickness specified by the designer.

IV-3.4 Precautions at Hydrotesting

Equipment fabricated from austenitic (300 series) and ferritic (400 series) stainless steels and requiring hydrostatic testing should be tested with deionized water, high purity steam condensate, or potable water, in decreasing order of preference.

NOTE: Potable water in this context follows U.S. practice, with 250 parts per million maximum chloride content, sanitized with chlorine or ozone.

After testing is completed, equipment should be thoroughly drained with all high point vents open during draining, and dried by air blowing, swabbing, or other appropriate means. If immediate draining and drying are not possible, hydrotest water should be circulated in the piping for at least one hour daily to reduce the possibility of pitting and microbiologically influenced corrosion.

IV-4.0 EXTERNAL CORROSION CONTROL FOR PIPING EXPOSED TO THE ATMOSPHERE

IV-4.1

Piping which is exposed to the atmosphere should be protected against external corrosion by use of corrosion resistant materials or by application of protective coatings or paints.

IV-5.0 MONITORING OF PIPE WALL THINNING DUE TO EROSION/ CORROSION

IV-5.1 Definition

Erosion/corrosion (E/C) is a flow accelerated corrosion process which leads to loss of wall thickness in carbon or low alloy steel pipe exposed to water or wet steam. The parameters that affect the rate of metal loss include water or steam temperature, pH, oxygen content of the fluid, steam quality, flow velocity and piping layout, and the piping chromium, copper, and molybdenum content. This para., IV-5.0, does not apply to other wall thinning mechanisms, such as general corrosion, microbiologically influenced corrosion, or cavitation.

IV-5.2 Systems and Components Susceptible to Erosion/Corrosion

Erosion/corrosion has caused piping failures or severe wall thinning in the following systems:

Feedwater, auxiliary feedwater
Feedwater recirculation
Condensate recirculation
Blowdown
Turbine crossaround/crossover
Extraction steam
Moisture separator reheater
Feedwater heater drains, drips, and vents

Piping damage due to E/C is not limited to these systems and may occur in any system of carbon steel or low alloy piping that is exposed to water or wet steam and operates at a temperature greater than 200°F. System parameters and their effect on E/C rates are shown in Table IV-5.2.

Typical piping components known to experience wall thinning due to E/C include elbows, tees, reducers, and closely coupled fittings. Piping downstream and upstream of these fittings and downstream of orifices and control valves is also susceptible.

IV-5.3 Methods of Detection

Detection of wall thinning due to E/C may be accomplished by a number of NDE techniques including visual, radiographic, ultrasonic, and other measurement methods. However, the most widely used method for detection of wall thinning caused by E/C is ultrasonic thickness examination. Current industry practice sup-

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TABLE IV-5.2

Parameter	E/C Rate Increases if Parameter Is
Fluid velocity	Higher (> 10 fps for water) (> 150 fps for steam)
Fluid pH level	Less than 9.2
Fluid oxygen content	Less than 30 ppb
Fluid temperature	200°F–450°F (water) 200°F–500°F (wet steam)
Steam quality	Less than 100 %
Component geometry	Such as to create more turbulence
Component alloy content of chromium, copper, and molybdenum	Lower

ports use of a repeatable grid pattern with identifiable reference points at grid intersections. Grid sizes should not be greater than $2\sqrt{rt_n}$, where r is the outside radius and t_n is the nominal wall thickness of the piping item, except that grid sizes need not be smaller than 1 in. and should not be larger than 6 in. Thickness readings should be recorded at the grid intersection points and the pipe between the grid points scanned for detection of local thinning. If unacceptable thinning is detected, additional readings should be made and recorded with a refined or expanded grid. If thinning is detected within the boundaries of a component grid, a refined grid should be defined within the component to further define the region of wear and provide locations for documentation of measurements. If unacceptable thinning is found at the boundary of a grid, the grid should be expanded in the direction of thinning until thickness readings become acceptable.

IV-5.4 Acceptance Standards

The Code-required wall thickness t_m of each component inspected shall be determined in accordance with para. 104 of the Code. The required wall thickness should include consideration of the minimum wall thickness required to satisfy all of the stress requirements of para. 104.

A calculation of predicted wall thickness t_p at the next examination should be performed for all components with measured wall thickness less than 87.5% of nominal wall thickness t_n.

(A) All components with t_p at the next examination of less than t_m or 70% t_n, whichever is greater, should be identified. Additional examinations during the current inspection should be performed for:

(1) equivalent piping items in other trains when the system containing the subject piping item consists of more than one train;

(2) Additional components in the same system/pipeline which have been determined to be susceptible to E/C.

When (1) and (2) above reveal additional components which meet the criteria of (a)(1) above, this process should be repeated until no additional components meet the criteria.

(B) All components with predicted wall thickness at the next examination of less than or equal to the greater of t_m or $0.3t_n$ shall be repaired, replaced, or evaluated for acceptability for continued service. An acceptable evaluation procedure has been provided in [2] and [3] of para. IV-5.6.

IV-5.5 Repair/Replacement Procedures

Repair or replacement of piping components should be performed in accordance with Appendix V. Erosion rates for chrome-molybdenum alloys are significantly lower than carbon steels and virtually nonexistent for stainless steels. When replacement is chosen, consideration of the increased resistance of alloy steels to E/C should be included in the selection of the replacement component material. The use of backing rings, which can create areas of local turbulence which will promote E/C damage, should be avoided.

IV-5.6 References

[1] ASME Code Case N-480, Approved May 1, 1990.

[2] EPRI Report NP-5911M, "Acceptance Criteria for Structural Evaluation of Erosion/Corrosion Thinning in Carbon Steel Piping," July 1988.

[3] ASME B31G, Manual for Determining the Remaining Strength of Corroded Pipelines.

[4] NUREG-1344, "Erosion/Corrosion-Induced Pipe Wall Thinning in U. S. Nuclear Power Plants," April 1989.

[5] EPRI Report NP-3944, "Erosion/Corrosion in Nuclear Plant Steam Piping: Causes and Inspection Program Guidelines," April 1985.

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NONMANDATORY APPENDIX V[1]
RECOMMENDED PRACTICE FOR OPERATION, MAINTENANCE, AND MODIFICATION OF POWER PIPING SYSTEMS

FOREWORD

The B31.1 Power Piping Code prescribes minimum requirements for the construction of power and auxiliary service piping within the scope of para. 100.1. The Code, however, does not provide rules or other requirements for a determination of optimum system function, effective plant operations, or other measures necessary to assure the useful life of piping systems. These concerns are the responsibility of the designer and, after construction turnover, the Operating Company personnel responsible for plant activities.

Past experience has shown that a need exists for the definition of acceptable plant practices for achieving both reliable service and a predictable life in the operation of power piping systems. This nonmandatory Appendix is intended to serve that purpose. For this objective, Appendix V is structured in three parts that recognize and address the following basic concepts.

operation: the design of a piping system is based on specified service requirements and operating limitations. Subsequent operation within these defined limits is assumed and, for some systems, will be important for an acceptable service life.

maintenance: the design of a piping system assumes that reasonable maintenance and plant service will be provided. The lack of this support will, in some cases, introduce an increasing degree of piping system life uncertainty.

modifications: future modifications of a piping system or its operational functions are not assumed in original design unless specified. Modifications must not invalidate the integrity of a piping system design.

The practices in Appendix V are recommended for all plants and systems within the scope of the Power Piping Code, both for new construction and for existing plants in operation. An acceptable implementation of these or equivalent practices will be beneficial for new systems. The application of these practices is recommended for power piping systems in operating plants.

The recommended practices in this Appendix define minimum requirements for establishing a program to accommodate the basic considerations for piping system operation, maintenance, service, modification, and component replacement.

A record-keeping program is prescribed that can serve as a point of reference for analyzing piping system distortions or potential failures. Such a program is intended to identify distortions or failures and assure compatibility between the materials and components of existing piping systems with those portions undergoing repair, replacement, or modification.

DEFINITIONS[2]

Code: ASME Code for Pressure Piping, ASME B31.1 Power Piping

component: equipment, such as vessel, piping, pump, or valve, which are combined with other components to form a system

critical piping systems: those piping systems which are part of the feedwater-steam circuit of a steam generating power plant, and all systems which operate under two-phase flow conditions. Critical piping systems include runs of piping and their supports, restraints, and root valves. Hazardous gases and liquids, at all pressure and temperature conditions, are also included herein. The Operating Company may, in its judgment, consider other piping systems as being critical in which case it may consider them as part of this definition.

examination: an element of inspection consisting of investigation of materials, components, supplies, or services to determine conformance to those specified requirements which can be determined by such investi-

[1] Nonmandatory Appendices are identified by a Roman numeral; mandatory Appendices are identified by a letter. Therefore, Roman numeral I is not used in order to avoid confusion with the letter I.

[2] The definitions pertain specifically to this Appendix.

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gation. Examination is usually nondestructive and includes simple physical manipulation, gaging, and measurement.

failure: that physical condition which renders a system, component, or support inoperable

maintenance: actions required to assure reliable and continued operation of a power plant, including care, repair, and replacement of installed systems

modification: a change in piping design or operation and accomplished in accordance with the requirements and limitations of the Code

Operating Company: the Owner, user, or agent acting on behalf of the Owner who has the responsibility for performing the operations and maintenance functions on the piping systems within the scope of the Code

procedure: a document that specifies or describes how an activity is to be performed. It may include methods to be employed, equipment or materials to be used, and sequences of operations

qualification (personnel): demonstration of the abilities gained through training and/or experience that enable an individual to perform a required function

renewal: that activity which discards an existing component and replaces it with new or existing spare materials of the same or better qualities as the original component

repair: to restore the system or component to its designed operating condition as necessary to meet all Code requirements

specification: a set of requirements to be satisfied by a product, material, or process, indicating, whenever appropriate, the procedure by means of which it may be determined whether the requirements given are satisfied

V-1.0 GENERAL

V-1.1 Application

V-1.1.1 This Appendix recommends minimum requirements for programs to operate and maintain ASME B31.1 Power Piping systems and also for the repairs to these systems.

V-1.1.2 Local conditions and the location of piping systems (such as indoors, outdoors, in trenches, or buried) will have considerable bearing on the approach to any particular operating and maintenance procedure. Accordingly, the methods and procedures set forth herein serve as a general guide. The Operating Company is responsible for the inspection, testing, operation and maintenance of the piping system and shall have the responsibility for taking prudent action to deal with inherent plant conditions.

V-1.2 Conformance

V-1.2.1 When conformance with time periods for examination recommended in this document is impractical, an extension may be taken if an evaluation demonstrates that no safety hazard is present.

V-1.3 Requirements

V-1.3.1 This Appendix recommends that the following listed items be established and implemented:

(A) complete design and installation records of the "as built" large bore piping systems, including expansion joints, hangers, restraints, and other supporting components. The Operating Company shall define those sizes considered to be large bore pipe.

(B) records of operation and maintenance history;

(C) programs for periodic inspection and monitoring;

(D) procedures for reporting and analyzing failures;

(E) procedures for maintenance, repairs, and replacements;

(F) procedures for abandoning piping systems and for maintaining piping systems in and out-of-service condition; and

(G) procedures for assuring that all personnel engaged in direct maintenance of such piping systems as defined in para. V-4.2.1(C) are qualified by training or experience for their tasks or work.

V-2.0 OPERATING AND MAINTENANCE PROGRAM

V-2.1

Each Operating Company shall develop an operating and maintenance program comprising a series of written procedures, keeping in mind that it is not possible to prescribe a single set of detailed operating and maintenance procedures applicable to all piping systems. The operating and maintenance procedures shall include: personnel qualifications as defined by the Operating Company, material history and records, and supplementary plans to be implemented in case of piping system failures.

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V-2.2

Each plant should maintain and file the following documentation that exists for each unit:

(A) current piping drawings;

(B) construction isometrics (or other drawings) that identify weld locations;

(C) pipeline specifications covering material, outside diameter, and wall thickness;

(D) flow diagrams;

(E) support drawings;

(F) support setting charts;

(G) records of any piping system modifications;

(H) material certification records;

(I) records of operating events that exceed design criteria of the piping or supports;

(J) valve data;

(K) allowable reactions at piping connections to equipment;

(L) welding procedures and records.

V-3.0 REQUIREMENTS OF THE OPERATING, MAINTENANCE, AND MODIFICATION PROCEDURES

V-3.1

The Operating Company shall have procedures for the following:

(A) to perform normal operating and maintenance work. These procedures shall include sufficiently detailed instructions for employees engaged in operating and maintaining the piping systems,

(B) to prescribe action required in the event of a piping system failure or malfunction that may jeopardize personnel safety, safe operation, or system shutdown. Procedures shall consider:

(B.1) requirements defined for piping system operations and maintenance and should include failure conditions under which shutdown may be required. Procedures should include both the action required and the consequence of the action on related systems or subsystems.

(B.2) the designation of personnel responsible for the implementation of required action, and minimum requirements for the instruction, training, and qualification of these personnel.

(C) to periodically inspect and review changes in conditions affecting the safety of the piping system. These procedures shall provide for a system of reporting to a designated responsible person in order that corrective measures may be taken.

(D) to assure that modifications are designed and implemented by qualified personnel and in accordance with the provisions of the Code;

(E) to analyze failures to determine the cause and develop corrective action to minimize the probability of recurrence;

(F) to intentionally abandon unneeded piping systems, or portions thereof, and to maintain those which are out of service for extended periods of time as defined by the Operating Company;

(G) to ensure that instruction books and manuals are consulted in performing maintenance operations;

(H) to log, file, maintain, and update instruction books;

(I) to log operating and maintenance records; and

(J) to periodically review and revise procedures as dictated by experience and changes in conditions.

V-4.0 PIPING AND PIPE SUPPORT MAINTENANCE PROGRAM AND PERSONNEL REQUIREMENTS

V-4.1 Maintenance Program

V-4.1.1 The maintenance program shall include the following listed features:

(A) a purpose for the program;

(B) the frequency for performing all elements of maintenance and inspection listed in the program;

(C) generic requirements as related to initial hanger positions at time of unit startup, changes and adjustments in hanger positions at periodic inspections, and review of manufacturer's instruction and maintenance manuals applicable to components included in the program;

(D) updating and modification as may be desirable by reason of Code revisions and technological advances or other considerations;

(E) steps to keep maintenance and inspection personnel aware of program revisions.

V-4.2 Personnel

V-4.2.1 To the extent necessary for conformance with the maintenance program of the Operating Company, only qualified and trained personnel shall be utilized for the following:

(A) observation, measurement, and recording the position of piping systems and hanger readings;

(B) adjustment of hangers and all other components of support and restraint systems; and

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(C) repair and periodic maintenance routines including, but not limited to:

(C.1) routine piping assembly, including welding of integral attachments;

(C.2) mechanical repair of valves, traps, and similar types of piping specialty components, including packings;

(C.3) removal and replacement of piping insulation;

(C.4) lubrication of applicable piping and hanger components, such as valves and constant supports, maintenance of fluid levels in hydraulic restraints; and stroking of hydraulic and mechanical dynamic restraints (snubbers).

(C.5) routine surveillance for changing conditions including changes in position of piping and settings of piping hangers and shock suppressors (snubbers).

V-4.2.2 Review of records and failure reports and decisions concerning corrective actions or repairs should be carried out by or under the direction of a qualified piping engineer.

V-4.2.3 Welding and Heat Treatment Personnel

(A) Welders shall be qualified to approved welding procedures. Qualification of weld procedures and the qualification performance of the welder shall be in accord with the requirements of para. 127.5.

(B) Trained personnel shall perform preheat and postheat treatment operations as described in the requirements of para. 131.

V-4.2.4 Examination, Inspection, and Testing Personnel. Trained personnel shall perform nondestructive examinations (NDE), including visual inspections and leak tests (LT), all in accord with the requirements of para. 136.

V-5.0 MATERIAL HISTORY

V-5.1 Records

V-5.1.1 Records shall be maintained to the extent necessary to permit a meaningful failure analysis or reconstruction of a prior condition should the need arise. These records may be limited to those systems identified as critical as defined herein.

V-5.1.2 The records listed below are recommended for inclusion in the materials history and, where possible, be traceable to specific components in a piping system:

(A) procurement documents including specifications;

(B) original service date and operating conditions;

(C) list of materials, both original and replacement, with system location and material specification;

(D) physical and mechanical properties from material test reports (if available), including, the following as applicable:

(D.1) Manufacturer's Material Test Reports or Certificate of Conformance;

(D.2) chemical analysis;

(D.3) impact tests;

(D.4) special processing, i.e., heat treatment, mechanical working, etc.

(E) wall thicknesses where available from construction or maintenance records, including design minimum wall requirements;

(F) record of alterations or repairs;

(G) nondestructive examination reports (including radiographs, if available);

(H) special coatings, linings, or other designs for corrosion or erosion resistance;

(I) failure reports.

V-5.2 Failure Reports

V-5.2.1 The Operating Company shall be responsible for investigating all material failures in critical piping systems. The cause for failure shall be established. A report of the results of this investigation shall be included in the material history file and shall, as a minimum, contain the following information:

(A) summary of design requirements;

(B) record of operating and test experience of failed components;

(C) any previous history of the component;

(D) any special conditions (corrosion, extraordinary loads, thermal excursions, etc.) which may have contributed to failure;

(E) conclusions as to cause;

(F) recommendations for corrective actions to minimize recurrence;

(G) corrective actions that were taken, including verification of satisfactory implementation;

(H) corrective action details and recommendations, if any, for similar action in other piping systems.

V-5.3 Restoration after Failure

V-5.3.1 Defective component(s) shall be repaired or replaced with comparable or upgraded materials permissible by this Code after evaluation of the failure and taking into account conclusions as to cause. Even when materials are replaced by same or upgraded items, a formal failure report should follow as in para. V-5.2.

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V-5.3.2 Care shall be exercised when replacing system components to ensure no parts of the system are overstressed. The stresses in the repaired system shall be equal to or less than the original stresses unless analysis permits increased stresses. During the replacement of the component, the piping system should be temporarily supported or restrained on both sides of the component to be removed so as to maintain its as-found cold position until the component(s) is (are) installed. If the desired piping position cannot be maintained, an analysis shall be made to determine the reason for the problem. A new stress analysis may be necessary. Care shall be exercised when working on a system that has been subjected to self-springing or cold pull.

V-5.3.3 Weld preparations and fit-up of the weld joints shall meet the requirements of Chapter V.

V-5.3.4 Welding procedures and preheat/postheat treatments of the weld joints shall meet the minimum requirements of Chapter V.

V-5.4 Weld Records

V-5.4.1 Records shall be maintained for all welds in critical piping systems. These records shall include, but not be limited to, the following:

(A) original installation records, where available;

(B) repair and modification welds including excavation location and depth;

(C) welding procedures and qualification tests;

(D) nondestructive examination reports;

(E) heat treatment performed.

V-5.5 Inspection Program for Materials With Adverse History

V-5.5.1 Materials which have been reported to the industry to exhibit an adverse performance under certain conditions shall be given special attention by the Operating Company through a program of planned examination and testing. This program shall include the development of procedures for repair or replacement of the material when the Operating Company determines that such action is necessary.

V-5.5.2 Methods of surveillance and analysis shall be determined by the Operating Company.

V-5.5.3 The frequency of the material inspection shall also consider the expected service life of the component.

V-5.6 Nondestructive Examination

V-5.6.1 Nondestructive examinations used to investigate any suspect materials or problem areas shall be in accordance with Chapter VI.

V-6.0 PIPING POSITION HISTORY

V-6.1 General

V-6.1.1 Movements of critical piping systems from their design locations shall be used to assess piping integrity. The Operating Company shall have a program requiring such movements be taken on a periodic basis along with a procedure precluding the unnecessary removal of insulation when measurements are taken; refer to para. V-6.3. Piping system movement records shall be maintained. The Operating Company shall evaluate the effects of position changes on the safety of the piping systems and shall take appropriate corrective action.

V-6.1.2 Although the Code recognizes that high temperature piping systems seldom return to their exact original positions after each heat cycle due to relaxation, critical piping systems as defined herein, must be maintained within the bounds of engineering evaluated limitations.

V-6.2 Visual Survey

V-6.2.1 The critical piping systems shall be observed visually, as frequently as deemed necessary, and any unusual conditions shall be brought to the attention of personnel as prescribed in procedures of para. V-3.1. Observations shall include determination of interferences with or from other piping or equipment, vibrations, and general condition of the supports, hangers, guides, anchors, supplementary steel, and attachments, etc..

V-6.3 Piping Position Markers

V-6.3.1 For the purpose of easily making periodic position determinations, it is recommended that permanent markings on critical piping systems be made by providing markings or pointers attached to piping components. The position of these markings or pointers should be noted and recorded with respect to stationary datum reference points.

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V-6.3.2 Placement of pointers shall be such that personnel safety hazards are not created.

V-6.4 Hangers and Supports on Critical Piping Systems and Other Selected Systems

V-6.4.1 Hanger position scale readings of variable and constant support hangers shall be determined periodically. It is recommended that readings be obtained while the piping is in its fully hot position, and if practical, when the system is reasonably cool or cold sometime during the year as permitted by plant operation. Pipe temperature at time of reading hangers shall be recorded.

V-6.4.2 Variable and constant support hangers, vibration snubbers, shock suppressors, dampeners, slide supports and rigid rod hangers shall be maintained in accordance with the limits specified by the manufacturers and designers. Maintenance of these items shall include, but not necessarily be limited to, cleaning, lubrication and corrosion protection. All dynamic restraints (snubbers) should be stroked periodically.

V-6.5 Records on Critical Piping Systems and Other Selected Systems

V-6.5.1 Pipe location readings and travel scale readings of variable and constant support hangers shall be recorded on permanent log sheets in such a manner that will be simple to interpret. See Fig. V-6.5 for suggested hanger record data sheet. Records of settings of all hangers shall be made before the original commercial operation of the plant. Log sheets should be accompanied by a pipe support location plan or piping system drawing with hanger mark numbers clearly identified. In addition, records are to be maintained showing movements of or in expansion joints including records of hot and cold or operating and shutdown positions, particularly those not equipped with control rods or gimbals.

V-6.6 Recommendations

V-6.6.1 After complete examination of the records (para. V-6.5), recommendations for corrective actions needed shall be made by a piping engineer or a qualified responsible individual or organization. Repairs and/or modifications are to be carried out by qualified maintenance personnel for all of the following items:

(A) excessively corroded hangers and other support components;

(B) broken springs or any hardware item which is part of the complete hanger or support assembly;

(C) excessive piping vibration; valve operator shaking or movements;

(D) piping interferences;

(E) excessive piping deflection which may require the installation of spring units having a greater travel range;

(F) pipe sagging which may require hanger adjustment or the reanalysis and redesign of the support system;

(G) hanger unit riding at either the top or the bottom of the available travel;

(H) need for adjustment of hanger load carrying capacity;

(I) need for adjustments of hanger rods or turnbuckle for compensation of creep or relaxation of the piping,

(J) loose or broken anchors;

(K) inadequate clearances at guides;

(L) inadequate safety valve vent clearances at outlet of safety valves;

(M) any failed or deformed hanger, guide, U-bolt, anchor, snubber, or shock absorber, slide support, dampener, or supporting steel;

(N) unacceptable movements in expansion joints;

(O) low fluid levels in hydraulic pipe restraints.

V-7.0 PIPING CORROSION

V-7.1 General

V-7.1.1 This section pertains to the requirements for inspection of critical piping systems that may be subject to internal or external corrosion-erosion, such as buried pipe, piping in a corrosive atmosphere, or piping having corrosive or erosive contents. Requirements for inspection of piping systems in order to detect wall thinning of piping and piping components due to erosion/corrosion, or flow-assisted corrosion, is also included. Erosion/corrosion of carbon steel piping may occur at locations where high fluid velocity exists adjacent to the metal surface, either due to high velocity or the presence of some flow discontinuity (elbow, reducer, expander, tee, control valve, etc.) causing high levels of local turbulence. The erosion/corrosion process may be associated with wet steam or high purity, low oxygen content water systems. Damage may occur under both single and two-phase flow conditions. Piping systems that may be damaged by erosion/corrosion include, but are not limited to, feedwater, condensate, heater drains, and wet steam extraction lines. Mainte-

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Company _____ System _____ Prepared by _____
Plant Name _____ Unit No. _____ Sheet _____ Of _____
Date _____

Hanger Mk. No.	Hanger Size[1]	Hanger Type[2]	Dsgn. Mvt.	Constant Support Hanger Data		Rigid & Variable Support Data		Design Elev. Cold,[3] ft.-in.	Hanger Scale Reading[4]							
									Date:		Date:		Date:		Date:	
				Design Load, lb	Design Total Travel	Design Load, lb		(4)	Cold	Read by	Hot	Read by	Cold	Read by	Hot	Read by
						H	C									

NOTES:
(1) Hanger size to be taken from hanger fabrication drawing.
(2) For constant support and variable support types indicate by CS or VS. For rigid, anchor, guide, sliding, or other type support, indicate by letter R, A, G, or S, respectively.
(3) Elevation of center line of pipe after cold springing and final hanger settings with line cold.
(4) "0" indicated the highest scale position with "5" being the midpoint, and "10" being the lowest scale position.

FIG. V-6.5 HANGER RECORD SHEET

nance of corrosion control equipment and devices is also part of this section. Measures in addition to those listed herein may be required.

V-7.1.2 Where corrosion is cited in this section, it is to be construed to include any mechanism of corrosion and/or erosion. Recommended methods for monitoring and detection, acceptance standards, and repair/replacement procedures for piping components subjected to various erosion/corrosion mechanisms, including flow-assisted corrosion, are provided in nonmandatory Appendix IV.

V-7.1.3 Guidance for the evaluation and monitoring of carbon steel piping susceptible to erosion/corrosion (flow assisted corrosion) is provided in Appendix IV, para. IV-5.0.

V-7.2 Procedures

V-7.2.1 The Operating Company shall establish procedures to cover the requirements of this paragraph.

V-7.2.2 Procedures shall be carried out by or under the direction of persons qualified by training or experience in corrosion control and evaluation of piping systems for corrosion damage.

V-7.2.3 Procedures for corrosion control shall include, but not be limited to the following:

(A) maintenance painting to resist external ambient conditions;

(B) coating and/or wrapping for external protection of buried or submerged systems;

(C) lining to resist internal corrosion from system fluid when applicable;

(D) determining the amount of corrosion or erosion of the piping system internals caused by the flowing fluid;

(E) determining the amount of external corrosion caused by ambient conditions, such as atmosphere, buried in soil, installed in tunnels or covered trenches, and submerged underwater;

(F) preparing records which shall include all known leakage information, type of repair made, location of cathodically protected pipe, and the locations of cathodic protection facilities including anodes; and

(G) examining records from previous inspection and performing additional inspections where needed for historical records.

V-7.3 Records

V-7.3.1 Tests, surveys, and inspection records to indicate the adequacy of corrosion control shall be maintained for the service life of the piping system. This should include records of measured wall thickness and rates of corrosion.

V-7.3.2 Inspection and maintenance records of cathodic protection systems shall be maintained for the service life of the protected piping.

V-7.3.3 Observations of the evidence of corrosion found during maintenance or revision to a piping system shall be recorded.

V-7.4 Examination of Records

V-7.4.1 Records shall be examined and evaluated by trained personnel.

V-7.4.2 Where inspections or leakage history indicate that active corrosion is taking place to the extent that a safety hazard is likely to result, applicable portions of the system shall be replaced with corrosion resistant materials or with materials which are protected from corrosion, or other suitable modifications shall be made.

V-7.5 Frequency of Examination

V-7.5.1 Within 3 years after original installation, each piping system shall be examined for evidence of corrosion in accordance with the requirements established by the Operating Company's procedures. Piping in severe service or environmental conditions should be inspected initially within a time frame commensurate with the severity of the service or environment. Corrective measures shall be taken if corrosion is above the amount allowed for in the original design.

V-7.5.2 Continued examination shall be made at intervals based upon the results of the initial inspection, but not to exceed 5 years, with corrective measures being taken each time that active corrosion is found.

V-7.5.3 Examination for evidence of internal corrosion shall be made by one of the following:

(A) drilled hole with subsequent plugging;

(B) ultrasonic test for wall thickness determination;

(C) removal of representative pipe section at flange connections or couplings;

(D) removal of short section of pipe;

(E) radiography for evidence of wall thinning;

(F) borescope or videoprobe examination; or

(G) a method equivalent to those above.

V-7.5.4 Examinations for evidence of external corrosion shall be made after removal of covering, insulation or soil on a representative short section of the piping system taking into consideration varying soil conditions.

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V-8.0 PIPING ADDITION TO EXISTING PLANTS

V-8.1 Piping Classification

V-8.1.1 Piping and piping components which are replaced, modified, or added to existing piping systems are to conform to the edition and addenda of the Code used for design and construction of the original systems, or to later Code editions or addenda as determined by the Operating Company. Any additional piping systems installed in existing plants shall be considered as new piping and shall conform to the latest issue of the Code.

V-8.2 Duplicate Components

V-8.2.1 Duplicates of original components and materials are permitted for permanent replacements, provided the renewal is a result of reasonable wear and not the result of the improper application of the material, such as temperature and corrosive environment.

V-8.3 Replacement Piping and Piping Components

V-8.3.1 Where replacement components differ from the original components with respect to weight, dimensions, layout, or material, the design of the affected piping system shall be rechecked for the following design considerations.

(A) Hangers and supports shall be adequate for additional or altered distribution of weight. They shall accommodate the flexibility characteristics of the altered piping system.

(B) Changes in stresses imposed on both existing and replacement components of the piping shall be evaluated and compensation shall be made to prevent overstress in any part of the entire altered piping system.

V-9.0 SAFETY, SAFETY RELIEF, AND RELIEF VALVES

V-9.1 General

V-9.1.1 This section is applicable to safety, safety relief, and relief valve installations (see Appendix II for definitions of these terms.) Except as otherwise noted, all reference to "safety" valve(s) shall be considered to include all three types. Safety valves shall be maintained in good working condition. Also, discharge pipes and their supports shall be inspected routinely and maintained properly. Any evidence of blowback at the drip pan of open safety valve vent systems should be noted and its cause determined and corrected.

V-9.2 Testing and Adjustment

V-9.2.1 Testing of safety valves for pressure setting shall be in accordance with written procedures which incorporate the requirements of regulatory agencies and manufacturer's instructions. Testing should be performed just prior to a planned outage so that any required repair or maintenance, except spring and blowdown ring adjustments, can be performed during the outage, thereby assuring tight valves upon return to service.

V-9.2.2 The setting or adjustment of safety valves shall be done by personnel trained in the operation and maintenance of such valves. Safety valves shall be tested after any change in setting of the spring or blowdown ring. Appropriate seals should be used to assure that there is no unauthorized tampering with valve settings. Repairs to safety valves and disassembly, reassembly, and/or adjustments affecting the pressure relief valve function, which are considered a repair, should be performed by an authorized repair organization.[3]

V-9.3 Operation

V-9.3.1 The precautions stated in the manufacturer's operating manual or instruction books shall be followed when operating safety valves. In general, these precautions will include the following.

(A) Hand lifting is permitted. Assistance, as required, may be accomplished by the use of small wires or chains.

(B) Striking or hammering the valve body shall not be permitted. Only the hand-test lever shall be used.

(C) Attempts to stop leakage through the valve seat shall not be made by compressing the spring.

V-10.0 DYNAMIC LOADING

V-10.1 Water Hammer

V-10.1.1 Water hammer includes any water or other liquid transient event such as pressure surge or impact loading resulting from sudden or momentary change in flow or flow direction.

[3] Examples of organizations which may be authorized by the owner or by the local jurisdiction to perform repairs on safety valves include but are not limited to the original valve manufacturer or a repair organization which holds a National Board of Boiler and Pressure Vessel Inspectors (NB-23) VR stamp.

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V-10.1.2 Should significant water hammer develop during plant operation, the cause should be determined and corrective action taken. Water hammer could be the result of an incorrectly sloped pipe intended for steam condensate drainage. Water hammer in piping systems may cause damage to hangers, valves, instrumentation, expansion joints, piping and equipment integral with the piping. The Operating Company should develop procedures to deter water hammer and to determine when corrective action is necessary.

V-10.1.3 Water hammer problems resulting from accumulated condensate in a steam line cannot be solved simply by adding restraints. Corrective action may include changing line slopes, adding drain pots, adding warm-up lines around valves, checking for leaking desuperheaters, faulty electrical controls on automatic drains, etc.

V-10.1.4 Water hammer due to column separation in feedwater or booster pump suction piping results when the deaerator pegging pressure is not maintained. This type of water hammer can be particularly severe and requires prompt attention to control and reduce it.

V-10.1.5 As a priority, corrective action should address the cause of waterhammer first. If such corrective action is ineffective in reducing the effects of water hammer to acceptable levels, installation of restraints may be necessary to limit piping displacements and/or damage from fatigue.

V-10.2 Steam Hammer

V-10.2.1 Dynamic loads due to rapid changes in flow conditions and fluid state in a steam piping system are generally called steam hammer loads. Piping response to these momentary unbalanced loads can be significant in high pressure steam systems, such as main steam, hot and cold reheat steam, bypass and auxiliary steam systems that are subject to rapid interruption or establishment of full steam flow.

V-10.2.2 The Operating Company should develop procedures to determine any adverse effects of steam hammer, such as excessive pipe movement, damage to hangers and restraints, and high pipe stress and reactions at pipe connections to equipment. Where such movements, stresses, and reactions exceed safe limits or allowable loadings, a program of remedial action should be implemented.

V-11.0 HIGH TEMPERATURE CREEP

V-11.1 General

V-11.1.1 Catastrophic failure, including rupture, can occur due to excessive creep strains resulting from operation of the piping above design pressure, or temperatures, or both, for extended periods of time. The expected life of a piping system operating in the creep range can be reduced significantly through prolonged exposure to pressure or temperature, particularly temperature, above design values. Paragraph 102.2.4 provides criteria for occasional short operating periods at higher than design pressure or temperature.

V-11.1.2 This section provides the minimum requirements for evaluating critical piping systems in order to detect creep damage and to assist in predicting the remaining life under expected operating conditions. The remaining useful life may be estimated by determining the extent of creep damage sustained by the pipe.

V-11.2 Procedures

V-11.2.1 The Operating Company shall establish procedures to cover the requirements of this paragraph.

V-11.2.2 The procedures shall be carried out by or under the direction of persons qualified by training or experience in metallurgical evaluation of high temperature creep effects in power plant piping.

V-11.2.3 An evaluation program to determine the extent of creep damage and estimate remaining life of high temperature piping shall be carried out in three phases, as follows:

(A) review of material specifications, design stress levels, and operating history;

(B) indirect measurements to determine extent of creep damage. These would include diametral measurements to detect creep swelling. In addition, dye penetrant, magnetic particle, ultrasonic, and radiographic methods may be used to detect internal and surface cracks.

(C) examination of the microstructure to determine the degree of material degradation. This can be performed by replication techniques or by metallography using specimens obtained by boat-sampling or trepanning.

V-11.3 Records

V-11.3.1 Records of creep damage evaluation survey findings shall be maintained for the service life of high temperature piping systems operating in the creep range.

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V-11.4 Examination of Records

V-11.4.1 Records of creep damage surveys and test reports shall be examined by personnel qualified by training and experience to evaluate and interpret NDE and metallographical studies.

V-11.4.2 Where surveys and inspections of critical piping systems indicate that high temperature creep damage has progressed to an unacceptable level, affected portions of the piping system shall be replaced.

V-11.5 Frequency of Examination

V-11.5.1 Periodically, all critical piping systems operating within the creep range shall be examined for evidence of high temperature creep damage. Particular attention shall be given to welds.

V-11.5.2 The examination shall be repeated at periodic intervals which shall be established on the basis of earlier survey findings, operating history, and severity of service.

V-12.0 RERATING PIPING SYSTEMS

V-12.1 Conditions

V-12.1.1 An existing piping system may be rerated for use at a higher pressure and/or temperature if all of the following conditions are met:

(A) a design analysis shall be performed to demonstrate that the piping system meets the requirements of the Code at the new design conditions;

(B) the condition of the piping system and support/restraint scheme shall be determined by field inspections and the examination of maintenance records, manufacturer's certifications, and/or other available information to ensure conformance with the Code requirements for the new design conditions;

(C) necessary repairs, replacements, or alterations to the piping system are made to conform with the requirements prescribed in (A) and (B) above;

(D) the system has been leak tested to a pressure equal to or greater than that required by the Code for a new piping system at the new design conditions;

(E) the rate of pressure and temperature increase to the higher maximum allowable operating conditions shall be gradual so as to allow sufficient time for periodic observations of the piping system movements and leak tightness;

(F) records of investigations, work performed, and pressure tests conducted in rerating the piping systems shall be preserved for the service life of the piping systems; and

(G) all safety valves, relief valves, and other pressure relieving devices must be examined, and recertified for the new pressure/temperature design conditions. Capacity of relieving equipment shall be investigated if the design pressure and/or temperature are changed in rerating a piping system.

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NONMANDATORY APPENDIX VI[1]
APPROVAL OF NEW MATERIALS

The ASME B31.1 Committee considers requests for adoption of new materials desired by the owner/user or fabricator, manufacturer, installer, assembler of piping or piping components constructed to the Code. In order for the material to receive proper consideration, information and data are required to properly categorize the material. In general this information and data include, but are not necessarily limited to the following:

(A) the chemical composition of the material including those elements that establish the characteristics and behavior of the material;

(B) the mechanical properties of the material, including tensile test data, ductility data, and other special mechanical test data, which will assist the Committee in its review of the material and its application:

(B.1) tensile test data (per ASTM E 21), including both ultimate tensile strength and yield strength, at room temperature and at 100°F or 50°C intervals to a temperature at least 100°F higher than the intended use of the material.

(B.2) when creep properties are expected to limit the allowable stress, creep and creep rupture data at temperature intervals of 100°F or 50°C are also required. Such data should be for four or more time intervals, one of which should be longer than 2000 hr but less than 6000 hr, and one of which should be longer than 6000 hr.

(C) if the material is to be used in welded construction, data from actual welding tests made in accordance with Section IX of the ASME Boiler and Pressure Vessel Code should be submitted. Welding test data should include:

(C.1) the welding processes and weld filler metal(s) intended for the fabrication of the material;

(C.2) all-weld-metal tensile test data for temperatures representative of intended service;

(C.3) any special restrictions on the welding of the material;

(C.4) the appropriate preheat and postweld heat treatment, if any, which will be given the material. If postweld heat treatment results in embrittlement of the material, the significance of such treatments with substantiating data should be forwarded. Toughness data on weld metal and heat affected zone in the as-welded and postweld heat treated conditions, when appropriate, should be submitted.

(D) where the material is intended for special applications, requires special handling or special welding procedures, or has known limitations or susceptibility to failure in certain services, precautionary requirements and information should also be submitted for review by the Committee.

(E) applicable product form(s) of the material, such as sheet, strip, plate, bars, shapes, seamless or welded pipe or tube forgings, castings, etc., for which application is to be considered must be identified.

The general data recommended should be submitted on a minimum of three heats, preferably commercial heats, of the material. Where the range of chemical composition affect the mechanical properties, the heats selected should cover both the high and low range of the effective chemical elements to show the effect on the mechanical properties. Any special heat treatment, whether applied by the material supplier or the fabricator, should be applied to the test pieces used to obtain the data.

If the material is covered by an ASTM specification, the specification number(s) and grade(s) involved must be identified in the application. If the material is not covered by an ASTM specification, application must be made to ASTM for specification coverage of this material.

Should there be a need for Code use prior to the inclusion of the material in ASTM specifications, the Committee will consider issuing a Code Case.

In addition to the information and data noted above, the Committee should be provided with an indication of user need, a copy of the letter to ASTM requesting specification coverage, and sufficient information for the Committee to modify an appropriate existing ASTM specification to establish the material specification requirements for the material product form.

When the new material is a minor modification of a material which is currently accepted by the Code,

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the data required may be reduced with the concurrence of the Committee. When the data supplied are insufficient for an adequate evaluation, the Committee will request additional data. Such requests will be returned, indicating those areas in which additional information is required.

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NONMANDATORY APPENDIX VII[1]
PROCEDURES FOR THE DESIGN OF RESTRAINED UNDERGROUND PIPING

FOREWORD

The Code contains rules governing the design, fabrication, materials, erection, and examination of power piping systems. Experience over the years has demonstrated that these rules may be conservatively applied to the design and analysis of buried piping systems. However, the ASME B31.1 rules were written for piping suspended in open space, with the supports located at local points on the pipe. Buried piping, on the other hand, is supported, confined, and restrained continuously by the passive effects of the backfill and the trench bedding. The effects of continuous restraint cannot be easily evaluated by the usual methods applied to exposed piping, since these methods cannot easily accommodate the effects of bearing and friction at the pipe/soil interface. Accordingly, this Appendix has been prepared to illustrate and clarify the application of Code rules to restrained buried piping.

All components in the buried piping system must be given consideration, including the building penetrations, branches, bends, elbows, flanges, valves, grade penetrations, and tank attachments. It is assumed that welds are made in accordance with this Code and that appropriate corrosion protection procedures are followed for buried piping.

This Appendix provides analytic and nomenclature definition figures to assist the designer, and is not intended to provide actual design layout. Sample calculations for various configurations of semirigid buried piping have been provided at the end of the text to assist the designer in the application of these procedures.

VII-1.0 SCOPE AND DEFINITIONS

VII-1.1 Scope

The scope of this Appendix is confined to the design of buried piping as defined in para. VII-1.2. Thermal expansion in buried piping affects the forces, the resulting bending moments and stresses throughout the burried portions of the system, particularly at the anchors, building penetrations, buried elbows and bends, and branch connections, and it is the designer's responsibility to consider these forces. This Appendix, however, deals only with the buried portions of the system, and not the complete system.

The design and analysis of buried piping requires that careful attention be paid to:

(A) all loads acting on the system;

(B) the forces and the bending moments in the piping and piping components resulting from the loads;

(C) the loading and stress criteria;

(D) general design practices.

VII-1.2 Definitions

confining pressure: the pressure imposed by the compacted backfill and overburden on a buried pipe. Confining pressure is assumed to act normal to the pipe circumference.

flexible coupling: a piping component that permits a small amount of axial or angular movement while maintaining the pressure boundary

friction: the passive resistance of soil to axial movement. Friction at the pipe/soil interface is a function of confining pressure and the coefficient of friction between the pipe and the backfill material. Friction forces exist only where there is actual or impending slippage between the pipe and soil

influence length: that portion of a transverse pipe run which is deflected or "influenced" by pipe thermal expansion along the axis of the longitudinal run

modulus of subgrade reaction: the rate of change of soil bearing stress with respect to compressive deformation of the soil. It is used to calculate the passive spring rate of the soil

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penetration: the point at which a buried pipe enters the soil either at grade or from a wall or discharge structure

settlement: the changes in volume of soil under constant load which results in the downward movement, over a period of time, of a structure or vessel resting on the soil

virtual anchor: a point or region along the axis of a buried pipe where there is no relative motion at the pipe/soil interface

VII-1.3 Nomenclature

a, b, c = quadratic equation functions
A = cross sectional metal area of pipe, in.[2]
A_c = surfaced area of a 1-in. long pipe segment, in.[2]
B_d = trench width at grade, in.
C_D = soil bearing parameter from Table VII-3.2.3, dimensionless
C_k = horizontal stiffness factor for backfill [8],[2] dimensionless
D = pipe outside diameter, in.
dL = length of pipe element, in.
E = Young's modulus for pipe, psi
f = unit friction force along pipe, lb/in.
f_{min}, f_{max} = minimum, maximum unit friction force on pipe, lb/in.
F_f = total friction force along effective length, lb
F_{max} = maximum axial force in pipe, lb
H = pipe depth below grade, in.
I = pipe section moment of inertia, in.[4]
k = soil modulus of subgrade reaction, psi
k_h = soil horizontal modulus of subgrade reaction, psi
$k_{i,j}$ = orthogonal soil springs on pipe, lb/in.
k_v = soil vertical modulus of subgrade reaction, psi
L_1 = length of transverse pipe run, in.
L_2 = length of longitudinal pipe run, in.
L_m = minimum slippage length of pipe, in.
L' = effective slippage length for short pipes, in.
L'' = effective slippage length for long pipes, in.
n = number of modeling elements for pipe springs, dimensionless
N_h = horizontal force factor [8], dimensionless
P = maximum operating pressure in pipe, psi
P_c = confining pressure of backfill on pipe, psi
S_A = allowable expansion stress range, psi
SE = expansion stress, psi
S_h = basic material allowable stress at T degrees fahrenheit, psi
t = pipe wall thickness, in.
T = maximum operating temperature, °F
T_o = ambient temperature of pipe, °F
w = soil density, pfc, pci
W_p = unit weight of pipe and contents, lb/in.
α = coefficient of thermal expansion of pipe, in./in./°F
β = pipe/soil system characteristic [2], in.$^{-1}$
ϵ = pipe unit thermal expansion, in./in.
μ = coefficient of friction, dimensionless
Ω = effective length parameter, in.

[2] Numbers enclosed in brackets [ ] correspond to references cited in VII-7.0.

VII-2.0 LOADS

VII-2.1 Thermal Expansion

Thermal displacements at the elbows, branch connections, and flanges in a buried piping system and the forces and moments resulting from the displacements may be determined by analyzing each buried run of pipe by the method described in this Appendix.

VII-2.1.1 Installations With Continuous Runs. For buried piping installations that contain continuous runs without flexible couplings, the passive restraining effects of soil bearing on the transverse legs at the ends of long runs subject to thermal expansion may be significant and result in high axial forces and elbow or branch connection bending moments.

VII-2.1.2 Installations With Flexible Couplings. For buried piping installations that incorporate flexible couplings into the pipe runs subject to thermal expansion, the bending moments and stresses may be substantially reduced. However, the flexible couplings must be chosen carefully to accommodate the thermal expansion in the pipe, and the friction forces or stiffness in the coupling must be considered.

VII-2.1.3 Installations With Penetration Anchors. For buried piping systems in which the building penetration provides complete restraint to the pipe, it is necessary to calculate the penetration reactions to thermal

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expansion in the initial buried run. If this run incorporates flexible couplings, piping reactions at the penetration resulting from unbalanced forces due to internal pressure must be considered.

VII-2.1.4 Installations With Flexible Penetrations. For buried piping systems in which the building penetrations permit some axial or angular movements, the interaction between the buried run outside the penetration and the point-supported portion of the system inside the building must be considered.

VII-2.2 Pressure

Pressure loads in buried piping are important for two primary reasons.

VII-2.2.1 In pipe runs which incorporate flexible couplings, there is no structural tie between the coupled ends, with the result that internal pressure loads must be reacted externally. External restraint may be provided by thrust blocks, external anchors, soil resistance to elbows or fittings at each end of the pipe run, or by control rods across the coupling. Where one or both of the ends terminate at a penetration or an anchor, or at connected equipment such as a pump or vessel, the pressure forces can be quite high and must be considered in the anchor or equipment design.

VII-2.2.2 For discharge strctures, the reaction forces due to upstream pressure and mass flow momentum in the discharge leg may be high and must be considered in the design of the last elbow or bend before the discharge.

VII-2.3 Earthquake

An earthquake subjects buried piping to axial loads and bending moments from soil strain due to seismic waves, or from ground faulting across the axis of the pipe. The seismic soil strain can be estimated for a design earthquake in a specific geographical region, from which design values for forces and moments in buried piping can be calculated. However, consideration of the magnitude and effects of seismic ground faulting on buried piping is beyond the scope of this Appendix.

VII-3.0 CALCULATIONS

The calculations for stresses in restrained underground piping are carried out in four steps, as follows.

VII-3.1 Assembling the Data

The pipe material and dimensions, soil characteristics, and operating conditions must be established.

VII-3.1.1 Pipe Data

(A) pipe outside diameter D, in.

(B) wall thickness t, in.

(C) length of pipe runs L_1 (transverse) and L_2 (longitudinal), in.

(D) Young's modulus E, psi, (from Appendix C)

(E) pipe depth below grade H, in.

VII-3.1.2 Soil Characteristics

(A) soil density w, pcf (from site tests)

(B) type of backfill

(C) pipe trench width at grade B_d, in.

(D) range of coefficient of friction μ between pipe and backfill

VII-3.1.3 Operating Conditions

(A) maximum operating pressure P, psi

(B) maximum pipe temperature T, °F

(C) ambient pipe temperature T_o, °F

(D) pipe coefficient of thermal expansion α, in./in./°F

VII-3.2 Calculations of Intermediate Parameters

The following parameters must be calculated.

VII-3.2.1 Maximum Relative Strain e at the Pipe/Soil Interface, in./in. For thermal expansion, this is the unit thermal elongation of the unrestrained pipe.

$$\epsilon = \alpha(T - T_o) \quad (1)$$

where

α = coefficient of thermal expansion

$T - T_o$ = difference between operating and installation temperatures

VII-3.2.2 Modulus of Subgrade Reaction k, psi. This is a factor which defines the resistance of the soil or backfill to pipe movement due to the bearing pressure at the pipe/soil interface. Several methods for calculating k have been developed in recent years byAudibert and Nyman, Trautmann and O'Rourke, and others [4, 5, 6, 7, 8]. For example [8], for pipe movement horizontally, the modulus of subgrade k_h may be found by

$$k_h = C_k N_h w D \text{ psi} \quad (2)$$

where

C_k = a dimensionless factor for estimating horizontal stiffness of compacted backfill. C_k may be estimated at 20 for loose soil, 30 for medium soil, and 80 for dense or compacted soil.

w = soil density, lb/in.^{3}

D = pipe outside diameter, in.

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N_h = a dimensionless horizontal force factor from Fig. 8 of [8]. For a typical value where the soil internal friction angle is 30 deg, the curve from [8] may be approximated by a straight line defined by

$$N_h = 0.285H/D + 4.3$$

where

H = the depth of pipe below grade at the pipe center line, in.

For pipe movement upward or downward,the procedures recommended in [4] may be applied. Conservatively, the resistance to upward movement may be considered the same as for horizontal movement with additional consideration for the weight of the soil. Resistance to downward movement may conservatively be considered as rigid for most expansion stress analysis.

VII-3.2.3 Unit Friction Force at the Pipe/Soil Interface f

$$f = \mu\,(P_c A_c + W_p) \text{ lb/in.} \quad (3)$$

where

μ = coefficient of friction between pipe and soil
P_c = confining pressure of soil on pipe, psi
A_c = surface area of a pipe segment, in.^{2}
W_p = unit weight of pipe and contents, lb/in.

For piping which is buried within 3 pipe diameters of the surface, confining pressure P_c may be estimated by

$$P_c = wH \text{ lb/in.}^2$$

where

w = the soil density, lb/in.^{3}
H = the depth below grade, in.

For piping which is buried more than 3 pipe diameters below grade, confining pressure P_c is found by using the modified Marston equation [9]:

$$P_c = wC_D B_D \text{ lb/in.}^2$$

where

C_D = a dimensionless parameter obtained from Table VII-3.2.3
B_D = the trench width, with a maximum value of 24 in. plus the pipe diameter

TABLE VII-3.2.3
APPROXIMATE SAFE WORKING VALUES OF C_D FOR USE IN MODIFIED MARSTON FORMULA

Ratio H/B_D	Damp Top Soil and Dry and Wet Sand	Saturated Top Soil	Damp Yellow Clay	Saturated Yellow Clay
0.5	0.46	0.47	0.47	0.48
1.0	0.85	0.86	0.88	0.90
1.5	1.18	1.21	1.25	1.27
2.0	1.47	1.51	1.56	1.62
2.5	1.70	1.77	1.83	1.91
3.0	1.90	1.99	2.08	2.19
3.5	2.08	2.18	2.28	2.43
4.0	2.22	2.35	2.47	2.65
4.5	2.34	2.49	2.53	2.85
5.0	2.45	2.61	2.19	3.02
5.5	2.54	2.72	2.90	3.18
6.0	2.61	2.91	3.01	3.32
6.5	2.68	2.89	3.11	3.44
7.0	2.73	2.95	3.19	3.55
7.5	2.78	3.01	3.27	3.65
8.0	2.82	3.06	3.33	3.74
9.0	2.88	3.14	3.44	3.89
10.0	2.92	3.20	3.52	4.01
11.0	2.95	3.25	3.59	4.11
12.0	2.97	3.28	3.63	4.19
13.0	2.99	3.31	3.67	4.25
14.0	3.00	3.33	3.70	4.30
15.0	3.01	3.34	3.72	4.34
∞	3.03	3.38	3.79	4.50

VII-3.2.4 Pipe/Soil System Characteristic [2]

$$\beta = [k/(4EI)]^{1/4} \text{ in.}^{-1} \quad (4)$$

where

k = soil modulus of subgrade reaction k_h or k_v, psi
E = Young's modulus for pipe, psi
I = area moment of inertia for pipe, in.^{4}

VII-3.2.5 Minimum Slippage Length L_m [1]

$$L_m = \epsilon AE/f \text{ in.} \quad (5)$$

where

A = pipe cross section area

VII-3.2.6 Maximum Axial Force F_{max} in the Longitudinal Pipe Run. The maximum axial force in a pipe long enough for friction force to develop to the point where a region of the pipe is totally restrained longitudinally by the soil is found by

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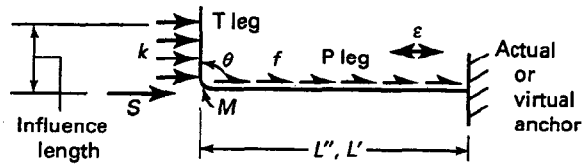


FIG. VII-3.3.2-1 ELEMENT CATEGORY A, ELBOW OR BEND

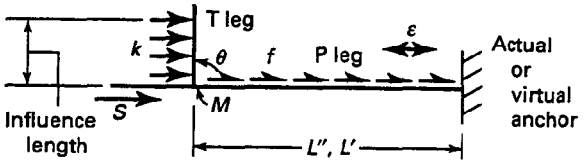


FIG. VII-3.3.2-2 ELEMENT CATEGORY B, BRANCH PIPE JOINING THE P LEG

$$F_{max} = fL_m = \epsilon AE \text{ lb} \quad (6)$$

VII-3.3 Classification of the Pipe Runs

VII-3.3.1 Purpose. The classification and subclassification of the buried pipe elements is used in choosing the proper equation for effective slippage length L' or L'' which is then used in calculating piping forces and stresses. The pipe segment identified by the dimension L' or L'' always begins at either an elbow, bend, tee, or branch connection and terminates at the point (described below as the "virtual anchor") at which there is no slippage or relative movement at the pipe/soil interface.

VII-3.3.2 Classification of the Pipe Elements. It is in the bends, elbows, and branch connections that the highest stresses are found in buried piping subject to thermal expansion of the pipe. These stresses are due to the soil forces that bear against the transverse run (the run running perpendicular or at some angle to the direction of the pipe expansion). The stresses are proportional to the amount of soil deformation at the elbow or branch connection.

Piping elements are divided into three major categories depending upon what type of transverse element is being analyzed, as follows:

Category A: elbow or bend (see Fig. VII-3.3.2-1)

Category B: branch pipe joining the longitudinal run (see Fig. VII-3.3.2-2)

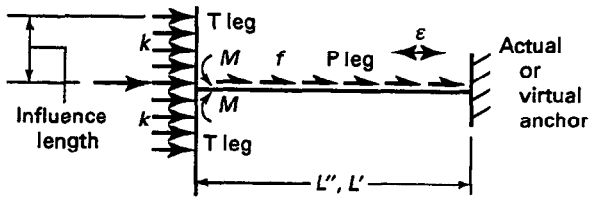
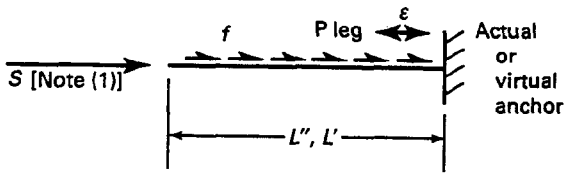


FIG. VII-3.3.2-3 ELEMENT CATEGORY C, TEE ON END OF P LEG



NOTE:
(1) Expansion joint pressure load plus sliding or convolution loads.

FIG. VII-3.3.2-4 ELEMENT CATEGORY D, STRAIGHT PIPE

Category C: longitudinal run ending in a tee (see Fig. VII-3.3.2-3)

Category D: straight pipe, no branch or transverse run (see Fig. VII-3.3.2-4)

Categories A, B, and C are further divided into three subcategories depending on the configuration of the pipe run at the end opposite that being analyzed. The piping elements are classified as follows:

A1, B1, C1: other end free or terminating in a flexible coupling or joint

A2, B2, C2: other end contains an elbow or tee

A3, B3, C3: other end is anchored

Category D elements include straight runs between an anchor (either actual or virtual) and a free end or a pipe section that is connected to an expansion joint.

The elements are further broken down into subtypes depending upon whether the longitudinal run (the pipe or P leg) and the transverse run (called the T leg) are long or short with respect to certain criteria. The transverse or T leg is the run against which the soil bears, producing an in-plane bending moment in elbow, branch, or tee. (Category D elements have no transverse leg.)

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The strict criterion for a long or short transverse leg is whether the length of the transverse run L_1 is longer or shorter than $3\pi/4\beta$, the length at which the hyperbolic functions in Hetenyi's equations [2] approach unit. The critical value for L_1 is often called the "influence" length, or that portion of transverse or T run which is deflected or "influenced" by seismic soil strain or pipe thermal expansion along the axis of the longitudinal or P run. In practice, a critical influence length L_1 of $1/\beta$ to $1.2/\beta$ may often be used, since there is very little deformation or load in that portion of the transverse run which exceeds this length. This implies that the vast majority of the bearing load on the transverse or T leg occurs in the first several feet of the pipe at the bend or branch. In summary, a transverse pipe is "long" if

$$L_1 \geq 3\pi/4\beta \text{ (conservative)}$$

or

$$L_1 \geq 1/\beta \text{ to } 1.2/\beta \text{ (usually acceptable)}$$

The criterion for a short or long P leg is whether or not its length L_2 is sufficiently long to experience the maximum force that can develop at the friction interface. For full maximum friction force ($F_{max} = \epsilon AE$) to occur in a straight pipe axially free at each end, its length L_2 would have to equal or exceed $2L_m$ with L_m calculated by Eq. (5). If one end terminates in an elbow or a tee, with the other end remaining axially unrestrained, the total length L_2 necessary for full friction to develop is $L'' + L_m$; the friction force over L_m is equal to the soil bearing force S plus the friction force acting on the length L' or L'', which is called the effective slippage length. The effective slippage length is the maximum length along which slippage occurs at the pipe/soil interface of a pipe with a transverse leg or branch. The effective slippage length L'' for long pipes with long transverse legs is calculated by

$$L'' = \Omega[(1 + 2F_{max}/f\Omega)^{1/2} - 1] \text{ in.} \quad (7)$$

where

$\Omega = AE\beta/k$

and F_{max} is calculated by Eq. (6).

Equation (7) applies to bends, tees, and branches. Although Eq. (7) was developed for the case where $L_2 = L'' + L_m$, it applies also for any case where $L_2 > L'' + L_m$, since the length of the region where there is zero slippage at the friction interface is immaterial [1]. Using L'' as calculated by Eq. (7), it can now be established that a P leg is classified long if it meets these criteria:

(A) For Types A1, B1, C1, $L_2 \geq L_m + L''$;

(B) For Types A2, B2, C2, $L_2 \geq 2L''$;

(C) For Types A3, B3, C3, D, $L_2 \geq L''$.

That point which is located a distance L' or L'' from the bend, branch, or tee, is called the virtual anchor, since it acts as if it were a three-axis restraint on the pipe.

VII-3.3.4 Locating the Virtual Anchor. Calculation of the forces and moments in buried piping at the changes in direction requires that the location of the virtual anchor (the effective slippage length L' away from the bend or branch element) in the P run and deformation δ of the soil at the buried element be established. For elements of all types with long P legs, L'' may be calculated by Eq. (7).

For Types A1, B1, and C1 elements (with one end of the P leg free or unrestrained axially) with "short" P legs L' must be found by a less direct method as follows [1]:

$$L' = [-b + (b^2 - 4ac)^{1/2}]/2a \text{ in.} \quad (8)$$

where

$a = 3f/(2AE)$

$b = \epsilon - fL_2/(AE) + 2f\beta/k$

$c = -f\beta L_2/k$

However, the most highly stressed runs in a buried piping system typically are restrained at both ends, either by a combination of transverse runs or a transverse and an anchor (either real or virtual).

For Types A2, B2, and C2 elements with short P legs, L' is expressed by

$$L' = L_2/2 \text{ in.} \quad (9)$$

For Types A3, B3, C3, and D elements with short P legs, L' is expressed by

$$L' = L_2 \text{ in.} \quad (10)$$

VII-4.0 COMPUTER MODELING OF BURIED PIPING

VII-4.1 Determination of Stresses

With f, k, and L' or L'' established, the stresses in a buried pipe due to thermal expansion can be determined with a general purpose pipe stress computer program. A buried piping system can be modeled

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with a typical mainframe or microcomputer pipe stress program by breaking the buried portions into elements of convenient length and then imposing a transverse spring at the center of each element to simulate the passive resistance of the soil. The entire pipe can be divided into spring-restrained elements in this manner; however, the only regions of the pipe that really need to be modeled in this manner are the lengths entering and leaving elbows or tees. The analyst should refer to the program users' manual for guidance in modeling soil springs.

All pipe stress computer programs with buried piping analysis options require that the following factors be calculated or estimated:

(A) Location of the virtual anchor (dimension L' or L'')

(B) Soil spring rate $k_{i,j}$, which is a function of the modulus of subgrade reaction k.

(C) Influence length, also a function of k.

Some programs ignore the friction at the pipe/soil interface; this is conservative for calculating bending stresses on the buried elbows and branch connections, but may be unconservative for calculating anchor reactions.

VII-4.2 Determination of Element Lengths

The element lengths and transverse soil spring rates for each element are calculated by the following procedure:

VII-4.2.1 Establish the element length dL and the number n of elements, as follows:

(A) Set the element length to be equal to between 2 and 3 pipe diameters. For example, dL for a NPS 6 may be set at either 1 ft or 2 ft, whichever is more convenient for the analyst.

(B) Establish the number n of elements by:

$$n = (3\pi/4\beta)/dL \tag{11}$$

This gives the number of elements, each being dL inches in length, to which springs are to be applied in the computer model. The number n of elements is always rounded up to an integer.

VII-4.2.2 Calculate the lateral spring rate $k_{i,j}$ to be applied at the center of each element.

$$k_{i,j} = kdL \text{ lb/in.} \tag{12}$$

where

k = the modulus of subgrade reaction calculated from Eq. (2).

VII-4.2.3 Calculate the equivalent axial load necessary to simulate friction resistance to expansion. The friction resistance at the pipe/soil interface can be simulated in the computer model by imposing a single force F_f in a direction opposite that of the thermal growth.

$$F_f = fL'/2 \text{ or } fL''/2 \text{ lb} \tag{13}$$

VII-4.2.4 Incorporate the springs and the friction force in the model. The mutually orthogonal springs $k_{i,j}$ are applied to the center of each element, perpendicular to the pipe axis. Shorter elements, with proportionally smaller values for the springs on these elements, may be necessary in order to model the soil restraint at elbows and bends. The friction force F_f for each expanding leg is imposed at or near the elbow tangent node, opposite to the direction of expansion.

VII-4.3 Determination of Soil Parameters

Soil parameters are difficult to establish accurately due to variations in backfill materials and degree of compaction. Consequently, values for elemental spring constants on buried pipe runs can only be considered as rational approximations. Stiffer springs can result in higher elbow stresses and lower bending stresses at nearby anchors, while softer springs can have the opposite effects. Backfill is not elastic, testing has shown that soil is stiffest for very small pipe movements, but becomes less stiff as the pipe movements increase. References [4], [7], and [8] discuss soil stiffness and recommend procedures for estimating values for k which are consistent with the type of soil and the amount of pipe movement expected. The analyst should consult the project geotechnical engineer for assistance in resolving any uncertainties in establishing soils parameters, such as the modulus of subgrade reaction k, confining pressure p_c, and coefficient of friction μ.

VII-4.4 Pipe With Expansion Joints

An expansion joint must be considered as a relatively free end in calculating stresses on buried elbows and loads on anchors. Since incorporation of expansion joints or flexible couplings introduces a structural discontinuity in the pipe, the effects of the unbalanced pressure load and the axial joint friction or stiffness must be superimposed on the thermal expansion effects

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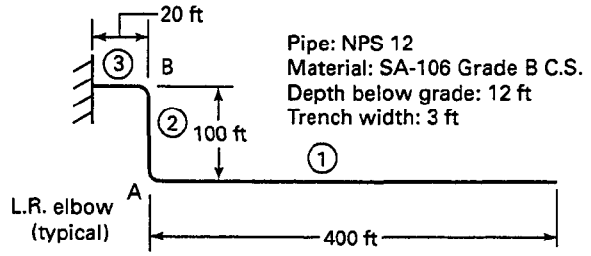

FIG. VII-5.0 PLAN OF EXAMPLE BURIED PIPE

in order to determine the maximum pipe stresses and anchor loads.

VII-4.5 Pipe Stresses at Building Penetrations

Stresses at building penetrations can be calculated easily after the reactions due to thermal expansion in the buried piping have been determined. If the penetration is an anchor, then the stress due to the axial force F_{max} and the lateral bending moment M can be found by

$$S_E = F_{max}/A + M/Z \text{ psi} \quad (14)$$

If the penetration is not an anchor, but is instead a simple support with a flexible water seal, it is necessary to determine the stiffness affects of the water seal material in order to calculate the stress in the pipe at the penetration. Differential movement due to building or trench settlement can generate high theoretical stresses at piping penetrations to buildings. Calculation of such stresses is beyond the scope of this Appendix.

VII-5.0 ALLOWABLE STRESS IN BURIED PIPE

Buried piping under axial stress can theoretically fail in one of two ways: either by column buckling (pipe pops out of the ground at mid-span) or local failure by crippling or tensile failure (much more serious than column buckling). Since buried piping stresses are secondary in nature, and since the piping is continuously supported and restrained (see Fig. VII-5.0), higher total stresses may be permitted as follows:

$$S_C \le S_A + S_h \quad (15)$$

where S_A and S_h are as defined in para. 102.3.2.

VII-6.0 EXAMPLE CALCULATIONS

VII-6.1 Assemble the Data

VII-6.1.1 Pipe Data

(A) diameter D = 12.75 in.
(B) wall thickness = 0.375 in.
(C) length of runs:
(C.1) Run 1: L_1 = 100 ft, L_2 = 400 ft
(C.2) Run 2: L_1 = 20 ft, L_2 = 100 ft
(C.3) Run 3: L_1 = 100 ft, L_2 = 20 ft
(D) Young's modulus $E = 27.9 \times 10^6$ psi
(E) moment of inertia I = 279.3 in^4
(F) cross section metal area A = 14.57 in.^{2}

VII-6.1.2 Soil Characteristics

(A) soil density w = 130 lb/ft^3
(B) pipe depth below grade H = 12 ft (144 in.)
(C) type of backfill: dense sand
(D) trench width B_d = 3 ft (36 in.)
(E) coefficient of friction μ = 0.3 min. to 0.5 max. (estimated)
(F) horizontal soil stiffness factor C_k = 80

VII-6.1.3 Operating Conditions

(A) pressure P = 100 psig
(B) temperature = 140°F
(C) ambient temperature = 70°F

VII-6.2 Calculate the Intermediate Parameters

VII-6.2.1 Relative Strain at the Pipe/Soil Interface. Thermal expansion for SA-106 Grade B carbon steel pipe from 70°F to 140°F is 0.0053 in./ft. Therefore,

$$\epsilon = (0.0053 \text{ in./ft})/(12 \text{ in./ft})$$
$$= 0.000424 \text{ in./in.}$$

VII-6.2.2 Modulus of Subgrade Reaction k [8]. Since the expansion is in the horizontal plane, use k_h from Eq. (2):

$$k_h = C_k N_h w D \quad (2)$$

$$C_k = 80$$

$$N_h = 0.285\, H/D + 4.3$$

$$= 0.285 \text{ (12 ft)(12 in./ft)/12.75 in.} + 4.3$$

$$= 7.519$$

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$$w = 130 \text{ pcf}/(1728 \text{ in.}^3/\text{ft}^3)$$

$$= 0.0752 \text{ lb/in.}^3$$

$$D = 12.75 \text{ in.}$$

$$k_h = (80)(7.519)(0.0752)(12.75) = 577 \text{ lb/in.}^2$$

VII-6.2.3 Friction Forces per Unit Length Acting at the Pipe/Soil Interface

$$f = \mu(P_c A_c + W_p) \quad (3)$$

Since the pipe lies more than 3 diameters below grade, the modified Marston equation from [1] is used to determine the confining pressure P_c of soil on the pipe.

$$P_c = wC_D B_d$$

$$C_D = 2.22 \text{ for } H/B_d = 12 \text{ ft.}/3 \text{ ft.}$$

$$= 4 \text{ (see Table VII-3.2.3 for sand)}$$

$$P_c = (130 \text{ pcf})(2.22)(3 \text{ ft.})/(144 \text{ in.}^2/\text{ft}^2)$$

$$= 6.01 \text{ psi}$$

$$A_c = D(1 \text{ in.}) = (12.75 \text{ in.})(1 \text{ in.})$$

$$= 40.05 \text{ in.}^2/\text{in. of length}$$

$W_p = 8.21$ lb/in. for water-filled carbon steel pipe

Maximum value of friction force per unit length f_{max}:

$$f_{max} = 0.5 [(6.01 \text{ psi})(40.05 \text{ in.}^2/\text{in.}) + 8.21 \text{ lb/in.}] \quad (3)$$

$$= 124.5 \text{ lb/in.}$$

Minimum value of friction force per unit length f_{min}:

$$f_{min} = 0.3 [(6.01)(40.05) + 8.21] \quad (3)$$

$$= 74.7 \text{ lb/in.}$$

VII-6.2.4 Pipe/Soil System Characteristic β [2]

$$\beta = [k_h/(4EI)]^{1/4} \quad (4)$$

$$= [577 \text{ psi}/4(27.9 \times 10^6 \text{ psi})(279.3 \text{ in.}^4)]^{1/4}$$

$$= 0.01166 \text{ in.}^{-1}$$

VII-6.2.5 Minimum Slippage Length L_m

$$L_m = \epsilon AE/f_{min} \quad (5)$$

$$= (0.000424 \text{ in./in.})(14.57 \text{ in.}^2)(27.9 \times 10^6 \text{ psi})$$

$$/74.7 \text{ lb/in.}$$

$$= 2307 \text{ in. or } 192 \text{ ft } 4 \text{ in.}$$

VII-6.2.6 Maximum Axial Force F_{max} Corresponding to L_m

$$F_{max} = \epsilon AE = (0.000424)(14.57)(27.9 \times 10^6) \quad (6)$$

$$= 172{,}357 \text{ lb}$$

VII-6.3 Classification of Runs

Classify the pipe runs in accordance with the models given in Table VII-6.3 and calculate the effective slippage length L' or L'' for each run.

VII-6.3.1 Run 1 is a Category A1 (elbow on one end, the other end free). Check to see if the transverse leg L_1 is long or short.

$$L_1 = 1200 \text{ in.}$$

$$3\pi/(4)(0.01166 \text{ in.}^{-1}) = 202 \text{ in.}$$

Since 1200 in. > 202 in., L_1 is long. Check to see if the longitudinal leg L_2 is long or short, that is, longer or shorter than $L_m + L''$. Using Eq. (7) to calculate L'',

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TABLE VII-6.3
EQUATIONS FOR CALCULATING EFFECTIVE LENGTH L' OR L''

Element Category	Equations for L' or L''	
	Short P Leg L'	Long P Leg L''
A1, B1, C1	If $L_2 < L_m + L''$, $L' = [-b + (b^2 - 4ac)^{1/2}]/2a$ (8) where $a = 3fI/(2AE)$, $b = \epsilon - fL_2/(AE) + 2f\beta/k$, $c = -f\beta L_2/k$	If $L_2 \geq L_m + L''$, $L'' = \Omega[(1 + 2F_{max}/f_{min}\Omega)^{1/2} - 1]$ (7)
A2, B2, C2	If $L_2 < 2L''$, $L' = L_2/2$ (9)	If $L_2 \geq 2L''$, $L'' = \Omega[(1 + 2F_{max}/f_{min}\Omega)^{1/2} - 1]$ (7)
A3, B3, C3	If $L_2 < L''$, $L' = L_2$ (10)	If $L_2 \geq L''$, $L'' = \Omega[(1 + 2F_{max}/f_{min}\Omega)^{1/2} - 1]$ (7)
D	If $L_2 < L_m$, $L' = L_2$ (10)	If $L_2 \geq L_m$, $L'' = L_m = \epsilon AE/f$ (5)

$$L'' = \Omega[(1 + 2F_{max}/f_{min}\Omega)^{1/2} - 1] \quad (7)$$

$$\Omega = AE\beta/k = (14.57 \text{ in.}^2)(27.9 \times 10^6 \text{ psi}) \times (0.01166 \text{ in.}^{-1})/577 \text{ psi} = 8214 \text{ in.}$$

$$L'' = 8214\{[1 + 2 \times 172{,}357/(74.7 \times 8214)]^{1/2} - 1\}$$

$$= 2051 \text{ in.}$$

$$L_m + L'' = 2307 + 2051 = 4358 \text{ in.}$$

Since L_2 = 400 ft or 4800 in., then since 4800 > 4358, the pipe run length L_2 is long, and Run 1 can be fully classified as Category A1 (long transverse, long pipe).

NOTE: If $L_m + L''$ would have exceeded L_2, then L' would be recalculated using Eq. (8), the correct equation for a short pipe.

VII-6.3.2 Run 2 is a Category A2 (elbow on each end). Check to see if the legs L_1 and L_2 are long or short.

Since $L_1 > 3\pi/4\beta$ (240 in. > 202 in.) and since $L_2 < 2L''$ [1200 in. < 2(2051 in.)], then Run 2 can be fully classified as a Category A2 (long transverse, short pipe). Then

$$L' = L_2/2 = (1200 \text{ in.})/2 = 600 \text{ in.}$$

VII-6.3.3 Run 3 is a Category A3 (anchor on one end, elbow on the other). Check to see if the legs L_1 and L_2 are long or short.

Since $L_1 > 3\pi/4\beta$ (1200 in. > 202 in.) and $L_2 < L''$ (240 in. < 2051 in.), then Run 3 can be fully classified as a Category A3 (long transverse, short pipe). Then

$$L' = L_2 = 240 \text{ in.}$$

NOTE: In order to fully qualify a buried piping system, it may also be necessary to include stresses due to weight of overburden (backfill) and vehicular loads [5, 6].

VII-6.4 Computer Modeling

Calculate the soil springs and friction force for use in a computer model of the buried pipe.

VII-6.4.1 Element Length. Set the element length to be ≈ 3 pipe diameters. dL = 36 in.

VII-6.4.2 Number of Elements. Only the soil within a length $3\pi/4\beta$ from the elbow will be subject to bearing force from the pipe. For the example system, $3\pi/4\beta$ = 202 in. Therefore, the number of elements needed is found by

$$n = (3\pi/4\beta)/dL = 202/36 = 5.61 \quad (11)$$

Therefore, use 6 elements, each 36 in. long.

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VII-6.4.3 Spring Rate k_{ij}. The spring rate to be applied to each element is found by

$$k_{i,j} = kdL \tag{12}$$

where k is from Eq. (2)

$$k_{i,j} = (577 \text{ psi})(36 \text{ in.}) = 20{,}772 \text{ lb/in.}$$

This is the theoretical spring rate to be imposed at the center of each element and normal to the surface of the pipe, with k_i in the plane of the expansion, and k_j perpendicular to the plane of expansion.

VII-6.4.4 Friction Force F_f. The friction forces to be applied at the elbow tangent points in Runs 1 and 2 are calculated as follows:

Parallel to Run 1:

$$F_f = fL''/2 \tag{13}$$

where

$f = f_{\min} = 74.7$ lb/in.
$L'' = 2051$ in.

$$F_f = (74.7 \text{ lb/in.})(2051 \text{ in.})/2 = 76{,}605 \text{ lb}$$

Parallel to Run 2:

$$F_f = (74.7 \text{ lb/in.})(600 \text{ in.})/2 = 22{,}410 \text{ lb} \tag{13}$$

The friction force to be applied at the elbow tangent point in Run 3 is calculated as follows:

Parallel to Run 3:

$$F_f = (74.7 \text{ lb/in.})(240 \text{ in.})/2 = 8964 \text{ lb} \tag{13}$$

The computer model then appears as is shown in Fig. VII-6.4.4.

VII-6.5 Results of Analysis

Computer analysis of the model shown in Fig. VII-6.4.4 gives combined stress S_C at various locations in the buried pipe as follows:

Location	S_C, psi
Virtual anchor	7,036
Elbow A	26,865
Elbow B	9,818
Penetration anchor	2,200

NOTE: S_C for this example includes longitudinal pressure stress, intensified bending stresses, and direct stresses due to axial loads from friction and soil bearing loads. It does not include weight of backfill or live loads.

The allowable stress as given by Eq. (15) is $S_A + S_h$, which for SA-106 Grade B steel pipe is 22,500 psi + 15,000 psi = 37,500 psi. Therefore, since the maximum S_C of 26,865 psi < 37,500 psi, the Code conditions are met.

VII-6.6 Anchor Load Example

If Element 1 were simply a straight pipe anchored at one end with the other end terminating in an expansion joint (see Fig. VII-6.6), the load on the anchor is found as follows.

(A) Calculate the maximum friction force acting along the friction interface.

$$F_f = F_{\max} = \epsilon AE \tag{6}$$

$$F_{\max} = \epsilon AE = (0.000424)(14.57)(27.9 \times 10^6) \tag{6}$$

$$= 172{,}357 \text{ lb}$$

(B) Calculate the load S at the expansion joint.

$$S = F_j + S_p$$

where

F_j = expansion joint friction force
= 9000 lb (from vendor data)
S_p = pressure force
= PA_s
where
P = design pressure
= 100 psig
A_s = effective cross-sectional area
= $\pi D^2/4$
= $\pi\ (12.75^2)/4$
= 127.6 in.^{2}

$$S_p = (100)(127.6) = 12{,}760 \text{ lb}$$

$$S = 9{,}000 + 12{,}760 = 21{,}760 \text{ lb}$$

(C) The total axial load F_a at the anchor then becomes

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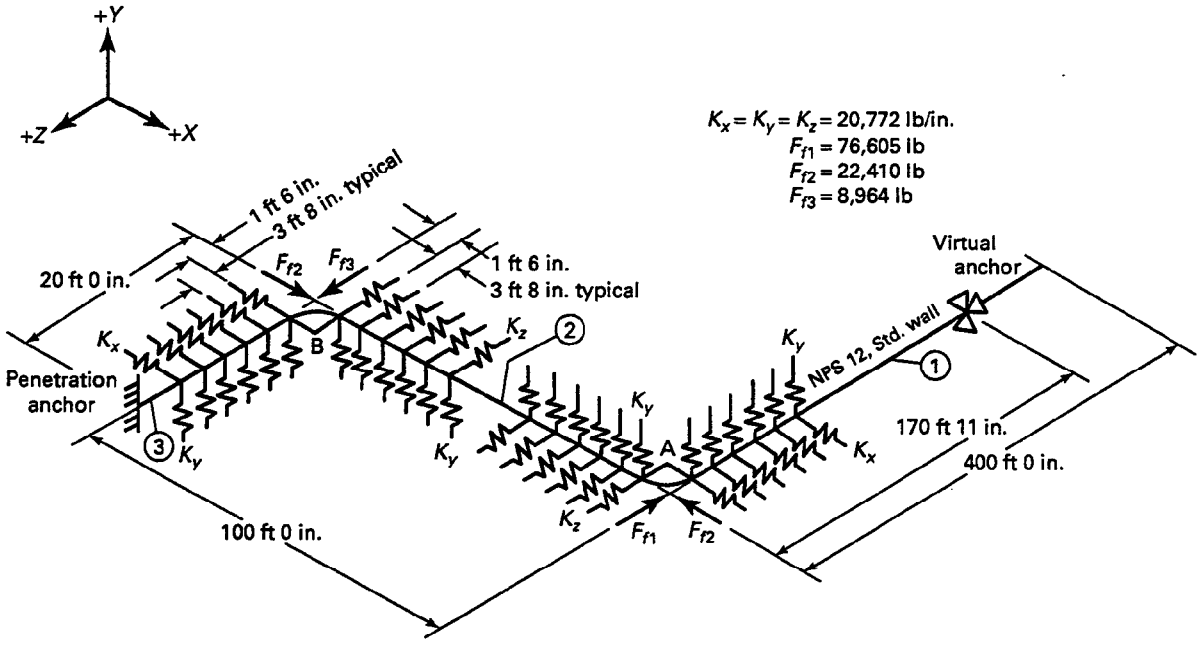

FIG. VII-6.4.4 COMPUTER MODEL OF EXAMPLE PIPE

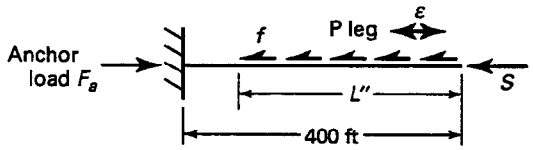

FIG. VII-6.6 EXAMPLE PLAN OF ELEMENT 1 AS A CATEGORY D ELEMENT

$$F_a = 172{,}357 + 21{,}760 = 194{,}117 \text{ lb}$$

If anchor loads must be limited, then the expansion joint should be located closer to the anchor in order to reduce the force due to friction at the pipe/soil interface.

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ASME CODE FOR PRESSURE PIPING, B31

B31.1	Power Piping	2001
B31.2[1]	Fuel Gas Piping	1968
B31.3	Process Piping	1999
B31.4	Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids	1998
B31.5	Refrigeration Piping and Heat Transfer Components	2001
B31.8	Gas Transmission and Distribution Piping Systems	1999
B31.9	Building Services Piping	1996
B31.11	Slurry Transportation Piping Systems	1989 (R1998)
B31G-1991	Manual for Determining the Remaining Strength of Corroded Pipelines: A Supplement to ASME B31 Code for Pressure Piping	

NOTE:

(1) USAS B31.2-1968 was withdrawn as an American National Standard on February 18, 1988. ASME will continue to make available USAS B31.2-1968 as a historical document for a period of time.

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ASME B31.1

INTERPRETATIONS VOL. 35

Replies to Technical Inquiries
January 1, 2000, Through June 30, 2000

It has been agreed to publish intepretations issued by the B31 Committee concerning B31.1 as part of the update service to the Code. The interpretations have been asssigned numbers in chronological order. Each interpretation applies either to the latest Edition or Addenda at the time of issuance of the interpretation or the Edition or Addenda stated in the reply. Subsequent revisions to the Code may have superseded the reply.

The replies are taken verbatim from the original letters, except for a few typographical and editorial corrections made for the purpose of improved clarity. In some instances, a review of the interpretation revealed a need for corrections of a technical nature. In these cases, a revised reply bearing the original interpretation number with the suffix R is presented. In the case where an interpretation is corrected by Errata, the original interpretation number with the suffix E is used.

ASME procedures provide for reconsideration of these interpretations when or if additional information is available which the inquirer believes might affect the interpretation. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. As stated in the Statement of Policy in the Code documents, ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

Interpretations Nos. 2 through 7 were included with the update service to the 1983 Edition and Interpretations Nos. 8 through 13 were included with the update service to the 1986 Edition. Interpretations Nos. 14 through 19 were included with the update service to the 1989 Edition. Interpretations Nos. 20 through 25 were included with the update service to the 1992 Edition. Interpretations Nos. 26 through 30 were included with the update service to the 1995 Edition. Interpretations Nos. 31 through 34 were included with the update service to the 1998 Edition. For the 2001 Edition, interpretations will be issued as necessary up to twice a year until the publication of the 2004 Edition.

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B31.1

Subject	Interpretation	File No.
Para. 124, ASTM A 671, CC70 Class 22 Pipe Material Application	35-3	B31-99-036
Para. 136.4.3(B), Magnetic Particle Examination	35-2	B31-99-015
Welding of Butt Welded Fittings	35-1	B31-97-055

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Interpretation: 35-1

Subject: B31.1, Welding of Butt Welded Fittings

Date Issued: April 24, 2000

File: B31-97-055

Question: Does ASME B31.1 prohibit butt welding fittings to be welded directly to fillet welding fittings (e.g., a butt welding elbow to a slip on flange) using fillet welds?

Reply: No, if neither fitting is modified to fabricate the assembly. However, if one or both of the fittings are modified, the fitting or fittings may no longer be considered to be standard fittings and shall be qualified in accordance with para. 104.7.2. The requirements of para. 104.8 shall be met considering the effect of any modifications

Interpretation: 35-2

Subject: B31.1, Para. 136.4.3(B), Magnetic Particle Examination

Date Issued: April 24, 2000

File: B31-99-015

Question: When using MT, what size of indication is considered relevant?

Reply: All MT indications that do not meet the acceptance criteria of para. 136.4.3(B) are considered relevant.

Interpretation: 35-3

Subject: B31.1, Para. 124, ASTM A 671, CC70 Class 22 Pipe Material Application

Date Issued: June 9, 2000

File: B31-99-036

Question: Does ASME B31.1 prohibit the use of ASTM A 671, CC70, Class 22, Specification for Electric-Fusion Welded Steel Pipe for Atmospheric and Lower Temperatures, for service at temperatures for which allowable stress values are listed in Appendix A?

Reply: No. Refer to para. 124.9.

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ASME B31.1

INTERPRETATIONS VOL. 36

Replies to Technical Inquiries
July 1, 2000, Through December 31, 2000

It has been agreed to publish intepretations issued by the B31 Committee concerning B31.1 as part of the update service to the Code. The interpretations have been asssigned numbers in chronological order. Each interpretation applies either to the latest Edition or Addenda at the time of issuance of the interpretation or the Edition or Addenda stated in the reply. Subsequent revisions to the Code may have superseded the reply.

The replies are taken verbatim from the original letters, except for a few typographical and editorial corrections made for the purpose of improved clarity. In some instances, a review of the interpretation revealed a need for corrections of a technical nature. In these cases, a revised reply bearing the original interpretation number with the suffix R is presented. In the case where an interpretation is corrected by Errata, the original interpretation number with the suffix E is used.

ASME procedures provide for reconsideration of these interpretations when or if additional information is available which the inquirer believes might affect the interpretation. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. As stated in the Statement of Policy in the Code documents, ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

Interpretations Nos. 2 through 7 were included with the update service to the 1983 Edition and Interpretations Nos. 8 through 13 were included with the update service to the 1986 Edition. Interpretations Nos. 14 through 19 were included with the update service to the 1989 Edition. Interpretations Nos. 20 through 25 were included with the update service to the 1992 Edition. Interpretations Nos. 26 through 30 were included with the update service to the 1995 Edition. Interpretations Nos. 31 through 34 were included with the update service to the 1998 Edition. For the 2001 Edition, interpretations will be issued as necessary up to twice a year until the publication of the 2004 Edition.

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B31.1

Subject	Interpretation	File No.
Para. 102.3.1(C), Allowable Stresses	36-2	B31-99-016
Para. 104.3.1(E), Branch Connections	36-1	B31-99-014

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Interpretation: 36-1

Subject: B31.1, Para. 104.3.1(E), Branch Connections

Date Issued: October 3, 2000

File: B31-99-014

Question (1): Per 1998 Edition of ASME B31.1, Power Piping, is Formula (3) or (3A) given in para. 104.1.2 to be used to determine t_{mh} when designing a branch connection for external pressure?

Reply (1): Neither; t_{mh} shall be determined in accordance with para. 104.1.3, provided D_{oh}, D_{ob}, and t_r, if reinforcement is required, are reduced to compensate for external corrosion.

Question (2): Is t_{mh} then used in the formula in paragraph 104.3.1(E) to determine the required reinforcement area?

Reply (2): Yes.

Interpretation: 36-2

Subject: B31.1, Para. 102.3.1(C), Allowable Stresses

Date Issued: October 3, 2000

File: B31-99-016

Question: May the allowable stresses listed in Tables 1A and 1B of Section II, Part D of the ASME Boiler and Pressure Vessel Code, for usage by Section I of that Code, be used in B31.1 designs, provided that the material has been approved by B31.1?

Reply: No. B31.1 does not permit the use of Section II values.

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B31.1 — Cases No. 27

A Case is the official method of handling a reply to an inquiry when study indicates that the Code wording needs clarification, or when the reply modifies the existing requirements of the Code, or grants permission to use new materials or alternative constructions.

ASME has agreed to publish Cases issued by the B31 Committee concerning B31.1 as part of the update service to B31.1. The text of proposed new and revised Cases and reaffirmations of current Cases appear in *Mechanical Engineering* for public review. A notice also appears in *Mechanical Engineering* when new and revised Cases are approved. New and revised Cases, as well as announcements of reaffirmed Cases and annulments, then appear in the next update. All Cases currently in effect at the time of publication of the 1989 Edition of the Code were included in the update that immediately followed, Interpretations No. 14 and Cases No. 9. As of the 1992 and later Editions, all Cases currently in effect at the time of publication of an Edition are included with it as an update.

This update, Cases No. 27, which is included after the last page of the 2001 Edition and the Interpretations No. 35 that follow, contains the following Cases.

145	153	163	165	173
146-1	162	164	170	

Cases 147, 151, 154, 159, 161, and 168, which were included in the first update to the 1998 Edition (Cases No. 25), were allowed to expire. Case 169, which was included in the second update (Cases No. 26), was also allowed to expire.

The page numbers for the Cases supplements included with updates to the 2001 Edition start with C-1 and will continue consecutively through the last update to this Edition. The Cases affected by this supplement are as follows:

Page	*Location*	*Change*
C-1	Case 145	(1) Reaffirmed: July 2000 (2) New expiration date: July 31, 2003
C-2, C-3	Case 146-1	(1) Reaffirmed: March 2001 (2) New expiration date: March 31, 2004
C-8, C-9	Case 163	(1) Reaffirmed: July 2000 (2) New expiration date: July 31, 2003
C-10	Case 164	(1) Reaffirmed: September 2000 (2) New expiration date: September 30, 2003
C-11	Case 165	(1) Reaffirmed: July 2001 (2) New expiration date: July 31, 2004
C-14	Case 173	Added

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B31 CASE 145
Nickel–Molybdenum–Chromium Alloys (UNS N10276), ANSI/ASME B31.1 Construction

Approval Date: August 1985
Reaffirmation Date: July 2000

This case shall expire on July 31, 2003, unless previously annulled or reaffirmed

Inquiry: May nickel–molybdenum–chromium alloy (UNS N10276) fittings, rod, plate, and strip, seamless and welded pipe and tube conforming to ASTM B 366, B 574, B 575, B 619, B 622, and B 626 be used for ANSI/ASME B31.1 construction?

Reply: It is the opinion of the Committee that nickel–molybdenum–chromium alloy (UNS N10276) may be used in ANSI/ASME B31.1 construction provided:

(1) the maximum allowable stress values for the material shall be those given in Table I. For welded components, these values shall be multiplied by a factor of 0.85.

(2) welded fabrication shall conform to the applicable requirements of B31.1:

(a) Welding Procedure and Performance Qualifications shall be conducted in accordance with Section IX, ASME Boiler and Pressure Vessel Code.

(b) Welding shall be done by any welding process capable of meeting the requirements.

(c) All filler metal, including consumable insert material, shall comply with the requirements of Section IX.

(d) When welding repair of a defect is required, it shall be in accordance with ANSI/ASME B31.1, para. 127.4.11. When a defect is removed but welding repair is unnecessary, the surface shall be contoured to eliminate any sharp notches or corners. The contoured surface shall be reinspected by the same means originally used for locating the defect to assure it has been completely removed.

(e) Heat treatment after fabrication or forming is neither required nor prohibited.

(3) this Case number shall be identical in the Data Report.

TABLE I

For Metal Temperature Not Exceeding, °F	Maximum Allowable Stress, ksi[1]	Maximum Allowable Stress, ksi
100	25.0	25.0
200	25.0	25.0
300	25.0	23.0
400	24.3	21.2
500	23.9	20.0
600	23.5	18.8
650	23.3	18.3
700	23.1	17.8
750	22.9	17.4
800	22.8	17.1
850	22.6	16.8
900	22.3	16.6
950	22.1	16.5
1000	21.8	16.5

NOTE:
(1) Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. These higher stress values exceed 67% but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for the flanges of the gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction.

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B31 CASE 146-1
Nickel–Chromium–Molybdenum–Columbium Alloy (UNS N06625) in ASME B31.1 Construction

Approval Date: March 1989
Reaffirmation Date: March 2001

This case shall expire on March 31, 2004, unless previously annulled or reaffirmed

Inquiry: May nickel–chromium–molybdenum–columbium alloy (UNS N06625) conforming to the specifications listed in Table I be used for construction of ASME B31.1 Power Piping systems?

Reply: It is the opinion of the Committee that nickel–chromium–molybdenum–columbium alloy (UNS N06625) conforming to the product specifications shown in Table I may be used in the construction of power piping complying with the rules of ASME B31.1 provided the following additionl requirements are met.

(1) THESE MATERIALS SHALL NOT BE USED FOR BOILER EXTERNAL PIPING. See para. 100.1.2(A).

(2) The allowable stress values shall be those listed in Table II.

(3) All longitudinal welds in any of the materials listed in Table I shall be completely examined by radiography. Radiographic examination shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, latest edition, para. UW-51.

(4) The welding procedure qualification and performance qualifications shall be conducted in accordance with ASME Boiler and Pressure Vessel Code, Section IX. For qualifying welding procedures, the material is P-No. 43.

(5) Postweld heat treatment of this material is neither required nor prohibited. However, no postweld heat treatment shall be performed except by agreement between the owner and the manufacturer, installer, or erector. The temperature, time, and method of heat treatment shall be covered by the agreement.

(6) Longitudinally seam welded pipe, with or without filler metal added, is permitted. Longitudinally seam welded pipe shall be fabricated from plate meeting the requirements of ASTM B 443. All seam welded pipe shall comply with the following requirements.

(a) The welds shall be made by an electric arc process.

(b) The joints shall be full penetration double-welded or single-welded butt joints employing fusion welding processes as defined under para. 100.2 Definitions of ASME B31.1. Where backing rings or strips are used, the ring or strip material shall be of the same P-Number as the plate being joined. Backing rings or strips shall be completely removed after welding prior to radiography, and the exposed weld surface shall be examined visually for conformance to the requirement of the following paragraph. Welds made by procedures using backing rings which remain in place are prohibited.

(c) The weld surface on the outside diameter side of the pipe shall be flush with the base plate or shall have a reasonably uniform crown in accordance with Table 127.4.2 of ASME B31.1. The weld reinforcement on the inside diameter side of the pipe may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be reasonably smooth and free of irregularities. The deposited metal shall be fused uniformly into the plate surface. No concavity of contour is permitted.

(d) Weld defects shall be repaired by removal to sound metal and rewelding. Subsequent heat treatment and inspection shall be as required on the original welds.

(e) When heat treatment is required, such heat treatment shall be done in accordance with para. 5, after all welding.

(f) The requirements of ASTM A 530 for welded pipe shall be met. Variations in wall thickness and length for longitudinally seam welded pipe with filler metal added shall be the same as required in ASTM A 530 for seamless or longitudinally seam welded pipe without filler metal.

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TABLE I

Plate, Sheet, and Strip	B 443-84
Seamless Pipe and Tube	B 444-84
Rod and Bar	B 446-84
Forgings	B 564-86
Wrought Fittings	B 366-87

TABLE II
ALLOWABLE STRESS VALUES

Spec No.	Metal Temp. [Note (1)], °F, Not Exceeding	Allowable [Notes (2), (3)] Stress Values, ksi	Spec No.	Metal Temp. [Note (1)], °F, Not Exceeding	Allowable [Notes (2), (4)] Stress Values, ksi
B 443 Grade 1	300	27.5	B 443 Grade 2	100	25.0
B 444 Grade 1	400	26.8	B 444 Grade 2	200	24.6
B 446 Grade 1	500	26.1	B 446 Grade 2	300	24.0
B 564	600	25.4	B 366 (made	400	22.5
B 366 (made	700	25.0	with Grade	500	21.7
with Grade	800	24.6	2 material)	600	21.0
1 material)	900	24.0		700	20.7
	1000	23.7		800	20.1
	1100	23.4		900	19.8
	1150	21.0		1000	19.6
	1200	13.2		1100	19.3
				1150	19.3
				1200	19.3

NOTES:
(1) Alloy 625 suffers severe loss of impact strength after longtime aging in the temperature range 1000°F–1400°F.
(2) These stress values may be interpolated to determine values for intermediate temperatures.
(3) Allowable stresses are based on 110,000 psi tensile strength, the minimum strength for annealed material (Grade 1).
(4) Allowable stresses are based on 100,000 psi tensile strength, the minimum strength for solution annealed material (Grade 2).

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B31 CASE 153
Use of Alloy UNS S31803 Material in ASME B31.1 Construction

Approval Date: November 1989
Reaffirmation Date: November 1998

This case shall expire on November 30, 2001, unless previously annulled or reaffirmed

TABLE 1
ASTM PRODUCT SPECIFICATIONS

Piping	A 790-87
Tubing	A 789-87
Forgings	A 182-87
Plate, Sheet, and Strip	A 240-87
Bars and Shapes	A 276-87
Wrought Piping Fittings	A 815-86

Inquiry: May solution annealed austenitic–ferritic stainless steel, 22Cr–5½Ni–3Mo alloy (UNS S31803), materials be used in ASME B31.1 construction?

Reply: The product specifications shown in Table 1 for solution annealed ferritic–austenitic steel, 22Cr–5½Ni–3Mo alloy, may be used in the construction of power piping complying with the rules of ASME B31.1, provided the following additional requirements are met.

(1) These materials shall not be used for Boiler External Piping. See para. 100.1.2(A).

(2) Material shall be furnished in the heat treated condition. The heat treatment shall be performed at 1870°F to 2010°F with subsequent quenching in water or rapid cooling by other means.

(3) The allowable stress values shall be as follows:

For Metal Temperature Not Exceeding, °F	Max. Allowable Stress Values, ksi
100	22.5
200	22.5
300	21.7
400	20.9
500	20.4
600	20.2

(4) All longitudinal weld joints shall be completely examined by radiography. Radiographic examination shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, latest Edition, UW-51.

(5) The Welding Procedure Qualification and Performance Qualifications shall be conducted in accordance with Section IX. For qualifying welding procedures, the material shall be considered as P-No. 10H Gr. No. 1 of QW-422.

(6) Heat treatment after forming or fabrication is neither required nor prohibited [except as noted in para. (7)(e)], but any heat treatment applied shall be performed at 1870°F to 2010°F, followed by a rapid cool.

(7) Plate may be made into longitudinally welded pipe with filler metal added. Requirements of A 790 shall be met with the following modifications.

(a) The welds shall be made by an electric arc process involving the deposition of filler metal.

(b) The joints shall be full penetration double-welded or single-welded butt joints employing fusion welding processes, as defined under "Definitions," ASME Boiler and Pressure Vessel Code, Section IX. Where backing rings or strips are employed, the ring or strip material shall be of the same P-Number (QW-422 of Section IX) as the plate being joined. Backing rings or strips shall be completely removed after welding, prior to any required radiography, and the exposed weld surface shall be examined visually for conformance to the requirements of the following paragraph. Welds made by procedures employing backing rings which remain in place are prohibited.

(c) The weld surface on the O.D. side of the pipe shall be flush with the base plate or shall have a reasonably uniform crown in accordance with Table 127.4.2 in the Code. The weld surface on the I.D. side of the reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be reasonably smooth and free of irregularities. The deposited metal shall be fused uniformly into the plate surface. No concavity of contour is permitted unless the resulting thickness of the weld metal is equal to or greater than the minimum thickness of the adjacent base metal.

(d) Weld defects shall be repaired by removal to sound metal and rewelding. Subsequent heat treatment and inspection shall be as required on the original welds.

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(e) All welding shall be done prior to heat treatment. After welding, solution heat treatment shall be in accordance with para. 2.

(8) CAUTIONARY NOTE: This Case allows the use of this material only for the temperature range given in para. (3). This material may be expected to exhibit embrittlement at room temperature after service above 600°F.

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B31 CASE 162
Use of 21Cr–11Ni–N Alloy (S30815) for ASME B31.1 Construction

Approval Date: September 1992
Reaffirmation Date: September 1998

This case shall expire on September 30, 2001, unless previously annulled or reaffirmed

Inquiry: May solution annealed 21Cr–11Ni–N Alloy (S30815) seamless tubes and pipes, welded tubes and pipes, plate, sheet, strip, forging, and bar, conforming to the specifications of A 213, A 312, A 249, A 358, A 409, A 240, A 182 and A 479 be used in ASME B31.1 construction?

Reply: It is the opinion of the Committee that solution annealed 21Cr–11Ni–N Alloy (UNS S30815) seamless tubes and pipes, welded tubes and pipes, plate, sheet, strip, forging, and bar as described in the Inquiry may be used in ASME B31.1 construction provided:

(a) the material meets the chemical analysis and minimum tensile requirements detailed in the specification and noted here in Tables 1 and 2, respectively; otherwise conforming to all other requirements of the respective ASTM material specification;

(b) the maximum allowable design stress values shall be as given in Table 3, except that for welded tube and pipe, a joint efficiency factor, E_j, of 0.85 shall be used;

(c) welding shall be performed using any welding process or combination of processes capable of meeting the requirements of Section IX for P-No. 8, Group No. 2 materials. If postweld heat treatment is performed, the material shall be heated to 1560–1740°F for 10–15 minutes, followed by cooling in air.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Percent
Carbon	0.05–0.10
Manganese, max	0.80
Phosphorus, max	0.40
Sulphur, max	0.030
Silicon	1.40–2.00
Nickel	10.0–12.0
Chromium	20.0–22.0
Nitrogen	0.14–0.20
Cerium	0.03–0.08
(Balance Iron)	

TABLE 2
MECHANICAL PROPERTY REQUIREMENTS

Tensile strength, min, ksi	87
Yield strength, 0.2% offset min, ksi	45
Elongated in 2 in. min, %	40

(d) heat treatment after forming is neither required nor prohibited. If heat treatment is used, the solution treatment shall consist of heating to a temperature of 1920°F to 2100°F and quenching in water or rapidly cooling by other means.

(e) this Case number shall be referenced in the documentation and marking of the material and recorded on the Manufacturer's Data Report.

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TABLE 3

For Metal Temperature Not Exceeding, °F	Max. Allowable Stress Values, ksi		For Metal Temperature Not Exceeding, °F	Max. Allowable Stress Values, ksi	
	...	Note (1)		...	Note (1)
100	21.8	21.8	1050	11.6	11.6
200	21.6	21.6	1100	9.0	9.0
300	20.4	20.4	1150	6.9	6.9
400	19.6	19.6	1200	5.2	5.2
500	18.4	19.1	1250	4.0	4.0
600	17.7	18.7	1300	3.1	3.1
650	17.5	18.6	1350	2.4	2.4
700	17.3	18.4	1400	1.9	1.9
750	17.1	18.2	1450	1.6	1.6
800	16.8	18.0	1500	1.3	1.3
850	16.6	17.8	1550	1.0	1.0
900	16.3	17.5	1600	0.86	0.86
950	16.1	17.2	1650	0.71	0.71
1000	14.9	14.9			

NOTE:

(1) Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. These higher stress values exceed 67%, but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction.

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B31 CASE 163
Use of Ni–Cr–Co–Mo Alloy (UNS N06617) for ASME B31.1 Construction

Approval Date: July 1994
Reaffirmation Date: July 2000

This case shall expire on July 31, 2003, unless previously annulled or reaffirmed

Inquiry: May solution annealed Ni–Cr–Co–Mo alloy (UNS N06617) wrought plate, sheet, rod, bar, forgings, welded pipe, and seamless tube that meet the chemical composition requirements given in Table 1, the mechanical property requirements given in Table 2, and that further meet all other applicable requirements of the specifications listed in Table 3 be used in ASME B31.1, welded construction at temperatures up to and including 1500°F?

Reply: It is the opinion of the Committee that solution annealed Ni–Cr–Co–Mo alloy (UNS N06617) as described in the Inquiry may be used for construction, provided that all applicable requirements of ASME B31.1 and the following additional requirements are met.

(a) This material shall not be used for boiler external piping. See para. 100.1.2(A).

(b) Material shall be solution annealed at a temperature of 2100°F–2250°F and quenched in water or rapidly cooled by other means.

(c) The maximum allowable stress values for the material shall be those given in Table 4. For welded components, these values shall be multiplied by a factor of 0.85, except when 100% radiography is performed as noted in para. 136.4.5.

(d) Separate welding procedures and performance qualifications shall be required for this material. The welding procedure qualifications and performance qualification shall be conducted as prescribed in Section IX of the ASME Boiler and Pressure Vessel Code.

(e) Heat treatment after forming or fabrication is neither required nor prohibited. When heat treatment is performed, it shall be in accordance with (b) above.

(f) For external pressure design, refer to para. 104.1.3.

(g) For para. 104.1.2, which requires a temperature dependent parameter y, the y values are the same as nickel alloys listed in Table 104.1.2(A) and shall be as follows:

1150°F and below	$y = 0.4$
1200°F	$y = 0.5$
1250°F and above	$y = 0.7$

TABLE 1
CHEMICAL REQUIREMENTS

Element	Percent
Carbon	0.05–0.15
Manganese, max.	1.0
Silicon, max.	1.0
Sulfur, max.	0.015
Iron, max.	3.0
Chromium	20.00–24.00
Cobalt	10.0–15.0
Molybdenum	8.0–10.0
Aluminum	0.8–1.5
Titanium, max.	0.6
Copper, max.	0.5
Boron, max.	0.006
Nickel, min.	44.5

TABLE 2
MECHANICAL PROPERTY REQUIREMENTS

Tensile strength, min., ksi	95
Yield strength, min., ksi	35
Elongation in 2 in. or 4 diameters, min., %	35

TABLE 3
PRODUCT SPECIFICATIONS

Rod and bar	B 166
Plate, sheet, and strip	B 168
Tube	B 444
Forgings	B 564
Welded pipe	B 546

(h) Pressure parts machined from bar shall be restricted to NPS 4 or smaller. Hubbed flanges, elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

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TABLE 4

For Metal Temperature Not Exceeding, °F	Maximum Allowable Stress, ksi	Maximum Allowable Stress, ksi [Note (1)]
100	23.3	23.3
200	20.5	23.3
300	19.1	23.3
400	18.1	23.3
500	17.3	23.3
600	16.7	22.5
700	16.2	21.9
800	15.9	21.5
900	15.7	21.1
1000	15.5	20.9
1100	15.4	20.7
1150	15.4	20.7
1200	15.3	16.9
1250	13.0	13.0
1300	10.0	10.0
1350	7.7	7.7
1400	6.0	6.0
1450	4.6	4.6
1500	3.6	3.6

NOTE:

(1) Due to the relatively low yield strength of this material, these higher stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. These higher stress values exceed 67%, but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction.

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B31 CASE 164
Use of Micro-Alloyed Carbon Steel Bar in ASME B31.1 Construction

Approval Date: September 1994
Reaffirmation Date: September 2000

This case shall expire on September 30, 2003, unless previously annulled or reaffirmed

Inquiry: May micro-alloyed carbon steel bar with additions of aluminum, vanadium, and nitrogen, a chemical composition as specified in Table 1, material properties as specified in Table 2, and otherwise conforming to the requirements of ASTM A 675 be used for ASME B31.1 construction?

Reply: It is the opinion of the Committee that the hot rolled bar material described in this Case may be used in welded and unwelded construction under the rules of ASME B31.1 provided the following additional requirements are met.

(a) The allowable stress values tabulated in Table 3 shall not be exceeded. The material shall not be used for design temperatures above or below those for which the allowable stress values are given in this Code Case.

(b) The material shall be limited to service application NPS 2 and smaller and supplied for manufacturer as round bar not exceeding 4 in. diameter.

(c) Separate welding procedures and performance qualifications shall be required for this material. The welding process shall be GTAW. The welding procedure qualification and performance qualification shall be conducted in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

(d) The material shall not be used for Boiler External Piping.

(e) The material described in this Inquiry is one of the highest tensile strength materials approved for use in ASME pressure component applications. The ASME materials data base has little fatigue data on these high strength materials. When calculating the allowable expansion stress range S_A using Eq. (1) in para. 102.3.2(C), the allowable stresses for A 106 Grade B shall be used. Further, fittings manufactured using this material shall be fatigue tested to assure comparable behavior with ASME materials to be used in installed assemblies.

(f) All applicable requirements of ASME B31.1 shall be met.

TABLE 1
CHEMICAL COMPOSITION
(Heat or Cast Analysis)

Element	Percent Weight
Carbon	0.19–0.26
Manganese	1.35–1.65
Phosphorus	0.040 max.
Sulfur	0.050 max.
Silicon	0.15–0.35
Vanadium	0.02–0.20
Aluminum	0.015–0.050
Nitrogen	0.03 max.

GENERAL NOTE: Addition of elements intended to enhance machinability, such as lead, selenium, bismuth and tellurium, is not allowed.

TABLE 2
MINIMUM MECHANICAL PROPERTIES

Property	Value
Tensile Strength	110 ksi
Yield Strength (0.2% offset)	80 ksi min.
Elongation (in 2 in.)	15% min.

TABLE 3
ALLOWABLE STRESS VALUES

For Metal Temperature Not Exceeding, °F	Maximum Stress Value, ksi
−20 to 650	23.8

GENERAL NOTE: The allowable stress value is based on a tensile strength value of 95 ksi.

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B31 CASE 165
Use of Alloy S32550 (25.5Cr–5.5Ni–3.5Mo–Cu), P-No. 10H in ASME B31.1 Construction

Approval Date: July 1995
Reaffirmation Date: July 2001

This Case shall expire on July 31, 2004, unless previously annulled or reaffirmed

Inquiry: May Alloy S32550 (25.5Cr–5.5Ni–3.5Mo–Cu), P-No. 10H, be used in power piping applications constructed in accordance with the B31.1 Code at temperatures up to and including 500°F?

Reply: Alloy S32550 may be used for ASME B31.1 construction to the specifications noted in this Code Case provided that all of the following requirements are met.

(a) THESE MATERIALS ARE NOT ACCEPTABLE FOR USE ON BOILER EXTERNAL PIPING — SEE PARA. 100.1.2.

(b) All applicable requirements of ASME B31.1 shall be met.

(c) Allowable stress values shown in Table 1 shall not be exceeded. These materials shall not be used at temperatures above those for which allowable stress values are given in this Code Case.

(d) All openings 4 in. and larger shall conform to para. 127.4.8 except that full penetration welds shall be used and separate reinforcing pads shall not be used.

(e) Butt weld joints shall be examined radiographically for their full length as prescribed in para. 136.4.5 when the wall thickness at the weld joint exceeds $1\frac{1}{2}$ in.

(f) Branch connection welds shall be radiographically (para. 136.4.5) or U.T. (para. 136.4.6) examined. See Table 136.4 when the size of the branch exceeds NPS 4.

(g) All welds where material thickness exceeds $\frac{3}{4}$ in. shall be examined by the liquid penetrant method.

(h) Pipe under external pressure shall meet requirements of para. 104.1.3.

(i) Heat treatment of product form is neither required nor prohibited but if performed shall be done in accordance with respective product specifications. See Table 132.

(j) Charpy impact testing shall be done in accordance with requirements of UHA-51(c)(2) when material wall thickness is greater than $\frac{3}{8}$ in.

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TABLE 1

Spec. No.	Notes	Specified Minimum Tensile, ksi	Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature up to and Including 500°F. [Note (1)]				
			-20 to 100	200	300	400	500
Seamless Pipe and Tube							
A789	...	110	27.5	27.4	25.7	24.7	24.7
A790	...	110	27.5	27.4	25.7	24.7	24.7
Welded Pipe and Tube							
A789	(2)	110	23.4	23.3	21.9	21.0	21.0
A790	(2)	110	23.4	23.3	21.9	21.0	21.0
Plate							
A240	...	110	27.5	27.4	25.7	24.7	24.7
Bar							
A479	...	110	27.5	27.4	25.7	24.7	24.7

NOTES:
(1) This steel may be expected to develop embrittlement after exposure to temperatures above 500°F for prolonged times. See ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, UHA-109.
(2) A factor of 0.85 has been applied in arriving at the maximum allowable stress values in tension for this material. Divide tabulated values by 0.85 for maximum allowable longitudinal tensile stress.

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B31 CASE 170
PWHT Exemptions for P-Nos. 4 and 5A Materials for ASME B31.1 Construction

Approval Date: March 1999

This Case shall expire on March 31, 2002, unless previously annulled or reaffirmed

Inquiry: What additional exemption to postweld heat treatment may be taken for P-Nos. 4 and 5A materials used for ASME B31.1 construction?

Reply: An additional exemption may be taken for nominal pipe sizes greater than NPS 4. All other rules for exemption in Table 132 for P-Nos. 4 and 5A shall remain in effect.

If this Case is used on boiler external piping, the Case number shall be identified in the Manufacturer's Data Report Form.

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B31 CASE 173
Alternative Maximum Allowable Stresses Based on a Factor of Safety of 3.5 on Tensile Strength for ASME B31.1 Construction

Approval Date: May 2001

This Case shall expire on May 31, 2004, unless previously annulled or reaffirmed

Inquiry: New maximum allowable stresses based on a factor of 3.5 on tensile strength and the other existing B31.1 criteria for establishing maximum allowable stresses are under development for incorporation into the B31.1 Code. Until the development and incorporation of new maximum allowable stresses into B31.1 are completed, may alternative allowable stresses be used?

Reply: It is the opinion of the committee that allowable stresses other than those listed in B31.1, Appendix A may be used for B31.1 construction provided the following requirements are met.

(a) The materials shall be limited to ASTM materials listed in Table 126.1 that have a corresponding ASME material, as allowed by B31.1, para. 123.1 (D).

(b) Boiler external piping shall use maximum allowable stress values provided in ASME BPVC, Section II, Part D, 1999 Addenda, Tables 1A and 1B, as permitted for Section I design. Only ASME materials shall be used.

(c) Nonboiler external piping shall use maximum allowable stress values provided in either ASME BPVC, Section II, Part D, 1999 Addenda, Tables 1A and 1B as permitted for Section I design, or ASME BPVC, Section II, Part D, 1999 Addenda, Tables 1A and 1B as permitted for Section VIII, Division 1 design.

(d) For materials with a minimum tensile strength of over 70 ksi, the allowable expansion stress range S_A shall be calculated using allowable stresses for A 106 Grade B in Eq. (1) of para. 102.3.2(C) and Eq. (13) of para. 104.8.3.

(e) This Case number and the materials for which it applies shall be shown on the Manufacturer's Data Report (if applicable).

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ASME CODE FOR PRESSURE PIPING, B31
AN AMERICAN NATIONAL STANDARD

ASME B31.3b-2001

ADDENDA

to

ASME B31.3-1999 EDITION
PROCESS PIPING

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
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SUMMARY OF CHANGES

Addenda to the 1999 Edition of the Code are issued in the form of replacement pages. Revisions, additions, or deletions are incorporated directly into the affected pages. It is advisable, however, that all replaced pages be retained for reference.

Replace or insert the pages listed. Changes given below are identified on the pages by a margin note, **A01**, placed next to the affected area. Revisions to the 1999 Edition and 2000 Addenda are indicated by **99** and **A00**, respectively. For the listing below, the *Page* references the affected area. A margin note, **A01**, placed next to the heading indicates *Location*. Revisions are listed under *Change*.

Page	*Location*	*Change*
iv, viii, xvii	Contents	Updated to reflect Addenda changes
xxi–xxiv-1	Roster	Updated
1, 1.1	300(b)	Subparagraphs (1) and (4) revised
10	Table 300.4	Appendix Q added
12	301.5.3	Reference to ASCE revised
	301.5.4	Last two lines revised
15	302.3.2(d)(3)	Revised
	302.3.2(d)(8)	Merged with former subpara. (e)
	302.3.2(e)	Redesignated from former subpara. (f)
31, 31.1	306.4	Revised in its entirety
39	319.4.1(c)	In the nomenclature, K_1 revised
56, 57	Table 326.1	MSS SP-42, 43, 51, and 71 revised
78	Criterion Value Notes for Table 341.3.2	Under *Acceptable Value Limits*, second entry revised
86	345.9.1(a)	Revised
91	Part 2	Title Revised
	A304	Title revised
93	Part 3	Title revised
94	Part 4	Title revised
102, 103	Table A326.1	(1) API 15LP deleted (2) ASTM F 1412 and F 1673 added
104	A328.2.5(a)	Subparagraphs (1) and (2) revised
105	A328.5.4(b)	Last sentence revised
107	Fig. A328.5.4	Revised
125	K302.3.2	(1) Former subpara. (c) merged with subpara. (b)(3)(b) (2) Subparagraphs (d) and (e) redesignated as (c) and (d), respectively

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Page	*Location*	*Change*
127	K304.1.1(b)	In the nomenclature, *S* revised
129	K304.7.2	(1) First paragraph revised (2) Subparagraph (c) redesignated as (d) (3) New subpara. (c) added
135, 135.1	K323.2.4(a)	Revised
136	Table K323.3.1	For Tests on Welds in Fabrication or Assembly, Test pieces revised
140	K328.2.1(a)	Revised
153, 154	Specification Index for Appendix A	B 547 added
184	Table A-1	Revised
198, 199	Table A-1	Revised
200, 201	Table A-1	Revised
209, 210	Table A-1	Revised
218	Table A-1B	B 547 added
255	Table D300	Under *Description* and *Flexibility Characteristic*, fourth entry revised
256	Table D300	Under *Description* and *Flexibility Characteristic*, third entry revised
258	Table D300	Note (11) revised
259–263	Appendix E	Revised
265, 265.1	F301	Revised
	F301.11	Added
267	F323(a)	Revised
293	Table K-1	Revised
295	Table K-1	Revised
300, 301	Table K-1	Revised
310.1	Appendix Q	Added
337	B31 List	Revised

NOTES:

The interpretations to ASME B31.3 issued between December 1, 1999 through March 31, 2001, follow the last page of this Addenda as a separate supplement, Interpretations No. 18.

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B31 NATIONAL INTEREST REVIEW GROUP

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Chemical Manufacturers Association — D.R. Frikken
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National Association of Plumbing-Heating-Cooling Contractors — R.E. White
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CHAPTER I
SCOPE AND DEFINITIONS

300 GENERAL STATEMENTS

(a) Identification. This Process Piping Code is a Section of the American Society of Mechanical Engineers Code for Pressure Piping, ASME B31, an American National Standard. It is published as a separate document for convenience of Code users.

A01 *(b) Responsibilities*

(1) Owner. The owner of a piping installation shall have overall responsibility for compliance with this Code, and for establishing the requirements for design, construction, examination, inspection, and testing which will govern the entire fluid handling or process installation of which the piping is a part. The owner is also responsible for designating piping in certain fluid services and for determining if a specific Quality System is to be employed. [See paras. 300(d)(4), (d)(5), (e), and Appendix Q.]

(2) Designer. The designer is responsible to the owner for assurance that the engineering design of piping complies with the requirements of this Code and with any additional requirements established by the owner.

(3) Manufacturer, Fabricator, and Erector. The manufacturer, fabricator, and erector of piping are responsible for providing materials, components, and workmanship in compliance with the requirements of this Code and of the engineering design.

(4) Owner's Inspector. The owner's Inspector (see para. 340) is responsible to the owner for ensuring that the requirements of this Code for inspection, examination, and testing are met. If a Quality System is specified by the owner to be employed, the owner's inspector is responsible for verifying that it is implemented.

(c) Intent of the Code

(1) It is the intent of this Code to set forth engineering requirements deemed necessary for safe design and construction of piping installations.

(2) This Code is not intended to apply to the operation, examination, inspection, testing, maintenance, or repair of piping that has been placed in service. The provisions of this Code may optionally be applied for those purposes, although other considerations may also be necessary.

(3) Engineering requirements of this Code, while considered necessary and adequate for safe design, generally employ a simplified approach to the subject. A designer capable of applying a more rigorous analysis shall have the latitude to do so; however, the approach must be documented in the engineering design and its validity accepted by the owner. The approach used shall provide details of design, construction, examination, inspection, and testing for the design conditions of para. 301, with calculations consistent with the design criteria of this Code. A00

(4) Piping elements should, insofar as practicable, conform to the specifications and standards listed in this Code. Piping elements neither specifically approved nor specifically prohibited by this Code may be used provided they are qualified for use as set forth in applicable Chapters of this Code.

(5) The engineering design shall specify any unusual requirements for a particular service. Where service requirements necessitate measures beyond those required by this Code, such measures shall be specified by the engineering design. Where so specified, the Code requires that they be accomplished.

(6) Compatibility of materials with the service and hazards from instability of contained fluids are not within the scope of this Code. See para. F323.

(d) Determining Code Requirements

(1) Code requirements for design and construction include fluid service requirements, which affect selection and application of materials, components, and joints. Fluid service requirements include prohibitions, limitations, and conditions, such as temperature limits or a requirement for safeguarding (see para. 300.2 and Appendix G). Code requirements for a piping system are the most restrictive of those which apply to any of its elements.

(2) For metallic piping not in Category M or high pressure fluid service, Code requirements are found in Chapters I through VI (the base Code), and fluid service requirements are found in:

(a) Chapter III for materials;

(b) Chapter II, Part 3, for components;

(c) Chapter II, Part 4, for joints.

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(3) For nonmetallic piping and piping lined with nonmetals, all requirements are found in Chapter VII. (Paragraph designations begin with "A.")

(4) For piping in a fluid service designated by the owner as Category M (see para. 300.2 and Appendix M), all requirements are found in Chapter VIII. (Paragraph designations begin with "M.")

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from the hypotenuse of the largest right triangle that can be inscribed in the weld cross section to the root of the joint

(b) actual throat: the shortest distance from the root of a fillet weld to its face

(c) effective throat: the minimum distance, minus any reinforcement (convexity), between the weld root and the face of a fillet weld

toe of weld: the junction between the face of a weld and the base material

tube: see *pipe*

tungsten electrode: a nonfiller-metal electrode used in arc welding or cutting, made principally of tungsten

unbalanced piping system: see para. 319.2.2(b)

undercut: a groove melted into the base material adjacent to the toe or root of a weld and left unfilled by weld material

visual examination: see para. 344.2.1

weld: a localized coalescence of material wherein coalescence is produced either by heating to suitable temperatures, with or without the application of pressure, or by application of pressure alone, and with or without the use of filler material

weld reinforcement: weld material in excess of the specified weld size

welder: one who performs a manual or semi-automatic welding operation. (This term is sometimes erroneously used to denote a welding machine.)

welding operator: one who operates machine or automatic welding equipment

welding procedure: the detailed methods and practices involved in the production of a weldment

welding procedure specification (WPS): the document which lists the parameters to be used in construction of weldments in accordance with requirements of this Code

weldment: an assembly whose component parts are joined by welding

300.3 Nomenclature

Dimensional and mathematical symbols used in this Code are listed in Appendix J, with definitions and location references to each. Lowercase and uppercase English letters are listed alphabetically, followed by Greek letters.

300.4 Status of Appendices

Table 300.4 indicates for each Appendix of this Code whether it contains Code requirements, guidance, or supplemental information. See the first page of each Appendix for details.

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TABLE 300.4
STATUS OF APPENDICES IN B31.3

Appendix	Title	Status
A	Stress Tables for Metallic Piping and Bolting Materials	Requirements
B	Stress Tables and Allowable Pressure Tables for Nonmetals	Requirements
C	Physical Properties of Piping Materials	Requirements (1)
D	Flexibility and Stress Intensification Factors	Requirements (1)
E	Reference Standards	Requirements
F	Precautionary Considerations	Guidance (2)
G	Safeguarding	Guidance (2)
H	Sample Calculations for Branch Reinforcement	Guidance
J	Nomenclature	Information
K	Allowable Stress for High Pressure Piping	Requirements (3)
L	Aluminum Alloy Pipe Flanges	Specification (5)
M	Guide to Classifying Fluid Services	Guidance (2)
Q	Quality System Program	Guidance (2)
V	Allowable Variations in Elevated Temperature Service	Guidance (2)
X	Metallic Bellows Expansion Joints	Requirements
Z	Preparation of Technical Inquiries	Requirements (4)

NOTES:
(1) Contains default requirements, to be used unless more directly applicable data are available.
(2) Contains no requirements but Code user is responsible for considering applicable items.
(3) Contains requirements applicable only when use of Chapter IX is specified.
(4) Contains administrative requirements.
(5) Contains pressure-temperature ratings, materials, dimensions, and markings of forged aluminum alloy flanges.

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on measurements support the use of another temperature. Where piping is heated or cooled by tracing or jacketing, this effect shall be considered in establishing component design temperatures.

301.3.4 Internally Insulated Piping. The component design temperature shall be based on heat transfer calculations or tests.

301.4 Ambient Effects

See Appendix F, para. F301.4.

301.4.1 Cooling: Effects on Pressure. The cooling of a gas or vapor in a piping system may reduce the pressure sufficiently to create an internal vacuum. In such a case, the piping shall be capable of withstanding the external pressure at the lower temperature, or provision shall be made to break the vacuum.

301.4.2 Fluid Expansion Effects. Provision shall be made in the design either to withstand or to relieve increased pressure caused by the heating of static fluid in a piping component. See also para. 322.6.3(b)(2).

301.4.3 Atmospheric Icing. Where the design minimum temperature of a piping system is below 0°C (32°F), the possibility of moisture condensation and buildup of ice shall be considered and provisions made in the design to avoid resultant malfunctions. This applies to surfaces of moving parts of shutoff valves, control valves, pressure relief devices including discharge piping, and other components.

301.4.4 Low Ambient Temperature. Consideration shall be given to low ambient temperature conditions for displacement stress analysis.

301.5 Dynamic Effects

See Appendix F, para. F301.5.

301.5.1 Impact. Impact forces caused by external or internal conditions (including changes in flow rate, hydraulic shock, liquid or solid slugging, flashing, and geysering) shall be taken into account in the design of piping.

301.5.2 Wind. The effect of wind loading shall be taken into account in the design of exposed piping. The method of analysis may be as described in ASCE 7, Minimum Design Loads for Buildings and Other Structures, or the Uniform Building Code.

301.5.3 Earthquake. Piping shall be designed for earthquake-induced horizontal forces. The method of analysis may be as described in ASCE 7 or the Uniform Building Code. A01

301.5.4 Vibration. Piping shall be designed, arranged, and supported so as to eliminate excessive and harmful effects of vibration which may arise from such sources as impact, pressure pulsation, turbulent flow vortices, resonance in compressors, and wind. A01

301.5.5 Discharge Reactions. Piping shall be designed, arranged, and supported so as to withstand reaction forces due to let-down or discharge of fluids.

301.6 Weight Effects

The following weight effects, combined with loads and forces from other causes, shall be taken into account in the design of piping.

301.6.1 Live Loads. These loads include the weight of the medium transported or the medium used for test. Snow and ice loads due to both environmental and operating conditions shall be considered.

301.6.2 Dead Loads. These loads consist of the weight of piping components, insulation, and other superimposed permanent loads supported by the piping.

301.7 Thermal Expansion and Contraction Effects

The following thermal effects, combined with loads and forces from other causes, shall be taken into account in the design of piping. See also Appendix F, para. F301.7.

301.7.1 Thermal Loads Due to Restraints. These loads consist of thrusts and moments which arise when free thermal expansion and contraction of the piping are prevented by restraints or anchors.

301.7.2 Loads Due to Temperature Gradients. These loads arise from stresses in pipe walls resulting from large rapid temperature changes or from unequal temperature distribution as may result from a high heat flux through a comparatively thick pipe or stratified two-phase flow causing bowing of the line.

301.7.3 Loads Due to Differences in Expansion Characteristics. These loads result from differences in thermal expansion where materials with different thermal expansion coefficients are combined, as in bimetallic, lined, jacketed, or metallic–nonmetallic piping.

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ature for bolting materials shall not exceed the lowest of the following:

A00 *(1)* except as provided in (3) below, the lower of one-fourth of specified minimum tensile strength at room temperature (S_T) and one-fourth of tensile strength at temperature;

A00 *(2)* except as provided in (3) below, the lower of two-thirds of specified minimum yield strength at room temperature (S_Y) and two-thirds of yield strength at temperature;

A00 *(3)* at temperatures below the creep range, for bolting materials whose strength has been enhanced by heat treatment or strain hardening, the lower of one-fifth of S_T and one-fourth of S_Y (unless these values are lower than corresponding values for annealed material, in which case the annealed values shall be used);

(4) two-thirds of the "yield strength at temperature" [see para. 302.3.2(f)];

(5) 100% of the average stress for a creep rate of 0.01% per 1000 hr;

(6) 67% of the average stress for rupture at the end of 100,000 hr;

(7) 80% of minimum stress for rupture at the end of 100,000 hr.

(b) Cast Iron. Basic allowable stress values at temperature for cast iron shall not exceed the lower of the following:

(1) one-tenth of the specified minimum tensile strength at room temperature;

(2) one-tenth of the tensile strength at temperature [see para. 302.3.2(f)].

(c) Malleable Iron. Basic allowable stress values at temperature for malleable iron shall not exceed the lower of the following:

(1) one-fifth of the specified minimum tensile strength at room temperature;

(2) one-fifth of the tensile strength at temperature [see para. 302.3.2(f)].

(d) Other Materials. Basic allowable stress values at temperature for materials other than bolting materials, cast iron, and malleable iron shall not exceed the lowest of the following:

A00 *(1)* the lower of one-third of S_T and one-third of tensile strength at temperature;

A00 *(2)* except as provided in (3) below, the lower of two-thirds of S_Y and two-thirds of yield strength at temperature;

A00 A01 *(3)* for austenitic stainless steels and nickel alloys having similar stress–strain behavior, the lower of two-thirds of S_Y and 90% of yield strength at temperature;

(4) 100% of the average stress for a creep rate of 0.01% per 1000 hr;

(5) 67% of the average stress for rupture at the end of 100,000 hr;

(6) 80% of the minimum stress for rupture at the end of 100,000 hr;

(7) for structural grade materials, the basic allowable stress shall be 0.92 times the lowest value determined in paras. 302.3.2(d)(1) through (6).

(8) In the application of these criteria, the yield strength at room temperature is considered to be $S_Y R_Y$, and the tensile strength at room temperature is considered to be $1.1 S_T R_T$. A00 A01

Application of stress values so determined is not recommended for flanged joints and other components in which slight deformation can cause leakage or malfunction. [These values are shown in italics or boldface in Table A-1, as explained in Note (4) to Appendix A Tables.] Instead, either 75% of the stress value in Table A-1 or two-thirds of the yield strength at temperature listed in the BPV Code, Section II, Part D, Table Y-1 should be used.

(e) Unlisted Materials. For a material which conforms to para. 323.1.2, the tensile (yield) strength at temperature shall be derived by multiplying the average expected tensile (yield) strength at temperature by the ratio of S_T (S_Y) divided by the average expected tensile (yield) strength at room temperature. A00 A01

302.3.3 Casting Quality Factor E_c

(a) General. The casting quality factors E_c defined herein shall be used for cast components not having pressure-temperature ratings established by standards in Table 326.1.

(b) Basic Quality Factors. Castings of gray and malleable iron, conforming to listed specifications, are assigned a basic casting quality factor E_c of 1.00 (due to their conservative allowable stress basis). For most other metals, static castings which conform to the material specification and have been visually examined as required by MSS SP-55, Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components — Visual Method, are assigned a basic casting quality factor E_c of 0.80. Centrifugal castings which meet specification requirements only for chemical analysis, tensile, hydrostatic, and flattening tests, and visual examination are assigned a basic casting quality factor of 0.80. Basic casting quality factors are tabulated for listed specifications in Table A-1A.

(c) Increased Quality Factors. Casting quality factors may be increased when supplementary examinations are performed on each casting. Table 302.3.3C states the increased casting quality factors E_c which may

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TABLE 302.3.3C[4]
INCREASED CASTING QUALITY FACTORS, E_C

Supplementary Examination in Accordance With Note(s)	Factor, E_C
(1)	0.85
(2)(a) or (2)(b)	0.85
(3)(a) or (3)(b)	0.95
(1) and (2)(a) or (2)(b)	0.90
(1) and (3)(a) or (3)(b)	1.00
(2)(a) or (2)(b) and (3)(a) or (3)(b)	1.00

NOTES:
(1) Machine all surfaces to a finish of 6.3 μm R_a (250 μin. R_a per ASME B46.1), thus increasing the effectiveness of surface examination.
(2) (a) Examine all surfaces of each casting (magnetic material only) by the magnetic particle method in accordance with ASTM E 709. Judge acceptability in accordance with MSS SP-53, using reference photos in ASTM E 125.
(b) Examine all surfaces of each casting by the liquid penetrant method, in accordance with ASTM E 165. Judge acceptability of flaws and weld repairs in accordance with Table 1 of MSS SP-53, using ASTM E 125 as a reference for surface flaws.
(3) (a) Fully examine each casting ultrasonically in accordance with ASTM E 114, accepting a casting only if there is no evidence of depth of defects in excess of 5% of wall thickness.
(b) Fully radiograph each casting in accordance with ASTM E 142. Judge in accordance with the stated acceptance levels in Table 302.3.3D.
(4) Titles of standards referenced in this Table are as follows:
ASTM
E 114 Practice for Ultrasonic Pulse-Echo Straight-Beam Testing by the Contact Method
E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings
E 142 Method for Controlling Quality of Radiographic Testing
E 165 Practice for Liquid Penetrant Inspection Method
E 709 Practice for Magnetic Particle Examination
ASME
B46.1 Surface Texture (Surface Roughness, Waviness and Lay)
MSS
SP-53 Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components—Magnetic Particle Examination Method

TABLE 302.3.3D[1]
ACCEPTANCE LEVELS FOR CASTINGS

Material Examined Thickness, T	Applicable Standard	Acceptance Level (or Class)	Acceptable Discontinuities
Steel $T \leq 25$ mm (1 in.)	ASTM E 446	1	Types A, B, C
Steel $T > 25$ mm, ≤ 51 mm (2 in.)	ASTM E 446	2	Types A, B, C
Steel $T > 51$ mm, ≤ 114 mm ($4\frac{1}{2}$ in.)	ASTM E 186	2	Categories A, B, C
Steel $T > 114$ mm, ≤ 305 mm (12 in.)	ASTM E 280	2	Categories A, B, C
Aluminum & magnesium	ASTM E 155	...	Shown in reference radiographs
Copper, Ni–Cu	ASTM E 272	2	Codes A, Ba, Bb
Bronze	ASTM E 310	2	Codes A and B

NOTE:
(1) Titles of standards referenced in this Table are as follows:
ASTM
E 155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings
E 186 Reference Radiographs for Heavy-Walled [2 to 4-$\frac{1}{2}$-in. (51 to 114-mm)] Steel Castings
E 272 Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Castings
E 280 Reference Radiographs for Heavy-Walled [4-$\frac{1}{2}$ to 12-in. (114 to 305-mm)] Steel Castings
E 310 Reference Radiographs for Tin Bronze Castings
E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness

be used for various combinations of supplementary examination. Table 302.3.3D states the acceptance criteria for the examination methods specified in the Notes to Table 302.3.3C. Quality factors higher than those shown in Table 302.3.3C do not result from combining tests 2a and 2b, or 3a and 3b. In no case shall the quality factor exceed 1.00.

Several of the specifications in Appendix A require machining of all surfaces and/or one or more of these supplementary examinations. In such cases, the appropriate increased quality factor is shown in Table A-1A.

302.3.4 Weld Joint Quality Factor, E_j

(a) Basic Quality Factors. The weld joint quality factors E_j tabulated in Table A-1B are basic factors for straight or spiral longitudinal welded joints for pressure-containing components as shown in Table 302.3.4.

(b) Increased Quality Factors. Table 302.3.4 also indicates higher joint quality factors which may be substituted for those in Table A-1B for certain kinds of welds if additional examination is performed beyond that required by the product specification.

302.3.5 Limits of Calculated Stresses Due to Sustained Loads and Displacement Strains

(a) Internal Pressure Stresses. Stresses due to internal pressure shall be considered safe when the wall

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(3) cast, with factor $E_c \geq 0.90$.[8]

A00 (b) Fittings conforming to MSS SP-43, MSS SP-119, and proprietary "Type C" lap-joint stub-end welding fittings shall not be used under severe cyclic conditions.

306.2 Pipe Bends

306.2.1 General. A pipe bend made in accordance with paras. 332.2.1 and 332.2.2, and verified for pressure design in accordance with para. 304.2.1, is suitable for the same service as the pipe from which it is made.

306.2.2 Corrugated and Other Bends. Bends of other designs (such as creased or corrugated) shall be qualified for pressure design as required by para. 304.7.2.

306.2.3 Bends for Severe Cyclic Conditions. A pipe bend designed as creased or corrugated shall not be used under severe cyclic conditions.

306.3 Miter Bends

306.3.1 General. Except as stated in para. 306.3.2, a miter bend made in accordance with para. 304.2.3 and welded in accordance with para. 311.1 is suitable for use in Normal Fluid Service.

306.3.2 Miter Bends for Category D Fluid Service. A miter bend which makes a change in direction at a single joint (angle α in Fig. 304.2.3) greater than 45 deg, or is welded in accordance with para. 311.2.1, may be used only for Category D Fluid Service.

306.3.3 Miter Bends for Severe Cyclic Conditions. A miter bend to be used under severe cyclic conditions shall be made in accordance with para. 304.2.3 and welded in accordance with para. 311.2.2, and shall have an angle α (see Fig. 304.2.3) $\leq$ 22.5 deg.

A01 ### 306.4 Laps

The following requirements do not apply to fittings conforming to para. 306.1, specifically lap-joint stub ends conforming to ASME B16.9, nor to laps integrally hot-forged on pipe ends, except as noted in paras. 306.4.3 and 306.4.4(a).

306.4.1 Fabricated Laps. A fabricated lap is suitable for use in Normal Fluid Service, provided that all of the following requirements are met.

(a) The outside diameter of the lap shall be within the dimensional tolerances of the corresponding ASME B16.9 lap-joint stub end.

(b) The lap thickness shall be at least equal to the nominal wall thickness of the pipe to which it is attached.

(c) The lap material shall be listed in Table A-1 and shall have an allowable stress at least as great as that of the pipe.

(d) Welding shall be in accordance with para. 311.1 and fabrication shall be in accordance with para. 328.5.5.

306.4.2 Flared Laps. See para. 308.2.5 for requirements of lapped flanges for use with flared laps. A flared lap is suitable for use in Normal Fluid Service, provided that all of the following requirements are met.

(a) The pipe used shall be of a specification and grade listed in Table A-1 suitable for forming without cracks, surface buckling, or other defects.

(b) The outside diameter of the lap shall be within the dimensional tolerances of the corresponding ASME B16.9 lap-joint stub end.

(c) The radius of fillet shall not exceed 3 mm ($\frac{1}{8}$ in.).

(d) The lap thickness at any point shall be at least 95% of the minimum pipe wall thickness T multiplied by the ratio of the pipe outside diameter to the diameter at which the lap thickness is measured.

(e) Pressure design shall be qualified as required by para. 304.7.2.

306.4.3 Forged Laps. A lap integrally hot-forged on a pipe end is suitable for Normal Fluid Service only when the requirements of para. 332 are met. Its dimensions shall conform to those for lap-joint stub ends given in ASME B16.9.

306.4.4 Laps for Severe Cyclic Conditions

(a) A forged lap-joint stub end per para. 306.1 or a lap integrally hot-forged on a pipe end per para. 306.4.3 may be used under severe cyclic conditions.

(b) A fabricated lap to be used under severe cyclic conditions shall conform to the requirements of para. 306.4.1, except that welding shall be in accordance with para. 311.2.2. A fabricated lap shall conform to a detail shown in Fig. 328.5.5, sketch (d) or (e).

(c) A flared lap is not permitted under severe cyclic conditions.

306.5 Fabricated Branch Connections

The following requirements do not apply to fittings conforming to para. 306.1.

306.5.1 General. A fabricated branch connection made and verified for pressure design in accordance with para. 304.3, and welded in accordance with para. 311.1, is suitable for use in Normal Fluid Service.

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306.5.2 Fabricated Branch Connections for Severe Cyclic Conditions. A fabricated branch connection to be used under severe cyclic conditions shall conform to the requirements of para. 306.5.1, except that welding shall be in accordance with para. 311.2.2, with fabrication limited to a detail equivalent to Fig. 328.5.4D sketch (2) or (4), or to Fig. 328.5.4E.

307 VALVES AND SPECIALTY COMPONENTS

The following requirements for valves shall also be met as applicable by other pressure containing piping

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components, such as traps, strainers, and separators. See also Appendix F, paras. F301.4 and F307.

307.1 General

307.1.1 Listed Valves. A listed valve is suitable for use in Normal Fluid Service, except as stated in para. 307.2.

307.1.2 Unlisted Valves. Unlisted valves may be used only in accordance with para. 302.2.3. Unless pressure-temperature ratings are established by the method set forth in Appendix F to ASME B16.34, pressure design shall be qualified as required by para. 304.7.2.

307.2 Specific Requirements

A bolted bonnet valve whose bonnet is secured to the body by less than four bolts, or by a U-bolt, may be used only for Category D Fluid Service.

308 FLANGES, BLANKS, FLANGE FACINGS, AND GASKETS

308.1 General

308.1.1 Listed Components. A listed flange, blank, or gasket is suitable for use in Normal Fluid Service, except as stated elsewhere in para. 308.

308.1.2 Unlisted Components. Unlisted flanges, blanks, and gaskets may be used only in accordance with para. 302.2.3.

(99) ### 308.2 Specific Requirements for Flanges

See Appendix F, paras. F308.2 and F312.

308.2.1 Slip-On Flanges

(a) A slip-on flange shall be double-welded as shown in Fig. 328.5.2B when the service is:

(1) subject to severe erosion, crevice corrosion, or cyclic loading;

(2) flammable, toxic, or damaging to human tissue;

(3) under severe cyclic conditions;

(4) at temperatures below −101°C (−150°F).

(b) The use of slip-on flanges should be avoided where many large temperature cycles are expected, particularly if the flanges are not insulated.

(c) Slip-on Flanges as Lapped Flanges. A slip-on flange may be used as a lapped flange only as shown in Table 308.2.1 unless pressure design is qualified in accordance with para. 304.5.1. A corner radius or bevel shall conform to one of the following as applicable:

(1) for an ASME B16.9 lap joint stub end or a forged lap (see para. 306.4.3) the corner radius shall be as specified in ASME B16.5, Tables 9 and 12, dimension *r*.

(2) for a fabricated lap, the corner bevel shall be at least half the nominal thickness of the pipe to which the lap is attached (see Fig. 328.5.5).

(3) for a flared lap see para. 308.2.5.

TABLE 308.2.1
PERMISSIBLE SIZES/RATING CLASSES FOR SLIP-ON FLANGES USED AS LAPPED FLANGES[1]

Rating		Maximum Flange Size	
PN	Class	DN	NPS
20	150	300	12
50	300	200	8

NOTE:
(1) Actual thickness of flange at bolt circle shall at least equal minimum required flange thickness in ASME B16.5.

308.2.2 Expanded-Joint Flanges. A flange having an expanded-joint insert is subject to the requirements for expanded joints in para. 313.

308.2.3 Socket Welding and Threaded Flanges. A socket welding flange is subject to the requirements for socket welds in para. 311.2.4. A threaded flange is subject to the requirements for threaded joints in para. 314.4.

308.2.4 Flanges for Severe Cyclic Conditions. Unless it is safeguarded, a flange to be used under severe cyclic conditions shall be welding neck conforming to ASME B16.5 or ASME B16.47, or a similarly proportioned flange designed in accordance with para. 304.5.1.

308.2.5 Flanges for Flared Metallic Laps. For a flange used with a flared metallic lap (para. 306.4.2), the intersection of face and bore shall be beveled or rounded approximately 3 mm (⅛ in.). See also para. 308.2.1(c).

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A01 *(c)* is of uniform size, has no more than two points of fixation, no intermediate restraints, and falls within the limitations of empirical Eq. (16):[9]

$$\frac{Dy}{(L-U)^2} \le K_1 \qquad (16)$$

where

D = outside diameter of pipe, mm (in.)
y = resultant of total displacement strains, mm (in.), to be absorbed by the piping system
L = developed length of piping between anchors, m (ft)
U = anchor distance, straight line between anchors, m (ft)
K_1 = 208,000 S_A/E_a, $(mm/m)^2$
= 30 S_A/E_a, $(in./ft)^2$

where

S_A = allowable displacement stress range per Eq. (1a), MPa (ksi)
E_a = reference modulus of elasticity at 21°C (70°F), MPa (ksi)

319.4.2 Formal Analysis Requirements

(a) Any piping system which does not meet the criteria in para. 319.4.1 shall be analyzed by a simplified, approximate, or comprehensive method of analysis, as appropriate.

(b) A simplified or approximate method may be applied only if used within the range of configurations for which its adequacy has been demonstrated.

(c) Acceptable comprehensive methods of analysis include analytical and chart methods which provide an evaluation of the forces, moments, and stresses caused by displacement strains (see para. 319.2.1).

(d) Comprehensive analysis shall take into account stress intensification factors for any component other than straight pipe. Credit may be taken for the extra flexibility of such a component.

[9] *WARNING*: No general proof can be offered that this equation will yield accurate or consistently conservative results. It is not applicable to systems used under severe cyclic conditions. It should be used with caution in configurations such as unequal leg U-bends ($L/U > 2.5$) or near-straight "sawtooth" runs, or for large thin-wall pipe ($i \ge 5$), or where extraneous displacements (not in the direction connecting anchor points) constitute a large part of the total displacement. There is no assurance that terminal reactions will be acceptably low, even if a piping system falls within the limitations of Eq. (16).

319.4.3 Basic Assumptions and Requirements. Standard assumptions specified in para. 319.3 shall be followed in all cases. In calculating the flexibility of a piping system between anchor points, the system shall be treated as a whole. The significance of all parts of the line and of all restraints introduced for the purpose of reducing moments and forces on equipment or small branch lines, and also the restraint introduced by support friction, shall be recognized. Consider all displacements, as outlined in para. 319.2.1, over the temperature range defined by para. 319.3.1.

319.4.4 Flexibility Stresses

(a) The range of bending and torsional stresses shall be computed using the reference modulus of elasticity at 21°C (70°F), E_a, except as provided in para. 319.2.2(b)(4), and then combined in accordance with Eq. (17) to determine the computed displacement stress range S_E, which shall not exceed the allowable stress range S_A in para. 302.3.5(d).

$$S_E = \sqrt{S_b^2 + 4S_t^2} \qquad (17)$$

where

S_b = resultant bending stress
S_t = torsional stress
= $M_t/2Z$
M_t = torsional moment
Z = section modulus of pipe

(b) The resultant bending stresses S_b to be used in Eq. (17) for elbows, miter bends, and full size outlet branch connections (Legs 1, 2, and 3) shall be calculated in accordance with Eq. (18), with moments as shown in Figs. 319.4.4A and 319.4.4B.

$$S_b = \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z} \qquad (18)$$

where

S_b = resultant bending stress
i_i = in-plane stress intensification factor from Appendix D
i_o = out-plane stress intensification factor from Appendix D
M_i = in-plane bending moment
M_o = out-plane bending moment
Z = section modulus of pipe

(c) The resultant bending stress S_b to be used in Eq. (17) for reducing outlet branch connections shall be calculated in accordance with Eqs. (19) and (20), with moments as shown in Fig. 319.4.4B.

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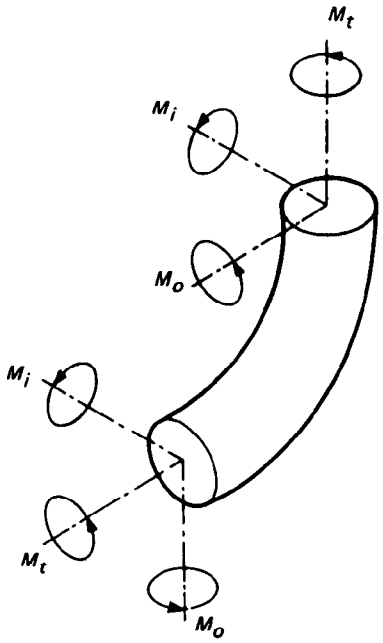

FIG. 319.4.4A MOMENTS IN BENDS

For header (Legs 1 and 2):

$$S_b = \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z} \qquad (19)$$

For branch (Leg 3):

$$S_b = \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z_e} \qquad (20)$$

where

S_b = resultant bending stress
Z_e = effective section modulus for branch,
$= \pi r_2^2 T_S$ (21)
r_2 = mean branch cross-sectional radius
T_S = effective branch wall thickness, lesser of $\overline{T}_h$ and $(i_i)(\overline{T}_b)$
$\overline{T}_h$ = thickness of pipe matching run of tee or header exclusive of reinforcing elements
$\overline{T}_b$ = thickness of pipe matching branch
i_o = out-plane stress intensification factor (Appendix D)
i_i = in-plane stress intensification factor (Appendix D)

319.4.5 Required Weld Quality Assurance. Any weld at which S_E exceeds $0.8S_A$ (as defined in para. 302.3.5) and the equivalent number of cycles N exceeds 7000 shall be fully examined in accordance with para. 341.4.3.

319.5 Reactions

Reaction forces and moments to be used in design of restraints and supports for a piping system, and in evaluating the effects of piping displacements on connected equipment, shall be based on the reaction range R for the extreme displacement conditions, considering the temperature range defined in para. 319.3.1(b), and using E_a. The designer shall consider instantaneous maximum values of forces and moments in the original and extreme displacement conditions (see para. 319.2.3), as well as the reaction range, in making these evaluations.

319.5.1 Maximum Reactions for Simple Systems. For a two-anchor piping system without intermediate restraints, the maximum instantaneous values of reaction forces and moments may be estimated from Eqs. (22) and (23).

(a) For Extreme Displacement Conditions, R_m. The temperature for this computation is the maximum or minimum metal temperature defined in para. 319.3.1(b), whichever produces the larger reaction:

$$R_m = R\left(1 - \frac{2C}{3}\right)\frac{E_m}{E_a} \qquad (22)$$

where

C = cold-spring factor varying from zero for no cold spring to 1.0 for 100% cold spring. (The factor two-thirds is based on experience which shows that specified cold spring cannot be fully assured, even with elaborate precautions.)
E_a = reference modulus of elasticity at 21°C (70°F)
E_m = modulus of elasticity at maximum or minimum metal temperature
R = range of reaction forces or moments (derived from flexibility analysis) corresponding to the full displacement stress range and based on E_a
R_m = estimated instantaneous maximum reaction force or moment at maximum or minimum metal temperature

(b) For Original Condition, R_a. The temperature for

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CHAPTER IV
STANDARDS FOR PIPING COMPONENTS

326 DIMENSIONS AND RATINGS OF COMPONENTS

326.1 Dimensional Requirements

326.1.1 Listed Piping Components. Dimensional standards[1] for piping components are listed in Table 326.1. Dimensional requirements contained in specifications listed in Appendix A shall also be considered requirements of this Code.

326.1.2 Unlisted Piping Components. Dimensions of piping components not listed in Table 326.1 or Appendix A shall conform to those of comparable listed components insofar as practicable. In any case, dimensions shall be such as to provide strength and performance equivalent to standard components except as provided in paras. 303 and 304.

326.1.3 Threads. The dimensions of piping connection threads not otherwise covered by a governing component standard or specification shall conform to the requirements of applicable standards listed in Table 326.1 or Appendix A.

[1] It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and address of sponsoring organizations, are shown in Appendix E.

326.2 Ratings of Components

326.2.1 Listed Components. The pressure-temperature ratings of components listed in Table 326.1 are accepted for pressure design in accordance with para. 303.

326.2.2 Unlisted Components. The pressure-temperature ratings of unlisted piping components shall conform to the applicable provisions of para. 304.

326.3 Reference Documents A00

The documents listed in Table 326.1 contain references to codes, standards, and specifications not listed in Table 326.1. Such unlisted codes, standards, and specifications shall be used only in the context of the listed documents in which they appear.

The design, materials, fabrication, assembly, examination, inspection, and testing requirements of this Code are not applicable to components manufactured in accordance with the documents listed in Table 326.1, unless specifically stated in this Code, or the listed document.

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TABLE 326.1
COMPONENT STANDARDS[1]

Standard or Specification	Designation [Note (2)]
Bolting	
Square and Hex Bolts and Screws, Inch Series, Including Hex Cap Screws and Lag Screws	*ASME B18.2.1
Square and Hex Nuts (Inch Series)	*ASME B18.2.2
Metallic Fittings, Valves, and Flanges	
Cast Iron Pipe Flanges and Flanged Fittings	*ASME B16.1
Malleable Iron Threaded Fittings	*ASME B16.3
Gray Iron Threaded Fittings	*ASME B16.4
Pipe Flanges and Flanged Fittings	*ASME B16.5
Factory-Made Wrought Steel Buttwelding Fittings	*ASME B16.9
Face-to-Face and End-To-End Dimensions of Valves	*ASME B16.10
Forged Fittings, Socket-Welding and Threaded	*ASME B16.11
Ferrous Pipe Plugs, Bushings, and Locknuts With Pipe Threads	*ASME B16.14
Cast Bronze Threaded Fittings, Class 125 and 250 [Notes (3), (4)]	*ASME B16.15
Cast Copper Alloy Solder Joint Pressure Fittings	*ASME B16.18
Wrought Copper and Copper Alloy Solder Joint Pressure Fittings	*ASME B16.22
Bronze Pipe Flanges and Flanged Fittings Class 150, 300, 400, 600, 900, 1500, and 2500 and Flanged Fittings, Class 150 and 300	*ASME B16.24
Cast Copper Alloy Fittings for Flared Copper Tubes	*ASME B16.26
Wrought Steel Buttwelding Short Radius Elbows and Returns [Note (5)]	*ASME B16.28
Valves-Flanged, Threaded, and Welding End	*ASME B16.34
Orifice Flanges, Class 300, 600, 900, 1500, and 2500	*ASME B16.36
Malleable Iron Threaded Pipe Unions, Class 150, 250, and 300	*ASME B16.39
Ductile Iron Pipe Flanges and Flanged Fittings, Class 150 and 300	*ASME B16.42
Large Diameter Steel Flanges, NPS 26 Through NPS 60	*ASME B16.47
Flanged Steel Pressure-Relief Valves	API 526
Wafer and Wafer-Lug Check Valves	*API 594
Metal Plug Valves—Flanged and Welding Ends	API 599
Steel Gate Valves — Flanged and Buttwelding Ends, Bolted and Pressure Seal Bonnets	API 600
Compact Steel Gate Valves — Flanged, Threaded, Welding and Extended Body Ends	API 602
Class 150, Cast, Corrosion-Resistant, Flanged-End Gate Valves	*API 603
Metal Ball Valves-Flanged, Threaded, and Welding End	API 608
Lug- and Wafer-Type Butterfly Valves	*API 609
Ductile-Iron and Gray-Iron Fittings, 3 Inch Through 48 Inch (75 mm Through 1200 mm), for Water and Other Liquids	*AWWA C110
Flanged Ductile-Iron with Ductile-Iron or Gray-Iron Threaded Flanges	*AWWA C115
Steel Pipe Flanges for Water works Service, sizes 4 inch Through 144 inch (100 mm Through 3,600 mm)	*AWWA C207
Dimensions for Fabricated Steel Water Pipe Fittings	*AWWA C208
Metal-Seated Gate Valves for Water Supply Service	*AWWA C500
Rubber-Seated Butterfly Valves	*AWWA C504
Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings	MSS SP-6
Spot Facing for Bronze, Iron and Steel Flanges	MSS SP-9
Standard Marking Systems for Valves, Fittings, Flanges, and Unions	MSS SP-25
Class 150 (PN 20) Corrosion Resistant Gate, Globe, Angle and Check Valves With Flanged and Butt Weld Ends	MSS SP-42
Wrought Stainless Steel Butt-Welding Fittings Including Reference to Other Corrosion Resistant Materials	MSS SP-43
Steel Pipe Line Flanges	MSS SP-44

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TABLE 326.1 (CONT'D)
COMPONENT STANDARDS[1]

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Standard or Specification	Designation [Note (2)]
Bypass and Drain Connections	MSS SP-45
Class 150LW Corrosion Resistant Flanges and Cast Flanged Fittings	MSS SP-51
High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets	MSS SP-65
Cast Iron Gate Valves, Flanged and Threaded Ends	MSS SP-70
Gray Iron Swing Check Valves, Flanged and Threaded Ends	MSS SP-71
Ball Valves With Flanged or Buttwelding Ends for General Service	MSS SP-72
Specifications for High Test Wrought Buttwelding Fittings	MSS SP-75
Socket-Welding Reducer Inserts	MSS SP-79
Bronz Gate, Globe, Angle and Check Valves	MSS SP-80
Stainless Steel, Bonnetless, Flanged, Knife Gate Valves	MSS SP-81
Class 3000 Steel Pipe Unions, Socket-Welding and Threaded	MSS SP-83
Cast Iron Globe and Angle Valves, Flanged and Threaded Ends	MSS SP-85
Diaphragm Type Valves	MSS SP-88
Swage (d) Nipples and Bull Plugs	MSS SP-95
Integrally Reinforced Forged Branch Outlet Fittings — Socket Welding, Threaded, and Buttwelding Ends	MSS SP-97
Instrument Valves for Code Applications	MSS SP-105
Belled End Socket Welding Fittings, Stainless Steel and Copper Nickel [Note (7)]	MSS SP-119
Refrigeration Tube Fittings — General Specifications	SAE J513
Hydraulic Tube Fittings	SAE J514
Hydraulic Flanged Tube, Pipe, and Hose Connections, Four-Bolt Split Flanged Type	*SAE J518
Metallic Pipe and Tubes [Note (6)]	
Welded and Seamless Wrought Steel Pipe	*ASME B36.10M
Stainless Steel Pipe	*ASME B36.19M
Flanged Ductile-Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges	*AWWA C115
Thickness Design of Ductile-Iron Pipe	*AWWA C150
Ductile-Iron Pipe, Centrifugally Cast, for Water and Other Liquids	*AWWA C151
Steel Water Pipe 6 inches (150 mm) and Larger	AWWA C200
Miscellaneous	
Unified Inch Screw Threads (UN and UNR Thread Form)	*ASME B1.1
Pipe Threads, General Purpose (Inch)	*ASME B1.20.1
Dryseal Pipe Threads (Inch)	*ASME B1.20.3
Hose Coupling Screw Threads (Inch)	*ASME B1.20.7
Metallic Gaskets for Pipe Flanges—Ring: Joint, Spiral Wound, and Jacketed	*ASME B16.20
Nonmetallic Flat Gaskets for Pipe Flanges	*ASME B16.21
Buttwelding Ends	*ASME B16.25
Surface Texture (Surface Roughness, Waviness, and Lay)	*ASME B46.1
Specification for Threading, Gaging and Thread Inspection of Casing, Tubing, and Line Pipe Threads	API 5B
Rubber Gasket Joints for Ductile-Iron Pressure Pipe and Fittings	*AWWA C111
Pipe Hangers and Supports — Materials, Design, and Manufacture	MSS SP-58
Brazing Joints for Wrought and Cast Copper Alloy Solder Joint Fittings	MSS SP-73
Standard for Fire Hose Connections	NFPA 1963

Notes to this Table follow on next page

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TABLE 326.1 (CONT'D)

NOTES:
(1) It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.
(2) An asterisk (*) preceding the designation indicates that the standard has been approved as an American National Standard by the American National Standards Institute.
(3) This standard allows the use of unlisted materials; see para. 323.1.2.
(4) This standard allows straight pipe threads in sizes ≤ DN 15 (NPS ½); see para. 314.2.1(d).
(5) *Cautionary Note:* Pressure ratings of components manufactured in accordance with editions prior to the 1994 edition of this standard were derated to 80% of equivalent seamless pipe. This derating is no longer required for components manufactured in accordance with the 1994 Edition.
(6) See also Appendix A.
(7) MSS SP-119 includes three classes of fittings: MP, MARINE, and CR. Only the MP class fittings are considered a "Listed Component" for the purpose of this Code. *Cautionary Note*: See MSS SP-119 (Section 6) for special provisions concerning ratings. (In accordance with MSS SP-119, the pressure ratings for MP class fittings are 87.5% of those calculated for straight seamless pipe of *minimum* wall thickness.)

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TABLE 341.3.2
ACCEPTANCE CRITERIA FOR WELDS

Kind of Imperfection	Criteria (A to M) for Types of Welds, for Service Conditions, and for Required Examination Methods [Note (1)]																		
	Normal Fluid Service						Severe Cyclic Conditions								Category D Fluid Service				
	Methods		Types of Weld				Methods				Types of Weld				Method	Types of Weld			
	Visual	Radiography	Girth and Miter Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]	Visual	Radiography	Magnetic Particle	Liquid Penetrant	Girth and Miter Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]	Visual	Girth and Miter Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]
Crack	X	X	A	A	A	A	X	X	X	X	A	A	A	A	X	A	A	A	A
Lack of fusion	X	X	A	A	A	A	X	X	...	...	A	A	A	A	X	C	A	NA	A
Incomplete penetration	X	X	B	A	NA	B	X	X	...	...	A	A	NA	A	X		A	NA	B
Internal porosity	...	X	E	E	NA	E	...	X	...	...	D	D	NA	D	...	...	...	...	...
Slag inclusion, tungsten inclusion, or elongated indication	...	X	G	G	NA	G	...	X	...	...	F	F	NA	F	...	...	...	...	...
Undercutting	X	...	H	A	H	H	X	X	...	...	A	A	A	A	X	I	A	H	H
Surface porosity or exposed slag inclusion [Note (5)]	X	...	A	A	A	A	X	...	...	...	A	A	A	A	X	A	A	A	A
Surface finish	...	...	...	...	...	...	X	...	...	...	J	J	J	J	...	...	...	...	...
Concave root surface (suck-up)	X	X	K	K	NA	K	X	X	...	...	K	K	NA	K	X	K	K	NA	K
Reinforcement or internal protrusion	X	...	L	L	L	L	X	...	...	...	L	L	L	L	X	M	M	M	M

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Criterion Value Notes for Table 341.3.2

Symbol	Criterion Measure	Acceptable Value Limits [Note (6)]	
A	Extent of imperfection	Zero (no evident imperfection)	
B	Depth of incomplete penetration Cumulative length of incomplete penetration	≤ 1 mm (1/32 in.) and ≤ $0.2\overline{T}_w$ ≤ 38 mm (1.5 in.) in any 150 mm (6 in.) weld length	
C	Depth of lack of fusion and incomplete penetration Cumulative length of lack of fusion and incomplete penetration [Note (7)]	≤ $0.2\overline{T}_w$ ≤ 38 mm (1.5 in.) in any 150 mm (6 in.) weld length	
D	Size and distribution of internal porosity	See BPV Code, Section VIII, Division 1, Appendix 4	
E	Size and distribution of internal porosity	For $\overline{T}_w$ ≤ 6 mm (1/4 in.), limit is same as D For $\overline{T}_w$ > 6 mm (1/4 in.), limit is 1.5 × D	
F	Slag inclusion, tungsten inclusion, or elongated indication Individual length Individual width Cumulative length	 ≤ $\overline{T}_w/3$ ≤ 2.5 mm (3/32 in.) and ≤ $\overline{T}_w/3$ ≤ $\overline{T}_w$ in any $12\overline{T}_w$ weld length	
G	Slag inclusion, tungsten inclusion, or elongated indication Individual length Individual width Cumulative length	 ≤ $2\overline{T}_w$ ≤ 3 mm (1/8 in.) and ≤ $\overline{T}_w/2$ ≤ $4\overline{T}_w$ in any 150 mm (6 in.) weld length	
H	Depth of undercut	≤ 1 mm (1/32 in.) and ≤ $\overline{T}_w/4$	
I	Depth of undercut	≤ 1.5 mm (1/16 in.) and ≤ [$\overline{T}_w/4$ or 1 mm (1/32 in.)]	
J	Surface roughness	≤ 500 min. Ra per ASME B46.1	
K	Depth of root surface concavity	Total joint thickness, incl. weld reinf., ≥ $\overline{T}_w$	
L	Height of reinforcement or internal protrusion [Note (8)] in any plane through the weld shall be within limits of the applicable height value in the tabulation at right, except as provided in Note (9). Weld metal shall merge smoothly into the component surfaces.	For $\overline{T}_w$, mm (in.) ≤ 6 (1/4) > 6 (1/4), ≤ 13 (1/2) > 13 (1/2), ≤ 25 (1) > 25 (1)	Height, mm (in.) ≤ 1.5 (1/16) ≤ 3 (1/8) ≤ 4 (5/32) ≤ 5 (3/16)
M	Height of reinforcement or internal protrusion [Note (8)] as described in L. Note (9) does not apply.	Limit is twice the value applicable for L above	

X = required examination NA = not applicable ... = not required

Notes follow on next page

test. Test temperature is important in this regard and must be considered when the designer chooses the material of construction. See para. 345.2.2(c) and Appendix F, para. F323.4.

345.5.2 Pressure Relief Device. A pressure relief device shall be provided, having a set pressure not higher than the test pressure plus the lesser of 345 kPa (50 psi) or 10% of the test pressure.

345.5.3 Test Fluid. The gas used as test fluid, if not air, shall be nonflammable and nontoxic.

345.5.4 Test Pressure. The test pressure shall be 110% of design pressure.

345.5.5 Procedure. The pressure shall be gradually increased until a gage pressure which is the lesser of one-half the test pressure or 170 kPa (25 psi) is attained, at which time a preliminary check shall be made, including examination of joints in accordance with para. 341.4.1(a). Thereafter, the pressure shall be gradually increased in steps until the test pressure is reached, holding the pressure at each step long enough to equalize piping strains. The pressure shall then be reduced to the design pressure before examining for leakage in accordance with para. 345.2.2(a).

345.6 Hydrostatic-Pneumatic Leak Test

If a combination hydrostatic-pneumatic leak test is used, the requirements of para. 345.5 shall be met, and the pressure in the liquid filled part of the piping shall not exceed the limits stated in para. 345.4.2.

345.7 Initial Service Leak Test

This test is applicable only to piping in Category D Fluid Service, at the owner's option. See para. 345.1(a).

345.7.1 Test Fluid. The test fluid is the service fluid.

345.7.2 Procedure. During or prior to initial operation, the pressure shall be gradually increased in steps until the operating pressure is reached, holding the pressure at each step long enough to equalize piping strains. A preliminary check shall be made as described in para. 345.5.5 if the service fluid is a gas or vapor.

345.7.3 Examination for Leaks. In lieu of para. 345.2.2(a), it is permissible to omit examination for leakage of any joints and connections previously tested in accordance with this Code.

345.8 Sensitive Leak Test

The test shall be in accordance with the Gas and Bubble Test method specified in the BPV Code, Section V, Article 10, or by another method demonstrated to have equal sensitivity. Sensitivity of the test shall be not less than 10^{-3} atm·ml/sec under test conditions.

(a) The test pressure shall be at least the lesser of 105 kPa (15 psi) gage, or 25% or the design pressure.

(b) The pressure shall be gradually increased until a gage pressure the lesser of one-half the test pressure or 170 kPa (25 psi) is attained, at which time a preliminary check shall be made. Then the pressure shall be gradually increased in steps until the test pressure is reached, the pressure being held long enough at each step to equalize piping strains.

345.9 Alternative Leak Test

The following procedures and leak test method may be used only under the conditions stated in para. 345.1(c).

345.9.1 Examination of Welds. Welds, including those used in the manufacture of welded pipe and fittings, which have not been subjected to hydrostatic or pneumatic leak tests in accordance with this Code, shall be examined as follows.

(a) Circumferential, longitudinal, and spiral groove welds shall be 100% radiographed in accordance with para. 344.5 or 100% ultrasonically examined in accordance with para. 344.6. A01

(b) All welds, including structural attachment welds, not covered in (a) above, shall be examined using the liquid penetrant method (para. 344.4) or, for magnetic materials, the magnetic particle method (para. 344.3).

345.9.2 Flexibility Analysis. A flexibility analysis of the piping system shall have been made in accordance with the requirements of para. 319.4.2 (b), if applicable, or (c) and (d).

345.9.3 Test Method. The system shall be subjected to a sensitive leak test in accordance with para. 345.8.

346 RECORDS

346.2 Responsibility

It is the responsibility of the piping designer, the manufacturer, the fabricator, and the erector, as applicable, to prepare the records required by this Code and by the engineering design.

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A302.3.3 Limits of Calculated Stresses due to Sustained Loads[1]

(a) Internal Pressure Stresses. Limits of stress due to internal pressure are covered in para. A304.

(b) External Pressure Stresses. Stresses due to uniform external pressure shall be considered safe when the wall thickness of the component and its means of stiffening have been qualified as required by para. A304.7.2.

(c) External Loading Stresses. Design of piping under external loading shall be based on the following:

(1) Thermoplastic Piping. ASTM D 2321 or AWWA C900;

(2) Reinforced Thermosetting Resin (RTR) and Reinforced Plastic Mortar (RPM) Piping. ASTM D 3839 or Appendix A of AWWA C950;

(3) strain and possible buckling shall be considered when determining the maximum allowable deflection in (1) or (2) above, but in no case shall the allowable diametral deflection exceed 5% of the pipe inside diameter;

(4) nonmetallic piping not covered in (1) or (2) above shall be subjected to a crushing or three-edge bearing test in accordance with ASTM C 14 or C 301; the allowable load shall be 25% of the minimum value obtained.

A302.3.4 Limits of Calculated Stresses due to Occasional Loads

(a) Operation. The sum of the stresses in any component in a piping system due to pressure, weight, and other sustained loadings and of the stresses produced by occasional loads, such as wind and earthquake, shall not exceed the limits in the applicable part of para. A302.3.3. Wind and earthquake forces need not be considered as acting concurrently.

(b) Test. Stresses due to test conditions are not subject to the limitations in para. A302.3.3. It is not necessary to consider other occasional loads, such as wind and earthquake, as occurring concurrently with test loads.

A302.4 Allowances

Paragraph 302.4 applies in its entirety.

A01

PART 2
PRESSURE DESIGN OF PIPING COMPONENTS

A303 GENERAL

Paragraph 303 applies, except that references to Table A326.1 and para. A302.2.1 replace references to Table 326.1 and para. 302.2.1. For nonmetallic components, reference to para. A304 replaces reference to para. 304.

A304 PRESSURE DESIGN OF PIPING COMPONENTS A01

A304.1 Straight Pipe

A304.1.1 General

(a) The required thickness of straight sections of pipe shall be determined by Eq. (25).

$$t_m = t + c \tag{25}$$

The minimum thickness T for the pipe selected, considering manufacturer's minus tolerance, shall be not less than t_m.

(b) The following nomenclature is used in the equations for pressure design of straight pipe.

t_m = minimum required thickness, including mechanical, corrosion, and erosion allowances

t = pressure design thickness, as calculated in accordance with para. A304.1.2 for internal pressure or as determined in accordance with para. A304.1.3 for external pressure

c = the sum of mechanical allowances (thread or groove depth) plus corrosion and erosion allowance. For threaded components, the nominal thread depth (dimension h of ASME B1.20.1 or equivalent) shall apply. For machined surfaces or grooves where the tolerance is not specified, the tolerance shall be assumed to be 0.5 mm (0.02 in.) in addition to the specified depth of the cut.

T = pipe wall thickness (measured or minimum per purchase specification)

F = service (design) factor. See para. A302.3.2(c).

P = internal design gage pressure

D = outside diameter of pipe

S = design stress from applicable Table in Appendix B

A304.1.2 Straight Pipe Under Internal Pressure. The internal pressure design thickness t shall be not less than that calculated by one of the following equations, using stress values listed in or derived from the appropriate table in Appendix B.

(a) Thermoplastic Pipe [See Para. A302.3.2(a)]

$$t = \frac{PD}{2S + P} \text{ (Table B-1)} \tag{26a}$$

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(b) RTR (Laminated) Pipe [See Para. A302.3.2(b)]

$$t = \frac{PD}{2S + P} \text{(Table B-2)} \qquad (26b)^3$$

(c) RTR (Filament Wound) and RPM (Centrifugally Cast) Pipe [See Para. A302.3.2(c)]

$$t = \frac{PD}{2SF + P} \text{(Table B-3)} \qquad (26c)^3$$

A304.1.3 Straight Pipe Under External Pressure

(a) Nonmetallic Pipe. The external pressure design thickness t shall be qualified as required by para. A304.7.2.

(b) Metallic Pipe Lined With Nonmetals

(1) The external pressure design thickness t for the base (outer) material shall be determined in accordance with para. 304.1.3.

(2) The external pressure design thickness t for the lining material shall be qualified as required by para. A304.7.2.

A304.2 Curved and Mitered Segments of Pipe

A304.2.1 Pipe Bends. The minimum required thickness t_m of a bend, after bending, shall be determined as for straight pipe in accordance with para. A304.1.

A304.2.2 Elbows. Manufactured elbows not in accordance with para. A303 shall be qualified as required by para. A304.7.2.

A304.2.3 Miter Bends. Miter bends shall be qualified as required by para. A304.7.2.

A304.3 Branch Connections

A304.3.1 General. A pipe having a branch connection is weakened by the opening that must be made in it and, unless the wall thickness of the pipe is sufficiently in excess of that required to sustain the pressure, it is necessary to provide added reinforcement. The amount of reinforcement shall be qualified as required by para. A304.7.2 except as provided in para. A304.3.2.

A304.3.2 Branch Connections Using Fittings. It may be assumed without calculation that a branch connection has adequate strength to sustain the internal and external pressure which will be applied to it if it utilizes a fitting (a tee, lateral, or cross) in accordance with para. A303.

A304.3.3 Additional Design Considerations. The requirements of paras. A304.3.1 and A304.3.2 are intended to assure satisfactory performance of a branch connection subjected only to internal or external pressure. The designer shall also consider paras. 304.3.5(a), (c), and (d).

A304.4 Closures

Closures not in accordance with para. A303 shall be qualified as required by para. A304.7.2.

A304.5 Pressure Design of Flanges

A304.5.1 General

(a) Flanges not in accordance with para. A303 or A304.5.1(b) or (c) shall be qualified as required by para. A304.7.2.

(b) Flanges for use with flat ring gaskets may be designed in accordance with BPV Code, Section VIII, Division 1, Appendix 2, except that the allowable stresses and temperature limits of this Code shall govern. Nomenclature shall be as defined in the BPV Code, except for the following:

P = design gage pressure
S_a = bolt design stress at atmospheric temperature[4]
S_b = bolt design stress at design temperature[4]
S_f = allowable stress for flange material from Table B-1, B-2, or B-3

(c) The flange design rules in para. A304.5.1(b) are not applicable to designs employing full face gaskets which extend beyond the bolts, usually to the outside diameter of the flange, or whose flanges are in solid contact beyond the bolts. The forces and reactions in such a joint differ from those joints employing flat ring gaskets, and the flange should be designed in accordance with BPV Code, Section VIII, Division 1, Appendix Y.

A304.5.2 Blind Flanges. Blind flanges not in accordance with para. A303 may be designed in accordance with para. 304.5.2, except that allowable stress S shall be taken from Tables in Appendix B. Otherwise, they shall be qualified as required by para. A304.7.2.

[3] The internal design pressure thickness t shall not include any thickness of the pipe wall reinforced with less than 20% by weight of reinforcing fibers.

[4] Bolt design stresses shall not exceed those in Table A-2.

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A304.6 Reducers

Reducers not in accordance with para. A303 shall be qualified as required by para. A304.7.2.

A304.7 Pressure Design of Other Components

A304.7.1 Listed Components. Other pressure containing components, manufactured in accordance with standards in Table A326.1 but not covered elsewhere in para. A304, may be utilized in accordance with para. A303.

A304.7.2 Unlisted Components and Elements. Pressure design of unlisted components and joints, to which the rules elsewhere in para. A304 do not apply, shall be based on calculations consistent with the design criteria of this Code. Calculations shall be substantiated by one or both of the means stated in (a) and (b) below, considering applicable ambient and dynamic effects in paras. 301.4 through 301.11:

(a) extensive, successful service experience under comparable design conditions with similarly proportioned components made of the same or like material;

(b) performance test under design conditions including applicable dynamic and creep effects, continued for a time period sufficient to determine the acceptability of the component or joint for its design life;

(c) for (a) or (b) above, the designer may interpolate between sizes, wall thicknesses, and pressure classes, and may determine analogies among related materials.

A304.7.3 Nonmetallic Components With Metallic Pressure Parts. Components not covered by standards in Table A326.1, in which both nonmetallic and metallic parts contain the pressure, shall be evaluated by applicable requirements of para. 304.7.2 as well as those of para. A304.7.2.

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PART 3
FLUID SERVICE REQUIREMENTS FOR PIPING COMPONENTS

A305 PIPE

Listed nonmetallic pipe may be used in Normal Fluid Service, subject to the limitations of the pressure-containing material and para. A323.4. Unlisted pipe may be used only in accordance with para. A302.2.3.

A306 NONMETALLIC FITTINGS, BENDS, MITERS, LAPS, AND BRANCH CONNECTIONS

General. Fittings, bends, miters, laps, and branch connections may be used in accordance with paras. A306.1 through A306.5. Pipe and other materials used in such components shall be suitable for the manufacturing process and the fluid service.

A306.1 Pipe Fittings

A306.1.1 Listed Fittings. Listed fittings may be used in Normal Fluid Service subject to limitations on materials.

A306.1.2 Unlisted Fittings. Unlisted fittings may be used only in accordance with para. A302.2.3.

A306.2 Pipe Bends

A306.2.1 General. A bend made in accordance with para. A332 and verified for pressure design in accordance with para. A304.2.1 shall be suitable for the same service as the pipe from which it is made.

A306.2.2 Corrugated and Other Bends. Bends of other designs (such as creased or corrugated) shall be qualified for pressure design as required by para. A304.7.2.

A306.3 Miter Bends

Except as specified in para. 306.3.2, a miter bend which conforms to para. A304.2.3 may be used in Normal Fluid Service.

A306.4 Fabricated or Flared Laps

The following requirements do not apply to fittings conforming to para. A306.1.

A306.4.1 Fabricated Laps

(a) The requirements in paras. 306.4.1(a) and (b) shall be met.

(b) Lap material shall be suitable for the service conditions. Pressure design shall be qualified as required by para. A304.7.2.

A306.4.2 Flared Laps. Flared laps shall not be used in nonmetallic piping.

A306.5 Fabricated Branch Connections

The following requirements do not apply to fittings conforming to para. A306.1.

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A306.5.1 General. A fabricated branch connection made by bonding the branch pipe directly to the header pipe, with or without added reinforcement as stated in para. 328.5.4, and shown in Fig. 328.5.4, may be used in Normal Fluid Service, provided that pressure design is qualified as required by para. A304.7.2.

A306.5.2 Specific Requirements. Fabricated branch connections shall be made as specified in para. A328.5.

A307 NONMETALLIC VALVES AND SPECIALTY COMPONENTS

Paragraph 307 applies in its entirety, except that in para. 307.1.2 reference to paras. A302.2.3 and A304.7.2 replaces reference to paras. 302.2.3 and 304.7.2, respectively.

A308 FLANGES, BLANKS, FLANGE FACINGS, AND GASKETS

A308.1 General

Paragraph 308.1 applies, except that in para. 308.1.2 reference to para. A302.2.3 replaces reference to para. 302.2.3.

A308.2 Nonmetallic Flanges

A308.2.1 General

(a) Nonmetallic flanges shall be adequate, with suitable facing, gasketing, and bolting, to develop the full rating of the joint and to withstand expected external loadings.

(b) The designer should consult the manufacturer for ratings of nonmetallic flanges.

A308.2.2 Threaded Flanges. Threaded flanges are subject to the requirements for threaded joints in para. A314.

A308.3 Flange Facings

Paragraph 308.3 applies in its entirety.

A308.4 Limitations on Gaskets

See also Appendix F, para. F308.4.

A308.4.1 Lining Used as Facing or Gasket. Lining material extended over the flange face and used as a gasket shall conform to para. 308.4.

A309 BOLTING

Bolting includes bolts, bolt studs, studs, cap screws, nuts, and washers. See Appendix F, para. F309.

A309.1 General

Paragraph 309.1 applies in its entirety.

A309.2 Specific Bolting

Any bolting which meets the requirements of para. 309.1 may be used with any combination of flange materials and flange facings. Joint assembly shall conform to the requirements of para. A335.2.

A309.3 Tapped Holes in Nonmetallic Components

Tapped holes for pressure retaining bolting in nonmetallic piping components may be used provided pressure design is qualified as required by para. A304.7.2.

PART 4 A01
FLUID SERVICE REQUIREMENTS FOR PIPING JOINTS

A310 GENERAL

Paragraph 310 applies in its entirety.

A311 BONDED JOINTS IN PLASTICS

A311.1 General

Bonding shall be in accordance with para. A328 and examination shall be in accordance with para. A341.4.1 for use in Normal Fluid Service, subject to the limitations of the material.

A311.2 Specific Requirements

A311.2.1 Fillet Bonds. A fillet bond may be used only in conjunction with a qualified hot gas welding procedure for bonding (see para. A328.5.2).

A311.2.2 Seal Bonds. A seal bond may be used only to prevent leakage of a threaded joint and only if it has been demonstrated that there will be no deleterious effect on the materials bonded.

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PART 8
PIPING COMPONENTS, STANDARDS

A326 DIMENSIONS AND RATINGS OF COMPONENTS

A326.1 Requirements

Paragraph 326 applies in its entirety except that references to Table A326.1 and Appendix B replace references to Table 326.1 and Appendix A, respectively.

A00 **A326.4 Abbreviations in Table A326.1 and Appendix B**

The abbreviations tabulated below are used in this Chapter to replace lengthy phrases in the text and in the titles of standards in Table A326.1 and the Specifications Index for Appendix B. Those marked with an asterisk (*) are in accordance with ASTM D 1600, Terminology Relating to Abbreviations, Acronyms, and Codes for Terms Relating to Plastics.

Abbreviation	Term
*ABS	Acrylonitrile-Butadiene-Styrene
*CAB	Cellulose Acetate-Butyrate
CP	Chlorinated Polyether
*CPVC	Chlorinated Poly (Vinyl Chloride)
ECTFE	Ethylene-Chlorotrifluoroethylene
ETFE	Ethylene-Tetrafluoroethylene
*FEP	Perfluoro (Ethylene-Propylene) copolymer
PB	Polybutylene
*PE	Polyethylene
PFA	Perfluoro (Alkoxyalkane) copolymer
*POM	Polyacetal, Poly (Oxymethylene)
POP	Poly (Phenylene Oxide)
*PP	Polypropylene
*PPS	Poly (Phenylene Sulfide)
PR	Pressure Rated
*PTFE	Polytetrafluoroethylene
*PVC	Poly (Vinyl Chloride)
*PVDC	Poly (Vinylidene Chloride)
*PVDF	Poly (Vinylidene Fluoride)
RPM	Reinforced Plastic Mortar
RTR	Reinforced Thermosetting Resin
SDR	Standard Dimensional Ratio

PART 9
FABRICATION, ASSEMBLY, AND ERECTION

A327 GENERAL

Piping materials and components are prepared for assembly and erection by one or more of the fabrication processes in paras. A328, A329, A332, and A334. When any of these processes is used in assembly and erection, requirements are the same as for fabrication.

A328 BONDING OF PLASTICS

Paragraph A328 applies only to joints in thermoplastic, RTR, and RPM piping. Bonding shall conform to paras. A328.1 through A328.7 and the applicable requirements of para. A311.

A328.1 Bonding Responsibility

Each employer is responsible for the bonding done by personnel of his organization and, except as provided in paras. A328.2.2 and A328.2.3, shall conduct the required performance qualification tests to qualify bonding procedure specifications (BPS) and bonders or bonding operators.

A328.2 Bonding Qualifications

A328.2.1 Qualification Requirements

(a) Qualification of the BPS to be used, and of the performance of bonders and bonding operators, is required. To qualify a BPS, all tests and examinations specified therein and in para. A328.2.5 shall be completed successfully.

(b) In addition to the procedure for making the bonds, the BPS shall specify at least the following:

(1) all materials and supplies (including storage requirements);

(2) tools and fixtures (including proper care and handling);

(3) environmental requirements (e.g., temperature, humidity, and methods of measurement);

(4) joint preparation;

(5) dimensional requirements and tolerances;

(6) cure time;

(7) protection of work;

(8) tests and examinations other than those required by para. A328.2.5; and

(9) acceptance criteria for the completed test assembly.

A328.2.2 Procedure Qualification by Others. Subject to the specific approval of the Inspector, a BPS qualified by others may be used provided that:

(a) the Inspector satisfies himself that the proposed qualified BPS has been prepared and executed by a responsible recognized organization with expertise in the field of bonding;

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TABLE A326.1
COMPONENT STANDARDS[1]

Standard or Specification	Designation [Note (2)]
Nonmetallic Fittings	
Process Glass Pipe and Fittings	ASTM C 599
Threaded PVC Plastic Pipe Fittings, Sch 80	ASTM D 2464
PVC Plastic Pipe Fittings, Sch 40	ASTM D 2466
Socket-Type PVC Plastic Pipe Fittings, Sch 80	ASTM D 2467
Socket-Type ABS Plastic Pipe Fittings, Sch 40	ASTM D 2468
Thermoplastic Gas Pressure Pipe, Tubing, and Fittings	ASTM D 2513
Reinforced Epoxy Resin Gas Pressure Pipe and Fittings	ASTM D 2517
Plastic Insert Fittings for PE Plastic Pipe	ASTM D 2609
Socket-Type PE Fittings for Outside Diameter-Controlled PE Pipe and Tubing	ASTM D 2683
CPVC Plastic Hot and Cold Water Distribution Systems	ASTM D 2846
Butt Heat Fusion PE Plastic Fittings for PE Plastic Pipe and Tubing	ASTM D 3261
PB Plastic Hot-Water Distribution Systems	ASTM D 3309
Fiberglass RTR Pipe Fittings for Nonpressure Applications [Note (3)]	ASTM D 3840
RTR Flanges	ASTM D 4024
Contact Molded Fiberglass RTR Flanges [Note (3)]	ASTM D 5421
PTFE Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 423
Threaded CPVC Plastic Pipe Fittings, Sch 80	ASTM F 437
Socket-Type CPVC Plastic Pipe Fittings, Sch 40	ASTM F 438
Socket-Type CPVC Plastic Pipe Fittings, Sch 80	ASTM F 439
PVDF Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 491
Propylene and PP Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 492
FEP Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 546
PVDC Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 599
PFA Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 781
Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing	ASTM F 1055
Plastic-Lined Ferrous Metal Pipe, Fittings, and Flanges [Note (4), (5)]	ASTM F 1545
Nonmetallic Pipes and Tubes	
PE Line Pipe	API 15LE
Low Pressure Fiberglass Line Pipe	API 15LR
Reinforced Concrete Low-Head Pressure Pipe	ASTM C 361
Process Glass Pipe and Fittings	ASTM C 599
ABS Plastic Pipe, Sch 40 and 80	ASTM D 1527
PVC Plastic Pipe, Sch 40, 80 and 120	ASTM D 1785
PE Plastic Pipe, Sch 40	ASTM D 2104
PE Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter	ASTM D 2239
PVC Plastic Pressure-Rated Pipe (SDR Series)	ASTM D 2241
ABS Plastic Pipe (SDR-PR)	ASTM D 2282
Classification for Machine-Made RTR Pipe	ASTM D 2310
PE Plastic Pipe, Sch 40 & 80, Based on Outside Diameter	ASTM D 2447
Thermoplastic Gas Pressure Pipe, Tubing, and Fittings	ASTM D 2513
Reinforced Epoxy Resin Gas Pressure Pipe and Fittings	ASTM D 2517
PB Plastic Pipe (SDR-PR)	ASTM D 2662
PB Plastic Tubing	ASTM D 2666

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TABLE A326.1 (CONT'D)
COMPONENT STANDARDS[1]

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Standard or Specification	Designation [Note (2)]
Bell End PVC Plastic Pipe	ASTM D 2672
PE Plastic Tubing	ASTM D 2737
CPVC Plastic Hot and Cold Water Distribution System	ASTM D 2846
Filament-Wound Fiberglass RTR Pipe [Note (3)]	ASTM D 2996
Centrifugally Cast RTR Pipe	ASTM D 2997
PB Plastic Pipe (SDR-PR) Based on Outside Diameter	ASTM D 3000
PE Plastic Pipe (SDR-PR) Based on Controlled Outside Diameter	ASTM D 3035
PB Plastic Hot-Water Distribution Systems	ASTM D 3309
Fiberglass RTR Pressure Pipe [Note (3)]	ASTM D 3517
Fiberglass RTR Sewer and Industrial Pressure Pipe [Note (3)]	ASTM D 3754
PTFE Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 423
CPVC Plastic Pipe	ASTM F 441
CPVC Plastic Pipe (SDR-PR)	ASTM F 442
PVDF Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 491
Propylene and PP Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 492
FEP Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 546
PVDC Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 599
PFA Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 781
Standard Specification for Polyolefin Pipe and Fittings for Corrosive Waste Drainage Systems [Notes (4), (5)]	ASTM F 1412
Plastic-Lined Ferrous Metal Pipe, Fittings, and Flanges [Notes (4), (5)]	ASTM F 1545
Standard Specification for Polyvinylidene Fluorine (PVDF) Corrosive Water Drainage Systems	ASTM F 1673
Reinforced Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids	AWWA C300
Prestressed Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids	AWWA C301
Reinforced Concrete Pressure Pipe, Noncylinder Type, for Water and Other Liquids	AWWA C302
PVC Pressure Pipe, 4-inch through 12-inch, for Water	AWWA C900
Glass-Fiber-Reinforced Thermosetting Resin Pressure Pipe	*AWWA C950
Miscellaneous	
Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion Resistant Equipment	ASTM C 582
Threads for Fiberglass RTR Pipe (60 deg stub) [Note (3)]	ASTM D 1694
Solvent Cements for ABS Plastic Pipe and Fittings	ASTM D 2235
Solvent Cements for PVC Plastic Pipe and Fittings	ASTM D 2564
Bell End PVC Plastic Pipe	ASTM D 2672
Joints for Plastic Pressure Pipes using Flexible Elastomeric Seals	ASTM D 3139
Fiberglass RTR Pipe Joints Using Flexible Elastomeric Seals [Note (3)]	ASTM D 4161
Design and Construction of Nonmetallic Enveloped Gaskets for Corrosive Service	ASTM F 336
Solvent Cements for CPVC Plastic Pipe and Fittings	ASTM F 493

NOTES:
(1) It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.
(2) An asterisk (*) preceding the designation indicates that the standard has been approved as an American National Standard by the American National Standards Institute.
(3) The term *fiberglass RTR* takes the place of the ASTM designation: "*fiberglass*" (*glass-fiber-reinforced thermosetting resin*).
(4) This Standard allows the use of unlisted materials; see para. 323.1.2.
(5) This Standard contains no pressure-temperature ratings.

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(b) by signature, the employer accepts both the BPS and procedure qualification record (PQR) as his own; and

(c) the employer has at least one currently employed bonder who, while in his employ, has satisfactorily passed a performance qualification test using the proposed qualified BPS.

A328.2.3 Performance Qualification by Others. Without the Inspector's specific approval, an employer shall not accept a performance qualification test made by a bonder or bonding operator for another employer. If approval is given, it is limited to work on piping using the same or equivalent BPS. An employer accepting such performance qualification tests shall obtain a copy of the performance qualification test record from the previous employer showing the name of the employer by whom the bonder or bonding operator was qualified, the date of such qualification, and the date the bonder or bonding operator last bonded pressure piping under such performance qualification.

A328.2.4 Qualification Records. The employer shall maintain a self-certified record, available to the owner or owner's agent and to the Inspector, of the BPS used and the bonders or bonding operators employed by him, and showing the dates and results of BPS qualifications and bonding performance qualifications.

A328.2.5 Qualification Tests. Tests, as specified in para. A328.2.1(a), shall be performed to qualify each BPS and the performance of each bonder and bonding operator. Test assemblies shall conform to (a) below and the test method shall be in accordance with either (b) or (c).

A01 *(a) Test Assembly.* The assembly shall be fabricated in one pipe size in accordance with the BPS and shall contain at least one of each different type of joint identified in the BPS. More than one test assembly may be prepared if necessary to accommodate all of the joint types or to assure that at least one of each joint type is loaded in both circumferential and longitudinal directions. The size of pipe and fittings in the assembly shall be as follows.

(1) When the largest size to be joined is DN 100 (NPS 4) or smaller, the test assembly shall be the largest size to be joined.

(2) When the largest size to be joined is greater than DN 100 (NPS 4), the size of the test assembly shall be between 25% and 100% of the largest piping size to be joined, but shall be a minimum of DN 100 (NPS 4).

(b) Burst Test Method. The test assembly shall be subjected to a burst test in accordance with the applicable sections of ASTM D 1599.[5] The time to burst in this standard may be extended. The test is successful if failure initiates outside of any bonded joint.

(c) Hydrostatic Test Method. The test assembly shall be subjected to hydrostatic pressure of at least P_T for not less than 1 hr with no leakage or separation of joints.

(1) For thermoplastics, P_T shall be determined in accordance with Eq. (27):

$$P_T = 0.80\overline{T}\left(\frac{(S_S + S_H)}{D - \overline{T}}\right) \quad (27)$$

where

D = outside diameter of pipe
$\overline{T}$ = nominal thickness of pipe
S_S = mean short term burst stress in accordance with ASTM D 1599,[5] from Table B-1 if listed, otherwise from manufacturer's data.
S_H = mean long term hydrostatic strength (LTHS) in accordance with ASTM D 2837. Use twice the 23°C (73°F) HDB design stress from Table B-1 if listed; or use manufacturer's data.

(2) For RTR (laminated and filament-wound) and RPM, P_T shall be three times the manufacturer's allowable pressure for the components being joined.

(3) The test shall be conducted so that the joint is loaded in both the circumferential and longitudinal directions.

A328.2.6 Performance Requalification. Renewal of a bonding performance qualification is required when:

(a) a bonder or bonding operator has not used the specific bonding process for a period of 6 months or more; or (99) A00

(b) there is specific reason to question the individual's ability to make bonds that meet the BPS.

A328.3 Bonding Materials and Equipment

A328.3.1 Materials. Bonding materials that have deteriorated by exposure to air or prolonged storage, or will not spread smoothly, shall not be used in making joints.

A328.3.2 Equipment. Fixtures and tools used in making joints shall be in such condition as to perform their functions satisfactorily.

[5] Titles of referenced standards and specifications are listed in Table A326.1, except ASTM D 1599 and ASTM D 2855, Practice for Making Solvent-Cemented Joints with PVC Pipe and Fittings.

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A328.4 Preparation for Bonding

Preparation shall be defined in the BPS and shall specify such requirements as:

(a) cutting;
(b) cleaning;
(c) preheat;
(d) end preparation; and
(e) fit-up.

(99) ### A328.5 Bonding Requirements

A328.5.1 General

(a) Production joints shall be made only in accordance with a written bonding procedure specification (BPS) that has been qualified in accordance with para. A328.2. Manufacturers of piping materials, bonding materials, and bonding equipment should be consulted in the preparation of the BPS.

(b) Production joints shall be made only by qualified bonders or bonding operators who have appropriate training or experience in the use of the applicable BPS and have satisfactorily passed a performance qualification test that was performed in accordance with a qualified BPS.

(c) Each qualified bonder and bonding operator shall be assigned an identification symbol. Unless otherwise specified in the engineering design, each pressure containing bond or adjacent area shall be stenciled or otherwise suitably marked with the identification symbol of the bonder or bonding operator. Identification stamping shall not be used and any marking paint or ink shall not be detrimental to the piping material. In lieu of marking the bond, appropriate records may be filed.

(d) Qualification in one BPS does not qualify a bonder or bonding operator for any other bonding procedure.

(e) Longitudinal joints are not covered in para. A328.

A328.5.2 Hot Gas Welded Joints in Thermoplastic Piping[5]

(a) Preparation. Surfaces to be hot gas welded together shall be cleaned of any foreign material. For butt welds, the joining edges should be beveled at 20 deg to 40 deg with 1 mm ($^1/_{32}$ in.) root face and root gap.

(b) Procedure. Joints shall be made in accordance with the qualified BPS.

(c) Branch Connections. A fabricated branch connection shall be made by inserting the branch pipe in the hole in the run pipe. Dimensions of the joint shall conform to Fig. 328.4.4 sketch (c). The hole in the run pipe shall be beveled at 45 deg. Alternatively, a fabricated branch connection shall be made using a manufactured full reinforcement saddle with integral socket.

A328.5.3 Solvent Cemented Joints in Thermoplastic Piping[5]

(a) Preparation. PVC and CPVC surfaces to be solvent cemented shall be cleaned by wiping with a clean cloth moistened with acetone or methylethyl ketone. Cleaning for ABS shall conform to ASTM D 2235. A slight interference fit between pipe and fitting socket is preferred and diametral clearance between pipe and entrance of fitting socket shall not exceed 1.0 mm (0.04 in.). This fit shall be checked before solvent cementing.

(b) Procedure. Joints shall be made in accordance with the qualified BPS. ASTM D 2855 provides a suitable basis for development of such a procedure. Solvent cements for PVC, CPVC, and ABS shall conform to ASTM D 2564, D 2846, and D 2235, respectively. Application of cement to both surfaces to be joined and assembly of these surfaces shall produce a continuous bond between them with visual evidence of cement at least flush with the outer end of the fitting bore around the entire joint perimeter. See Fig. A328.5.3.

(c) Branch Connections. A fabricated branch connection shall be made using a manufactured full reinforcement saddle with integral branch socket. The reinforcement saddle shall be solvent cemented to the run pipe over its entire contact surface.

A328.5.4 Heat Fusion Joints in Thermoplastic Piping[5]

(a) Preparation. Surfaces to be heat fused together shall be cleaned of all foreign material.

(b) Procedure. Joints shall be made in accordance with the qualified BPS. The general procedures in ASTM D 2657, Techniques I — Socket Fusion, II — Butt Fusion, and III — Saddle Fusion, provide a suitable basis for development of such a procedure. Uniform heating of both surfaces to be joined and assembly of these surfaces shall produce a continuous homogeneous bond between them and shall produce a small fillet of fused material at the outer limits of the joint. See Fig. A328.5.4 for typical heat fusion joints. Fixtures shall be used to align components when joints are made. A01

(c) Branch Connections. A fabricated branch connection is permitted only where molded fittings are unavailable.

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A328.5.5 Electrofusion Joints in Thermoplastic Piping

(a) Preparation. Surfaces to be heat fused together shall be cleaned of all foreign material.

(b) Procedure. Joints shall be made in accordance with the qualified BPS. The general procedures in ASTM F 1290, Technique I — Coupling Procedure and Technique II — Saddle Procedure provide a suitable basis for the development of such a procedure. See Fig. A328.5.5.

A328.5.6 Adhesive Joints in RTR and RPM Piping

(a) Procedure. Joints shall be made in accordance with the qualified BPS. Application of adhesive to the surfaces to be joined and assembly of these surfaces shall produce a continuous bond between them and shall seal over all cuts to protect the reinforcement from the service fluid. See Fig. A328.5.6.

(b) Branch Connections. A fabricated branch connection shall be made using a manufactured full reinforcement saddle having a socket or integral length of branch pipe suitable for a nozzle or coupling. The hole in the run pipe shall be made with a hole saw; the cut edges of the hole shall be sealed with adhesive at the time the saddle is bonded to the run pipe.

A328.5.7 Butt-and-Wrapped Joints in RTR and RPM Piping[5]

(a) Procedure. Joints shall be made in accordance with the qualified BPS. Application of plies of reinforcement saturated with catalyzed resin to the surfaces to be joined shall produce a continuous structure with them. Cuts shall be sealed to protect the reinforcement from the service fluid. See Fig. A328.5.7.

(b) Branch Connections. For a fabricated branch connection made by inserting the branch pipe into a hole in the run pipe, the hole shall be made with a hole saw.

A328.6 Bonding Repair

Defective material, joints, and other workmanship that fails to meet the requirements of this Code and of the engineering design shall be repaired or replaced. See also para. 341.3.3.

A328.7 Seal Bonds

If threaded joints are to be seal bonded in accordance with para. A311.2.2, the work shall be done by qualified bonders and all exposed threads shall be covered by the seal bond.

A329 FABRICATION OF PIPING LINED WITH NONMETALS

A329.1 Welding of Metallic Piping

A329.1.1 General

(a) Paragraph A329.1 applies only to welding subassemblies of metallic piping that have previously been lined with nonmetals.

(b) Welding which conforms to para. A329.1 may be used in accordance with para. A318.3.1.

A329.1.2 Specific Welding Requirements. Welding shall conform to the requirements of para. 328 and the following additional requirements.

(a) Modifications made in preparation for welding to suit manufacturer's recommendations shall be specified in the engineering design.

(b) Welding shall be performed so as to maintain the continuity of the lining and its serviceability.

(c) If a lining has been damaged, it shall be repaired or replaced.

(d) Qualification to one WPS for a specific lining material does not qualify a welder or welding operator for any other welding procedure involving different lining materials.

A329.2 Flaring of Nonmetallic Linings

A329.2.1 General

(a) Paragraph A329.2 applies only to the flaring of linings in pipe that has previously been lined with nonmetals.

(b) Flaring which conforms to para. A329.2 may be used in accordance with para. A318.3.2.

(c) Flaring shall be performed only in accordance with a written flaring procedure specification, and only by qualified operators who have appropriate training or experience in the use of the applicable flaring procedure specification.

A332 BENDING AND FORMING

A332.1 General

Paragraph 332.1 applies in its entirety.

A332.2 Bending

Paragraph 332.2 applies, except para. 332.2.2.

A332.3 Forming

Paragraph 332.3 applies, except for heat treatment.

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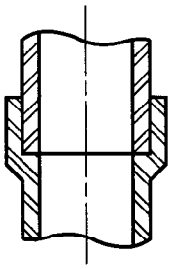
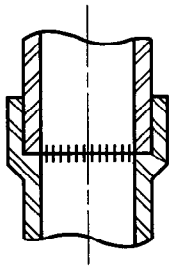
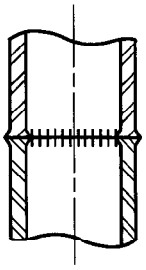


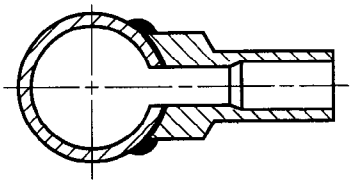
Socket Joint



Socket Joint



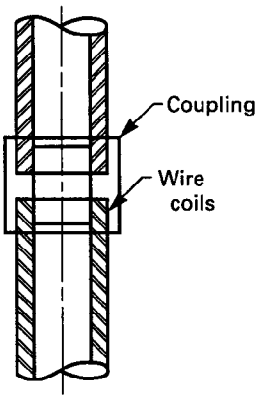
Butt Joint

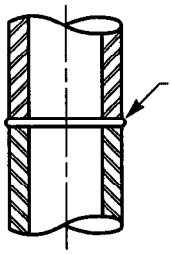


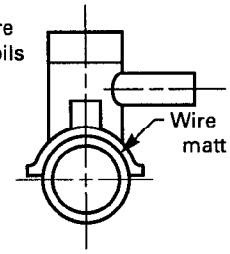
Saddle Joint

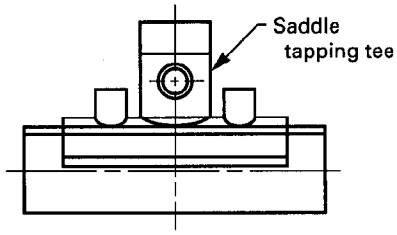
FIG. A328.5.3 THERMOPLASTIC SOLVENT CEMENTED JOINT

FIG. A328.5.4 THERMOPLASTIC HEAT FUSION JOINTS A01









Coupling Butt Saddle

FIG. A328.5.5 THERMOPLASTIC ELECTROFUSION JOINTS

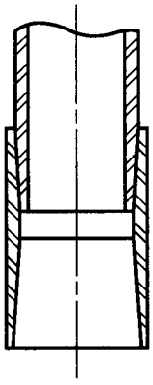
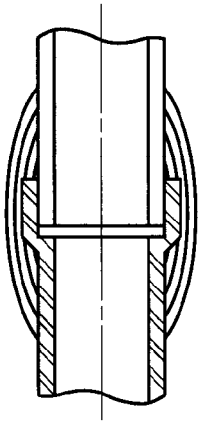
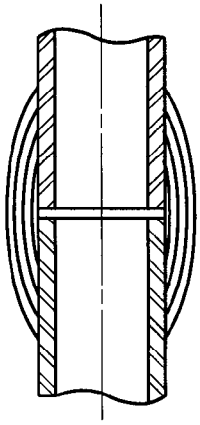


FIG. A328.5.6 FULLY TAPERED THERMOSETTING ADHESIVE JOINT



Overwrapped Bell and Spigot Joint



Butt and Wrapped Joint

FIG. A328.5.7 THERMOSETTING WRAPPED JOINTS

FIG. A328.5 TYPICAL PLASTIC PIPING JOINTS (99)

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A334 JOINING NONPLASTIC PIPING

A334.1 Borosilicate Glass Piping

Short unflanged pieces used to correct for differences between fabrication drawings and field dimensions may be cut to length and finished in the field.

A334.2 Repair of Defects

Defective material, joints, and other workmanship in nonplastic piping that fail to meet the requirements of para. A334 or of the engineering design shall be repaired or replaced.

Completed repairs and replacements shall be examined, subject to the same limitations on imperfections as the original work.

A335 ASSEMBLY AND ERECTION

A335.1 General

Paragraph 335.1.1 applies in its entirety.

A335.2 Flanged and Mechanical Joints

Paragraph 335.2 applies in its entirety.

A335.2.5 Nonmetallic Bolted Joints

(a) Bolted joints in nonmetallic piping may be assembled with any combination of flange material and flange facings, except that when other than flat face flanges and full face gaskets are used:

(1) consideration shall be given to the strength of the flanges, and to sustained loads, displacement strains, and occasional loads described in paras. A302.3.4 and A302.3.5; and

(2) an appropriate bolt-up sequence shall be specified.

(b) Appropriate limits shall be specified for bolt-up torque, and those limits shall not be exceeded.

(c) Flat washers shall be used under bolt heads and nuts.

A335.2.6 Metallic Piping Lined With Nonmetals. In assembling mechanical joints in metallic piping lined with nonmetals, consideration shall be given to means for maintaining electrical continuity between pipe sections, where static sparking could cause ignition of flammable vapors. See Appendix F, para. FA323.4(a).

A335.3 Threaded Joints

Paragraph 335.3 applies except for para. 335.3.2. See para. A335.3.2.

A335.3.2 Joints for Seal Bonding. A threaded joint to be seal bonded shall be made up without thread compound. A joint containing thread compound which leaks during leak testing may be seal bonded in accordance with para. A328.6, provided all compound is removed from exposed threads.

A335.3.4 General, Nonmetallic Piping. Either strap wrenches or other full circumference wrenches shall be used to tighten threaded pipe joints. Tools and other devices used to hold or apply forces to the pipe shall be such that the pipe surface is not scored or deeply scratched.

A335.3.5 RTR and RPM Piping. In assembling threaded joints in RTR and RPM piping, where threads may be exposed to fluids which can attack the reinforcing material, threads shall be coated with sufficient resin to cover the threads and completely fill the clearance between the pipe and the fitting.

A335.4 Tubing Joints

A335.4.1 Flared Joints in Thermoplastic Tubing. In addition to preparation in accordance with para. 335.4.1, flared joints shall be made in accordance with ASTM D 3140, Flared Joints for Polyolefins.

A335.4.2 Flareless and Compression Tubing Joints. Paragraph 335.4.2 applies.

A335.5 Caulked Joints

Paragraph 335.5 applies.

A335.6 Special Joints

Paragraph 335.6 applies, except that expanded joints are not permitted.

A335.6.3 Flexible Elastomeric Sealed Joints. Assembly of flexible elastomeric sealed joints shall be in accordance with the manufacturer's recommendations and the following.

(a) Seal and bearing surfaces shall be free from injurious imperfections.

(b) Any lubricant used to facilitate joint assembly shall be compatible with the joint components and the intended service.

(c) Proper joint clearances and piping restraints (if not integral in the joint design) shall be provided to

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K302.2.5 Ratings at Junction of Different Services. Paragraph 302.2.5 applies.

K302.3 Allowable Stresses and Other Design Limits

K302.3.1 General. The allowable stresses defined below shall be used in design calculations unless modified by other provisions of this Chapter.

(a) Tension. Allowable stresses in tension for use in design in accordance with this Chapter are listed in Table K-1, except that maximum allowable stress values and design stress intensity values for bolting, respectively, are listed in the BPV Code, Section II, Part D, Tables 3 and 4.

The tabulated stress values in Table K-1 are grouped by materials and product form and are for stated temperatures up to the limit provided for the materials in para. K323.2.1. Straight line interpolation between temperatures to determine the allowable stress for a specific design temperature is permissible. Extrapolation is not permitted.

(b) Shear and Bearing. Allowable stress in shear shall be 0.80 times the allowable stress in tension tabulated in Table K-1. Allowable stress in bearing shall be 1.60 times the allowable stress in tension.

(c) Compression. Allowable stress in compression shall be no greater than the allowable stress in tension tabulated in Table K-1. Consideration shall be given to structural stability.

(d) Fatigue. Allowable values of stress amplitude, which are plotted as a function of design life in the BVP Code, Section VIII, Division 2, Appendix 5, may be used in fatigue analysis in accordance with para. K304.8.

A01 **K302.3.2 Bases for Allowable Stresses.** The bases for establishing allowable stress values for materials in this Chapter are as follows.

(99) *(a) Bolting Materials.* The criteria of Section II, Part D, Appendix 2, para. 2-120 or 2-130, or Section VIII, Division 3, Article KD-6, para. KD-620, as applicable, apply.

(b) Other Materials. For materials other than bolting materials, the following rules apply.

(1) Except as provided in (b)(2) below, allowable stress values at design temperature for materials listed in Section II, Part D shall not exceed the lower of: two-thirds of the specified minimum yield strength at room temperature (SMYS), and two-thirds of the yield strength at temperature.

(2) For solution heat treated austenitic stainless steels and certain nickel alloys with similar stress-strain behavior, allowable stress values shall not exceed the lower of: two-thirds of the SMYS, and 90% of the yield strength at temperature.

(3) Allowable stresses for materials which are not listed in Section II, Part D shall not exceed the following:

(a) Temperatures not exceeding 100°F. Two-thirds of the SMYS.

(b) Temperatures exceeding 100°F. The corresponding values listed in Table A-1 (see para. 302.3.2).

Application of stress values so determined is not recommended for flanged joints and other components in which slight deformation can cause leakage or malfunction. [These values are shown in *italics* or **boldface** in Table K-1, as explained in Note (5) to Appendix K Tables.] Instead, either 75% of the stress value in Table K-1 or two-thirds of the yield strength at temperature listed in Section II, Part D, Table Y-1 should be used.

(c) Unlisted Materials. For a material which conforms to para. K323.1.2, the yield strength at temperature shall be derived by multiplying the average expected yield strength at temperature by the SMYS divided by the average expected yield strength at room temperature.

(d) Cyclic Stresses. Allowable values of alternating stress shall be in accordance with Section VIII, Division 2, Appendices 4 and 5.

K302.3.3 Casting Quality Factor.[1] The casting quality factor E_c shall be 1.00 by conformance to all of the following supplementary requirements.

(a) All surfaces shall have a surface finish not rougher than 6.3 μm R_a (250 μin. R_a per ASME B46.1).

(b) All surfaces shall be examined by either the liquid penetrant method in accordance with ASTM E 165, or the magnetic particle method in accordance with ASTM E 709. Acceptability of imperfections and weld repairs shall be judged in accordance with MSS SP-53, using ASTM E 125 as reference.

(c) Each casting shall be fully examined either ultrasonically in accordance with ASTM E 114, or radiographically in accordance with ASTM E 142. Cracks and hot tears (Category D and E discontinuities per the standards listed in Table K302.3.3D) and imperfections whose depth exceeds 3% of nominal wall thickness

[1] See Notes to Tables 302.3.3C and 302.3.3D for titles of standards referenced herein.

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TABLE K302.3.3D
ACCEPTABLE SEVERITY LEVELS FOR STEEL CASTINGS

Thickness Examined, mm (in.)	Applicable Standards	Acceptable Severity Level	Acceptable Discontinuity Categories
$\overline{T} \le 51$ (2)	ASTM E 446	1	A, B, C
$51 < \overline{T} \le 114$ (4.5)	ASTM E 186	1	A, B, C
$114 < \overline{T} \le 305$ (12)	ASTM E 280	1	A, B, C

are not permitted. Acceptable severity levels for radiographic examination of castings shall be in accordance with Table K302.3.3D.

K302.3.4 Weld Joint Quality Factor. Piping components containing welds shall have a weld joint quality factor $E_j = 1.00$ (see Table 302.3.4 for requirements) except that the acceptance criteria for these welds shall be in accordance with para. K341.3.2. Spiral welds are not permitted.

K302.3.5 Limits of Calculated Stresses Due to Sustained Loads and Displacement Strains

(a) Internal Pressure Stresses. Stresses due to internal pressure shall be considered safe when the wall thickness of the piping component, and its means of stiffening, meet the requirements of para. K304.

(b) External Pressure Stresses. Stresses due to external pressure shall be considered safe when the wall thickness of the piping component, and its means of stiffening, meet the requirements of para. K304.

(c) Longitudinal Stresses S_L. The sum of longitudinal stresses in any component in a piping system, due to pressure, weight, and other sustained loadings S_L shall not exceed S_h in (d) below. The thickness of pipe used in calculating S_L shall be the nominal thickness minus mechanical, corrosion, and erosion allowance c.

(d) Allowable Displacement Stress Range S_A. The computed displacement stress range S_E in a piping system (see para. 319.4.4) shall not exceed the allowable displacement stress range S_A (see para. 319.2.3) calculated by

$$S_A = 1.25S_c + 0.25S_h \quad (32)$$

In the above equation,

S_c = allowable stress from Table K-1 at minimum metal temperature expected during the displacement cycle under analysis

S_h = allowable stress from Table K-1 at maximum metal temperature expected during the displacement cycle under analysis

K302.3.6 Limits of Calculated Stresses Due to Occasional Loads

(a) Operation. The sum of the longitudinal stresses due to pressure, weight, and other sustained loadings S_L, and of the stresses produced by occasional loads such as wind or earthquake, may be as much as 1.2 times the allowable stress given in Table K-1. Wind and earthquake forces need not be considered as acting concurrently.

(b) Test. Stresses due to test conditions are not subject to the limitations in para. K302.3. It is not necessary to consider other occasional loads, such as wind and earthquake, as occurring concurrently with test loads.

K302.4 Allowances

In determining the minimum required thickness of a piping component, allowances shall be included for corrosion, erosion, and thread or groove depth. See the definition of c in para. K304.1.1(b).

K302.4.1 Mechanical Strength. Paragraph 302.4.1 applies. In addition, a fatigue analysis in accordance with para. K304.8 shall be performed for any means used to increase the strength of a piping component.

PART 2
PRESSURE DESIGN OF PIPING COMPONENTS

K303 GENERAL

Components manufactured in accordance with standards listed in Table K326.1 shall be considered suitable for use at pressure-temperature ratings in accordance with para. K302.2.

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K304 PRESSURE DESIGN OF HIGH PRESSURE COMPONENTS

K304.1 Straight Pipe

K304.1.1 General

(a) The required wall thickness of straight sections of pipe shall be determined in accordance with Eq. (33).

$$t_m = t + c \tag{33}$$

The minimum wall thickness T for the pipe selected, considering manufacturer's minus tolerance, shall be not less than t_m.

A01 *(b)* The following nomenclature is used in the equation for pressure design of straight pipe.

t_m = minimum required wall thickness, including mechanical, corrosion, and erosion allowances

t = pressure design wall thickness, as calculated in para. K304.1.2 for internal pressure, or in accordance with the procedure listed in para. K304.1.3 for external pressure

$c = c_I + c_o$

= the sum of mechanical allowances[2] (thread or groove depth) plus corrosion and erosion allowances (where c_I = the sum of *internal* allowances and c_o = the sum of *external* allowances). For threaded components, the nominal thread depth (dimension h of ASME B1.20.1 or equivalent) shall apply, except that for straight threaded connections, the external thread groove depth need not be considered provided:

(a) it does not exceed 20% of the wall thickness;

(b) the ratio of outside to inside diameter, D/d, is greater than 1.1;

(c) the internally threaded attachment provides adequate reinforcement; and

(d) the thread plus the undercut area, if any, does not extend beyond the reinforcement for a distance more than the nominal wall thickness of the pipe.

Adequate reinforcement by the attachment is defined as that necessary to ensure that the static burst pressure of the connection will equal or exceed that of the unthreaded portion of the pipe. The adequacy of the reinforcement shall be substantiated as required by para. K304.7.2.

T = pipe wall thickness (measured or minimum per purchase specification)

P = internal design gage pressure

D = outside diameter of pipe. For design calculations in accordance with this Chapter, the outside diameter of the pipe is the maximum value allowable under the specifications.

d = inside diameter of pipe. For design calculations in accordance with this Chapter, the inside diameter of the pipe is the maximum value allowable under the specifications.

S = allowable stress from Table K-1

K304.1.2 Straight Pipe Under Internal Pressure. The internal pressure design wall thickness t shall be not less than that calculated in accordance with Eq. (34a) for pipe with a specified outside diameter and minimum wall thickness, or Eq. (34b) for pipe with a specified inside diameter and minimum wall thickness.

$$t = \frac{D - 2c_o}{2}\left[1 - \exp\left(\frac{-1.155P}{S}\right)\right] \tag{34a}^{3,4,5}$$

or

$$t = \frac{d + 2c_I}{2}\left[\exp\left(\frac{1.155P}{S}\right) - 1\right] \tag{34b}^{3,4,5}$$

Alternatively, the internal design gage pressure P may be calculated by Eq. (35a) or (35b).

$$P = \frac{S}{1.155}\ln\left[\frac{D - 2c_o}{D - 2(T - c_I)}\right] \tag{35a}^{4,5}$$

or

$$P = \frac{S}{1.155}\ln\left[\frac{d + 2(T - c_o)}{d + 2c_I}\right] \tag{35b}^{4,5}$$

[2] For machined surfaces or grooves where the tolerance is not specified, the tolerance shall be assumed to be 0.5 mm (0.02 in.) in addition to the specified depth of the cut.

[3] An exponential [e.g., the term exp $(-1.155P/S)$] represents the base of natural logarithms e raised to the stated power (i.e., $-1.155P/S$).

[4] The intent of this equation is to provide a factor of not less than 2.0 on the pressure required, according to the von Mises theory, to initiate yielding on the outside surface of a cylinder made from a perfect elastic-plastic material.

[5] Any mechanical, corrosion, or erosion allowance c not specified as internal c_I or external c_o shall be assumed to be internal, i.e., $c = c_I$ and $c_o = 0$.

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K304.1.3 Straight Pipe Under External Pressure. The pressure design thickness for straight pipe under external pressure shall be determined in accordance with para. K304.1.2 for pipe where $D/t < 3.33$, if at least one end of the pipe is exposed to full external pressure, producing a compressive axial stress. For $D/t \geq 3.33$, and for $D/t < 3.33$ where external pressure is not applied to at least one end of the pipe, the pressure design wall thickness shall be determined in accordance with para. 304.1.3 except that the stress values shall be taken from Table K-1.

K304.2 Curved and Mitered Segments of Pipe

K304.2.1 Pipe Bends. The minimum required wall thickness t_m of a bend, after bending, may be determined as for straight pipe in accordance with para. K304.1, provided that the bend radius of the pipe center line is equal to or greater than ten times the nominal pipe outside diameter and the tolerances and strain limits of para. K332 are met. Otherwise the design shall be qualified as required by para. K304.7.2.

K304.2.2 Elbows. Manufactured elbows not in accordance with para. K303 and pipe bends not in accordance with para. K304.2.1 shall be qualified as required by para. K304.7.2.

K304.2.3 Miter Bends. Miter bends are not permitted.

K304.2.4 Curved Segments of Pipe Under External Pressure. The wall thickness of curved segments of pipe subjected to external pressure may be determined as specified for straight pipe in para. K304.1.3 provided the design length L is the running center line length between any two sections which are stiffened in accordance with para. 304.1.3.

K304.3 Branch Connections

K304.3.1 General. Acceptable branch connections include: a fitting in accordance with para. K303; an extruded outlet in accordance with para. 304.3.4; or a branch connection fitting (see para. 300.2) similar to that shown in Fig. K328.5.4.

K304.3.2 Strength of Branch Connections

(a) The opening made for a branch connection reduces both static and fatigue strength of the run pipe. There shall be sufficient material in the branch connection to contain pressure and meet reinforcement requirements.

(b) Static pressure design of a branch connection not in accordance with para. K303 shall conform to para. 304.3.4 for an extruded outlet or shall be qualified as required by para. K304.7.2.

K304.3.3 Reinforcement of Welded Branch Connections. Branch connections made as provided in para. 304.3.3 are not permitted.

K304.4 Closures

(a) Closures not in accordance with para. K303 or (b) below shall be qualified as required by para. K304.7.2.

(b) Closures may be designed in accordance with (99) the rules, allowable stresses, and temperature limits of the BPV Code, Section VIII, Division 2 or Division 3, and Section II, Part D.

K304.5 Pressure Design of Flanges and Blanks

K304.5.1 Flanges — General

(a) Flanges not in accordance with para. K303 or (b) below shall be qualified as required by para. K304.7.2.

(b) A flange may be designed in accordance with (99) the rules, allowable stresses, and temperature limits of Section VIII, Division 2, Appendix 3 (or Appendices 4, 5, and 6) or Division 3, Article KD-6, and Section II, Part D.

K304.5.2 Blind Flanges (99)

(a) Blind flanges not in accordance with para. K303 or (b) or (c) below shall be qualified as required by para. K304.7.2.

(b) A blind flange may be designed in accordance with Eq. (36). The thickness of the flange selected shall be not less than t_m (see para. K304.1.1 for nomenclature), considering manufacturing tolerance.

$$t_m = t + c \qquad (36)$$

The rules, allowable stresses, and temperature limits of Section VIII, Division 2, AD-700 may be used, with the following changes in nomenclature, to calculate t_m.

t = pressure design thickness (in place of T) as calculated for the given style of blind flange using the appropriate equation of AD-700.

c = sum of mechanical allowances, defined in para. K304.1.1.

(c) A blind flange may be designed in accordance with the rules, allowable stresses, and temperature limits of Section VIII, Division 3, Article KD-6 and Section II, Part D.

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K304.5.3 Blanks. Design of blanks shall be in accordance with para. 304.5.3, except that E shall be 1.00 and the definitions of S and c shall be in accordance with para. K304.1.1.

K304.6 Reducers

Reducers not in accordance with para. K303 shall be qualified as required by para. K304.7.2.

K304.7 Pressure Design of Other Components

K304.7.1 Listed Components. Other pressure containing components manufactured in accordance with standards in Table K326.1 may be utilized in accordance with para. K303.

A01 **K304.7.2 Unlisted Components and Elements.** Static pressure design of unlisted components and other piping elements, to which the rules in paras. K304.1 through K304.6 do not apply, shall be based on calculations consistent with the design philosophy of this Chapter. These calculations shall be substantiated by one or more of the means stated in (a), (b), and (c) below, considering applicable ambient and dynamic effects in paras. 301.4 through 301.11:

(a) extensive, successful service experience under comparable design conditions with similarly proportioned components made of the same or like material;

(b) performance testing sufficient to substantiate both the static pressure design and fatigue life at the intended operating conditions. Static pressure design may be substantiated by demonstrating that failure or excessive plastic deformation does not occur at a pressure equivalent to two times the internal design pressure P. The test pressure shall be two times the design pressure multiplied by the ratio of allowable stress at test temperature to the allowable stress at design temperature, and by the ratio of actual yield strength to the specified minimum yield strength at room temperature from Table K-1;

(c) detailed stress analysis (e.g., finite element method) with results evaluated as described in Section VIII, Division 3, Article KD-2;

(d) for (a), (b), and (c) above, interpolations supported by analysis, are permitted between sizes, wall thicknesses, and pressure classes, as well as analogies among related materials with supporting material property data. Extrapolation is not permitted.

K304.7.3 Components With Nonmetallic Parts. Except for gaskets and packing, nonmetallic parts are not permitted.

K304.7.4 Bellows Type Expansion Joints. Bellows type expansion joints are not permitted.

K304.8 Fatigue Analysis

K304.8.1 General. A fatigue analysis shall be performed on each piping system, including all components[6] and joints therein, and considering the stresses resulting from attachments, to determine its suitability for the cyclic operating conditions[7] specified in the engineering design. Except as permitted in (a) and (b) below, or in paras. K304.8.5 and K304.8.6, this analysis shall be in accordance with the BPV Code, Section VIII, Division 2.[8] The cyclic conditions shall include pressure variations as well as thermal variations or displacement stresses. The requirements of para. K304.8 are in addition to the requirements for a flexibility analysis stated in para. K319. No formal fatigue analysis is required in systems that:

(a) are duplicates of successfully operating installations or replacements without significant change of systems with a satisfactory service record; or

(b) can readily be judged adequate by comparison with previously analyzed systems.

K304.8.2 Amplitude of Alternating Stress. The value of the alternating stress amplitude for comparison with design fatigue curves shall be determined in accordance with Section VIII, Division 2, Appendices 4 and 5.

K304.8.3 Allowable Amplitude of Alternating Stress. The allowable amplitude of alternating stress shall be determined from the applicable design fatigue curve in Section VIII, Division 2, Appendix 5. The designer is cautioned that the considerations listed in para. K302.1 may reduce the fatigue life of the component below the value predicted by that curve.

K304.8.4 Pressure Stress Evaluation for Fatigue Analysis

(a) For fatigue analysis of straight pipe, Eq. (37) may be used to calculate the stress intensity[9] at the

---

[6] Bore imperfections may reduce fatigue life.

[7] If the range of temperature change varies, equivalent full temperature cycles N may be computed as provided in footnote 6 to para. 302.3.5.

[8] Fatigue analysis in accordance with Section VIII, Division 2, requires that stress concentration factors be used in computing the cyclic stresses.

[9] The term "stress intensity" is defined in Section VIII, Division 2.

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inside surface due only to internal pressure.

$$S = \frac{PD^2}{2(T-c)[D-(T-c)]} \quad (37)$$

(b) For fatigue analysis of curved pipe, Eq. (37) may be used, with the dimensions of the straight pipe from which it was formed, to calculate the maximum stress intensity at the inside surface due only to internal pressure, provided that the center line bend radius is not less than ten times the nominal outside diameter of the pipe, and that the tolerance and strain limits of para. K332 are met. Bends of smaller radius shall be qualified as required by para. K304.7.2.

(c) If the value of S calculated by Eq. (37) exceeds three times the allowable stress from Table K-1 at the average temperature during the loading cycle, an inelastic analysis is required.

K304.8.5 Fatigue Evaluation by Test. With the owner's approval, the design fatigue life of a component may be established by destructive testing in accordance with para. K304.7.2 in lieu of the above analysis requirements.

K304.8.6 Extended Fatigue Life. The design fatigue life of piping components may be extended beyond that determined by the Section VIII, Division 2, Appendix 5 fatigue curves by the use of one of the methods listed below, provided that the component is qualified in accordance with para. K304.7.2:

(a) surface treatments, such as improved surface finish; and

(b) prestressing methods, such as autofrettage, shot peening, or shrink fit.

The designer is cautioned that the benefits of prestress may be reduced due to thermal, strain softening, or other effects.

PART 3
FLUID SERVICE REQUIREMENTS FOR PIPING COMPONENTS

K305 PIPE

Pipe includes components designated as "tube" or "tubing" in the material specification, when intended for pressure service.

TABLE K305.1.2
REQUIRED ULTRASONIC OR EDDY CURRENT EXAMINATION OF PIPE AND TUBING FOR LONGITUDINAL DEFECTS

Diameter, mm (in.)	Examination Required	Paragraph Reference
$d < 3.2$ ($\frac{1}{8}$) or $D < 6.4$ ($\frac{1}{4}$)	None	...
$3.2 \le d \le 17.5$ ($\frac{11}{16}$) and $6.4 \le D \le 25.4$ (1)	Eddy Current (ET) (1) or Ultrasonic (UT)	K344.8 K344.6
$d > 17.5$ or $D > 25.4$	Ultrasonic (UT)	K344.6

NOTE:
(1) This examination is limited to cold drawn austenitic stainless steel pipe and tubing.

K305.1 Requirements

K305.1.1 General. Pipe and tubing shall be either seamless or longitudinally welded with straight seam and a joint quality factor $E_j = 1.00$, examined in accordance with Note (2) of Table K341.3.2.

K305.1.2 Additional Examination. Pipe and tubing shall have passed a 100% examination for longitudinal defects in accordance with Table K305.1.2. This examination is in addition to acceptance tests required by the material specification.

K305.1.3 Heat Treatment. Heat treatment, if required, shall be in accordance with para. K331.

K305.1.4 Unlisted Pipe and Tubing. Unlisted pipe and tubing may be used only in accordance with para. K302.2.3.

K306 FITTINGS, BENDS, AND BRANCH CONNECTIONS

Pipe and other materials used in fittings, bends, and branch connections shall be suitable for the manufacturing or fabrication process and otherwise suitable for the service.

K306.1 Pipe Fittings

K306.1.1 General. All castings shall have a casting

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A00 **K323.2.2 Lower Temperature Limits, Listed Materials**

(a) The lowest permitted service temperature for a component or weld shall be the impact test temperature determined in accordance with para. K323.3.4(a), except as provided in (b) or (c) below.

(b) For a component or weld subjected to a longitudinal or circumferential stress ≤ 41 MPa (6 ksi), the lowest service temperature shall be the lower of −46°C (−50°F) or the impact test temperature determined in para. K323.3.4(a).

(c) For materials exempted from Charpy testing by Note (6) of Table K323.3.1, the service temperature shall not be lower than −46°C (−50°F).

A00 **K323.2.3 Temperature Limits, Unlisted Materials.** An unlisted material acceptable under para. K323.1.2 shall be qualified for service at all temperatures within a stated range from design minimum temperature to design (maximum) temperature, in accordance with para. K323.2.4. The requirements of para. K323.2.1(c) also apply.

K323.2.4 Verification of Serviceability

A01 *(a)* When an unlisted material is used, or when a listed material is to be used above the highest temperature for which stress values appear in Appendix K, the designer is responsible for demonstrating the validity of the allowable stresses and other design limits, and of the approach taken in using the material, including the derivation of stress data and the establishment of temperature limits.

(b) Paragraph 323.2.4(b) applies except that allowable stress values shall be determined in accordance with para. K302.3.

K323.3 Impact Testing Methods and Acceptance Criteria

K323.3.1 General. Impact testing shall be performed in accordance with Table K323.3.1 on representative samples using the testing methods described in paras. K323.3.2, K323.3.3, and K323.3.4. Acceptance criteria are described in para. K323.3.5.

K323.3.2 Procedure. Paragraph 323.3.2 applies.

K323.3.3 Test Specimens

(a) Each set of impact test specimens shall consist of three specimen bars. Impact tests shall be made using standard 10 mm (0.394 in.) square cross section Charpy V-notch specimen bars oriented in the transverse direction.

(b) Where component size and/or shape does not permit specimens as specified in (a) above, standard 10 mm square cross-section longitudinal Charpy specimens may be prepared.

(c) Where component size and/or shape does not permit specimens as specified in (a) or (b) above, subsize longitudinal Charpy specimens may be prepared. Test temperature shall be reduced in accordance with Table 323.3.4. See also Table K323.3.1, Note (6).

(d) If necessary in (a), (b), or (c) above, corners of specimens parallel to and on the side opposite the notch may be as shown in Fig. K323.3.3.

K323.3.4 Test Temperatures. For all Charpy impact tests, the test temperature criteria in (a) or (b) below shall be observed.

(a) Charpy impact tests shall be conducted at a temperature no higher than the lowest metal temperature at which a piping component or weld will be subjected to a stress greater than 41 MPa (6 ksi). In specifying the required test temperature, the following shall be considered:

(1) range of operating conditions;

(2) upset conditions;

(3) ambient temperature extremes; and

(4) required leak test temperature.

(b) Where the largest possible test specimen has a width along the notch less than the lesser of 80% of the material thickness or 8 mm (0.315 in.), the test shall be conducted at a reduced temperature in accordance with Table 323.3.4, considering the temperature as reduced below the test temperature required by (a) above.

K323.3.5 Acceptance Criteria

(a) Minimum Energy Requirements for Materials Other Than Bolting. The applicable minimum impact energy requirements for materials shall be those shown in Table K323.3.5. Lateral expansion shall be measured in accordance with ASTM A 370 (for title see para. 323.3.2). The results shall be included in the impact test report.

(b) Minimum Energy Requirements for Bolting Materials. The applicable minimum energy requirements shall be those shown in Table K323.3.5 except as provided in Table K323.3.1.

(c) Weld Impact Test Requirements. Where two base metals having different required impact energy values are joined by welding, the impact test energy requirements shall equal or exceed the requirements of the base material having the lower required impact energy.

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(d) Retests

(1) Retest for Absorbed Energy Criteria. When the average value of the three specimens equals or exceeds the minimum value permitted for a single specimen, and the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, a retest of three additional specimens shall be made. The value for each of these retest specimens shall equal or exceed the required average value.

(2) Retest for Erratic Test Results. When an erratic result is caused by a defective specimen or uncertainty in the test, a retest will be allowed. The report giving

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TABLE K323.3.1
IMPACT TESTING REQUIREMENTS

	Test Characteristics	Column A Pipe, Tubes, and Components Made From Pipe or Tubes	Column B Other Components, Fittings, Etc.	Column C Bolts
Tests on Materials	Number of tests	As required by the material specification, or one test set per lot [see Note (1)], whichever is greater, except as permitted by Note (6).		
	Location and orientation of specimens [see Note (2)]	(a) Transverse to the longitudinal axis, with notch parallel to axis. [See Note (3).] (b) Where component size and/or shape does not permit specimens as specified in (a) above, paras. K323.3.3(b), (c), and (d) apply as needed.	(a) Transverse to the direction of maximum elongation during rolling or to direction of major working during forging. Notch shall be oriented parallel to direction of maximum elongation or major working. (b) If there is no single identifiable axis, e.g., for castings or triaxial forgings, specimens shall either meet the longitudinal values of Table K323.3.5, or three sets of orthogonal specimens shall be prepared, and the lowest impact values obtained from any set shall meet the transverse values of Table K323.3.5. (c) Where component size and/or shape does not permit specimens as specified in (a) or (b) above, paras. K323.3.3(c) and (d) apply as needed.	(a) Bolts ≤ 52 mm (2 in.) nominal size made in accordance with ASTM A 320 shall meet the impact requirements of that specification. (b) For all other bolts, longitudinal specimens shall be taken. The impact values obtained shall meet the transverse values of Table K323.3.5.
Tests on Welds in Fabrication or Assembly	Test pieces [see Note (5)]	Test pieces for preparation of impact specimens shall be made for each welding procedure, type of electrode, or filler metal (i.e., AWS E-XXXX classification) and each flux to be used. All test pieces shall be subject to heat treatment, including cooling rates and aggregate time at temperature or temperatures, essentially the same as the heat treatment which the finished component will have received.		
	Number of test pieces [see Note (4)]	(1) One test piece with a thickness T for each range of material thicknesses which can vary from $\frac{1}{2}T$ to $T + 6$ mm ($\frac{1}{4}$ in.). (2) Unless otherwise specified in this Chapter [see Note (3)] or the engineering design, test pieces need not be made from individual material lots, or from material for each job, provided welds in other certified material of the same thickness ranges and to the same specification (type and grade, not heat or lot) have been tested as required and the records of those tests are made available.		
	Location and orientation of specimens	(1) Weld metal impact specimens shall be taken across the weld with the notch in the weld metal. Each specimen shall be oriented so that the notch axis is normal to the surface of the material and one face of the specimen shall be within 1.5 mm ($\frac{1}{16}$ in.) of the surface of the material. (2) Heat affected zone impact specimens shall be taken across the weld and have sufficient length to locate the notch in the heat affected zone, after etching. The notch shall be cut approximately normal to the material surface in such a manner as to include as much heat affected zone material as possible in the resulting fracture. (3) The impact values obtained from both the weld metal and heat affected zone specimens shall be compared to the transverse values in Table K323.3.5 for the determination of acceptance criteria.		

Notes to this Table follow on next page

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TABLE K326.1
COMPONENT STANDARDS[1]

Standard or Specification	Designation [Note (3)]
Bolting	
Square and Hex Bolts and Screws, Inch Series; Including Hex Cap Screws and Lag Screws	*ASME B18.2.1
Square and Hex Nuts (Inch Series)	*ASME B18.2.2
Metallic Fittings, Valves, and Flanges	
Pipe Flanges and Flanged Fittings [Note (2)]	*ASME B16.5
Factory Made Wrought Steel Buttwelding Fittings [Note (2)]	*ASME B16.9
Forged Fittings, Socket Welding and Threaded [Note (2)]	*ASME B16.11
Valves—Flanged, Threaded, and Welding End [Note (2)]	*ASME B16.34
Standard Marking System for Valves, Fittings, Flanges, and Unions	MSS SP-25
High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets	MSS SP-65
Metallic Pipe and Tubes	
Welded and Seamless Wrought Steel Pipe [Note (2)]	*ASME B36.10M
Stainless Steel Pipe [Note (2)]	*ASME B36.19M
Miscellaneous	
Unified Inch Screw Threads (UN and UNR Thread Form)	*ASME B1.1
Specification for Threading, Gaging and Thread Inspection of Casing, Tubing, and Line Pipe Threads	API 5B
Metallic Gaskets for Pipe Flanges	*ASME B16.20
Buttwelding Ends	*ASME B16.25
Surface Texture (Surface Roughness, Waviness, and Lay)	*ASME B46.1

NOTES:
(1) It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.
(2) The use of components made in accordance with these standards is permissible provided they meet all of the requirements of this Chapter.
(3) An asterisk (*) preceding the designation indicates that the standard has been approved as an American National Standard by the American National Standards Institute.

PART 9
FABRICATION, ASSEMBLY, AND ERECTION

K327 GENERAL

Piping materials and components are prepared for assembly and erection by one or more of the fabrication processes covered in paras. K328, K330, K331, K332, and K333. When any of these processes is used in assembly or erection, requirements are the same as for fabrication.

K328 WELDING

Welding which conforms to the requirements of para. K328 may be used in accordance with para. K311.

K328.1 Welding Responsibility

Each employer is responsible for the welding done by the personnel of his organization and shall conduct the tests required to qualify welding procedures, and to qualify and as necessary requalify welders and welding operators.

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K328.2 Welding Qualifications

K328.2.1 Qualification Requirements. Qualification of the welding procedures to be used and of the performance of welders and welding operators shall comply with the requirements of the BPV Code, Section IX, except as modified herein.

A01 *(a)* Impact tests shall be performed for all procedure qualifications in accordance with para. K323.3.

(b) Test weldments shall be made using the same specification and type or grade of base metal(s), and the same specification and classification of filler metal(s) as will be used in production welding.

(c) Test weldments shall be subjected to essentially the same heat treatment, including cooling rate and cumulative time at temperature, as the production welds.

(d) When tensile specimens are required by Section IX, the yield strength shall also be determined, using the method required for the base metal. The yield strength of each test specimen shall be not less than the specified minimum yield strength (SMYS) for the base metals joined. Where two base metals having different SMYS values are joined by welding, the yield strength of each test specimen shall be not less than the lower of the two SMYS values.

(e) Mechanical testing is required for all performance qualification tests.

(f) Qualification on pipe or tubing shall also qualify for plate, but qualification on plate does not qualify for pipe or tubing.

(g) For thickness greater than 51 mm (2 in.), the procedure test coupon shall be at least 75% as thick as the thickest joint to be welded in production.

(h) Paragraph 328.2.1(f) applies.

K328.2.2 Procedure Qualification by Others. Qualification of welding procedures by others is not permitted.

K328.2.3 Performance Qualification by Others. Welding performance qualification by others is not permitted.

K328.2.4 Qualification Records. Paragraph 328.2.4 applies.

K328.2.5 Performance Requalification. Requalification of welders and welding operators is required in accordance with para. K328.2.1 when:

(a) welder or welding operator has not used the specific process for a period of 3 months or more; or

(b) there is specific reason to question the individual's ability to produce welds that meet the requirements of this Chapter.

K328.3 Materials

K328.3.1 Filler Metal. Filler metal shall be specified in the engineering design and shall conform to the requirements of the BPV Code, Section IX. A filler metal not yet incorporated in Section IX may be used with the owner's approval if a procedure qualification test, including an all-weld-metal test, is first successfully made.

K328.3.2 Weld Backing Material. Backing rings shall not be used.

K328.3.3 Consumable Inserts. Paragraph 328.3.3 applies, except that procedures shall be qualified as required by para. K328.2.

K328.4 Preparation for Welding

K328.4.1 Cleaning. Paragraph 328.4.1 applies.

K328.4.2 End Preparation

(a) General

(1) Butt weld end preparation is acceptable only if the surface is machined or ground to bright metal.

(2) Butt welding end preparation contained in ASME B16.25 or any other end preparation which meets the procedure qualification is acceptable. [For convenience, the basic bevel angles taken from B16.25, with some additional J-bevel angles, are shown in Fig. 328.4.2 sketches (a) and (b).]

(b) Circumferential Welds

(1) If components ends are trimmed as shown in Fig. 328.4.2 sketch (a) or (b) to accommodate consumable inserts, or as shown in Fig. K328.4.3 to correct internal misalignment, such trimming shall not result in a finished wall thickness before welding less than the required minimum wall thickness t_m.

(2) It is permissible to size pipe ends of the same nominal size to improve alignment, if wall thickness requirements are maintained.

(3) Where necessary, weld metal may be deposited on the inside or outside of the component to permit alignment or provide for machining to ensure satisfactory seating of inserts.

(4) When a butt weld joins sections of unequal wall thickness and the thicker wall is more than $1\frac{1}{2}$ times the thickness of the other, end preparation and geometry shall be in accordance with acceptable designs for unequal wall thickness in ASME B16.5.

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SPECIFICATION INDEX FOR APPENDIX A

A00
A01

Spec. No.	Title
ASTM (Cont'd)	
B 466	Seamless Copper-Nickel Pipe and Tube
B 467	Welded Copper-Nickel Pipe
B 491	Aluminum and Aluminum Alloy Extruded Round Tubes for General-Purpose Applications
B 493	Zirconium and Zirconium Alloy Forgings
B 514	Welded Nickel-Iron-Chromium Alloy Pipe
B 517	Welded Nickel-Chromium-Iron UNS N06800 Pipe
B 523	Seamless and Welded Zirconium and Zirconium Alloy Tubes for Condensers and Heat Exchangers
B 547	Aluminum and Aluminum-Alloy Formed and Arc-Welded Round Tube
B 550	Zirconium and Zirconium Alloy Bar and Wire
B 551	Zirconium and Zirconium Alloy Strip, Sheet, and Plate
B 564	Nickel Alloy Forgings
B 574	Low-Carbon Nickel-Molybdenum-Chromium Alloy Rod
B 575	Low-Carbon Nickel-Molybdenum-Chromium Alloy Plate, Sheet and Strip
B 581	Nickel-Chromium-Iron-Molybdenum-Copper Alloy Rod
B 582	Nickel-Chromium-Iron-Molybdenum-Copper Alloy Plate, Sheet and Strip
B 584	Copper Alloy Sand Castings for General Applications
B 619	Welded Nickel and Nickel-Cobalt Alloy Pipe
B 620	Nickel-Iron-Chromium-Molybdenum Alloy (UNS N08320) Plate, Sheet and Strip
B 621	Nickel-Iron-Chromium-Molybdenum Alloy (UNS N08320) Rod
B 622	Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube
ASTM (Cont'd)	
B 625	Nickel Alloy Plate and Sheet
B 649	Ni-Fe-Cr-Mo-Cu Low Carbon Alloy (UNS N08904) and Ni-Fe-Cr-Mo-Cu-N Low Carbon Alloy UNS N08925, UNS N08031, and UNS N08926) Bar and Wire
B 658	Zirconium and Zirconium Alloy Seamless and Welded Pipe
B 675	UNS N08366 and UNS N08367 Welded Pipe
B 688	Chromium-Nickel-Molybdenum-Iron (UNS N08366 and UNS N08367) Plate, Sheet, and Strip
B 690	Iron-Nickel-Chromium-Molybdenum Alloys (UNS N08366 and UNS N08367) Seamless Pipe and Tube
B 705	Nickel-Alloy (UNS N06625 and N08825) Welded Pipe
B 725	Welded Nickel (UNS N02200/UNS N02201) and Nickel-Copper Alloy (UNS N04400) Pipe
B 729	Seamless UNS N08020, UNS N08026, UNS N08024 Nickel-Alloy Pipe and Tube
B 804	UNS N08367 Welded Pipe
E 112	Methods for Determining Average Grain Size
API	
5L	Line Pipe

GENERAL NOTE: It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.

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TABLE A-1 (CONT'D)

A00

BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																			
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Grade	Spec. No.
																		Stainless Steel (3) (4) (Cont'd) Pipes and Tubes (2) (Cont'd)	
19.0	18.6	18.5	18.4	*18.2*	*18.1*	*18.1*	*18.0*	*12.1*	9.1	6.1	4.4	3.3	2.2	1.5	1.2	0.9	0.8	TP347	A 312
																		347	A 358
																		TP347	A 376
																		TP347	A 409
																		TP348	A 312
																		348	A 358
																		TP348	A 376
																		TP348	A 409
18.8	18.3	18.0	17.4	*13.5*	*13.3*	*12.4*	10.5	8.4	6.4	5.0	3.7	2.9	2.3	1.7	1.3	0.9	0.8	CPH10 or CPH20	A 451
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	11.0	9.8	8.5	7.3	6.0	4.8	3.5	2.3	1.6	1.1	0.8	TP310	A 312
																		310S	A 358
18.0	17.5	17.2	17.1	*14.0*	*13.9*	*13.7*	*13.4*	*13.0*	*10.8*	8.0	5.0	3.5	2.7	2.0	1.4	1.1	1.0	CPF8C	A 451
17.9	17.5	17.2	16.9	*16.7*	*16.6*	*16.4*	*16.2*	*11.7*	9.1	6.9	5.4	4.1	3.2	2.5	1.9	1.5	1.1	TP321	A 312
																		321	A 358
																		TP321	A 376
																		TP321	A 409
																		TP321H	A 376
																		TP321H	A 312
16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	*14.5*	*12.4*	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	TP316	A 269
																		TP316	A 312
																		316	A 358
																		TP316	A 376
																		TP316	A 409
																		TP317	A 312
																		TP317	A 409
																		TP316H	A 376
16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	*14.5*	*12.4*	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	TP316H	A 312
19.0	18.6	18.5	18.4	18.2	18.1	18.1	18.0	*17.1*	*14.2*	10.5	7.9	5.9	4.4	3.2	2.5	1.8	1.3	TP347H	A 376
																		TP347	A 312
																		347	A 358
																		TP347	A 376
																		TP347	A 409
																		TP348	A 312
																		348	A 358
																		TP348	A 376
																		TP348	A 409
19.0	18.6	18.5	18.4	18.2	18.1	18.1	18.0	*17.1*	*14.2*	10.5	7.9	5.9	4.4	3.2	2.5	1.8	1.3	TP347H	A 312
																		TP348H	A 312

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.	Stress, ksi				
						Tensile	Yield	to 100	200	300	400	500	600
Stainless Steel (3) (4) (Cont'd)													
Pipes and Tubes (2) (Cont'd)													
18Cr-8Ni tube	A 269	8	TP304	(14)(26)(28)(31)(36)	−425	75	30	20.0	*20.0*	*20.0*	18.7	17.5	16.4
18Cr-8Ni pipe	A 312	8	TP304	(26)(28)	−425								
Type 304 A 240	A 358	8	304	(26)(28)(31)(36)	−425								
18Cr-8Ni pipe	A 376	8	TP304	(20)(26)(28)(31)(36)	−425								
18Cr-8Ni pipe	A 376	8	TP304H	(26)(31)(36)	−325								
18Cr-8Ni pipe	A 409	8	TP304	(26)(28)(31)(36)	−425								
18Cr-8Ni pipe	A 312	8	TP304H	(26)	−325	75	30	20.0	*20.0*	*20.0*	18.7	17.5	16.4
18Cr-10Ni-Mo	A 451	8	CPF8M	(26)(28)	−425	70	30	20.0	*20.0*	*20.0*	19.4	18.1	17.1
20Cr-Cu tube	A 268	10	TP443	(35)	−20	70	40	23.3	23.3	21.4	20.4	19.4	18.4
27Cr tube	A 268	10I	TP446										
25-10Ni-N	A 451	8	CPE20N	(35)(39)	−325	80	40	26.7	26.2	24.9	23.3	22.0	21.4
23Cr-4Ni-N	A 789	10H	S32304	(25)	−60	87	58	29.0	27.9	26.3	25.3	24.9	24.5
23Cr-4Ni-N	A 790												
12¾Cr	A 426	6	CPCA-15	(10)(35)	−20	90	65	30.0	...	...	...	...	...
22Cr-5Ni-3Mo	A 789	10H	S31803	(25)	−60	90	65	30.0	30.0	28.9	27.9	27.2	26.9
22Cr-5Ni-3Mo	A 790												
26Cr-4Ni-Mo	A 789	10H	S32900	(25)	−20	90	70	30.0	...	...	...	...	...
26Cr-4Ni-Mo	A 790												
25Cr-8Ni-3Mo-W-Cu-N	A 789	S-10H	S32760	(25)	−60	109	80	36.3	35.9	34.4	34.0	34.0	34.0
25Cr-8Ni-3Mo-W-Cu-N	A 790												
25Cr-7Ni-4Mo-N	A 789	10H	S32750	(25)	−20	116	80	38.7	35.0	33.1	31.9	31.4	31.2
25Cr-7Ni-4Mo-N	A 790												
Plates and Sheets													
18Cr-10Ni	A 240	8	305	(26)(36)(39)	−325	70	25	16.7	...	...	...	...	...
12Cr-Al	A 240	7	405	(35)	−20	60	25	16.7	15.3	14.8	14.5	14.3	14.0
18Cr-8Ni	A 240	8	304L	(36)	−425	70	25	16.7	*16.7*	*16.7*	15.6	14.8	14.0
16Cr-12Ni-2Mo	A 240	8	316L	(36)	−425	70	25	16.7	*16.7*	*16.7*	15.5	14.4	13.5
18Cr-Ti-Al	A 240	...	X8M	(35)	−20	65	30	20.0	...	...	...	...	...
18Cr-8Ni	A 167	S-8	302B	(26)(28)(31)(36)(39)	−325	75	30	20.0	*20.0*	*20.0*	18.7	17.4	16.4
18Cr-Ni	A 240	8	302	(26)(36)	−325	75	30	20.0	*20.0*	*20.0*	18.7	17.4	16.4

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																		UNS	Spec.
800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	No.	No.
																		Nickel and Nickel Alloy (4) Pipes and Tubes (2)	
5.9	5.8	4.5	3.7	3.0	2.4	2.0	1.5	1.2	...	...	...	...	...	...	...	...	...	N02201	B 161 B 725
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 161 B 725
7.2	5.8	4.5	3.7	3.0	2.4	2.0	1.5	1.2	...	...	...	...	...	...	...	...	...	N02201	B 161 B 725
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 161 B 725
12.7	11.8	8.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	B 165 B 725
14.0	*13.2*	*13.1*	*12.9*	*12.8*	*12.7*	*12.7*	10.0	7.0	6.0	4.6	3.6	2.8	2.1	1.7	...	...	...	N08800	B 407
16.7	*16.5*	*15.9*	*15.9*	7.0	4.5	3.0	2.2	2.0	...	...	...	...	...	...	...	...	...	N06600	B 167
15.3	*15.1*	*14.8*	*14.6*	*14.4*	*13.7*	*11.6*	9.3	7.4	5.9	4.7	3.8	3.0	2.4	1.9	1.5	1.2	1.0	N08810	B 407 B 514
15.3	*15.1*	*14.8*	*14.6*	*14.4*	*13.7*	12.9	10.4	8.3	6.7	5.4	4.3	3.4	2.7	2.2	1.7	1.4	1.1	N08811	B 407
14.2	11.0	8.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	B 165 B 725
17.2	....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08320	B 619 B 622
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02201	B 161 B 725
20.0	18.3	18.2	17.9	17.6	17.0	13.0	9.8	6.6	4.6	2.0	1.6	1.1	1.0	0.6	...	...	...	N08800	B 514
20.0	*19.6*	*16.0*	10.6	7.0	4.5	3.0	2.2	2.0	...	...	...	...	...	...	...	...	...	N06600	B 167 B 167
20.0	*18.3*	*18.2*	*17.9*	*17.6*	*17.0*	13.0	9.8	6.6	4.2	2.0	1.6	1.1	1.0	0.8	...	...	...	N08800	B 407
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 161 B 725
19.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08020	B 464 B 729
21.8	*20.2*	*20.0*	*19.5*	*18.9*	...	...	...	...	...	...	...	...	...	...	...	...	...	N06007	B 619
21.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06007	B 622
23.3	*20.0*	16.0	10.6	7.0	4.5	3.0	2.2	2.0	...	...	...	...	...	...	...	...	...	N06600	B 167 B 517
22.9	...	...	...	...	..	...	...	...	...	...	...	...	...	...	...	...	...	N06455	B 619

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	UNS No.	Class	Size Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi Tensile	Yield	Min. Temp. to 100	200	300	400	500	600	650	700
Nickel and Nickel Alloy (4) (Cont'd) Pipes and Tubes (2) (Cont'd)																	
Ni-Cr-Mo-Fe	B 619	43	N06002	Sol. ann.	...	(76)											
Ni-Cr-Mo-Fe	B 622	43	N06002	Sol. ann.	...	...	−325	100	40	26.7	*23.3*	*23.3*	*22.9*	*22.2*	*21.1*	*20.7*	*20.3*
Low C Ni-Fe-Cr-Mo-Cu	B 619	45	N08031	Annealed	...	(76)											
Low C Ni-Fe-Cr-Mo-Cu	B 622	45	N08031	Annealed	...	...	−325	94	40	26.7	*26.7*	26.6	24.8	23.2	22.1	21.8	21.2
Ni-Mo-Cr	B 622	44	N06455	Sol. ann.	...	...	−325	100	40	26.8	*26.7*	*26.7*	*26.7*	*26.7*	*26.7*	*26.7*	26.5
Ni-Mo-Cr	B 619	44	N10276	Sol. ann.	...	(76)											
Ni-Mo-Cr	B 622	44	N10276	Sol. ann.	...	...	−325	100	41	27.3	*27.3*	*27.3*	*27.3*	26.9	25.4	24.7	24.0
Ni-Cu	B 165	42															
Ni-Cu	B 725	S42	N04400	Str. rel.	...	(54)	−325	85	55	28.3	21.2	21.2	21.0	21.0	...	...	...
Fe-Ni-Cr-Mo-Cu-N	B 675	45	N08367	Annealed	$>^3/_{16}$	(76)											
Fe-Ni-Cr-Mo-Cu-N	B 690	45	N08367	Annealed	$>^3/_{16}$	(76)											
Fe-Ni-Cr-Mo-Cu-N	B 804	45	N08367	Annealed	$>^3/_{16}$	...	−325	95	45	30.0	*30.0*	*29.9*	*28.6*	27.7	26.2	25.6	25.1
Fe-Ni-Cr-Mo-Cu-N	B 675	45	N08367	Annealed	$\leq^3/_{16}$	(76)											
Fe-Ni-Cr-Mo-Cu-N	B 690	45	N08367	Annealed	$\leq^3/_{16}$	(76)											
Fe-Ni-Cr-Mo-Cu-N	B 804	45	N08367	Annealed	$\leq^3/_{16}$	...	−325	100	45	30.0	*30.0*	*30.0*	29.6	27.7	26.2	25.6	25.1
Ni-Cr-Mo	B 619	44	N06022	Sol. ann.	...	(76)											
Ni-Cr-Mo	B 622	44	N06022	Sol. ann.	...	...	−325	100	45	30.0	*30.0*	*30.0*	*30.0*	28.6	27.1	26.5	25.9
Low C-Ni-Cr-Mo	B 619	44	N06059	Sol. ann.	...	(76)											
Low C-Ni-Cr-Mo	B 622	44	N06059	Sol. ann.	...	...	−325	100	45	30.0	*30.0*	*30.0*	*30.0*	29.6	28.1	27.5	26.7
Ni-Mo	B 619																
Ni-Mo	B 622	44	N10001	Sol. ann.	...	...	−325	100	45	30.0	*30.0*	*30.0*	*30.0*	*30.0*	*30.0*	*30.0*	*30.0*
Ni-Mo	B 619	44	N10665	Sol. ann.	...	(76)											
Ni-Mo	B 622	44	N10665	Sol. ann.	...	...	−325	110	51	34.0	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*
Ni-Cr-Mo-Cb	B 444	43	N06625	Annealed	...	(64) (70)	−325	120	60	40.0	*40.0*	*40.0*	*40.0*	*38.9*	*38.0*	*37.7*	*37.4*
Plates and Sheets																	
Low C Ni	B 162	41	N02201	H.R. plt. ann.													
Low C Ni	B 162	41	N02201	H.R. plt as R.	...	...	−325	50	12	8.0	7.7	7.5	7.5	7.5	7.5	7.5	7.4
Ni	B 162	41	N02200	H.R. plt. ann.	...	...	−325	55	15	10.0	10.0	10.0	10.0	10.0	10.0	...	...
Ni	B 162	41	N02200	H.R. plt. as R.	...	...	−325	55	20	13.3	13.3	13.3	13.3	12.5	11.5	...	..
Ni-Fe-Cr	B 409	45	N08810	Annealed	All	...	−325	65	25	16.7	16.7	16.7	16.7	16.7	16.7	16.0	15.7
Ni-Fe-Cr	B 409	45	N08811	Annealed	All	...	−325	65	25	16.7	16.7	16.7	16.7	16.7	16.7	16.0	15.7

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																				
750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	UNS No.	Spec. No.
																			Nickel and Nickel Alloy (4) (Cont'd) Pipes and Tubes (2) (Cont'd)	
20.1	*19.8*	*19.7*	*19.6*	*19.5*	*19.3*	*19.3*	*17.5*	14.1	11.3	9.3	7.7	6.1	4.8	3.8	3.0	...	...	...	N06002	B 619 B 622
20.9	20.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08031	B 619 B 622
26.1	25.8	..	..	..	..	..	..	...	...	...	...	...	...	...	...	...	...	...	N06455	B 622
23.5	23.0	*22.6*	*22.3*	*22.1*	*21.8*	*18.5*	*15.0*	*12.2*	*9.8*	*7.8*	...	...	...	...	...	...	...	...	N10276	B 619 B 622
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	B 165 B 725
24.7	24.3	23.9	23.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08367	B 675 B 690 B 804
24.7	24.3	23.9	23.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08367	B 675 B 690 B 804
25.5	25.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06022	B 619 B 622
26.1	25.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06059	B 619 B 622
30.0	29.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N10001	B 619 B 622
34.0	*34.0*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N10665	B 619 B 622
37.4	*37.4*	*37.4*	*37.4*	*37.4*	*37.4*	*37.4*	27.7	21.0	13.2	...	...	...	...	...	...	...	...	...	N06625	B 444
																			Plates and Sheets	
7.3	7.2	5.8	4.5	3.7	3.0	2.4	2.0	1.5	1.2	...	...	...	...	...	...	...	...	...	N02201	B 162 B 162
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 162
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 162
15.4	15.3	15.1	14.8	14.6	14.4	13.7	11.6	9.3	7.4	5.9	4.7	3.8	3.0	2.4	1.9	1.5	1.2	1.0	N08810	B 409
15.4	15.3	15.1	14.8	14.6	14.4	13.7	12.9	10.4	8.3	6.7	5.4	4.3	3.4	2.7	2.2	1.7	1.4	1.1	N08811	B 409

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	UNS No.	Class	Size Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi Tensile	Yield	Min. Temp. to 100	200	300	400	500	600	650	700
Nickel and Nickel Alloy (4) Cont'd) Plates and Sheets (Cont'd)																	
Ni-Fe-Cr-Mo	B 620	45	N08320	Sol. ann.	All	...	−325	75	28	18.7	*18.7*	*18.6*	*17.9*	*17.6*	*17.5*	*17.5*	*17.5*
Ni-Cu	B 127	42	N04400	H.R. plt. ann.	...	...	−325	70	28	18.7	16.4	*15.4*	14.8	14.8	14.8	14.8	14.8
Ni-Cr-Fe-Mo-Cu	B 582	45	N06007	Sol. ann.	> 3/4	...	−325	85	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.4	19.2	19.0
Ni-Fe-Cr	B 409	45	N08800	Annealed	All	...	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
Cr-Ni-Fe-Mo-Cu-Cb	B 463	45	N08020	Annealed	All	...	−325	80	35	23.3	*20.0*	*19.8*	*19.4*	*19.3*	*19.3*	*19.2*	*19.2*
Ni-Cr-Fe-Mo-Cu	B 582	45	N06007	Sol. ann.	−3/4	...	−325	90	35	23.3	*23.3*	*23.3*	*23.3*	*23.3*	*22.7*	*22.5*	*22.3*
Ni-Cr-Fe-Mo	B 435	43	N06002	H.R. Sol. ann.	All	...	−325	95	35	23.3	21.1	18.9	16.6	16.0	15.5	15.5	15.5
Ni-Cr-Fe	B 168	43	N06600	H.R. plt. ann.	...	...	−325	80	35	23.3	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*
Ni-Cr-Fe	B 168	43	N06600	H.R. plt. as R.	...	...	−325	85	35	23.3	*21.2*	*21.2*	*21.2*	*21.2*	*21.2*	*21.2*	*21.2*
Ni-Cu	B 127	42	N04400	H.R. plt. as R.	...	...	−325	75	40	25.0	23.5	21.9	21.2	21.2	21.2	21.2	21.2
Low C-Ni-Fe-Cr-Mo-Cu	B 625	...	N08031	Annealed	All	...	−325	94	40	26.7	*26.7*	26.6	24.8	23.2	22.1	21.8	21.2
Low C-Ni-Mo-Cr	B 575	44	N06455	Sol. ann.	All	...	−325	100	40	26.7	*26.7*	*26.7*	*26.7*	*26.7*	*26.7*	*26.7*	26.5
Low C-Ni-Mo-Cr	B 575	44	N10276	Sol. ann.	All	...	−325	100	41	27.3	*27.3*	*27.3*	*27.3*	26.9	25.4	24.7	24.0
Ni-Cr-Mo-Cb	B 443	43	N06625	Annealed Plt.	All	(64) (70)	−325	110	55	36.7	36.7	36.7	36.7	35.6	34.8	34.6	34.3
Ni-Cr-Mo-Cb	B 575	44	N06022	Sol ann. sheet	< 3/16	...	−325	100	45	30.0	*30.0*	*30.0*	*30.0*	28.6	27.1	26.5	25.9
Fe-Ni-Cr-Mo-Cu-N	B 688	45	N08367	Annealed	> 3/16	...	−325	95	45	30.0	*30.0*	*29.9*	28.6	27.7	26.2	25.6	25.1
Fe-Ni-Cr-Mo-Cu-N	B 688	45	N08367	Annealed	≤ 3/16	...	−325	100	45	30.0	*30.0*	*30.0*	29.6	27.7	26.2	25.6	25.1
Low C-Ni-Cr-Mo	B 575	...	N06059	Sol. ann.	All	...	−325	100	45	30.0	*30.0*	*30.0*	*30.0*	29.6	28.1	27.5	26.7
Ni-Mo	B 333	44	N10001	Sol. ann. plt.	≥ 3/16, ≤ 2 1/2	...	−325	100	45	30.0	*30.0*	*30.0*	*30.0*	*30.0*	*30.0*	*30.0*	*30.0*
Ni-Fe-Cr-Mo	B 688	45	N08367	Annealed	< 3/16	...	−325	104	46	30.7	*30.7*	30.7	30.6	28.2	26.9	26.1	25.7
Ni-Mo	B 333	44	N10001	Sol. ann. sheet	< 3/16	...	−325	115	50	33.3	*33.3*	*33.3*	*33.3*	*33.3*	*33.3*	*33.3*	*33.3*
Ni-Mo	B 333	44	N10665	Sol. ann.	All	...	−325	110	51	34.0	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	34.0
Forgings and Fittings (2)																	
Low C-Ni	B 160	41	N02201	Annealed	All	(9) (9a)											
Low C-Ni	B 366	41	N02201	...	...												
Low C-Ni	B 366	41	N02201	...	...	(32) (74)	−325	50	10	6.7	6.4	6.3	6.2	6.2	6.2	6.2	6.2

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																				
750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	UNS No.	Spec. No.
																			Nickel and Nickel Alloy (4) (Cont'd) Plates and Sheets (Cont'd)	
17.4	17.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08320	B 620
14.6	14.2	11.0	8.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	B 127
18.8	18.6	*18.5*	*18.4*	*18.3*	*18.3*	...	...	...	...	...	...	...	...	...	...	...	...	...	N06007	B 582
20.0	*20.0*	18.3	18.2	17.9	17.6	17.0	13.0	9.8	6.6	4.2	2.0	1.6	1.1	1.0	0.8	...	...	...	N08800	B 409
19.2	19.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08020	B 463
22.0	*21.8*	*20.3*	*20.0*	*19.5*	*19.0*	...	...	...	...	...	...	...	...	...	...	...	...	...	N06007	B 582
15.5	15.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06002	B 435
23.3	*23.3*	*20.0*	16.0	10.6	7.0	4.5	3.0	2.2	2.0	...	...	...	...	...	...	...	...	...	N06600	B 168
21.2	*21.2*	*21.2*	*21.2*	*21.2*	14.5	10.3	7.2	5.8	5.5	...	...	...	...	...	...	...	...	...	N06600	B 168
20.9	20.3	8.2	4.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	B 127
20.9	20.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08031	B 625
26.1	25.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06455	B 575
23.5	23.0	*22.6*	*22.3*	*22.1*	*21.1*	*18.5*	*15.0*	*12.2*	*9.8*	*7.8*	...	...	...	...	...	...	...	...	N10276	B 575
34.3	34.3	34.3	34.3	34.3	34.3	34.3	25.4	21.0	13.2	...	...	...	...	...	...	...	...	...	N06625	B 443
25.5	25.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06022	B 575
24.7	24.3	23.9	23.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08367	B 688
24.7	24.3	23.9	23.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08367	B 688
26.1	25.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06059	B 575
30.0	29.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N10001	B 333
25.3	24.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08367	B 688
33.3	33.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N10001	B 333
34.0	34.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N10665	B 333
																			Forgings and Fittings (2)	
																			N02201	B 160
																			N02201	B 366
6.1	5.9	5.8	4.8	3.7	3.0	2.4	2.0	1.5	1.2	...	...	...	...	...	...	...	...	...	N02201	B 366

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	UNS No.	Class	Size Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.							
								Tensile	Yield	to 100	200	300	400	500	600	650	700
Nickel and Nickel Alloy (4) (Cont'd) Forgings and Fittings (2) (Cont'd)																	
Ni	B 366	S-41															
Ni	B 564	S-41	N02200	...	...	(32)(74)	−325	55	12	8.0	8.0	8.0	8.0	8.0	...	...	
Ni	B 564	S-41	N02200	Annealed	All	(9)	−325	55	15	10.0	10.0	10.0	10.0	10.0	10.0	...	...
Ni-Fe-Cr	B 564	45	N08810														
Ni-Fe-Cr	B 564	S-45	N08814	Annealed	...	(9)	−325	65	25	16.2	16.2	16.2	16.2	16.0	16.0	16.0	15.7
Ni-Cu	B 564	42	N04400	Annealed	...	(9)											
Ni-Cu	B 366	42	N04400	...	...	(32)(74)	−325	70	25	16.7	14.7	13.7	13.2	13.2	13.2	13.2	13.2
Ni-Cr-Fe	B 366	S-43	N06600	...	...	(32)(74)	−325	75	25	16.7	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*
Ni-Fe-Cr	B 366	45	N08800	Annealed	...	...											
Ni-Fe-Cr	B 564	45	N08800	Annealed	...	(9)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
Cr-Ni-Fe-Mo-Cu-Cb	B 366	45	N08020	Annealed	...	...											
Cr-Ni-Fe-Mo-Cu-Cb	B 462	45	N08020	Annealed	...	(9)	−325	80	35	23.3	*20.0*	*19.8*	*19.4*	19.3	*19.3*	*19.2*	19.2
Ni-Cr-Fe	B 564	43	N06600	Annealed	All	(9)	−325	80	35	23.3	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*
Ni-Cr-Mo-Fe	B 366	S-43	N06002	...	...	(32)(74)	−325	100	40	26.7	*23.3*	*23.3*	*22.9*	*22.3*	*21.1*	*20.7*	*20.3*
Low C-Ni-Fe-Cr-Mo-Cu	B 366																
Low C-Ni-Fe-Cr-Mo-Cu	B 564	S45	N08031	Annealed H.W.	All	...	−325	94	40	26.7	*26.7*	26.6	24.8	23.2	22.1	21.8	21.2
Ni-Mo-Cr	B 366	44	N10276	Sol. ann.	All	...											
Ni-Mo-Cr	B 564	44	N10276	Sol. ann.	All	(9)	−325	100	41	27.3	*27.3*	*27.3*	*27.3*	26.9	25.4	24.7	24.0
Ni-Mo	B 366	44	N10001	...	...	(32)(74)	−325	100	45	30.0	*25.0*	*25.0*	*24.7*	*24.3*	*24.2*	*24.1*	*24.0*
Ni-Mo-Cr	B 366	44	N06022	...	...	(32)(74)											
Ni-Cr-Mo	B 564	44	N06022	...	...	...	−325	100	45	30.0	*30.0*	*30.0*	*30.0*	28.6	27.1	26.5	25.9
Low C-Ni-Cr-Mo	B 366																
Low C-Ni-Cr-Mo	B 564	S44	N06059	H.W. Sol. ann.	All	...	−325	100	45	30.0	*30.0*	*30.0*	*30.0*	29.6	28.1	27.5	26.7
Ni-Cr-Mo-Cb	B 564	43	N06625	Annealed	≤ 4	(9)(64)	−325	120	60	40.0	*40.0*	*40.0*	*40.0*	38.3	38.0	37.7	37.4
Ni-Mo	B 366	44	N10665	Sol. ann.	All	...	−325	110	51	34.0	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Spec. No.	P-No. or S-No. (5)	Grade	Temper	Size or Thickness Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi Tensile	Specified Min. Strength, ksi Yield	Basic Allowable Stress S, ksi (1), at Metal Temperature, °F (7) Min. Temp. to 100	150	200	250	300	350	400
Aluminum Alloy (Cont'd)															
Seamless Pipes and Tubes (Cont'd)															
B 241	22	5652	0, H112	...	(33)	−452	25	10	6.7	6.7	6.7	6.2	5.6	4.1	2.3
B 210	23	6061	T4	...	(33)	−452	30	16	10.0	10.0	10.0	9.8	9.2	7.9	5.6
B 241	23														
B 345	S-23	6061	T4	...	(33)(63)	−452	26	16	8.7	8.7	8.7	8.5	8.0	7.9	5.6
B 210	23	6061	T6	...	(33)	−452	42	35	14.0	14.0	14.0	13.2	11.3	7.9	5.6
B 241	23	6061	T6	...	(33)(63)	−452	38	35	12.7	12.7	12.7	12.1	10.6	7.9	5.6
B 345	S-23														
B 210, B 241	23	6061	T4, T6 wld.	...	(22)(63)	−452	24	...	8.0	8.0	8.0	7.9	7.4	6.1	4.3
B 345	S-23														
B 210	23	6063	T4	...	(33)	−452	22	10							
B 241	23														
B 345	S-23	6063	T4	≤ 0.500	(33)	−452	19	10	6.7	6.7	6.7	6.7	6.7	3.4	2.0
B 241	23														
B 345	S-23	6063	T5	≤ 0.500	(33)	−452	22	16	7.3	7.3	7.2	6.8	6.1	3.4	2.0
B 210	23	6063	T6	...	(33)	−452	33	28	11.0	11.0	10.5	9.5	7.0	3.4	2.0
B 241	23														
B 345	S-23	6063	T6	...	(33)	−452	30	25	10.0	10.0	9.8	9.0	6.6	3.4	2.0
B 210, B 241	23	6063	T4, T5, T6 wld.	...	...	−452	17	...	5.7	5.7	5.7	5.6	5.2	3.0	2.0
B 345	S-23														
Welded Pipes and Tubes															
B 547	25	5083	0	...	...	−452	40	18	12.0	12.0	...	...	...	...	...
Structural Tubes															
B 221	21	1060	0, H112	...	(33)(69)	−452	8.5	2.5	1.7	1.7	1.6	1.5	1.3	1.1	0.8
B 221	21	1100	0, H112	...	(33)(69)	−452	11	3	2.0	2.0	2.0	1.9	1.7	1.3	1.0
B 221	21	3003	0, H112	...	(33)(69)	−452	14	5	3.3	3.3	3.3	3.1	2.4	1.8	1.4
B 221	21	Alclad 3003	0, H112	...	(33)(69)	−452	13	4.5	3.0	3.0	3.0	2.8	2.2	1.6	1.3
B 221	22	5052	0	...	(69)	−452	25	10	6.7	6.7	6.7	6.2	5.6	4.1	2.3
B 221	25	5083	0	...	(69)	−452	39	16	10.7	10.7	...	...	...	...	...
B 221	25	5086	0	...	(69)	−452	35	14	9.3	9.3	...	...	...	...	...
B 221	22	5154	0	...	(69)	−452	30	11	7.3	7.3	...	...	...	...	...
B 221	22	5454	0	...	(69)	−452	31	12	8.0	8.0	8.0	7.4	5.5	4.1	3.0
B 221	25	5456	0	...	(69)	−452	41	19	12.7	12.7	...	...	...	...	...

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Spec. No.	P-No. or S-No. (5)	Grade	Temper	Size or Thickness Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Basic Allowable Stress S, ksi (1), at Metal Temperature, °F (7)						
							Tensile	Yield	Min. Temp. to 100	150	200	250	300	350	400
Aluminum Alloy (Cont'd)															
Structural Tubes (Cont'd)															
B 221	23	6061	T4	...	(33)(63)(69)	−452	26	16	8.7	8.7	8.7	8.5	8.0	7.7	5.3
B 221	23	6061	T6	...	(33)(63)(69)	−452	38	35	12.7	12.7	12.7	12.1	10.6	7.9	5.6
B 221	23	6061	T4, T6 wld.	...	(22)(63)(69)	−452	24	...	8.0	8.0	8.0	7.9	7.4	6.1	4.3
B 221	23	6063	T4	≤ 0.500	(13)(33)(69)	−452	19	10	6.4	6.4	6.4	6.4	6.4	3.4	2.0
B 221	23	6063	T5	≤ 0.500	(13)(33)(69)	−452	22	16	7.3	7.3	7.2	6.8	6.1	3.4	2.0
B 221	23	6063	T6	...	(33)(69)	−452	30	25	10.0	10.0	9.8	9.0	6.6	3.4	2.0
B 221	23	6063	T4, T5, T6 wld.	...	(69)	−452	17	...	5.7	5.7	5.7	5.6	5.2	3.0	2.0
Plates and Sheets															
B 209	21	1060	0	...	...	−452	8	2.5	1.7	1.7	1.6	1.5	1.3	1.1	0.8
B 209	21	1060	H112	0.500–1.000	(13)(33)	−452	10	5	3.3	3.2	2.9	1.9	1.7	1.4	1.0
B 209	21	1060	H12	...	(33)	−452	11	9	3.7	3.7	3.4	2.3	2.0	1.8	1.1
B 209	21	1060	H14	...	(33)	−452	12	10	4.0	4.0	4.0	3.0	2.6	1.8	1.1
B 209	21	1100	0	...	...	−452	11	3.5	2.3	2.3	2.3	2.3	1.7	1.3	1.0
B 209	21	1100	H112	0.500–2.000	(13)(33)	−452	12	5	3.3	3.3	3.3	2.5	2.2	1.7	1.0
B 209	21	1100	H12	...	(33)	−452	14	11	4.7	4.7	4.7	3.2	2.8	1.9	1.1
B 209	21	1100	H14	...	(33)	−452	16	14	5.3	5.3	5.3	3.7	2.8	1.9	1.1
B 209	21	3003	0	...	...	−452	14	5	3.3	3.3	3.3	3.1	2.4	1.8	1.4
B 209	21	3003	H112	0.500–2.000	(13)(33)	−452	15	6	4.0	4.0	3.9	3.1	2.4	1.8	1.4
B 209	21	3003	H12	...	(33)	−452	17	12	5.7	5.7	5.7	4.0	3.6	3.0	2.3
B 209	21	3003	H14	...	(33)	−452	20	17	6.7	6.7	6.7	4.8	4.3	3.0	2.3
B 209	21	Alclad 3003	0	0.006–0.499	(66)	−452	13	4.5							
B 209	21	Alclad 3003	0	0.500–3.000	(68)	−452	14	5	3.0	3.0	3.0	2.8	2.2	1.6	1.3
B 209	21	Alclad 3003	H112	0.500–2.000	(33)(66)	−452	15	6	3.6	3.6	3.5	2.8	2.2	1.6	1.3
B 209	21	Alclad 3003	H12	0.017–0.499	(33)(66)	−452	16	11							
B 209	21	Alclad 3003	H12	0.500–2.000	(33)(68)	−452	17	12	5.1	5.1	5.1	3.6	3.2	2.7	2.1
B 209	21	Alclad 3003	H14	0.009–0.499	(33)(66)	−452	19	16							
B 209	21	Alclad 3003	H14	0.500–1.000	(33)(68)	−452	20	17	6.0	6.0	6.0	4.3	3.9	2.7	2.1
B 209	22	3004	0	...	...	−452	22	8.5	5.7	5.7	5.7	5.7	5.7	3.8	2.3
B 209	22	3004	H112	...	(33)	−452	23	9	6.0	6.0	6.0	6.0	5.8	3.8	2.3
B 209	22	3004	H32	...	(33)	−452	28	21	9.3	9.3	9.3	7.0	5.8	3.8	2.3
B 209	22	3004	H34	...	(33)	−452	32	25	10.7	10.7	10.7	8.0	5.8	3.8	2.3

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TABLE A-1B (CONT'D)

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BASIC QUALITY FACTORS FOR LONGITUDINAL WELD JOINTS IN PIPES, TUBES, AND FITTINGS E_j

These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

Spec. No.	Class (or Type)	Description	E_j (2)	Appendix A Notes
Stainless Steel (Cont'd)				
A 409	...	Electric fusion welded pipe, double butt seam	0.85	...
	...	Electric fusion welded pipe, single butt seam	0.80	...
A 487	...	Steel castings	0.80	(9)(40)
A 789	...	Seamless tube	1.00	...
	...	Electric fusion welded, 100% radiographed	1.00	...
	...	Electric fusion welded, double butt	0.85	...
	...	Electric fusion welded, single butt	0.80	...
A 790	...	Seamless pipe	1.00	...
	...	Electric fusion welded, 100% radiographed	1.00	...
	...	Electric fusion welded, double butt	0.85	...
	...	Electric fusion welded, single butt	0.80	...
A 815	...	Seamless fittings	1.00	...
	...	Welded fittings, 100% radiographed	1.00	(16)
	...	Welded fittings, double butt seam	0.85	...
	...	Welded fittings, single butt seam	0.80	...
Copper and Copper Alloy				
B 42	...	Seamless pipe	1.00	...
B 43	...	Seamless pipe	1.00	...
B 68	...	Seamless tube	1.00	...
B 75	...	Seamless tube	1.00	...
B 88	...	Seamless water tube	1.00	...
B 280	...	Seamless tube	1.00	...
B 466	...	Seamless pipe and tube	1.00	...
B 467	...	Electric resistance welded pipe	0.85	...
	...	Electric fusion welded pipe, double butt seam	0.85	...
	...	Electric fusion welded pipe, single butt seam	0.80	...
Nickel and Nickel Alloy				
B 160	...	Forgings and fittings	1.00	(9)
B 161	...	Seamless pipe and tube	1.00	...
B 164	...	Forgings and fittings	1.00	(9)
B 165	...	Seamless pipe and tube	1.00	...
B 167	...	Seamless pipe and tube	1.00	...
B 366	...	Seamless and welded fittings	1.00	(16)
B 407	...	Seamless pipe and tube	1.00	...
B 444	...	Seamless pipe and tube	1.00	...
B 464	...	Welded pipe	0.80	...
B 514	...	Welded pipe	0.80	...
B 517	...	Welded pipe	0.80	...
B 564	...	Nickel alloy forgings	1.00	(9)

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TABLE A-1B (CONT'D)
BASIC QUALITY FACTORS FOR LONGITUDINAL WELD JOINTS IN PIPES, TUBES, AND FITTINGS E_j

These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

Spec. No.	Class (or Type)	Description	E_j (2)	Appendix A Notes
Nickel and Nickel Alloy (Cont'd)				
B 619	...	Electric resistance welded pipe	0.85	...
	...	Electric fusion welded pipe, double butt seam	0.85	...
	...	Electric fusion welded pipe, single butt seam	0.80	...
B 622	...	Seamless pipe and tube	1.00	...
B 675	All	Welded pipe	0.80	...
B 690	...	Seamless pipe	1.00	...
B 705	...	Welded pipe	0.80	...
B 725	...	Electric fusion welded pipe, double butt seam	0.85	...
	...	Electric fusion welded pipe, single butt seam	0.80	...
B 729	...	Seamless pipe and tube	1.00	...
B 804	1, 3, 5	Welded pipe, 100% radiographed	1.00	...
	2, 4	Welded pipe, double fusion welded	0.85	...
	6	Welded pipe, single fusion welded	0.80	...
Titanium and Titanium Alloy				
B 337	...	Seamless pipe	1.00	...
	...	Electric fusion welded pipe, double butt seam	0.85	...
Zirconium and Zirconium Alloy				
B 523	...	Seamless tube	1.00	...
	...	Electric fusion welded tube	0.80	...
B 658	...	Seamless pipe	1.00	...
	...	Electric fusion welded pipe	0.80	...
Aluminum Alloy				
B 210	...	Seamless tube	1.00	...
B 241	...	Seamless pipe and tube	1.00	...
B 247	...	Forgings and fittings	1.00	(9)
B 345	...	Seamless pipe and tube	1.00	...
B 361	...	Seamless fittings	1.00	...
	...	Welded fittings, 100% radiograph	1.00	(18)(23)
	...	Welded fittings, double butt	0.85	(23)
	...	Welded fittings, single butt	0.80	(23)
B 547	...	Welded pipe and tube, 100% radiograph	1.00	
	...	Welded pipe, double butt seam	0.85	
	...	Welded pipe, single butt seam	0.80	

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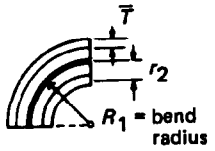
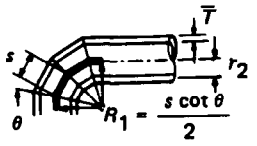
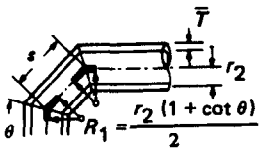
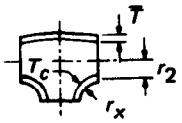
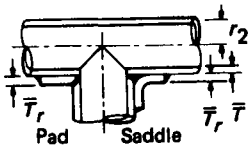
APPENDIX D
FLEXIBILITY AND STRESS INTENSIFICATION FACTORS

A01

TABLE D300[1]
FLEXIBILITY FACTOR, k AND STRESS INTENSIFICATION FACTOR, i

Description	Flexibility Factor, k	Stress Intensification Factor [Notes (2), (3)] Out-of-Plane, i_o	Stress Intensification Factor [Notes (2), (3)] In-Plane, i_i	Flexibility Characteristic, h	Sketch
Welding elbow or pipe bend [Notes (2), (4)-(7)]	$\frac{1.65}{h}$	$\frac{0.75}{h^{2/3}}$	$\frac{0.9}{h^{2/3}}$	$\frac{\overline{T}R_1}{r_2^2}$	
Closely spaced miter bend $s < r_2 (1 + \tan \theta)$ [Notes (2), (4), (5), (7)]	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.9}{h^{2/3}}$	$\frac{\cot \theta}{2}\left(\frac{s\overline{T}}{r_2^2}\right)$	
Single miter bend or widely spaced miter bend $s \geq r_2 (1 + \tan \theta)$ [Notes (2), (4), (7)]	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.9}{h^{2/3}}$	$\frac{1 + \cot \theta}{2}\left(\frac{\overline{T}}{r_2}\right)$	
Welding tee per ASME B16.9 [Notes (2), (4), (6), (11), (13)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4} i_o + \frac{1}{4}$	$3.1 \frac{\overline{T}}{r_2}$	
Reinforced fabricated tee with pad or saddle [Notes (2), (4), (8), (12), (13)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4} i_o + \frac{1}{4}$	$\frac{(\overline{T} + \frac{1}{2}\overline{T}_r)^{2.5}}{\overline{T}^{1.5} r_2}$	

Notes to this Table follow on p. 258

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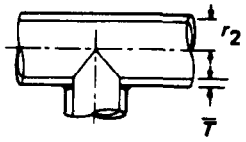
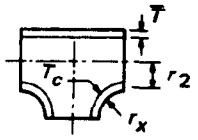
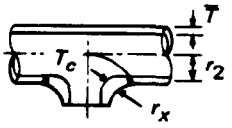
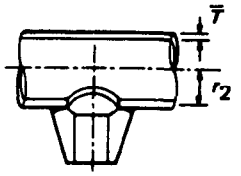
A01

TABLE D300[1] (CONT'D)
FLEXIBILITY FACTOR, k AND STRESS INTENSIFICATION FACTOR, i

Description	Flexibility Factor, k	Stress Intensification Factor [Notes (2), (3)] Out-of-Plane, i_o	Stress Intensification Factor [Notes (2), (3)] In-Plane, i_i	Flexibility Characteristic, h	Sketch
Unreinforced fabricated tee [Notes (2), (4), (12), (13)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4}i_o + \frac{1}{4}$	$\frac{\overline{T}}{r_2}$	
Extruded welding tee with $r_x \geq 0.05\ D_b$ $\overline{T}_c < 1.5\ \overline{T}$ [Notes (2), (4), (13)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4}i_o + \frac{1}{4}$	$\left(1 + \frac{r_x}{r_2}\right)\frac{\overline{T}}{r_2}$	
Welded-in contour insert [Notes (2), (4), (11), (13)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4}i_o + \frac{1}{4}$	$3.1\frac{\overline{T}}{r_2}$	
Branch welded-on fitting (integrally reinforced) [Notes (2), (4), (9), (12)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{0.9}{h^{2/3}}$	$3.3\frac{\overline{T}}{r_2}$	

Description	Flexibility Factor, k	Stress Intensification Factor, i [Note (1)]
Butt welded joint, reducer, or weld neck flange	1	1.0
Double-welded slip-on flange	1	1.2
Fillet welded joint, or socket weld flange or fitting	1	Note (14)
Lap joint flange (with ASME B16.9 lap joint stub)	1	1.6
Threaded pipe joint, or threaded flange	1	2.3
Corrugated straight pipe, or corrugated or creased bend [Note (10)]	5	2.5

Notes to this Table follow on p. 258

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TABLE D300[1] (CONT'D)
FLEXIBILITY FACTOR, k AND STRESS INTENSIFICATION FACTOR, i

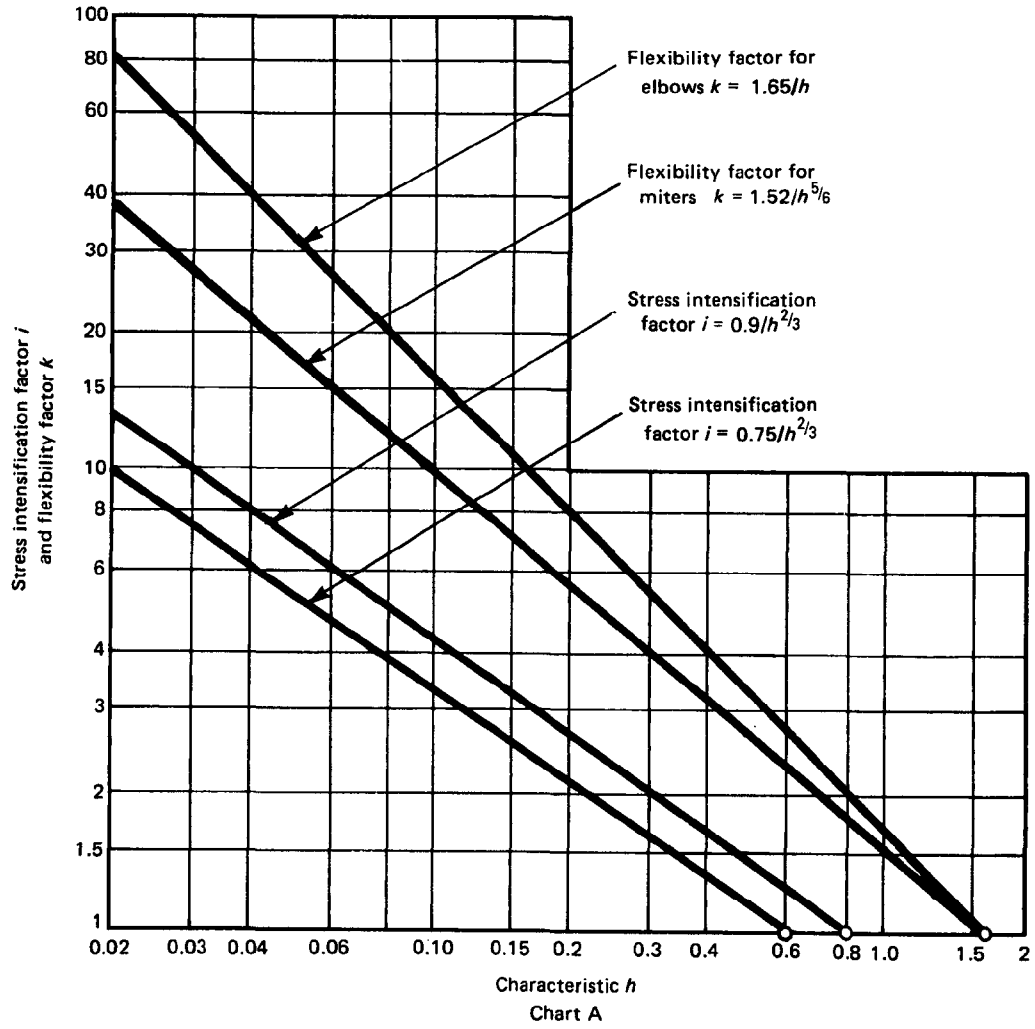

Chart A

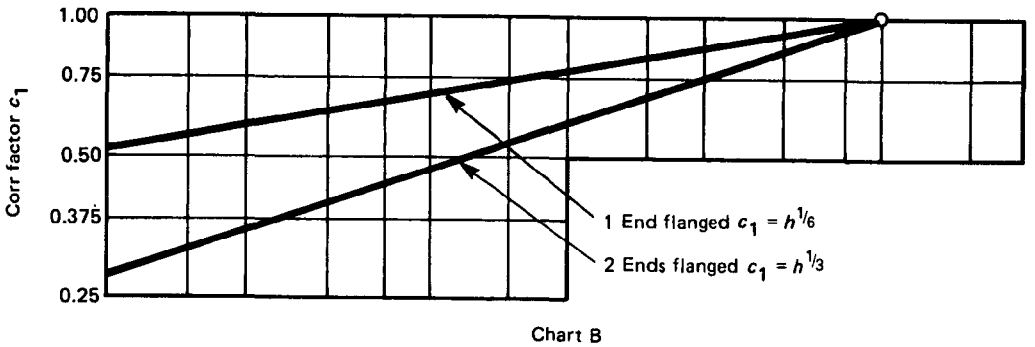

Chart B

Notes to this Table follow on next page

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TABLE D300 (CONT'D)

NOTES:

(1) Stress intensification and flexibility factor data in Table D300 are for use in the absence of more directly applicable data (see para. 319.3.6). Their validity has been demonstrated for $D/\overline{T} \leq 100$.

(2) The flexibility factor k in the Table applies to bending in any plane. The flexibility factors k and stress intensification factors i shall not be less than unity; factors for torsion equal unity. Both factors apply over the effective arc length (shown by heavy center lines in the sketches) for curved and miter bends, and to the intersection point for tees.

(3) A single intensification factor equal to $0.9/h^{2/3}$ may be used for both i_i and i_o if desired.

(4) The values of k and i can be read directly from Chart A by entering with the characteristic h computed from the formulas given above. Nomenclature is as follows:

$\overline{T}$ = for elbows and miter bends, the nominal wall thickness of the fitting
= for tees, the nominal wall thickness of the matching pipe
$\overline{T}_c$ = the crotch thickness of tees
$\overline{T}_r$ = pad or saddle thickness
θ = one-half angle between adjacent miter axes
r_2 = mean radius of matching pipe
R_1 = bend radius of welding elbow or pipe bend
r_x = see definition in para. 304.3.4(c)
s = miter spacing at center line
D_b = outside diameter of branch

(5) Where flanges are attached to one or both ends, the values of k and i in the Table shall be corrected by the factors C_1, which can be read directly from Chart B, entering with the computed h.

(6) The designer is cautioned that cast buttwelded fittings may have considerably heavier walls than that of the pipe with which they are used. Large errors may be introduced unless the effect of these greater thicknesses is considered.

(7) In large diameter thin-wall elbows and bends, pressure can significantly affect the magnitudes of k and i. To correct values from the Table, divide k by

$$\left[1 + 6\left(\frac{P}{E}\right)\left(\frac{r_2}{\overline{T}}\right)^{7/3}\left(\frac{R_1}{r_2}\right)^{1/3}\right]$$

divide i by

$$\left[1 + 3.25\left(\frac{P}{E}\right)\left(\frac{r_2}{\overline{T}}\right)^{5/2}\left(\frac{R_1}{r_2}\right)^{2/3}\right]$$

For consistency, use kPa and mm for SI metric, and psi and in. for US customary notation.

(8) When $\overline{T}_r$ is $> 1\frac{1}{2}\ \overline{T}$, use $h = 4\ \overline{T}/r_2$.

(9) The designer must be satisfied that this fabrication has a pressure rating equivalent to straight pipe.

(10) Factors shown apply to bending. Flexibility factor for torsion equals 0.9.

A01 (11) If $r_x \geq \frac{1}{8}\ D_b$ and $T_c \geq \overline{T}$, a flexibility characteristic of $4.4\ \overline{T}/r_2$ may be used.

(12) The out-of-plane stress intensification factor (SIF) for a reducing branch connection with branch-to-run diameter ratio of $0.5 < d/D < 1.0$ may be nonconservative. A smooth concave weld contour has been shown to reduce the SIF. Selection of the appropriate SIF is the designer's responsibility.

(13) Stress intensification factors for branch connections are based on tests with at least two diameters of straight run pipe on each side of the branch center line. More closely loaded branches may require special consideration.

(14) 2.1 max. or $2.1\ \overline{T}/C_x$, but not less than 1.3. C_x is the fillet weld leg length (see Fig. 328.5.2C. For unequal leg lengths, use the smaller leg for C_x.

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APPENDIX E
REFERENCE STANDARDS[1, 2]

(99)
A00
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Standards incorporated in this Code by reference, and the names and addresses of the sponsoring organizations are shown in this Appendix. It is not practical to refer to a specific edition of each standard throughout the Code text; instead, the specific edition reference dates are shown here. Subsequent issues and revisions of these referenced standards and any new standards incorporated in the Code by reference in Code Addenda will be listed (after review and acceptance by the Code Committee) in revisions of this Appendix E.

A component ordinarily is not marked to indicate the edition date of the standard to which it is manufactured. It is therefore possible that an item taken from inventory was produced in accordance with a superseded edition, or an edition not yet approved by the Code (because it is of later date than that listed and is in use). If compliance with a specific edition is a requirement of the intended service, it usually will be necessary to state the specific requirement in the purchase specification and to maintain identification of the component until it is put in service.

ASTM Specifications

A 20-96a
A 36-97a
A 47-90 (R1996)
A 48-94a

A 53-97

A 105-98
A 106-97a
A 126-95
A 134-96
A 135-97
A 139-96

A 167-96
A 179-90a (R1996)
A 181-95b
A 182-97c
A 193-97a
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A 203-97
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A 210-96

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A 285-90 (R1996)
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ASTM Specifications (Cont'd)

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A 307-97
A 312-95a
A 320-97
A 325-97
A 333-98
A 334-96
A 335-95a
A 350-97

A 351-94a
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A 353-93
A 354-97
A 358-95a
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A 370-97a
A 376-96
A 381-96
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A 395-98

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A 409-95a
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A 487-93 (R1998)
A 494-98

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A 515-92 (R1997)
A 516-90 (R1996)
A 524-98
A 530-98
A 537-95

ASTM Specifications (Cont'd)

A 553-95
A 563-94
A 570-96
A 571-84 (R1992)
A 587-96

A 645-97

A 671-96
A 672-96
A 675-90a (R1995)
A 691-98

A 723-94 (R1999)

A 789-95
A 790-95
A 815-94
B 21-96
B 26-98
B 42-96
B 43-96
B 61-93
B 62-93
B 68-95
B 75-97
B 88-96
B 96-93
B 98-97

B 127-98
B 148-97
B 150-95a

B 152-97a
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B 161-93
B 162-93a
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B 166-97a
B 167-98

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REFERENCE STANDARDS (CONT'D)

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B 168-98
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B 209-96
B 210-95
B 211-95a
B 221-96
B 241-96
B 247-95a
B 265-95a

B 280-97
B 283-96

B 333-98
B 335-97
B 337-95
B 338-98
B 345-96

B 361-95
B 363-95
B 366-98a
B 381-97

B 407-96
B 409-96a
B 435-98a
B 443-99
B 444-94
B 446-98

B 462-97
B 463-98a
B 464-93
B 466-92a
B 467-88 (R1997)
B 491-95
B 493-83 (R1993)

B 514-95
B 517-98
B 523-97
B 547-95
B 550-97

B 551-97
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B 575-98
B 581-97
B 582-97
B 584-96

B 619-98
B 620-98a

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B 675-96
B 688-96
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B 705-94
B 725-93
B 729-95
B 804-96

C 14-95
C 301-98
C 361-96

C 582-95
C 599-91 (R1995)

D 1527-96a
D 1600-98
D 1694-95
D 1785-96b

D 2104-96
D 2235-96a
D 2239-96a
D 2241-96b
D 2282-96a
D 2310-97
D 2321-95
D 2447-95
D 2464-96a
D 2466-97
D 2467-96a
D 2468-96

D 2513-98a
D 2517-94
D 2564-96a
D 2609-97
D 2657-97
D 2662-96a
D 2666-96a
D 2672-96a
D 2683-98
D 2737-96a
D 2837-98
D 2846-97
D 2855-96
D 2992-96
D 2996-95
D 2997-95

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D 3309-96a

D 3517-96
D 3754-96
D 3839-94a
D 3840-94

D 4024-94
D 4161-96

D 5421-93

E 112-96
E 114-95
E 125-63 (R1997)
E 142-92
E 155-95e2
E 165-95
E 186-98
E 213-93
E 272-99
E 280-98
E 310-99
E 446-98

E 709-95
F 336-92
F 423-95
F 437-96a
F 438-97
F 439-97
F 441/441M-97
F 442/F 442M-97
F 491-95
F 492-95
F 493-97

F 546-95
F 599-95
F 781-95
F 1055-95a
F 1290-93
F 1412-00
F 1545-97
F 1673-95

ASCE Standard

ASCE 7-95

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REFERENCE STANDARDS (CONT'D)

ASME Codes

ASME Boiler and PressureVessel Code, 1998 Ed. (A2000)
* Section II, Part D
* Section V
* Section VIII, Div. 1, 1998 Ed.
* Section VIII, Div. 2, 1998 Ed.
* Section VIII, Div. 3, 1998 Ed. (A1999)
* Section IX

ASME Standards

B1.1-1989
* B1.20.1-1983 (1992)
B1.20.3-1976 (R1998)
B1.20.7-1991 (R1998)

* B16.1-1998
* B16.3-1999
* B16.4-1999
* B16.5-1996 (A1998)
* B16.9-1993
* B16.10-1992
* B16.11-1996
* B16.14-1991
* B16.15-1985 (R1994)
* B16.20-1993

* B16.21-1992
* B16.22-1995
* B16.24-1991 (R1998)
* B16.25-1997
* B16.26-1988
* B16.28-1994
* B16.34-1996 (A1998)
* B16.36-1996
* B16.39-1988

* B16.42-1998
* B16.47-1996

* B18.2.1-1999a
* B18.2.2-1987 (R1993)

* B36.10M-1996
* B36.19M-1985 (R1994)

* B46.1-1995

*American National Standards

A21.14-1984
A21.52-1982

B16.18-1984 (R1994)

B93.11-1981

API Specifications

5B, 1996
5L, 41st Ed., 1995
15LE, 3rd Ed., 1995
15LR, 6th Ed., 1990

API Standards

* 526, 1995
594, 4th Ed., 1991
599, 1994
600, 1997

602, 6th Ed., 1993
603, 5th Ed., 1991

608, 1995
609, 4th Ed., 1997

API Recommended Practice

RP 941, 5th Ed., 1997

ASNT Standard

SNT TC-1A-1996

ASQ Standards

Q 9000-1: 1994
Q 9000-2: 1997
Q 9000-3: 1997
Q 9001: 1994
Q 9002: 1994
Q 9003: 1994

AWS Standards

* A3.0-1994
* A5.1-1991
* A5.4-1992
* A5.5-1996
A5.9-1993
A5.11-1997
A5.14-1997
A5.22-1995

AWWA Standards

* C110-1993
* C111-1995
* C115-1994
* C150-1996
* C151-1996

AWWA Standards (Cont'd)

* C200-1991
* C207-1994
C208-1996
* C300-1997
* C301-1992
* C302-1995
* C500-1993

* C504-1994
* C900-1989
* C950-1995

CDA Publication

Copper Tube Handbook, 1995

CGA Publication

G-4.1-1996, 4th Ed.

CSA Publication

Z245.1-1998

EJMA Publication

EJMA Standards, 7th Ed., 2000a

ICBO Publication

Uniform Building Code, 1997 Edition

MSS Standard Practices

SP-6-1996
SP-9-1997
SP-25-1998

SP-42-1999
SP-43-1991 (R1996)
SP-44-1996
SP-45-1998
SP-51-2000
SP-53-1999
SP-55-1996
* SP-58-1993
SP-65-1999
SP-70-1998

SP-71-1997
SP-72-1999
SP-73-1991 (R1996)

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REFERENCE STANDARDS (CONT'D)

MSS Standard Practices (Cont'd)

SP-75-1998
SP-79-1999
SP-80-1997
SP-81-1995
SP-83-1995
SP-85-1994
SP-88-1993
SP-95-2000
SP-97-1995
SP-105-1996
SP-119-1996

NACE Publication

Corrosion Data Survey, 1985
MR 0175-97
RP 0170-93 (R1997)
RP 0472-95

NFPA Specification

* 1963-1993

PFI Standard

ES-7-1994 (R1994/RA2000)

PPI Technical Report

TR-21-1974

SAE Specifications

* J 513-1996
* J 514-1996
* J 518-1993

NOTES:
(1) The issue date shown immediately following the hyphen after the number of the standard (e.g., B16.9-1978, C207-1978, and A 47-77) is the effective date of the issue (edition) of the standard. Any additional number shown following the issue date and prefixed by the letter "R" is the latest date of reaffirmation [e.g., C101-1967 (R1977)]. Any edition number prefixed by the letter "A" is the date of the latest addenda accepted [e.g., B16.36-1975 (A1979)].
(2) * Indicates that the standard has been approved as an American National Standard by the American National Standards Institute.

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Specifications and standards of the following organizations, appear in Appendix E:

API American Petroleum Institute
Publications and Distribution Section
1220 L Street, NW
Washington, DC 20005-4070
202 682-8375
www.api.org

ASCE The American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia 20191-4400
703 295-6300 or 800 548-2723
www.asce.org

ASME ASME International
Three Park Avenue
New York, New York 10016-5990
212 591-8500 or 800 843-2763
www.asme.org

ASME Order Department
22 Law Drive
Box 2900
Fairfield, New Jersey 07007-2300
973 882-1170 or 800 843-2763

ASNT American Society for Nondestructive Testing, Inc.
P.O. Box 28518
1711 Arlingate Lane
Columbus, Ohio 43228-0518
614 274-6003 or 800 222-2768
www.asnt.org

ASQ American Society for Quality
611 East Wisconsin Ave.
Milwaukee, WI 53202
800-248-1946
www.asq.org

ASTM American Society for Testing and Materials
100 Barr Harbor Drive
West Conshohocken, Pennsylvania
19428-2959
610 832-9500
www.astm.org

AWWA *American Water Works Association*
6666 W. Quincy Avenue
Denver, Colorado 80235
303 794-7711 or 800 926-7337
www.awwa.org

AWS American Welding Society
550 NW LeJeune Road
Miami, Florida 33126
305 443-9353 or 800 443-9353
www.aws.org

CDA Copper Development Association, Inc.
260 Madison Avenue, 16th Floor
New York, New York 10016
212 251-7200 or 800 232-3282
www.copper.org

CGA Compressed Gas Association, Inc.
1725 Jefferson Davis Highway; Suite 1004
Arlington, Virginia 22202-4102
703 412-0900
www.cganet.com

CSA CSA International
178 Rexdale Boulevard
Etobicoke (Toronto), Ontario
M9W 1R3, Canada
416 747-2620 or 800 463-6727
www.csa-international.org

EJMA Expansion Joint Manufacturers Association
25 North Broadway
Tarrytown, New York 10591
914 332-0040
www.ejma.org

ICBO International Conference of Building Officials
5360 Workman Mill Road
Whittier, California 90601-2298
562 692-4226 or 800 284-4406
www.icbo.org

MSS Manufacturers Standardization Society ofthe Valve and Fittings Industry, Inc.
127 Park Street, NE
Vienna, Virginia 22180-4602
703 281-6613
www.mss-hq.com

NACE NACE International
1440 S. Creek Drive
Houston, Texas 77084
281 228-6200
www.nace.org

NFPA *National Fire Protection Association*
1 Batterymarch Park
Quincy, Massachusetts 02269
617 770-3000 or 800 344-3555
www.nfpa.org

PFI Pipe Fabrication Institute
655-32nd Avenue, Suite 201
Lachine, Quebec H8T3G6
Canada
514 634-3434
www.pfi-institute.org

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PPI Plastics Pipe Institute
1801 K Street NW; Suite 600K
Washington, DC 20006-1301
202 974-5318 or 800 541-0736
www.plasticpipe.org

SAE Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, Pennsylvania 15096-0001
724 776-4970 or 800 832-6723
www.sae.org

GENERAL NOTE TO LIST OF ORGANIZATIONS: Some of the organizations listed above publish standards that have been approved as American National Standards. Copies of these standards may also be obtained from:

ANSI American National Standards Institute, Inc.
11 West 42nd Street
New York, New York 10036
212 642-4900
www.ansi.org

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APPENDIX F
PRECAUTIONARY CONSIDERATIONS

F300 GENERAL

This Appendix provides guidance for the designer in the form of precautionary considerations relating to particular fluid services and piping applications. These are not Code requirements but should be taken into account as applicable in the engineering design. Further information on these subjects can be found in the literature.

A00 A01

F301 DESIGN CONDITIONS

Selection of pressures, temperatures, forces, and other conditions that may apply to the design of piping can be influenced by unusual requirements which should be considered when applicable. These include but are not limited to the following.

F301.4 Ambient Effects

Where fluids can be trapped (e.g., in double seated valves) and subjected to heating and consequent expansion, means of pressure relief should be considered to avoid excessive pressure buildup.

F301.5 Dynamic Effects

geysering: an effect that can occur in piping handling fluids at or near their boiling temperatures under conditions when rapid evolution of vapor within the piping causes rapid expulsion of liquid. In such cases a pressure surge can be generated that may be destructive to the piping. (Geysering usually is associated with vertical pipelines but may occur in inclined lines under certain conditions.)

F301.7 Thermal Expansion and Contraction Effects

bowing during cooldown: an effect that can occur, usually in horizontal piping, on introduction of a fluid at or near its boiling temperature and at a flow rate that allows stratified two-phase flow, causing largecircumferential temperature gradients and possibly unacceptable stresses at anchors, supports, guides, and within pipe walls. (Two-phase flow can also generate excessive pressure oscillations and surges that may damage the piping.)

F301.11 Condensation Effects

A01

Where there is a possibility of condensation occurring inside gaseous fluid piping, means should be considered to provide drainage from low areas to avoid damage from water hammer or corrosion.

F304 PRESSURE DESIGN

F304.7 Pressure Design of Other Metallic Components

F304.7.4 Expansion Joints. The following are specific considerations to be evaluated by the designer when specifying expansion joint requirements, in addition to the guidelines given in EJMA Standards:

(a) susceptibility to stress corrosion cracking of the materials of construction, considering specific alloy content, method of manufacture, and final heat treated condition;

(b) consideration of not only the properties of the flowing medium but also the environment external to the expansion joint and the possibility of condensation or ice formation due to the operation of the bellows at a reduced temperature;

(c) consideration of specifying a minimum bellows or ply thickness. The designer is cautioned that requiring excessive bellows thickness may reduce the fatigue life of the expansion joint and increase end reactions.

(d) accessibility of the expansion joint for maintenance and inspection;

(e) need for leak tightness criteria for mechanical seals on slip type joints;

(f) specification of installation procedures and shipping or preset bars so that the expansion joint will not be extended, compressed, or offset to compensate for improper alignment of piping, other than the intentional offset specified by the piping designer;

(g) need to request data from the expansion joint manufacturer, including:

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(1) effective thrust area;

(2) lateral, axial, and rotational stiffness (spring constant);

(3) calculated design cycle life under specified design conditions;

(4) friction force in hinges, tie rods, etc.;

(5) installed length and weight;

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(6) requirements for additional support or restraint in the piping;

(7) expansion joint elements that are designed to be uninsulated during operation;

(8) certification of pressure containing and/or restraining materials of construction;

(9) maximum test pressure;

(10) design calculations.

F307 VALVES

(a) Extended bonnet valves are recommended where necessary to establish a temperature differential between the valve stem packing and the fluid in the piping, to avoid packing leakage and external icing or other heat flux problems. The valve should be positioned to provide this temperature differential. Consideration should be given to possible packing shrinkage in low temperature fluid service.

(b) The effect of external loads on valve operability and leak tightness should be considered.

F308 FLANGES AND GASKETS

F308.2 Specific Flanges

Slip-On Flanges. The need for venting the space between the welds in double-welded slip-on flanges should be considered for fluid services (including vacuum) that require leak testing of the inner fillet weld, or when fluid handled can diffuse into the enclosed space, resulting in possible failure.

F308.4 Gaskets

(a) Gasket materials not subject to cold flow should be considered for use with raised face flanges for fluid services at elevated pressures with temperatures significantly above or below ambient.

(b) Use of full face gaskets with flat faced flanges should be considered when using gasket materials subject to cold flow for low pressure and vacuum services at moderate temperatures. When such gasket materials are used in other fluid services, the use of tongue-and-groove or other gasket-confining flange facings should be considered.

(c) The effect of flange facing finish should be considered in gasket material selection.

F309 BOLTING

F309.1 General

The use of controlled bolting procedures should be considered in high, low, and cycling temperature services, and under conditions involving vibration or fatigue, to reduce:

(a) the potential for joint leakage due to differential thermal expansion;

(b) the possibility of stress relaxation and loss of bolt tension.

F312 FLANGED JOINTS

F312.1 General

Three distinct elements of a flanged joint must act together to provide a leak-free joint: the flanges, the gasket, and the bolting. Factors that affect performance include:

(a) *Selection and Design*

(1) consideration of service conditions (including external loads, bending moments, and application of thermal insulation);

(2) flange rating, type, material, facing, and facing finish (see para. F308.2);

(3) gasket type, material, thickness, and design (see para. F308.4);

(4) bolt material, strength (cold and at temperature), and specifications for tightening of bolts (see para. F309.1); and

(5) design for access to the joint.

(b) *Installation*

(1) condition of flange mating surfaces;

(2) joint alignment and gasket placement before boltup; and

(3) implementation of specified bolting procedures.

F322 DESIGN CONSIDERATIONS FOR SPECIFIC SYSTEMS

F322.6 Pressure Relief Piping

Stop Valves in Pressure Relief Piping. If stop valves are located in pressure relief piping in accordance with para. 322.6.1(a), and if any of these stop valves are to be closed while the equipment is in operation, an authorized person should be present. The authorized person should remain in attendance at a location where

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the operating pressure can be observed and should have access to means for relieving the system pressure in the event of overpressure. Before leaving the station the authorized person should lock or seal the stop valves in the open position.

F323 MATERIALS

A01 *(a)* Selection of materials to resist deterioration in service is not within the scope of this Code. However, suitable materials should be specified or selected for use in piping and associated facilities not covered by this Code but which affect the safety of the piping. Consideration should be given to allowances made for temperature and pressure effects of process reactions, for properties of reaction or decomposition products, and for hazards from instability of contained fluids. Consideration should be given to the use of cladding, lining, or other protective materials to reduce the effects of corrosion, erosion, and abrasion.

(b) Information on material performance in corrosive environments can be found in publications, such as "The Corrosion Data Survey" published by the National Association of Corrosion Engineers.

F323.1 General Considerations

Following are some general considerations which should be evaluated when selecting and applying materials in piping (see also para. FA323.4):

(a) the possibility of exposure of the piping to fire and the melting point, degradation temperature, loss of strength at elevated temperature, and combustibility of the piping material under such exposure;

(b) the susceptibility to brittle failure or failure from thermal shock of the piping material when exposed to fire or to fire-fighting measures, and possible hazards from fragmentation of the material in the event of failure;

(c) the ability of thermal insulation to protect piping against failure under fire exposure (e.g., its stability, fire resistance, and ability to remain in place during a fire);

(d) the susceptibility of the piping material to crevice corrosion under backing rings, in threaded joints, in socket welded joints, and in other stagnant, confined areas;

(e) the possibility of adverse electrolytic effects if the metal is subject to contact with a dissimilar metal;

(f) the compatibility of lubricants or sealants used on threads with the fluid service;

(g) the compatibility of packing, seals, and O-rings with the fluid service;

(h) the compatibility of materials, such as cements, solvents, solders, and brazing materials, with the fluid service;

(i) the chilling effect of sudden loss of pressure on highly volatile fluids as a factor in determining the lowest expected service temperature;

(j) the possibility of pipe support failure resulting from exposure to low temperatures (which may embrittle the supports) or high temperatures (which may weaken them);

(k) the compatibility of materials, including sealants, gaskets, lubricants, and insulation, used in strong oxidizer fluid service (e.g., oxygen or fluorine).

F323.4 Specific Material Considerations — Metals

Following are some specific considerations which should be evaluated when applying certain metals in piping.

(a) Irons — Cast, Malleable, and High Silicon (14.5%). Their lack of ductility and their sensitivity to thermal and mechanical shock.

(b) Carbon Steel, and Low and Intermediate Alloy Steels

(1) the possibility of embrittlement when handling alkaline or strong caustic fluids;

(2) the possible conversion of carbides to graphite during long time exposure to temperatures above 427°C (800°F) of carbon steels, plain nickel steel, carbon-manganese steel, manganese-vanadium steel, and carbon-silicon steel;

(3) the possible conversion of carbides to graphite during long time exposure to temperatures above 468°C (875°F) of carbon-molybdenum steel, manganese-molybdenum-vanadium steel, and chromium-vanadium steel;

(4) the advantages of silicon-killed carbon steel (0.1% silicon minimum) for temperatures above 482°C (900°F);

(5) the possibility of damage due to hydrogen exposure at elevated temperature (see API RP 941); hydrogen damage (blistering) may occur at lower temperatures under exposure to aqueous acid solutions;[1]

[1] Titles of referenced documents are:
API RP 941, Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants
NACE MR 0175, Sulfide Stress-Cracking Resistant Metallic Materials for Oil Field Equipment
NACE RP 0472, Methods and Controls to Prevent In-Service Cracking of Carbon Steel (P-1) Welds in Corrosive Petroleum Refining Environments
NACE RP 0170, Protection of Austenitic Stainless Steel in Refineries Against Stress Corrosion Cracking by Use of Neutralizing Solutions During Shutdown

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(6) the possibility of stress corrosion cracking when exposed to cyanides, acids, acid salts, or wet hydrogen sulfide; a maximum hardness limit is usually specified (see NACE MR 0175 and RP 0472);[1]

(7) the possibility of sulfidation in the presence of hydrogen sulfide at elevated temperatures.

(c) High Alloy (Stainless) Steels

(99) (1) the possibility of stress corrosion cracking of austenitic stainless steels exposed to media such as chlorides and other halides either internally or externally; the latter can result from improper selection or application of thermal insulation, or from use of marking inks, paints, labels, tapes, adhesives, and other accessory materials containing chlorides or other halides;

(2) the susceptibility to intergranular corrosion of austenitic stainless steels sensitized by exposure to temperatures between 427°C and 871°C (800°F and 1600°F); as an example, stress corrosion cracking of sensitized metal at room temperature by polythionic acid (reaction of oxidizable sulfur compound, water, and air); stabilized or low carbon grades may provide improved resistance (see NACE RP 0170);[1]

(3) the susceptibility to intercrystalline attack of austenitic stainless steels on contact with liquid metals (including aluminum, antimony, bismuth, cadmium, gallium, lead, magnesium, tin, and zinc) or their compounds;

(4) the brittleness of ferritic stainless steels at room temperature after service at temperature above 371°C (700°F).

(d) Nickel and Nickel Base Alloys

(1) the susceptibility to grain boundary attack of nickel and nickel base alloys not containing chromium when exposed to small quantities of sulfur at temperatures above 316°C (600°F);

(2) the susceptibility to grain boundary attack of nickel base alloys containing chromium at temperatures above 593°C (1100°F) under reducing conditions and above 760°C (1400°F) under oxidizing conditions;

(3) the possibility of stress corrosion cracking of nickel-copper Alloy 400 in hydrofluoric acid vapor in the presence of air, if the alloy is highly stressed (including residual stresses from forming or welding).

(e) Aluminum and Aluminum Alloys

(1) the compatibility with aluminum of thread compounds used in aluminum threaded joints to prevent seizing and galling;

(2) the possibility of corrosion from concrete, mortar, lime, plaster, or other alkaline materials used in buildings or structures;

(3) the susceptibility of Alloy Nos. 5083, 5086, 5154, and 5456 to exfoliation or intergranular attack; and the upper temperature limit of 66°C (150°F) shown in Appendix A to avoid such deterioration.

(f) Copper and Copper Alloys

(1) the possibility of dezincification of brass alloys;

(2) the susceptibility to stress-corrosion cracking of copper-based alloys exposed to fluids such as ammonia or ammonium compounds;

(3) the possibility of unstable acetylide formation when exposed to acetylene.

(g) Titanium and Titanium Alloys. The possibility of deterioration of titanium and its alloys above 316°C (600°F);

(h) Zirconium and Zirconium Alloys. The possibility of deterioration of zirconium and zirconium alloys above 316°C (600°F);

(i) Tantalum. Above 299°C (570°F), the possibility of reactivity of tantalum with all gases except the inert gases. Below 299°C, the possibility of embrittlement of tantalum by nascent (monatomic) hydrogen (but not molecular hydrogen). Nascent hydrogen is produced by galvanic action, or as a product of corrosion by certain chemicals.

(j) Metals With Enhanced Properties. The possible loss of strength, in a material whose properties have been enhanced by heat treatment, during long-continued exposure to temperatures above its tempering temperature.

(k) The desirability of specifying some degree of production impact testing, in addition to the weld procedure qualification tests, when using materials with limited low temperature service experience below the minimum temperature stated in Table A-1.

F331 HEAT TREATMENT

F331.1 Heat Treatment Considerations

Heat treatment temperatures listed in Table 331.1.1 for some P-No. 4 and P-No. 5 materials may be higher than the minimum tempering temperatures specified in the ASTM specifications for the base material. For higher-strength normalized and tempered materials, there is consequently a possibility of reducing tensile properties of the base material, particularly if long holding times at the higher temperatures are used.

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TABLE K-1

A00

ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]

A01

Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding								Type or Grade	Spec. No.
100	200	300	400	500	600	650	700		
									Carbon Steel Pipes and Tubes (17)
23.3	21.3	20.7	20.0	18.9	17.3	16.9	16.8	B	A 53
								B	A 106
								6	A 333
								6	A 334
								B	API 5L
24.7	22.5	21.9	21.1	20.0	18.3	17.9	17.8	A-1	A 210
26.7	24.3	22.9	23.7	21.6	19.7	19.4	19.2	C	A 106, A 210
28.0	20.0	20.0	20.0	...	...	...	...	X42	API 5L
30.7	21.0	21.0	21.0	...	...	...	...	X46	API 5L
34.7	22.0	22.0	22.0	...	...	...	...	X52	API 5L
37.3	23.7	23.7	23.7	...	...	...	...	X56	API 5L
40.0	25.0	25.0	25.0	...	...	...	...	X60	API 5L
43.3	...	...	...	...	...	...	...	X65	API 5L
46.7	...	...	...	...	...	...	...	X70	API 5L
53.3	...	...	...	...	...	...	...	X80	API 5L
									Forgings and Fittings
23.3	21.3	20.7	20.0	18.9	17.3	16.9	16.8	WPB	A 234
								WPL6	A 420
24.0	21.9	21.3	20.6	19.5	17.7	17.5	17.3	LF2	A 350
								...	A 105
26.7	24.3	23.7	22.9	21.6	19.7	19.4	19.2	WPC	A 234
									Low and Intermediate Alloy Steel Pipes and Tubes (17)
20.0	18.5	17.5	16.9	16.3	15.7	15.4	15.1	P1	A 335
21.3	19.3	18.1	17.3	16.7	16.3	16.1	15.8	P12	A 335
20.0	18.7	17.9	17.5	17.2	16.7	16.2	15.7	P11	A 335
20.0	18.1	17.4	17.2	17.1	16.8	16.6	16.3	P5	A 335
20.0	18.5	18.1	17.9	17.9	17.9	17.9	17.9	P22	A 335

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]

Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	Type or Grade	Notes	Specified Min. Strength, ksi Tensile	Yield
Low and Intermediate Alloy Steel (Cont'd)						
Pipes and Tubes (17) (cont'd)						
3½Ni	A 333	9B	3			
3½Ni	A 334	9B	3	(8)	65	35
9Ni	A 333					
9Ni	A 334	11A	8	(8)	100	75
Forgings and Fittings						
3½Ni	A 420	9B	WPL3	(8)	65	35
3½Ni	A 350	9B	LF3	...	70	37.5
1Cr-½Mo	A 182	4	F12, Cl. 2	...	70	40
1¼Cr-½Mo	A 182	4	F11, Cl. 2	...	70	40
C-½Mo	A 182	3	F1	...	70	40
5Cr-½Mo	A 182	5B	F5	...	70	40
2¼Cr-1Mo	A 182	5A	F22, Cl. 3	...	75	45
9Ni	A 420	11A	WPL8	(8)	110	75
3½Ni-1¾Cr-½Mo	A 508	11A	4N, Cl. 2	...	115	100
Ni-Cr-Mo	A 723	...	1, 2, 3 Cl. 1	(11)	115	100
Ni-Cr-Mo	A 723	...	1, 2, 3 Cl. 2	(11)	135	120
Ni-Cr-Mo	A 723	...	1, 2, 3 Cl. 3	(11)	155	140
Stainless Steel (5)						
Pipes and Tubes (17)						
16Cr-12Ni-2Mo	A 312	8	TP316L	(12)		
316L, A 240	A 358	8	316L, Cl. 1 & 3	(12)(13)	70	25
16Cr-12Ni-2Mo-N	A 312	8	TP316LN	(12)		
316LN, A 240	A 358	8	316LN, Cl. 1 & 3	(12)(13)	75	30
18Cr-8Ni	A 312	8	TP304L	(12)		
304L, A 240	A 358	8	304L, Cl. 1 & 3	(12)(13)	70	25
18Cr-8Ni-N	A 312	8	TP304LN	(12)		
304LN, A 240	A 358	8	304L, Cl. 1 & 3	(12)(13)	75	30

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]
Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

(99) A00 A01

Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding								Type or Grade	Spec. No.
100	200	300	400	500	600	650	700		
								Low and Intermediate Alloy Steel (Cont'd) Pipes and Tubes (17) (Cont'd)	
23.3	21.3	20.7	20.0	18.9	17.3	17.0	15.7	3	A 333 A 334
50.0	31.7	...	...	...	...	...	...	8	A 333 A 334
								Forgings and Fittings	
23.3	21.3	19.6	...	...	...	...	...	WPL3	A 420
25.0	22.8	22.1	...	...	...	...	...	LF3	A 350
26.7	24.1	22.7	21.7	20.9	20.3	20.1	19.7	F12, Cl. 2	A 182
26.7	24.6	23.4	22.5	21.7	20.9	20.5	20.1	F11, Cl. 2	A 182
26.7	24.6	23.4	22.5	21.7	20.9	20.5	20.1	F1	A 182
26.7	24.1	23.2	22.9	22.7	22.4	22.1	21.7	F5	A 182
30.0	27.5	26.1	25.5	24.8	24.3	24.0	23.7	F22, Cl. 3	A 182
50.0	31.7	...	...	...	...	...	...	WPL8	A 420
66.7	62.8	60.8	59.5	58.5	57.4	56.7	...	4N, Cl. 2	A 508
66.7	64.0	62.3	61.3	60.3	59.3	58.5	57.3	1, 2, 3 Cl. 1	A 723
80.0	76.8	74.8	73.6	72.4	71.2	70.1	68.8	1, 2, 3 Cl. 2	A 723
93.3	89.6	87.3	85.9	84.5	83.1	81.9	80.3	1, 2, 3 Cl. 3	A 723
								Stainless Steel (5) Pipes and Tubes (17)	
16.7	*16.7*	*16.7*	15.8	14.8	14.0	13.8	13.5	TP316L 316L, Cl. 1 & 3	A 312 A 358
20	*20*	*20*	18.9	17.5	16.5	16.0	15.6	TP316LN 316LN, Cl. 1 & 3	A 312 A 358
16.7	*16.7*	*16.7*	15.8	14.7	14.0	13.7	13.4	TP304l 304l, Cl. 1 & 3	A 312 A 358
20.0	*20.0*	*20.0*	18.6	17.5	16.4	16.1	15.9	TP304LN 304LN, Cl. 1 & 3	A 312 A 358

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1–6, 18]

Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	Type or Grade	Notes	Specified Min. Strength, ksi Tensile	Yield
Stainless Steel (5) (Cont'd)						
Pipes and Tubes (17) (Cont'd)						
18Cr-10Ni-Ti smls. > 3/8 in. thick	A 312	8	TP321	...	70	25
18Cr-10Ni-Ti smls. ≤ 3/8 in. thick or wld.	A 312	8	TP321	(12)		
321, A 240	A 358	8	321, Cl. 1 & 3	(12)(13)	75	30
18Cr-8Ni	A 312	8	TP304	(12)(14)		
304, A 240	A 358	8	304, Cl. 1 & 3	(12)(13)(14)	75	30
16Cr-12Ni-2Mo	A 312	8	TP316	(12)(14)		
316, A 240	A 358	8	316, Cl. 1 & 3	(12)(13)(14)	75	30
18Cr-13Ni-3Mo	A 312	8	TP317	(12)(14)		
18Cr-10Ni-Cb	A 312	8	TP347	(12)		
347, A 240	A 358	8	347, Cl. 1 & 3	(12)(13)	75	30
18Cr-8Ni-N	A 312	8	TP304N	(12)(14)		
304N, A 240	A 358	8	304N, Cl. 1 & 3	(12)(13)(14)	80	35
16Cr-12Ni-2Mo-N	A 312	8	TP316N	(12)(14)		
316N, A 240	A 358	8	316N, Cl. 1 & 3	(12)(13)(14)	80	35
Forgings and Fittings						
16Cr-12Ni-2Mo	A 182	8	F316L	(19)		
16Cr-12Ni-2Mo	A 403	8	WP316L, Cl. S & WX	(12)	70	25
16Cr-12Ni-2Mo-N	A 182	8	F316LN	(20)		
16Cr-12Ni-2Mo-N	A 403	8	WP316LN, Cl. S & WX	(12)	75	30
18Cr-8Ni	A 182	8	F304L	(19)		
18Cr-8Ni	A 403	8	WP304L, Cl. S & WX	(12)	70	25
18Cr-8Ni-N	A 182	8	F304LN	(20)		
18Cr-8Ni-N	A 403	8	WP304LN, Cl. S & WX	(12)	75	30

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TABLE K-1 (CONT'D)

(99)

ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]

A00

Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding								Type or Grade	Spec. No.
100	200	300	400	500	600	650	700		
								Stainless Steel (5) (Cont'd) Forgings and Fittings (Cont'd)	
20.0	*20.0*	*20.0*	*20.0*	19.4	18.3	17.9	17.5	F321	A 182
								WP321, Cl. S & WX	A 403
20.0	*20.0*	*20.0*	18.6	17.5	16.4	16.1	15.9	F304	A 182
								WP304, Cl. S & WX	A 403
20.0	*20.0*	*20.0*	19.3	18.0	17.0	16.7	16.3	F316	A 182
								WP316, Cl. S & WX	A 403
								WP317, Cl. S & WX	A 403
20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.4	19.0	18.6	F347	A 182
								WP347, Cl. S & WX	A 403
23.3	*23.3*	22.5	20.3	18.8	17.8	17.6	17.2	F304N	A 182
								WP304N, Cl. S & WX	A 403
23.3	*23.3*	*23.3*	*23.3*	22.2	21.0	20.5	20.1	F316N	A 182
								WP316N, Cl. S & WX	A 403

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1–6, 18]
Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	UNS Number	Condition	Size Range, in.	Notes	Specified Min. Strength, ksi Tensile	Yield
Nickel and Nickel Alloys (5) Pipes and Tubes (17)								
Ni-Cu	B 165	42	N04400	Annealed	> 5 O.D.	...	70	25
Ni-Cr-Fe	B 167	43	N06600	H.W.	> 5 O.D.	...	75	25
Ni-Cr-Fe	B 167	43	N06600	H.W. ann.				
Ni-Cu	B 165	42	N04400	Annealed	≤ 5 O.D.	...	70	28
Ni-Cr-Fe	B 167	43	N06600	H.W.	≤ 5 O.D.	...	80	30
Ni-Cr-Fe	B 167	43	N06600	H.W. ann.	≤ 5 O.D.	...		
Ni-Cr-Fe	B 167	43	N06600	C.W. ann.	> 5 O.D.	...		
Ni-Cr-Fe	B 167	43	N06600	C.W. ann.	≤ 5 O.D.	...	80	35
Ni-Mo-Cr	B 622	44	N10276	...	All	...	100	41
Ni-Cu	B 165	42	N04400	Str. rel.	All	...	85	55
Forgings and Fittings								
Ni-Cu	B 366	S-42	N04400	...	All	(12)(15)	70	25
Ni-Cu	B 564	42	N04400	Annealed	All	...		
Ni-Cr-Fe	B 366	S-43	N06600	...	All	(12)(15)	75	25
Ni-Cr-Fe	B 564	43	N06600	Annealed	All	...	80	35
Ni-Mo-Cr	B 366	44	N10276	...	All	(12)	100	41
Ni-Mo-Cr	B 564	44	N10276	Annealed	All	...		
Rod and Bar								
Ni-Cu	B 164	42	N04400	Annealed	All	...	70	25
Ni-Cr-Fe	B 166	43	N06600	C.W. ann. & H.W. ann.	All	...	80	35
Ni-Cr-Fe	B 166	43	N06600	H.W., A.W.	sq. rec., & hex.			
Ni-Cr-Fe	B 166	43	N06600	H.W., A.W.	> 3 rd.	...	85	35
Ni-Cu	B 164	42	N04400	H.W.	Rod, sq., & rec. ≤ 12 hex. ≤ $2\frac{1}{8}$	...	80	40
Ni-Cr-Fe	B 166	43	N06600	H.W., A.W.	$\frac{1}{2}$ to 3 rd.	...	90	40
Ni-Mo-Cr	B 574	44	N10276	...	All	...	100	41
Ni-Cr-Fe	B 166	S-43	N06600	H.W., A.W.	$\frac{1}{4}$ to $\frac{1}{2}$ rd.	...	95	45

Abbreviations in Condition and Size Range Columns:

ann.	annealed	rd.	rounds
A.W.	as worked	rec.	rectangle
C.W.	cold worked	rel.	relieved
H.W.	hot worked	sq.	squares
hex.	hexagons	str.	stress
O.D.	outside diameter		

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TABLE K-1 (CONT'D)

A01

ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1–6, 18]

Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding								UNS	
100	200	300	400	500	600	650	700	Number	Spec. No.
								Nickel and Nickel Alloy (5) Pipes and Tubes (17)	
16.7	14.7	13.7	13.2	13.2	13.2	13.2	13.2	N04400	B 165
								N06600	B 167
16.7	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	N06600	B 167
18.7	16.5	15.4	14.8	14.8	14.8	14.8	14.8	N04400	B 165
								N06600	B 167
20.0	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	N06600	B 167
								N06600	B 167
23.3	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	N06600	B 167
27.3	*27.3*	*27.3*	*27.3*	26.9	25.2	24.6	24.0	N10276	B 622
36.7	32.3	30.2	29.1	29.1	...	...	...	N04400	B 165
								Forgings and Fittings	
								N04400	B 366
16.7	14.7	13.7	13.2	13.2	13.2	13.2	13.2	N04400	B 564
16.7	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	N06600	B 366
23.3	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	N06600	B 564
27.3	*27.3*	*27.3*	*27.3*	26.9	25.2	24.6	24.0	N10276	B 366
								Rod and Bar	
16.7	14.7	13.7	13.2	13.2	13.2	13.2	13.2	N04400	B 164
								N06600	B 166
								N06600	B 166
23.3	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	N06600	B 166
26.7	23.5	21.9	21.2	21.2	21.2	21.2	21.2	N04400	B 164
26.7	24.5	23.1	22.0	21.2	20.7	20.6	20.4	N06600	B 166
27.3	*27.3*	*27.3*	*27.3*	26.9	25.2	24.6	24.0	N10276	B 574
30.0	21.2	21.2	21.2	21.2	21.2	21.2	21.1	N06600	B 166

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]

Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	Grade	Notes	Specified Min. Strength, ksi	
					Tensile	Yield
Titanium and Titanium Alloy Pipes and Tubes (17)						
Ti	B 337	51	2	...	50	40
Ti	B 338					
Ti-0.2 Pd.	B 337	51	7			
Ti-0.2 Pd.	B 338					
Ti	B 337	52	3	(8)	65	55
Ti	B 338					
Forgings and Fittings						
Ti	B 363	51	WPT2	(12)	50	40
Ti	B 381	51	F2	...		
Ti-0.2 Pd	B 381	51	F7	...		
Ti	B 363	52	WPT3	(8)	65	55
Ti	B 381	52	F3	...		

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APPENDIX Q
QUALITY SYSTEM PROGRAM

A01

[This Appendix is a Code requirement only when specified by the owner in accordance with para. 300(b)(1).]

Design, construction, inspection, examination, testing, manufacture, fabrication, and erection of piping in accordance with this Code shall be performed under a Quality System Program following the principles of an appropriate standard such as the ISO 9000 series.[1] The details describing the quality system shall be documented and shall be available upon request. A determination of the need for registration and/or certification of the quality system program shall be the responsibility of the owner.

---

[1] The series is also available from the American National Standards Institute (ANSI) and the American Society for Quality (ASQ) as American National Standards that are identified by a prefix "Q" replacing the prefix "ISO." Each standard of the series is listed uner Appendix E.

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ASME CODE FOR PRESSURE PIPING, B31

A01

B31.1	Power Piping	1998	
B31.2[1]	Fuel Gas Piping	1968	
B31.3	Process Piping	1999	
B31.4	Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids	1998	
B31.5	Refrigeration Piping	1992	
B31.8	Gas Transmission and Distribution Piping Systems	1999	
B31.9	Building Services Piping	1996	
B31.11	Slurry Transportation Piping Systems	1989	(R1998)
B31G	Manual for Determining the Remaining Strength of Corroded Pipelines: A Supplement to ASME B31 Code for Pressure Piping	1991	

NOTE:
(1) USAS B31.2-1968 was withdrawn as an American National Standard on February 18, 1988. ASME will continue to make available USAS B31.2-1968 as an historical document for a period of time.

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ASME CODE FOR PRESSURE PIPING, B31
AN AMERICAN NATIONAL STANDARD

ASME B31.3a-2000

ADDENDA

to

ASME B31.3-1999 EDITION
PROCESS PIPING

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
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Date of Issuance: July 14, 2000
Mandatory Date: January 14, 2001

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SUMMARY OF CHANGES

Addenda to the 1999 Edition of the Code are issued in the form of replacement pages. Revisions, additions, or deletions are incorporated directly into the affected pages. It is advisable, however, that all replaced pages be retained for reference.

Replace or insert the pages listed. Changes given below are identified on the pages by a margin note, **A00**, placed next to the affected area. Revisions to the 1999 Edition are indicated by **99**. For the listing below, the *Page* references the affected area. A margin note, **A00**, placed next to the heading indicates *Location*. Revisions are listed under *Change*.

Page	*Location*	*Change*
iii, v, vi, vii, ix, xii	Contents	Updated to reflect Addenda changes
1, 1.1	300(c)(3)	Revised
8	300.2	Definition of *stress ratio* added
11, 11.1	301	Revised
	301.1	Revised
	301.2.1(d)	Added
	301.2.2(b)	Revised
15	302.3.2	(1) Subparagraphs (a)(1), (a)(2), (a)(3), (d)(1), (d)(2), (d)(3), and (f) revised (2) Subparagraph (d)(8) added
18–20.1	302.3.5(c)	Revised
	302.4.1	Revised
	304.1.2	(1) Equations (3b) and (3c) deleted (2) Equation (3d) redesignated as (3b)
	304.2.1	Revised
	304.2.2	Revised
	Fig. 304.2.1	Added
22, 22.1	304.3.3(c)(2)	Last paragraph added
30	305.2.3(c)	Revised
31	306.1.4(b)	Revised
33	309.2.3	In the second sentence, ANSI corrected by Errata to read ASME
34	311.2.4(b)(1)	Revised
43	321.2.1(c)	Reference to para. X2.2 corrected by Errata to read para. X301.2

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Page	*Location*	*Change*
47–49.1	323.2.2	Revised in its entirety
	Table 323.2.2	Revised
50	Fig. 323.2.2A	Redesignated from Fig. 323.2.2
50.1	Fig. 323.2.2B	Added
55	326.3	Added
56–58	Table 326.1	Revised
62	328.5.2(a)	Last line revised
73	Fig. 335.3.3	Revised
85, 85.1	345.3.3	Revised
101	A326.4	Redesignated from A326.3
104	A328.2.6(a)	Corrected by Errata
114	M306.1.3(a)	Revised
115	M308.2(b)	Corrected by Errata
116	M314.2.2	Corrected by Errata from N314.2.2
	M322.3(a)	Corrected by Errata
117, 117.1	M326.3	Added
123	K300.4	Revised
132	K314.3.1	Revised
134–135.1	K323.2	Paragraph added
	K323.2.1	Revised
	K323.2.2	Title revised
	K323.2.3	Last sentence added
138	K326	First line revised
139	Table K326.1	ANSI B18.2.2 and ANSI B16.20 corrected by Errata to read ASME B18.2.2 and ASME B16.20, respectively
151–154	Specification Index for Appendix A	Revised in its entirety
155–157	Notes for Appendix A Tables	(1) Notes (6), (42), (67), and (77) revised (2) Note (38) deleted
164, 165	Table A-1	API 5L, X60, X70, and X80 added
172, 173	Table A-1	A 691 added
180	Table A-1	Temperatures for Types TP321, TP316L, and 316L revised

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Page	*Location*	*Change*
182, 183	Table A-1	A 430 deleted
184, 185	Table A-1	A 430 and A 452 deleted
186	Table A-1	A 240 Type 321 revised
188	Table A-1	Types 321 and F321H revised
192, 193	Table A-1	Classifications and B 466 revised
194, 195	Table A-1	B 283 deleted
209	Table A-1	B 241 and B 345 Grades 23 and S-23 revised
214	Table A-1A	A 452 deleted
215, 216	Table A-1B	A 671, A 672, and A 691 revised
217	Table A-1B	A 430 deleted
220	Table A-2	A 194 Grades 2H and A 193 Grade B7 revised
232	Specification Index for Appendix B	Revised
259–263	Appendix E	Revised in its entirety
265	F301	Revised
283–287	Appendix J	Nomenclature updated to reflect Addenda changes
292, 293	Table K-1	Temperatures and Specified Min. Strength for A 335, Types P12 and P11 revised
294, 295	Table K-1	(1) A 333 and A 334, Type 3 revised (2) A 182 Types F12, F11, F1, and F22 revised (3) A 358 Type TP316L revised
297	Table K-1	(1) A 358 Types 304 and 347 revised (2) A 403 Types WP316L and WP304L revised
299	Table K-1	A 403 Type WP304 revised
311, 312	V300	Revised
	V301	Revised
	V302(c)	Revised
	Footnote 1	Deleted
	V303.1.2	Revised
	V303.1.3	Revised
	V303.2	Revised

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Page	*Location*	*Change*
313, 314	X301.2.2(a)	Revised

NOTES:

The interpretations to ASME B31.3 issued between April 1, 1998 through November 31, 1999, follow the last page of this Addenda as a separate supplement, Interpretations No. 17.

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CHAPTER I
SCOPE AND DEFINITIONS

300 GENERAL STATEMENTS

(a) Identification. This Process Piping Code is a Section of the American Society of Mechanical Engineers Code for Pressure Piping, ASME B31, an American National Standard. It is published as a separate document for convenience of Code users.

(b) Responsibilities

(1) Owner. The owner of a piping installation shall have overall responsibility for compliance with this Code, and for establishing the requirements for design, construction, examination, inspection, and testing which will govern the entire fluid handling or process installation of which the piping is a part. The owner is also responsible for designating piping in certain fluid services. [See paras. 300(d)(4) and (5) and 300(e).]

(2) Designer. The designer is responsible to the owner for assurance that the engineering design of piping complies with the requirements of this Code and with any additional requirements established by the owner.

(3) Manufacturer, Fabricator, and Erector. The manufacturer, fabricator, and erector of piping are responsible for providing materials, components, and workmanship in compliance with the requirements of this Code and of the engineering design.

(4) Owner's Inspector. The owner's Inspector (see para. 340) is responsible to the owner for ensuring that the requirements of this Code for inspection, examination, and testing are met.

(c) Intent of the Code

(1) It is the intent of this Code to set forth engineering requirements deemed necessary for safe design and construction of piping installations.

(2) This Code is not intended to apply to the operation, examination, inspection, testing, maintenance, or repair of piping that has been placed in service. The provisions of this Code may optionally be applied for those purposes, although other considerations may also be necessary.

A00 *(3)* Engineering requirements of this Code, while considered necessary and adequate for safe design, generally employ a simplified approach to the subject. A designer capable of applying a more rigorous analysis shall have the latitude to do so; however, the approach must be documented in the engineering design and its validity accepted by the owner. The approach used shall provide details of design, construction, examination, inspection, and testing for the design conditions of para. 301, with calculations consistent with the design criteria of this Code.

(4) Piping elements should, insofar as practicable, conform to the specifications and standards listed in this Code. Piping elements neither specifically approved nor specifically prohibited by this Code may be used provided they are qualified for use as set forth in applicable Chapters of this Code.

(5) The engineering design shall specify any unusual requirements for a particular service. Where service requirements necessitate measures beyond those required by this Code, such measures shall be specified by the engineering design. Where so specified, the Code requires that they be accomplished.

(6) Compatibility of materials with the service and hazards from instability of contained fluids are not within the scope of this Code. See para. F323.

(d) Determining Code Requirements

(1) Code requirements for design and construction include fluid service requirements, which affect selection and application of materials, components, and joints. Fluid service requirements include prohibitions, limitations, and conditions, such as temperature limits or a requirement for safeguarding (see para. 300.2 and Appendix G). Code requirements for a piping system are the most restrictive of those which apply to any of its elements.

(2) For metallic piping not in Category M or high pressure fluid service, Code requirements are found in Chapters I through VI (the base Code), and fluid service requirements are found in:

(a) Chapter III for materials;

(b) Chapter II, Part 3, for components;

(c) Chapter II, Part 4, for joints.

(3) For nonmetallic piping and piping lined with nonmetals, all requirements are found in Chapter VII. (Paragraph designations begin with "A.")

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(4) For piping in a fluid service designated by the owner as Category M (see para. 300.2 and Appendix M), all requirements are found in Chapter VIII. (Paragraph designations begin with "M.")

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(5) For piping in a fluid service designated by the owner as Category D (see para. 300.2 and Appendix M), piping elements restricted to Category D Fluid Service in Chapters I through VII, as well as elements suitable for other fluid services, may be used.

(6) Metallic piping elements suitable for Normal Fluid Service in Chapters I through VI may also be used under severe cyclic conditions unless a specific requirement for severe cyclic conditions is stated.

(e) High Pressure Piping. Chapter IX provides alternative rules for design and construction of piping designated by the owner as being in High Pressure Fluid Service.

(1) These rules apply only when specified by the owner, and only as a whole, not in part.

(2) Chapter IX rules do not provide for Category M Fluid Service. See para. K300.1.4.

(3) Paragraph designations begin with "K."

(f) Appendices. Appendices of this Code contain Code requirements, supplementary guidance, or other information. See para. 300.4 for a description of the status of each Appendix.

300.1 Scope

Rules for the Process Piping Code Section B31.3[1] have been developed considering piping typically found in petroleum refineries; chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants; and related processing plants and terminals.

300.1.1 Content and Coverage

(a) This Code prescribes requirements for materials and components, design, fabrication, assembly, erection, examination, inspection, and testing of piping.

(b) This Code applies to piping for all fluids, including:

(1) raw, intermediate, and finished chemicals;

(2) petroleum products;

(3) gas, steam, air, and water;

(4) fluidized solids;

(5) refrigerants; and

(6) cryogenic fluids.

(99) *(c)* See Fig. 300.1.1 for a diagram illustrating the application of B31.3 piping at equipment. The joint connecting piping to equipment is within the scope of B31.3.

[1] B31 references here and elsewhere in this Code are to the ASME B31 Code for Pressure Piping and its various Sections, which are identified and briefly described in the Introduction.

300.1.2 Packaged Equipment Piping.

Also included within the scope of this Code is piping which interconnects pieces or stages within a packaged equipment assembly.

300.1.3 Exclusions.

This Code excludes the following:

(a) piping systems designed for internal gage pressures at or above zero but less than 105 kPa (15 psi), provided the fluid handled is nonflammable, nontoxic, and not damaging to human tissue as defined in 300.2, and its design temperature is from −29°C (−20°F) through 186°C (366°F);

(b) power boilers in accordance with BPV Code[2] Section I and boiler external piping which is required to conform to B31.1;

(c) tubes, tube headers, crossovers, and manifolds of fired heaters, which are internal to the heater enclosure; and

(d) pressure vessels, heat exchangers, pumps, compressors, and other fluid handling or processing equipment, including internal piping and connections for external piping.

300.2 Definitions

Some of the terms relating to piping are defined below. For welding terms not shown here, definitions in accordance with ANSI/AWS Standard A3.0 apply.

air-hardened steel: a steel that hardens during cooling in air from a temperature above its transformation range

anneal heat treatment: see *heat treatment*

arc cutting: a group of cutting processes wherein the severing or removing of metals is effected by melting with the heat of an arc between an electrode and the base metal. (Includes carbon-arc cutting, metal-arc cutting, gas metal-arc cutting, gas tungsten-arc cutting, plasma-arc cutting, and air carbon-arc cutting.) See also *oxygen-arc cutting.*

arc welding (AW): a group of welding processes which produces coalescence of metals by heating them with an arc or arcs, with or without the application of pressure and with or without the use of filler metal

[2] BPV Code references here and elsewhere in this Code are to the ASME Boiler and Pressure Vessel Code and its various Sections as follows:
Section I, Power Boilers
Section II, Materials, Part D
Section V, Nondestructive Examination
Section VIII, Pressure Vessels, Divisions 1 and 2
Section IX, Welding and Brazing Qualifications

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pipe, according to the method of manufacture, are defined as follows:

(a) electric resistance-welded pipe: pipe produced in individual lengths or in continuous lengths from coiled skelp and subsequently cut into individual lengths, having a longitudinal butt joint wherein coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which the pipe is a part, and by the application of pressure

(b) furnace butt welded pipe, continuous welded: pipe produced in continuous lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt joint forge welded by the mechanical pressure developed in passing the hot-formed and edge-heated skelp through a set of round pass welding rolls

(c) electric-fusion welded pipe: pipe having a longitudinal butt joint wherein coalescence is produced in the preformed tube by manual or automatic electric-arc welding. The weld may be single (welded from one side) or double (welded from inside and outside) and may be made with or without the addition of filler metal.

(d) double submerged-arc welded pipe: pipe having a longitudinal butt joint produced by at least two passes, one of which is on the inside of the pipe. Coalescence is produced by heating with an electric arc or arcs between the bare metal electrode or electrodes and the work. The welding is shielded by a blanket of granular fusible material on the work. Pressure is not used and filler metal for the inside and outside welds is obtained from the electrode or electrodes.

(e) seamless pipe: pipe produced by piercing a billet followed by rolling or drawing, or both

(f) spiral welded pipe: pipe having a helical seam with either a butt, lap, or lock-seam joint which is welded using either an electrical resistance, electric fusion or double-submerged arc welding process

pipe-supporting elements: pipe-supporting elements consist of fixtures and structural attachments as follows:

(a) fixtures: fixtures include elements which transfer the load from the pipe or structural attachment to the supporting structure or equipment. They include hanging type fixtures, such as hanger rods, spring hangers, sway braces, counterweights, turnbuckles, struts, chains, guides, and anchors; and bearing type fixtures, such as saddles, bases, rollers, brackets, and sliding supports.

(b) structural attachments: structural attachments include elements which are welded, bolted, or clamped to the pipe, such as clips, lugs, rings, clamps, clevises, straps, and skirts

piping: assemblies of piping components used to convey, distribute, mix, separate, discharge, meter, control, or snub fluid flows. Piping also includes pipe-supporting elements, but does not include support structures, such as building frames, bents, foundations, or any equipment excluded from this Code (see para. 300.1.3).

piping components: mechanical elements suitable for joining or assembly into pressure-tight fluid-containing piping systems. Components include pipe, tubing, fittings, flanges, gaskets, bolting, valves, and devices such as expansion joints, flexible joints, pressure hoses, traps, strainers, in-line portions of instruments, and separators.

piping elements: any material or work required to plan and install a piping system. Elements of piping include design specifications, materials, components, supports, fabrication, examination, inspection, and testing.

piping installation: designed piping systems to which a selected Code Edition and Addenda apply

piping system: interconnected piping subject to the same set or sets of design conditions

plasma arc cutting (PAC): an arc cutting process that uses a constricted arc and removes molten metal with a high velocity jet of ionized gas issuing from the constricting orifice

preheating: the application of heat to the base material immediately before or during a forming, welding, or cutting process. See para. 330.

postweld heat treatment: see *heat treatment*

procedure qualification record (PQR): a document listing all pertinent data, including the essential variables employed and the test results, used in qualifying the procedure specification

process unit: an area whose boundaries are designated by the engineering design within which reactions, separations, and other processes are carried out. Examples of installations which are *not* classified as process units are loading areas or terminals, bulk plants, compounding plants, and tank farms and storage yards.

quench annealing: see *solution heat treatment* under *heat treatment*

quenching: see *heat treatment*

reinforcement: see paras. 304.3 and A304.3. See also *weld reinforcement.*

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root opening: the separation between the members to be joined, at the root of the joint

safeguarding: provision of protective measures of the types outlined in Appendix G, where deemed necessary. See Appendix G for detailed discussion.

seal bond: a bond intended primarily to provide joint tightness against leakage in nonmetallic piping

seal weld: a weld intended primarily to provide joint tightness against leakage in metallic piping

semiautomatic arc welding: arc welding with equipment which controls only the filler metal feed. The advance of the welding is manually controlled.

(99) *severe cyclic conditions:* conditions applying to specific piping components or joints in which S_E computed in accordance with para. 319.4.4 exceeds $0.8S_A$ (as defined in para. 302.3.5), and the equivalent number of cycles (N in para. 302.3.5) exceeds 7000; or other conditions which the designer determines will produce an equivalent effect

shall: a term which indicates that a provision is a Code requirement

shielded metal-arc welding (SMAW): an arc welding process which produces coalescence of metals by heating them with an arc between a covered metal electrode and the work. Shielding is obtained from decomposition of the electrode covering. Pressure is not used and filler metal is obtained from the electrode.

should: a term which indicates that a provision is recommended as good practice but is not a Code requirement

size of weld:

(a) fillet weld: the leg lengths (the leg length for equal-leg welds) of the sides, adjoining the members welded, of the largest triangle that can be inscribed within the weld cross section. For welds between perpendicular members, the definitions in Fig. 328.5.2A apply.

NOTE: When the angle between members exceeds 105 deg, size is of less significance than effective throat (see also *throat of a fillet weld*).

(b) groove weld: the joint penetration (depth of bevel plus the root penetration when specified). The size of a groove weld and its effective throat are the same.

slag inclusion: nonmetallic solid material entrapped in weld metal or between weld metal and base metal

soldering: a metal joining process wherein coalescence is produced by heating to suitable temperatures and by using a nonferrous alloy fusible at temperatures below 427°C (800°F) and having a melting point below that of the base metals being joined. The filler metal is distributed between closely fitted surfaces of the joint by capillary attraction. In general, solders are lead-tin alloys and may contain antimony, bismuth, and other elements.

solution heat treatment: see *heat treatment*

stress ratio: see Fig. 323.2.2B. A00

stress relief: see *heat treatment*

stress terms frequently used:

(a) basic allowable stress: this term, symbol S, represents the stress value for any material determined by the appropriate stress basis in para. 302.3.2

(b) bolt design stress: this term represents the design stress used to determine the required cross-sectional area of bolts in a bolted joint

(c) hydrostatic design basis: selected properties of plastic piping materials to be used in accordance with ASTM D 2837 or D 2992 to determine the HDS [see (d) below] for the material

(d) hydrostatic design stress (HDS): the maximum continuous stress due to internal pressure to be used in the design of plastic piping, determined from the hydrostatic design basis by use of a service (design) factor

submerged arc welding (SAW): an arc welding process which produces coalescence of metals by heating them with an arc or arcs between a bare metal electrode or electrodes and the work. The arc is shielded by a blanket of granular, fusible material on the work. Pressure is not used and filler metal is obtained from the electrode and sometimes from a supplemental source (welding rod, flux, or metal granules).

tack weld: a weld made to hold parts of a weldment in proper alignment until the final welds are made

tempering: see *heat treatment*

thermoplastic: a plastic which is capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature

thermosetting resin: a resin capable of being changed into a substantially infusible or insoluble product when cured at room temperature, or by application of heat, or by chemical means

throat of a fillet weld:

(a) theoretical throat: the perpendicular distance

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CHAPTER II
DESIGN

PART 1
CONDITIONS AND CRITERIA

A00 301 DESIGN CONDITIONS

Paragraph 301 states the qualifications of the Designer, defines the temperatures, pressures, and forces applicable to the design of piping, and states the consideration that shall be given to various effects and their consequent loadings. See also Appendix F, para. F301.

A00 301.1 Qualifications of the Designer

The Designer is the person(s) in charge of the engineering design of a piping system and shall be experienced in the use of this Code.

The qualifications and experience required of the Designer will depend on the complexity and criticality of the system and the nature of the individual's experience. The owner's approval is required if the individual does not meet at least one of the following criteria.

(a) Completion of an engineering degree, requiring four or more years of full-time study, plus a minimum of 5 years experience in the design of related pressure piping.

(b) Professional Engineering registration, recognized by the local jurisdiction, and experience in the design of related pressure piping.

(c) Completion of an engineering associates degree, requiring at least 2 years of full-time study, plus a minimum of 10 years experience in the design of related pressure piping.

(d) Fifteen years experience in the design of related pressure piping. Experience in the design of related pressure piping is satisfied by piping design experience that includes design calculations for pressure, sustained and occasional loads, and piping flexibility.

301.2 Design Pressure

301.2.1 General

(a) The design pressure of each component in a piping system shall be not less than the pressure at the most severe condition of coincident internal or external pressure and temperature (minimum or maximum) expected during service, except as provided in para. 302.2.4.

(b) The most severe condition is that which results in the greatest required component thickness and the highest component rating.

(c) When more than one set of pressure-temperature conditions exist for a piping system, the conditions governing the rating of components conforming to listed standards may differ from the conditions governing the rating of components designed in accordance with para. 304.

(d) When a pipe is separated into individualized pressure-containing chambers (including jacketed piping, blanks, etc.), the partition wall shall be designed on the basis of the most severe coincident temperature (minimum or maximum) and differential pressure between the adjoining chambers expected during service, except as provided in para. 302.2.4. A00

301.2.2 Required Pressure Containment or Relief

(a) Provision shall be made to safely contain or relieve (see para. 322.6.3) any pressure to which the piping may be subjected. Piping not protected by a pressure relieving device, or that can be isolated from a pressure relieving device, shall be designed for at least the highest pressure that can be developed.

(b) Sources of pressure to be considered include ambient influences, pressure oscillations and surges, improper operation, decomposition of unstable fluids, static head, and failure of control devices. A00

(c) The allowances of para. 302.2.4(f) are permitted, provided that the other requirements of para. 302.2.4 are also met.

301.3 Design Temperature

The design temperature of each component in a piping system is the temperature at which, under the coincident pressure, the greatest thickness or highest component rating is required in accordance with para. 301.2. (To satisfy the requirements of para. 301.2,

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different components in the same piping system may have different design temperatures.)

In establishing design temperatures, consider at least the fluid temperatures, ambient temperatures, solar radiation, heating or cooling medium temperatures, and the applicable provisions of paras. 301.3.2, 301.3.3, and 301.3.4.

301.3.1 Design Minimum Temperature. The design minimum temperature is the lowest component temperature expected in service. This temperature may establish special design requirements and material qualification requirements. See also paras. 301.4.4 and 323.2.2.

301.3.2 Uninsulated Components

(a) For fluid temperatures below 65°C (150°F), the component temperature shall be taken as the fluid temperature unless solar radiation or other effects result in a higher temperature.

(b) For fluid temperatures 65°C (150°F) and above, unless a lower average wall temperature is determined by test or heat transfer calculation, the temperature for uninsulated components shall be no less than the following values:

(1) valves, pipe, lapped ends, welding fittings, and other components having wall thickness comparable to that of the pipe: 95% of the fluid temperature;

(2) flanges (except lap joint) including those on fittings and valves: 90% of the fluid temperature;

(3) lap joint flanges: 85% of the fluid temperature;

(4) bolting: 80% of the fluid temperature.

301.3.3 Externally Insulated Piping. The component design temperature shall be the fluid temperature unless calculations, tests, or service experience based

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on measurements support the use of another temperature. Where piping is heated or cooled by tracing or jacketing, this effect shall be considered in establishing component design temperatures.

301.3.4 Internally Insulated Piping. The component design temperature shall be based on heat transfer calculations or tests.

301.4 Ambient Effects

See Appendix F, para. F301.4.

301.4.1 Cooling: Effects on Pressure. The cooling of a gas or vapor in a piping system may reduce the pressure sufficiently to create an internal vacuum. In such a case, the piping shall be capable of withstanding the external pressure at the lower temperature, or provision shall be made to break the vacuum.

301.4.2 Fluid Expansion Effects. Provision shall be made in the design either to withstand or to relieve increased pressure caused by the heating of static fluid in a piping component. See also para. 322.6.3(b)(2).

301.4.3 Atmospheric Icing. Where the design minimum temperature of a piping system is below 0°C (32°F), the possibility of moisture condensation and buildup of ice shall be considered and provisions made in the design to avoid resultant malfunctions. This applies to surfaces of moving parts of shutoff valves, control valves, pressure relief devices including discharge piping, and other components.

301.4.4 Low Ambient Temperature. Consideration shall be given to low ambient temperature conditions for displacement stress analysis.

301.5 Dynamic Effects

See Appendix F, para. F301.5.

301.5.1 Impact. Impact forces caused by external or internal conditions (including changes in flow rate, hydraulic shock, liquid or solid slugging, flashing, and geysering) shall be taken into account in the design of piping.

301.5.2 Wind. The effect of wind loading shall be taken into account in the design of exposed piping. The method of analysis may be as described in ASCE 7, Minimum Design Loads for Buildings and Other Structures, or the Uniform Building Code.

301.5.3 Earthquake. Piping shall be designed for earthquake-induced horizontal forces. The method of analysis may be as described in ASCE 7-88 or the Uniform Building Code.

301.5.4 Vibration. Piping shall be designed, arranged, and supported so as to eliminate excessive and harmful effects of vibration which may arise from such sources as impact, pressure pulsation, resonance in compressors, and wind loads.

301.5.5 Discharge Reactions. Piping shall be designed, arranged, and supported so as to withstand reaction forces due to let-down or discharge of fluids.

301.6 Weight Effects

The following weight effects, combined with loads and forces from other causes, shall be taken into account in the design of piping.

301.6.1 Live Loads. These loads include the weight of the medium transported or the medium used for test. Snow and ice loads due to both environmental and operating conditions shall be considered.

301.6.2 Dead Loads. These loads consist of the weight of piping components, insulation, and other superimposed permanent loads supported by the piping.

301.7 Thermal Expansion and Contraction Effects

The following thermal effects, combined with loads and forces from other causes, shall be taken into account in the design of piping. See also Appendix F, para. F301.7.

301.7.1 Thermal Loads Due to Restraints. These loads consist of thrusts and moments which arise when free thermal expansion and contraction of the piping are prevented by restraints or anchors.

301.7.2 Loads Due to Temperature Gradients. These loads arise from stresses in pipe walls resulting from large rapid temperature changes or from unequal temperature distribution as may result from a high heat flux through a comparatively thick pipe or stratified two-phase flow causing bowing of the line.

301.7.3 Loads Due to Differences in Expansion Characteristics. These loads result from differences in thermal expansion where materials with different thermal expansion coefficients are combined, as in bimetallic, lined, jacketed, or metallic–nonmetallic piping.

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ature for bolting materials shall not exceed the lowest of the following:

A00 *(1)* except as provided in (3) below, the lower of one-fourth of specified minimum tensile strength at room temperature (S_T) and one-fourth of tensile strength at temperature;

A00 *(2)* except as provided in (3) below, the lower of two-thirds of specified minimum yield strength at room temperature (S_Y) and two-thirds of yield strength at temperature;

A00 *(3)* at temperatures below the creep range, for bolting materials whose strength has been enhanced by heat treatment or strain hardening, the lower of one-fifth of S_T and one-fourth of S_Y (unless these values are lower than corresponding values for annealed material, in which case the annealed values shall be used);

(4) two-thirds of the "yield strength at temperature" [see para. 302.3.2(f)];

(5) 100% of the average stress for a creep rate of 0.01% per 1000 hr;

(6) 67% of the average stress for rupture at the end of 100,000 hr;

(7) 80% of minimum stress for rupture at the end of 100,000 hr.

(b) Cast Iron. Basic allowable stress values at temperature for cast iron shall not exceed the lower of the following:

(1) one-tenth of the specified minimum tensile strength at room temperature;

(2) one-tenth of the tensile strength at temperature [see para. 302.3.2(f)].

(c) Malleable Iron. Basic allowable stress values at temperature for malleable iron shall not exceed the lower of the following:

(1) one-fifth of the specified minimum tensile strength at room temperature;

(2) one-fifth of the tensile strength at temperature [see para. 302.3.2(f)].

(d) Other Materials. Basic allowable stress values at temperature for materials other than bolting materials, cast iron, and malleable iron shall not exceed the lowest of the following:

A00 *(1)* the lower of one-third of S_T and one-third of tensile strength at temperature;

A00 *(2)* except as provided in (3) below, the lower of two-thirds of S_Y and two-thirds of yield strength at temperature;

A00 *(3)* for austenitic stainless steels and nickel alloys having similar stress–strain behavior, the lower of two-thirds of S_Y and 90% of yield strength at temperature [see (e) below];

(4) 100% of the average stress for a creep rate of 0.01% per 1000 hr;

(5) 67% of the average stress for rupture at the end of 100,000 hr;

(6) 80% of the minimum stress for rupture at the end of 100,000 hr;

(7) for structural grade materials, the basic allowable stress shall be 0.92 times the lowest value determined in paras. 302.3.2(d)(1) through (6).

(8) In the application of these criteria, the yield strength at room temperature is considered to be $S_Y R_Y$, and the tensile strength at room temperature is considered to be $1.1 S_T R_T$. A00

(e) Application Limits. Application of stress values determined in accordance with para. 302.3.2(d)(3) is not recommended for flanged joints and other components in which slight deformation can cause leakage or malfunction. [These values are shown in italics or boldface in Table A-1, as explained in Note (4) to Appendix A Tables.] Instead, either 75% of the stress value in Table A-1 or two-thirds of the yield strength at temperature listed in the BPV Code, Section II, Part D, Table Y-1 should be used.

(f) Unlisted Materials. For a material which conforms to para. 323.1.2, the tensile (yield) strength at temperature shall be derived by multiplying the average expected tensile (yield) strength at temperature by the ratio of S_T (S_Y) divided by the average expected tensile (yield) strength at room temperature. A00

302.3.3 Casting Quality Factor E_c

(a) General. The casting quality factors E_c defined herein shall be used for cast components not having pressure-temperature ratings established by standards in Table 326.1.

(b) Basic Quality Factors. Castings of gray and malleable iron, conforming to listed specifications, are assigned a basic casting quality factor E_c of 1.00 (due to their conservative allowable stress basis). For most other metals, static castings which conform to the material specification and have been visually examined as required by MSS SP-55, Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components — Visual Method, are assigned a basic casting quality factor E_c of 0.80. Centrifugal castings which meet specification requirements only for chemical analysis, tensile, hydrostatic, and flattening tests, and visual examination are assigned a basic casting quality factor of 0.80. Basic casting quality factors are tabulated for listed specifications in Table A-1A.

(c) Increased Quality Factors. Casting quality factors may be increased when supplementary examinations are performed on each casting. Table 302.3.3C states the increased casting quality factors E_c which may

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TABLE 302.3.3C[4]
INCREASED CASTING QUALITY FACTORS, E_C

Supplementary Examination in Accordance With Note(s)	Factor, E_C
(1)	0.85
(2)(a) or (2)(b)	0.85
(3)(a) or (3)(b)	0.95
(1) and (2)(a) or (2)(b)	0.90
(1) and (3)(a) or (3)(b)	1.00
(2)(a) or (2)(b) and (3)(a) or (3)(b)	1.00

NOTES:
(1) Machine all surfaces to a finish of 6.3 μm R_a (250 μin. R_a per ASME B46.1), thus increasing the effectiveness of surface examination.
(2) (a) Examine all surfaces of each casting (magnetic material only) by the magnetic particle method in accordance with ASTM E 709. Judge acceptability in accordance with MSS SP-53, using reference photos in ASTM E 125.
(b) Examine all surfaces of each casting by the liquid penetrant method, in accordance with ASTM E 165. Judge acceptability of flaws and weld repairs in accordance with Table 1 of MSS SP-53, using ASTM E 125 as a reference for surface flaws.
(3) (a) Fully examine each casting ultrasonically in accordance with ASTM E 114, accepting a casting only if there is no evidence of depth of defects in excess of 5% of wall thickness.
(b) Fully radiograph each casting in accordance with ASTM E 142. Judge in accordance with the stated acceptance levels in Table 302.3.3D.
(4) Titles of standards referenced in this Table are as follows:
ASTM
E 114 Practice for Ultrasonic Pulse-Echo Straight-Beam Testing by the Contact Method
E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings
E 142 Method for Controlling Quality of Radiographic Testing
E 165 Practice for Liquid Penetrant Inspection Method
E 709 Practice for Magnetic Particle Examination
ASME
B46.1 Surface Texture (Surface Roughness, Waviness and Lay)
MSS
SP-53 Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components—Magnetic Particle Examination Method

TABLE 302.3.3D[1]
ACCEPTANCE LEVELS FOR CASTINGS

Material Examined Thickness, T	Applicable Standard	Acceptance Level (or Class)	Acceptable Discontinuities
Steel $T \le 25$ mm (1 in.)	ASTM E 446	1	Types A, B, C
Steel $T > 25$ mm, ≤ 51 mm (2 in.)	ASTM E 446	2	Types A, B, C
Steel $T > 51$ mm, ≤ 114 mm ($4\frac{1}{2}$ in.)	ASTM E 186	2	Categories A, B, C
Steel $T > 114$ mm, ≤ 305 mm (12 in.)	ASTM E 280	2	Categories A, B, C
Aluminum & magnesium	ASTM E 155	...	Shown in reference radiographs
Copper, Ni–Cu	ASTM E 272	2	Codes A, Ba, Bb
Bronze	ASTM E 310	2	Codes A and B

NOTE:
(1) Titles of standards referenced in this Table are as follows:
ASTM
E 155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings
E 186 Reference Radiographs for Heavy-Walled [2 to 4-$\frac{1}{2}$-in. (51 to 114-mm)] Steel Castings
E 272 Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Castings
E 280 Reference Radiographs for Heavy-Walled [4-$\frac{1}{2}$ to 12-in. (114 to 305-mm)] Steel Castings
E 310 Reference Radiographs for Tin Bronze Castings
E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness

be used for various combinations of supplementary examination. Table 302.3.3D states the acceptance criteria for the examination methods specified in the Notes to Table 302.3.3C. Quality factors higher than those shown in Table 302.3.3C do not result from combining tests 2a and 2b, or 3a and 3b. In no case shall the quality factor exceed 1.00.

Several of the specifications in Appendix A require machining of all surfaces and/or one or more of these supplementary examinations. In such cases, the appropriate increased quality factor is shown in Table A-1A.

302.3.4 Weld Joint Quality Factor, E_j

(a) Basic Quality Factors. The weld joint quality factors E_j tabulated in Table A-1B are basic factors for straight or spiral longitudinal welded joints for pressure-containing components as shown in Table 302.3.4.

(b) Increased Quality Factors. Table 302.3.4 also indicates higher joint quality factors which may be substituted for those in Table A-1B for certain kinds of welds if additional examination is performed beyond that required by the product specification.

302.3.5 Limits of Calculated Stresses Due to Sustained Loads and Displacement Strains

(a) Internal Pressure Stresses. Stresses due to internal pressure shall be considered safe when the wall

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TABLE 302.3.4
LONGITUDINAL WELD JOINT QUALITY FACTOR, E_j

(99)

No.	Type of Joint		Type of Seam	Examination	Factor, E_j
1	Furnace butt weld, continuous weld		Straight	As required by listed specification	0.60 [Note (1)]
2	Electric resistance weld		Straight or spiral	As required by listed specification	0.85 [Note (1)]
3	Electric fusion weld				
	(a) Single butt weld (with or without filler metal)		Straight or spiral	As required by listed specification or this Code	0.80
				Additionally spot radiographed per para. 341.5.1	0.90
				Additionally 100% radiographed per para. 344.5.1 and Table 341.3.2	1.00
	(b) Double butt weld (with or without filler metal)		Straight or spiral [except as provided in 4(a) below]	As required by listed specification or this Code	0.85
				Additionally spot radiographed per para. 341.5.1	0.90
				Additionally 100% radiographed per para. 344.5.1 and Table 341.3.2	1.00
4	Per specific specification				
	(a) API 5L	Submerged arc weld (SAW) Gas metal arc weld (GMAW) Combined GMAW, SAW 	Straight with one or two seams Spiral	As required by specification	0.95

NOTE:
(1) It is not permitted to increase the joint quality factor by additional examination for joint 1 or 2.

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thickness of the piping component, including any reinforcement, meets the requirements of para. 304.

(b) External Pressure Stresses. Stresses due to external pressure shall be considered safe when the wall thickness of the piping component, and its means of stiffening, meet the requirements of para. 304.

A00 *(c) Longitudinal Stresses S_L.* The sum of longitudinal stresses in any component in a piping system, due to pressure, weight, and other sustained loadings S_L shall not exceed S_h in (d) below. The thickness of pipe used in calculating S_L shall be the nominal thickness $\overline{T}$ minus mechanical, corrosion, and erosion allowance c, for the location under consideration. The loads due to weight should be based on the nominal thickness of all system components unless otherwise justified in a more rigorous analysis.

(d) Allowable Displacement Stress Range S_A. The computed displacement stress range S_E in a piping system (see para. 319.4.4) shall not exceed the allowable displacement stress range S_A (see paras. 319.2.3 and 319.3.4) calculated by Eq. (1a):

$$S_A = f(1.25S_c + 0.25S_h) \quad (1a)$$

When S_h is greater than S_L, the difference between them may be added to the term $0.25S_h$ in Eq. (1a). In that case, the allowable stress range is calculated by Eq. (1b):

$$S_A = f[1.25(S_c + S_h) - S_L] \quad (1b)$$

In Eqs. (1a) and (1b):

S_c = basic allowable stress[3] at minimum metal temperature expected during the displacement cycle under analysis

S_h = basic allowable stress[3] at maximum metal temperature expected during the displacement cycle under analysis

f = stress range reduction factor,[4] from Table 302.3.5 or calculated by Eq. (1c):[5]

TABLE 302.3.5
STRESS-RANGE REDUCTION FACTORS, f

Cycles, N	Factor, f
7,000 and less	1.0
Over 7,000 to 14,000	0.9
Over 14,000 to 22,000	0.8
Over 22,000 to 45,000	0.7
Over 45,000 to 100,000	0.6
Over 100,000 to 200,000	0.5
Over 200,000 to 700,000	0.4
Over 700,000 to 2,000,000	0.3

$$f = 6.0(N)^{-0.2} \leq 1.0 \quad (1c)$$

where

N = equivalent number of full displacement cycles during the expected service life of the piping system[6]

When the computed stress range varies, whether from thermal expansion or other conditions, S_E is defined as the greatest computed displacement stress range. The value of N in such cases can be calculated by Eq. (1d):

$$N = N_E + \sum(r_i^5 N_i) \text{ for } i = 1, 2, \ldots, n \quad (1d)$$

where

N_E = number of cycles of maximum computed displacement stress range, S_E

r_i = S_i/S_E

S_i = any computed displacement stress range smaller than S_E

N_i = number of cycles associated with displacement stress range S_i

302.3.6 Limits of Calculated Stresses due to Occasional Loads

(a) Operation. The sum of the longitudinal stresses due to pressure, weight, and other sustained loadings S_L and of the stresses produced by occasional loads, such as wind or earthquake, may be as much as 1.33 times the basic allowable stress given in Appendix A. For castings, the basic allowable stress shall be multiplied by the casting quality factor E_c. Where the allowable stress value exceeds two-thirds of yield strength at temperature, the allowable stress value must be reduced as specified in para. 302.3.2(e). Wind and earthquake forces need not be considered as acting concurrently.

[3] For castings, the basic allowable stress shall be multiplied by the applicable casting quality factor E_c. For longitudinal welds, the basic allowable stress need not be multiplied by the weld quality factor E_j.

[4] Applies to essentially noncorroded piping. Corrosion can sharply decrease cyclic life; therefore, corrosion resistant materials should be considered where a large number of major stress cycles is anticipated.

[5] Equation (1c) does not apply beyond approximately 2×10^6 cycles. Selection of f factors beyond 2×10^6 cycles is the designer's responsibility.

[6] The designer is cautioned that the fatigue life of materials operated at elevated temperature may be reduced.

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(b) Test. Stresses due to test conditions are not subject to the limitations in para. 302.3. It is not necessary to consider other occasional loads, such as wind and earthquake, as occurring concurrently with test loads.

302.4 Allowances

In determining the minimum required thickness of a piping component, allowances shall be included for corrosion, erosion, and thread depth or groove depth. See definition for c in para. 304.1.1(b).

A00 **302.4.1 Mechanical Strength.** When necessary, the wall thickness shall be increased to prevent overstress, damage, collapse, or buckling due to superimposed loads from supports, ice formation, backfill, transportation, handling, or other causes. Where increasing the thickness would excessively increase local stresses or the risk of brittle fracture, or is otherwise impracticable, the required strength may be obtained through additional supports, braces, or other means without an increased wall thickness. Particular consideration should be given to the mechanical strength of small pipe connections to piping or equipment.

PART 2
PRESSURE DESIGN OF PIPING COMPONENTS

303 GENERAL

Components manufactured in accordance with standards listed in Table 326.1 shall be considered suitable for use at pressure-temperature ratings in accordance with para. 302.2.1. The rules in para. 304 are intended for pressure design of components not covered in Table 326.1, but may be used for a special or more rigorous design of such components. Designs shall be checked for adequacy of mechanical strength under applicable loadings enumerated in para. 301.

304 PRESSURE DESIGN OF COMPONENTS

304.1 Straight Pipe

304.1.1 General

(a) The required thickness of straight sections of pipe shall be determined in accordance with Eq. (2):

$$t_m = t + c \tag{2}$$

The minimum thickness T for the pipe selected, considering manufacturer's minus tolerance, shall be not less than t_m.

(b) The following nomenclature is used in the equations for pressure design of straight pipe.

t_m = minimum required thickness, including mechanical, corrosion, and erosion allowances

t = pressure design thickness, as calculated in accordance with para. 304.1.2 for internal pressure or as determined in accordance with para. 304.1.3 for external pressure

c = the sum of the mechanical allowances (thread or groove depth) plus corrosion and erosion allowances. For threaded components, the nominal thread depth (dimension h of ASME B1.20.1, or equivalent) shall apply. For machined surfaces or grooves where the tolerance is not specified, the tolerance shall be assumed to be 0.5 mm (0.02 in.) in addition to the specified depth of the cut.

T = pipe wall thickness (measured or minimum per purchase specification)

d = inside diameter of pipe. For pressure design calculation, the inside diameter of the pipe is the maximum value allowable under the purchase specification.

P = internal design gage pressure

D = outside diameter of pipe as listed in tables of standards or specifications or as measured

E = quality factor from Table A-1A or A-1B

S = stress value for material from Table A-1

Y = coefficient from Table 304.1.1, valid for $t < D/6$ and for materials shown. The value of Y may be interpolated for intermediate temperatures.

For $t \geq D/6$,

$$Y = \frac{d + 2c}{D + d + 2c}$$

304.1.2 Straight Pipe Under Internal Pressure A00

(a) For $t < D/6$, the internal pressure design thickness for straight pipe shall be not less than that calculated in accordance with either Eq. (3a) or Eq. (3b):

$$t = \frac{PD}{2(SE + PY)} \tag{3a}$$

$$t = \frac{P(d + 2c)}{2[SE - P(1 - Y)]} \tag{3b}$$

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TABLE 304.1.1
VALUES OF COEFFICIENT Y
FOR $t < D/6$

Materials	Temperature, °C (°F) ≤ 482 (900 & Lower)	510 (950)	538 (1000)	566 (1050)	593 (1100)	≥ 621 (1150 & Up)
Ferritic steels	0.4	0.5	0.7	0.7	0.7	0.7
Austenitic steels	0.4	0.4	0.4	0.4	0.5	0.7
Other ductile metals	0.4	0.4	0.4	0.4	0.4	0.4
Cast iron	0.0	...	...	...	...	...

(b) For t ≥ $D/6$ or for $P/SE > 0.385$, calculation of pressure design thickness for straight pipe requires special consideration of factors such as theory of failure, effects of fatigue, and thermal stress.

304.1.3 Straight Pipe Under External Pressure. To determine wall thickness and stiffening requirements for straight pipe under external pressure, the procedure outlined in the BPV Code, Section VIII, Division 1, UG-28 through UG-30 shall be followed, using as the design length L the running center line length between any two sections stiffened in accordance with UG-29. As an exception, for pipe with $D_o/t < 10$, the value of S to be used in determining P_{a2} shall be the lesser of the following values for pipe material at design temperature:

(a) 1.5 times the stress value from Table A-1 of this Code; or

(b) 0.9 times the yield strength tabulated in Section II, Part D, Table Y-1 for materials listed therein.

(The symbol D_o in Section VIII is equivalent to D in this Code.)

304.2 Curved and Mitered Segments of Pipe

A00 **304.2.1 Pipe Bends.** The minimum required thickness t_m of a bend, after bending, in its finished form, shall be determined in accordance with Eq. (2) and Eq. (3c):

$$t = \frac{PD}{2[(SE/I) + PY]} \quad (3c)$$

where at the intrados (inside bend radius)

$$I = \frac{4(R_1/D) - 1}{4(R_1/D) - 2} \quad (3d)$$

and at the extrados (outside bend radius)

$$I = \frac{4(R_1/D) + 1}{4(R_1/D) + 2} \quad (3e)$$

and at the sidewall on the bend centerline radius, $I = 1.0$.

R_1 = bend radius of welding elbow or pipe bend

Thickness variations from the intrados to the extrados and along the length of the bend shall be gradual. The thickness requirements apply at the mid-span of the bend, $\gamma/2$, at the intrados, extrados, and bend centerline radius. The minimum thickness at the end tangents shall not be less than the requirements of para. 304.1 for straight pipe (see Fig. 304.2.1).

304.2.2 Elbows. Manufactured elbows not in accordance with para. 303 shall be qualified as required by para. 304.7.2 or designed in accordance with para. 304.2.1. A00

304.2.3 Miter Bends. An angular offset of 3 deg or less (angle α in Fig. 304.2.3) does not require design consideration as a miter bend. Acceptable methods for pressure design of multiple and single miter bends are given in (a) and (b) below.

(a) Multiple Miter Bends. The maximum allowable internal pressure shall be the lesser value calculated from Eqs. (4a) and (4b). These equations are not applicable when θ exceeds 22.5 deg.

$$P_m = \frac{SE(T-c)}{r_2}\left(\frac{T-c}{(T-c) + 0.643\tan\theta\sqrt{r_2(T-c)}}\right) \quad (4a)$$

$$P_m = \frac{SE(T-c)}{r_2}\left(\frac{R_1 - r_2}{R_1 - 0.5r_2}\right) \quad (4b)$$

(b) Single Miter Bends

(1) The maximum allowable internal pressure for a single miter bend with angle θ not greater than 22.5 deg shall be calculated by Eq. (4a).

(2) The maximum allowable internal pressure for

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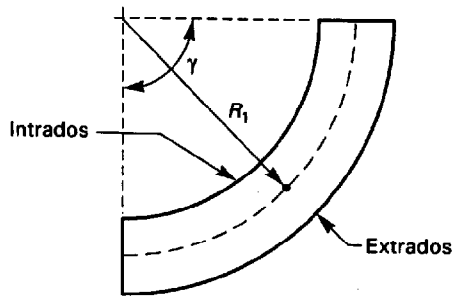

A00 FIG. 304.2.1 NOMENCLATURE FOR PIPE BENDS

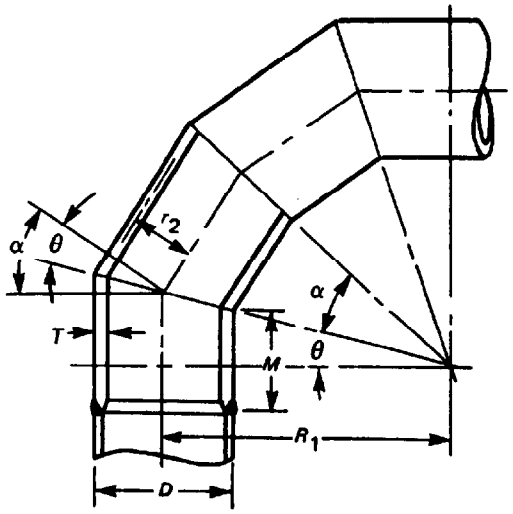

FIG. 304.2.3 NOMENCLATURE FOR MITER BENDS

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a single miter bend with angle θ greater than 22.5 deg shall be calculated by Eq. (4c):

$$P_m = \frac{SE(T-c)}{r_2}\left(\frac{T-c}{(T-c)+1.25\tan\theta\sqrt{r_2(T-c)}}\right) \quad (4c)$$

(c) The miter pipe wall thickness T used in Eqs. (4a), (4b), and (4c) shall extend a distance not less than M from the inside crotch of the end miter welds where

M = the larger of $2.5(r_2T)^{0.5}$ or $\tan\theta\,(R_1 - r_2)$

The length of taper at the end of the miter pipe may be included in the distance M.

(d) The following nomenclature is used in Eqs. (4a), (4b), and (4c) for the pressure design of miter bends:

c = same as defined in para. 304.1.1
E = same as defined in para. 304.1.1
P_m = maximum allowable internal pressure for miter bends
r_2 = mean radius of pipe using nominal wall $\overline{T}$
R_1 = effective radius of miter bend, defined as the shortest distance from the pipe center line to the intersection of the planes of adjacent miter joints
S = same as defined in para. 304.1.1
T = miter pipe wall thickness (measured or minimum per purchase specification)
θ = angle of miter cut
α = angle of change in direction at miter joint = 2θ

For compliance with this Code, the value of R_1 shall be not less than that given by Eq. (5):

$$R_1 = \frac{A}{\tan\theta} + \frac{D}{2} \quad (5)$$

where A has the following empirical values:

(1) for SI metric units:

$(T-c)$, mm	A
≤ 13	25
$13 < (T-c) < 22$	$2(T-c)$
≥ 22	$[2(T-c)/3]+30$

(2) for U.S. customary units:

$(T-c)$, mm	A
≤ 0.5	1.0
$0.5 < (T-c) < 0.88$	$2(T-c)$
≥ 0.88	$[2(T-c)/3]+1.17$

304.2.4 Curved and Mitered Segments of Pipe Under External Pressure. The wall thickness of curved and mitered segments of pipe subjected to external pressure may be determined as specified for straight pipe in para. 304.1.3.

304.3 Branch Connections

304.3.1 General

(a) Except as provided in (b) below, the requirements in paras. 304.3.2 through 304.3.4 are applicable to branch connections made in accordance with the following methods:

(1) fittings (tees, extruded outlets, branch outlet fittings per MSS SP-97, laterals, crosses);

(2) unlisted cast or forged branch connection fittings (see para. 300.2), and couplings not over DN 80 (NPS 3), attached to the run pipe by welding;

(3) welding the branch pipe directly to the run pipe, with or without added reinforcement, as covered in para. 328.5.4.

(b) The rules in paras. 304.3.2 through 304.3.4 are minimum requirements, valid only for branch connections in which (using the nomenclature of Fig. 304.3.3):

(1) the run pipe diameter-to-thickness ratio (D_h/T_h) is less than 100 and the branch-to-run diameter ratio (D_b/D_h) is not greater than 1.0;

(2) for run pipe with $(D_h/T_h) \geq 100$, the branch diameter D_b is less than one-half the run diameter D_h;

(3) angle β is at least 45 deg;

(4) the axis of the branch intersects the axis of the run.

(c) Where the provisions of (a) and (b) above are not met, pressure design shall be qualified as required by para. 304.7.2.

(d) Other design considerations relating to branch connections are stated in para. 304.3.5.

304.3.2 Strength of Branch Connections. A pipe having a branch connection is weakened by the opening that must be made in it and, unless the wall thickness of the pipe is sufficiently in excess of that required to sustain the pressure, it is necessary to provide added reinforcement. The amount of reinforcement required to sustain the pressure shall be determined in accordance with para. 304.3.3 or 304.3.4. There are, however, certain branch connections which have adequate pressure strength or reinforcement as constructed. It may be assumed without calculation that a branch connection has adequate strength to sustain the internal and external pressure which will be applied to it if:

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(a) the branch connection utilizes a listed fitting in accordance with para. 303;

(b) the branch connection is made by welding a threaded or socket welding coupling or half coupling directly to the run in accordance with para. 328.5.4, provided the size of the branch does not exceed DN 50 (NPS 2) nor one-fourth the nominal size of the run. The minimum wall thickness of the coupling anywhere in the reinforcement zone (if threads are in the zone, wall thickness is measured from root of thread to minimum outside diameter) shall be not less than that of the unthreaded branch pipe. In no case shall a coupling or half coupling have a rating less than Class 2000 per ASME B16.11.

(c) the branch connection utilizes an unlisted branch connection fitting (see para. 300.2), provided the fitting is made from materials listed in Table A-1 and provided that the branch connection is qualified as required by para. 304.7.2.

304.3.3 Reinforcement of Welded Branch Connections. Added reinforcement is required to meet the criteria in paras. 304.3.3(b) and (c) when it is not inherent in the components of the branch connection. Sample problems illustrating the calculations for branch reinforcement are shown in Appendix H.

(99) *(a) Nomenclature.* The nomenclature below is used in the pressure design of branch connections. It is illustrated in Fig. 304.3.3, which does not indicate details for construction or welding. Some of the terms defined in Appendix J are subject to further definitions or variations, as follows:

b = subscript referring to branch

d_1 = effective length removed from pipe at branch. For branch intersections where the branch opening is a projection of the branch pipe inside diameter (e.g., pipe-to-pipe fabricated branch), $d_1 = [D_h - 2(T_b - c)]/\sin\beta$

d_2 = "half width" of reinforcement zone
= d_1 or $(T_b - c) + (T_h - c) + d_1/2$, whichever is greater, but in any case not more than D_h

h = subscript referring to run or header

L_4 = height of reinforcement zone outside of run pipe
= $2.5(T_h - c)$ or $2.5(T_b - c) + T_r$, whichever is less

T_b = branch pipe thickness (measured or minimum per purchase specification) except for branch connection fittings (see para. 300.2). For such connections the value of T_b for use in calculating L_4, d_2, and A_3, is the thickness of the reinforcing barrel (minimum per purchase specification) provided that the barrel thickness is uniform (see Fig. K328.5.4) and extends at least to the L_4 limit (see Fig. 304.3.3).

T_r = minimum thickness of reinforcing ring or saddle made from pipe. (Use nominal thickness if made from plate.)
= 0, if there is no reinforcing ring or saddle

t = pressure design thickness of pipe, according to the appropriate wall thickness equation or procedure in para. 304.1. For welded pipe, when the branch does not intersect the longitudinal weld of the run, the basic allowable stress S for the pipe may be used in determining t_h for the purpose of reinforcement calculation only. When the branch does intersect the longitudinal weld of the run, the product SE (of the stress value S and the appropriate weld joint quality factor E_j from Table A-1B) for the run pipe shall be used in the calculation. The product SE of the branch shall be used in calculating t_b.

β = smaller angle between axes of branch and run

(b) Required Reinforcement Area. The reinforcement area A_1 required for a branch connection under internal pressure is

$$A_1 = t_h d_1 (2 - \sin\beta) \quad (6)$$

For a branch connection under external pressure, area A_1 is one-half the area calculated by Eq. (6), using as t_h the thickness required for external pressure.

(c) Available Area. The area available for reinforcement is defined as

$$A_2 + A_3 + A_4 \geq A_1 \quad (6a)$$

These areas are all within the reinforcement zone and are further defined below.

(1) Area A_2 is the area resulting from excess thickness in the run pipe wall:

$$A_2 = (2d_2 - d_1)(T_h - t_h - c) \quad (7)$$

(2) Area A_3 is the area resulting from excess thickness in the branch pipe wall: A00

$$A_3 = 2L_4(T_b - t_b - c)/\sin\beta \quad (8)$$

If the allowable stress for the branch pipe wall is less than that for the run pipe, its calculated area must be reduced in the ratio of allowable stress values of

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the branch to the run in determining its contributions to area A_3.

(3) Area A_4 is the area of other metal provided by welds and properly attached reinforcement. [See para. 304.3.3(f).] Weld areas shall be based on the minimum dimensions specified in para. 328.5.4, except

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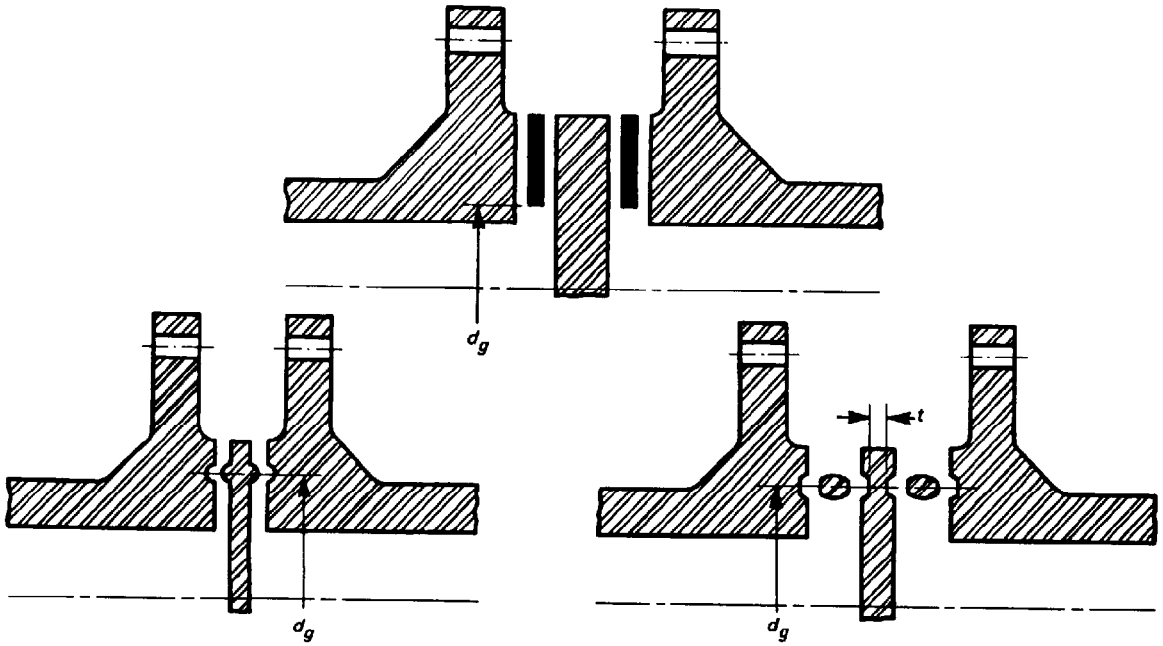

FIG. 304.5.3 BLANKS

paras. 304.7.2(a), (b), (c), or (d), and (e) shall be available for the owner's approval:

(a) extensive, successful service experience under comparable conditions with similarly proportioned components of the same or like material;

(b) experimental stress analysis, such as described in the BPV Code, Section VIII, Division 2, Appendix 6;

(c) proof test in accordance with either ASME B16.9, MSS SP-97, or Section VIII, Division 1, UG-101;

(d) detailed stress analysis (e.g., finite element method) with results evaluated as described in Section VIII, Division 2, Appendix 4, Article 4-1. The basic allowable stress from Table A-1 shall be used in place of S_m in Division 2. At design temperatures in the creep range, additional considerations beyond the scope of Division 2 may be necessary.

(e) For any of the above, the designer may interpolate between sizes, wall thicknesses, and pressure classes, and may determine analogies among related materials.

304.7.3 Metallic Components With Nonmetallic Pressure Parts. Components not covered by standards listed in Table 326.1, in which both metallic and nonmetallic parts contain the pressure, shall be evaluated by applicable requirements of para. A304.7.2 as well as those of para. 304.7.2.

304.7.4 Expansion Joints

(a) Metallic Bellows Expansion Joints. The design of bellows type expansion joints shall be in accordance with Appendix X. See also Appendix F, para. F304.7.4 for further design considerations.

(b) Slip Type Expansion Joints

(1) Pressure containing elements shall be in accordance with para. 318 and other applicable requirements of this Code.

(2) External piping loads shall not impose excessive bending on the joint.

(3) The effective pressure thrust area shall be computed using the outside diameter of the pipe.

(c) Other Types of Expansion Joint. The design of other types of expansion joint shall be qualified as required by para. 304.7.2.

PART 3
FLUID SERVICE REQUIREMENTS FOR PIPING COMPONENTS

305 PIPE

Pipe includes components designated as "tube" or "tubing" in the material specification, when intended for pressure service.

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305.1 General

Listed pipe may be used in Normal Fluid Service except as stated in paras. 305.2.1 and 305.2.2. Unlisted pipe may be used only as provided in para. 302.2.3.

305.2 Specific Requirements

305.2.1 Pipe for Category D Fluid Service. The following carbon steel pipe may be used only for Category D Fluid Service:

API 5L, Furnace Butt-Welded
ASTM A 53, Type F
ASTM A 134 made from other than ASTM A 285 plate

305.2.2 Pipe Requiring Safeguarding. When used for other than Category D Fluid Service, the following carbon steel pipe shall be safeguarded:

ASTM A 134 made from ASTM A 285 plate
ASTM A 139

305.2.3 Pipe for Severe Cyclic Conditions. Only the following pipe[7] may be used under severe cyclic conditions:

(a) Carbon Steel Pipe
API 5L, Grade A or B, seamless
API 5L, Grade A or B, SAW, str. seam, $E_j \geq 0.95$
API 5L, Grade X42, seamless
API 5L, Grade X46, seamless
API 5L, Grade X52, seamless
API 5L, Grade X56, seamless
API 5L, Grade X60, seamless
ASTM A 53, seamless
ASTM A 106
ASTM A 333, seamless
ASTM A 369
ASTM A 381, $E_j \geq 0.90$
ASTM A 524
ASTM A 671, $E_j \geq 0.90$
ASTM A 672, $E_j \geq 0.90$
ASTM A 691, $E_j \geq 0.90$

(b) Low and Intermediate Alloy Steel Pipe
ASTM A 333, seamless
ASTM A 335
ASTM A 369
ASTM A 426, $E_c \geq 0.90$
ASTM A 671, $E_j \geq 0.90$
ASTM A 672, $E_j \geq 0.90$
ASTM A 691, $E_j \geq 0.90$

(c) Stainless Steel Alloy Pipe A00
ASTM A 268, seamless
ASTM A 312, seamless
ASTM A 358, $E_j \geq 0.90$
ASTM A 376
ASTM A 451, $E_c \geq 0.90$

(d) Copper and Copper Alloy Pipe
ASTM B 42
ASTM B 466

(e) Nickel and Nickel Alloy Pipe
ASTM B 161
ASTM B 165
ASTM B 167
ASTM B 407

(f) Aluminum Alloy Pipe
ASTM B 210, Tempers 0 and H112
ASTM B 241, Tempers 0 and H112

306 FITTINGS, BENDS, MITERS, LAPS, AND BRANCH CONNECTIONS

Fittings, bends, miters, laps, and branch connections may be used in accordance with paras. 306.1 through 306.5. Pipe and other materials used in such components shall be suitable for the manufacturing or fabrication process and the fluid service.

306.1 Pipe Fittings

306.1.1 Listed Fittings. Listed fittings may be used in Normal Fluid Service in accordance with para. 303.

306.1.2 Unlisted Fittings. Unlisted fittings may be used only in accordance with para. 302.2.3.

306.1.3 Specific Fittings

(a) Proprietary welding branch outlet fittings which (99) have been design proof tested successfully as prescribed in ASME B16.9, MSS SP-97 or the BPV Code, Section VIII, Division 1, UG-101 may be used within their established ratings.

(b) The lap thickness of a proprietary "Type C" lap-joint stub-end buttwelding fitting shall conform to the requirements of para. 306.4.2 for flared laps.

306.1.4 Fittings for Severe Cyclic Conditions

(a) Only the following fittings may be used under severe cyclic conditions:

(1) forged;

(2) wrought, with factor $E_j \geq 0.90$;[8] or

[7] Casting or joint factors E_c or E_j specified for cast or welded pipe which do not correspond with E factors in Table A-1A or A-1B are established in accordance with paras. 302.3.3 and 302.3.4.

[8] See paras. 302.3.3 and 302.3.4.

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(3) cast, with factor $E_c \geq 0.90$.[8]

A00 *(b)* Fittings conforming to MSS SP-43, MSS SP-119, and proprietary "Type C" lap-joint stub-end welding fittings shall not be used under severe cyclic conditions.

306.2 Pipe Bends

306.2.1 General. A pipe bend made in accordance with paras. 332.2.1 and 332.2.2, and verified for pressure design in accordance with para. 304.2.1, is suitable for the same service as the pipe from which it is made.

306.2.2 Corrugated and Other Bends. Bends of other designs (such as creased or corrugated) shall be qualified for pressure design as required by para. 304.7.2.

306.2.3 Bends for Severe Cyclic Conditions. A pipe bend designed as creased or corrugated shall not be used under severe cyclic conditions.

306.3 Miter Bends

306.3.1 General. Except as stated in para. 306.3.2, a miter bend made in accordance with para. 304.2.3 and welded in accordance with para. 311.1 is suitable for use in Normal Fluid Service.

306.3.2 Miter Bends for Category D Fluid Service. A miter bend which makes a change in direction at a single joint (angle α in Fig. 304.2.3) greater than 45 deg, or is welded in accordance with para. 311.2.1, may be used only for Category D Fluid Service.

306.3.3 Miter Bends for Severe Cyclic Conditions. A miter bend to be used under severe cyclic conditions shall be made in accordance with para. 304.2.3 and welded in accordance with para. 311.2.2, and shall have an angle α (see Fig. 304.2.3) $\leq$ 22.5 deg.

306.4 Fabricated or Flared Laps

The following requirements do not apply to fittings conforming to para. 306.1, nor to laps integrally hot-forged on pipe ends.

306.4.1 Fabricated Laps. A fabricated lap is suitable for use in Normal Fluid Service, provided that all of the following conditions are met.

(a) The outside diameter of the lap shall be in accordance with the dimension of an ASME B16.9 lap-joint stub end.

(b) The lap thickness shall be at least equal to the nominal wall thickness of the pipe to which it is attached.

(c) The lap material shall be listed in Table A-1 and shall have an allowable stress at least as great as that of the pipe.

(d) Welding shall be in accordance with para. 311.1 and fabrication shall be in accordance with para. 328.5.5.

306.4.2 Flared Laps. A flared lap is suitable for use in Normal Fluid Service, provided that all of the following conditions are met.

(a) The outside diameter of the lap shall be in accordance with the dimension of an ASME B16.9 lap-joint stub end.

(b) The radius of fillet of the flared lap shall not exceed 3 mm ($\frac{1}{8}$ in.), and the backing flange shall meet the requirements of para. 308.2.5.

(c) The lap thickness, measured at any point, shall be at least 95% of the minimum pipe wall thickness T multiplied by the ratio of the pipe outside radius to the radius at which the lap thickness is measured.

(d) Pressure design shall be qualified as required by para. 304.7.2.

306.4.3 Laps for Severe Cyclic Conditions

(a) A fabricated lap to be used under severe cyclic conditions shall conform to the requirements of para. 306.4.1, except that welding shall be in accordance with para. 311.2.2, with fabrication limited to a detail equivalent to Fig. 328.5.5 sketch (d) or (e).

(b) Flared laps shall not be used under severe cyclic conditions.

306.5 Fabricated Branch Connections

The following requirements do not apply to fittings conforming to para. 306.1.

306.5.1 General. A fabricated branch connection made and verified for pressure design in accordance with para. 304.3, and welded in accordance with para. 311.1, is suitable for use in Normal Fluid Service.

306.5.2 Fabricated Branch Connections for Severe Cyclic Conditions. A fabricated branch connection to be used under severe cyclic conditions shall conform to the requirements of para. 306.5.1, except that welding shall be in accordance with para. 311.2.2, with fabrication limited to a detail equivalent to Fig. 328.5.4D sketch (2) or (4), or to Fig. 328.5.4E.

307 VALVES AND SPECIALTY COMPONENTS

The following requirements for valves shall also be met as applicable by other pressure containing piping

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components, such as traps, strainers, and separators. See also Appendix F, paras. F301.4 and F307.

307.1 General

307.1.1 Listed Valves. A listed valve is suitable for use in Normal Fluid Service, except as stated in para. 307.2.

307.1.2 Unlisted Valves. Unlisted valves may be used only in accordance with para. 302.2.3. Unless pressure-temperature ratings are established by the method set forth in Appendix F to ASME B16.34, pressure design shall be qualified as required by para. 304.7.2.

307.2 Specific Requirements

A bolted bonnet valve whose bonnet is secured to the body by less than four bolts, or by a U-bolt, may be used only for Category D Fluid Service.

308 FLANGES, BLANKS, FLANGE FACINGS, AND GASKETS

308.1 General

308.1.1 Listed Components. A listed flange, blank, or gasket is suitable for use in Normal Fluid Service, except as stated elsewhere in para. 308.

308.1.2 Unlisted Components. Unlisted flanges, blanks, and gaskets may be used only in accordance with para. 302.2.3.

(99) ### 308.2 Specific Requirements for Flanges

See Appendix F, paras. F308.2 and F312.

308.2.1 Slip-On Flanges

(a) A slip-on flange shall be double-welded as shown in Fig. 328.5.2B when the service is:

(1) subject to severe erosion, crevice corrosion, or cyclic loading;

(2) flammable, toxic, or damaging to human tissue;

(3) under severe cyclic conditions;

(4) at temperatures below −101°C (−150°F).

(b) The use of slip-on flanges should be avoided where many large temperature cycles are expected, particularly if the flanges are not insulated.

(c) Slip-on Flanges as Lapped Flanges. A slip-on flange may be used as a lapped flange only as shown in Table 308.2.1 unless pressure design is qualified in accordance with para. 304.5.1. A corner radius or bevel shall conform to one of the following as applicable:

(1) for an ASME B16.9 lap joint stub end or a forged lap (see para. 306.4.3) the corner radius shall be as specified in ASME B16.5, Tables 9 and 12, dimension *r*.

(2) for a fabricated lap, the corner bevel shall be at least half the nominal thickness of the pipe to which the lap is attached (see Fig. 328.5.5).

(3) for a flared lap see para. 308.2.5.

TABLE 308.2.1
PERMISSIBLE SIZES/RATING CLASSES FOR SLIP-ON FLANGES USED AS LAPPED FLANGES[1]

Rating		Maximum Flange Size	
PN	Class	DN	NPS
20	150	300	12
50	300	200	8

NOTE:
(1) Actual thickness of flange at bolt circle shall at least equal minimum required flange thickness in ASME B16.5.

308.2.2 Expanded-Joint Flanges. A flange having an expanded-joint insert is subject to the requirements for expanded joints in para. 313.

308.2.3 Socket Welding and Threaded Flanges. A socket welding flange is subject to the requirements for socket welds in para. 311.2.4. A threaded flange is subject to the requirements for threaded joints in para. 314.4.

308.2.4 Flanges for Severe Cyclic Conditions. Unless it is safeguarded, a flange to be used under severe cyclic conditions shall be welding neck conforming to ASME B16.5 or ASME B16.47, or a similarly proportioned flange designed in accordance with para. 304.5.1.

308.2.5 Flanges for Flared Metallic Laps. For a flange used with a flared metallic lap (para. 306.4.2), the intersection of face and bore shall be beveled or rounded approximately 3 mm (⅛ in.). See also para. 308.2.1(c).

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308.3 Flange Facings

The flange facing shall be suitable for the intended service and for the gasket and bolting employed.

308.4 Gaskets

Gaskets shall be selected so that the required seating load is compatible with the flange rating and facing, the strength of the flange, and its bolting. Materials shall be suitable for the service conditions. See also Appendix F, para. F308.4.

309 BOLTING

Bolting includes bolts, bolt studs, studs, cap screws, nuts, and washers. See also Appendix F, para. F309.

309.1 General

309.1.1 Listed Bolting. Listed bolting is suitable for use in Normal Fluid Service, except as stated elsewhere in para. 309.

309.1.2 Unlisted Bolting. Unlisted bolting may be used only in accordance with para. 302.2.3.

309.1.3 Bolting for Components. Bolting for components conforming to a listed standard shall be in accordance with that standard if specified therein.

309.1.4 Selection Criteria. Bolting selected shall be adequate to seat the gasket and maintain joint tightness under all design conditions.

309.2 Specific Bolting

309.2.1 Low Yield Strength Bolting. Bolting having not more than 207 MPa (30 ksi) specified minimum yield strength shall not be used for flanged joints rated ASME B16.5 PN 68 (Class 400) and higher, nor for flanged joints using metallic gaskets, unless calculations have been made showing adequate strength to maintain joint tightness.

309.2.2 Carbon Steel Bolting. Except where limited by other provisions of this Code, carbon steel bolting may be used with nonmetallic gaskets in flanged joints rated ASME B16.5 PN 50 (Class 300) and lower for bolt metal temperatures at −29°C to 204°C (−20°F to 400°F), inclusive. If these bolts are galvanized, heavy hexagon nuts, threaded to suit, shall be used.

A00 **309.2.3 Bolting for Metallic Flange Combinations.** Any bolting which meets the requirements of para. 309 may be used with any combination of flange material and facing. If either flange is to the ASME B16.1, ASME B16.24, MSS SP-42, or MSS SP-51 specification, the bolting material shall be no stronger than low yield strength bolting unless:

(a) both flanges have flat faces and a full face gasket is used; or,

(b) sequence and torque limits for bolt-up are specified, with consideration of sustained loads, displacement strains, and occasional loads (see paras. 302.3.5 and 302.3.6), and strength of the flanges.

309.2.4 Bolting for Severe Cyclic Conditions. Low yield strength bolting (see para. 309.2.1) shall not be used for flanged joints under severe cyclic conditions.

309.3 Tapped Holes

Tapped holes for pressure retaining bolting in metallic piping components shall be of sufficient depth that the thread engagement will be at least seven-eighths times the nominal thread diameter.

PART 4
FLUID SERVICE REQUIREMENTS FOR PIPING JOINTS

310 GENERAL

Piping joints shall be selected to suit the piping material and the fluid service, with consideration of joint tightness and mechanical strength under expected service and test conditions of pressure, temperature, and external loading.

311 WELDED JOINTS

Joints may be made by welding in any material for which it is possible to qualify welding procedures, welders, and welding operators in conformance with the rules in Chapter V.

311.1 General

Except as provided in paras. 311.2.1 and 311.2.2, welds shall conform to the following.

(a) Welding shall be in accordance with para. 328.

(b) Preheating and heat treatment shall be in accordance with paras. 330 and 331, respectively.

(c) Examination shall be in accordance with para. 341.4.1.

(d) Acceptance criteria shall be those in Table 341.3.2 for Normal Fluid Service.

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311.2 Specific Requirements

311.2.1 Welds for Category D Fluid Service. Welds which meet the requirements of para. 311.1, but for which examination is in accordance with para. 341.4.2, and acceptance criteria are those in Table 341.3.2 for Category D Fluid Service, may be used only in that service.

311.2.2 Welds for Severe Cyclic Conditions. Welds for use under severe cyclic conditions shall meet the requirements of para. 311.1 with the exceptions that examination shall be in accordance with para. 341.4.3, and acceptance criteria shall be those in Table 341.3.2 for severe cyclic conditions.

311.2.3 Backing Rings and Consumable Inserts

(a) If a backing ring is used where the resulting crevice is detrimental (e.g., subject to corrosion, vibration, or severe cyclic conditions), it should be removed and the internal joint face ground smooth. When it is impractical to remove the backing ring in such a case, consideration shall be given to welding without backing rings or to the use of consumable inserts or removable nonmetallic backing rings.

(b) Split backing rings shall not be used under severe cyclic conditions.

311.2.4 Socket Welds

(a) Socket welded joints (para. 328.5.2) should be avoided in any service where crevice corrosion or severe erosion may occur.

(b) Socket welded joints shall conform to the following.

A00 *(1)* Socket dimensions shall conform to ASME B16.5 for flanges and ASME B16.11 or MSS SP-119 for other socket-welding components.

(2) Weld dimensions shall not be less than those shown in Figs. 328.5.2B and 328.5.2C.

(c) Socket welds larger than DN 50 (NPS 2) shall not be used under severe cyclic conditions.

(d) A drain or bypass in a component may be attached by socket welding, provided the socket dimensions conform to Fig. 4 in ASME B16.5.

311.2.5 Fillet Welds

(a) Fillet welds in accordance with para. 328.5.2 may be used as primary welds to attach socket welding components and slip-on flanges.

(b) Fillet welds may also be used to attach reinforcement and structural attachments, to supplement the strength or reduce stress concentration of primary welds, and to prevent disassembly of joints.

311.2.6 Seal Welds. Seal welds (para. 328.5.3) may be used only to prevent leakage of threaded joints and shall not be considered as contributing any strength to the joints.

312 FLANGED JOINTS

312.1 Joints Using Flanges of Different Ratings

Where flanges of different ratings are bolted together, the rating of the joint shall not exceed that of the lower rated flange. Bolting torque shall be limited so that excessive loads will not be imposed on the lower rated flange in obtaining a tight joint.

312.2 Metal to Nonmetal Flanged Joints

Where a metallic flange is bolted to a nonmetallic flange, both should be flat-faced. A full-faced gasket is preferred. If a gasket extending only to the inner edge of the bolts is used, bolting torque shall be limited so that the nonmetallic flange is not overloaded.

313 EXPANDED JOINTS

(a) Expanded joints shall not be used under severe cyclic conditions. For other services, adequate means shall be provided to prevent separation of the joint. If the fluid is toxic or damaging to human tissue, safeguarding is required.

(b) Consideration shall be given to the tightness of expanded joints when subjected to vibration, differential expansion or contraction due to temperature cycling, or external mechanical loads.

314 THREADED JOINTS

314.1 General

Threaded joints are suitable for Normal Fluid Service except as stated elsewhere in para. 314. They may be used under severe cyclic conditions only as provided in paras. 314.2.1(c) and 314.2.2.

(a) Threaded joints should be avoided in any service where crevice corrosion, severe erosion, or cyclic loading may occur.

(b) When threaded joints are intended to be seal welded, thread sealing compound shall not be used.

(c) Layout of piping employing threaded joints should, insofar as possible, minimize stress on joints, giving special consideration to stresses due to thermal expansion and operation of valves (particularly a valve

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(e) Attachments welded or bonded to the piping shall be of a material compatible with the piping and service. For other requirements, see para. 321.3.2.

321.1.5 Threads. Screw threads shall conform to ANSI B1.1 unless other threads are required for adjustment under heavy loads. Turnbuckles and adjusting nuts shall have the full length of internal threads engaged. Any threaded adjustment shall be provided with a locknut, unless locked by other means.

321.2 Fixtures

321.2.1 Anchors and Guides

(a) A supporting element used as an anchor shall be designed to maintain an essentially fixed position.

(b) To protect terminal equipment or other (weaker) portions of the system, restraints (such as anchors and guides) shall be provided where necessary to control movement or to direct expansion into those portions of the system which are designed to absorb them. The design, arrangement, and location of restraints shall ensure that expansion joint movements occur in the directions for which the joint is designed. In addition to the other thermal forces and moments, the effects of friction in other supports of the system shall be considered in the design of such anchors and guides.

A00 *(c)* Piping layout, anchors, restraints, guides, and supports for all types of expansion joints shall be designed in accordance with para. X301.2 of Appendix X.

321.2.2 Inextensible Supports Other Than Anchors and Guides[10]

(a) Supporting elements shall be designed to permit the free movement of piping caused by thermal expansion and contraction.

(b) Hangers include pipe and beam clamps, clips, brackets, rods, straps, chains, and other devices. They shall be proportioned for all required loads. Safe loads for threaded parts shall be based on the root area of the threads.

(c) Sliding Supports. Sliding supports (or shoes) and brackets shall be designed to resist the forces due to friction in addition to the loads imposed by bearing. The dimensions of the support shall provide for the expected movement of the supported piping.

321.2.3 Resilient Supports[10]

(a) Spring supports shall be designed to exert a supporting force, at the point of attachment to the pipe, equal to the load as determined by weight balance calculations. They shall be provided with means to prevent misalignment, buckling, or eccentric loading of the springs, and to prevent unintentional disengagement of the load.

(b) Constant-support spring hangers provide a substantially uniform supporting force throughout the range of travel. The use of this type of spring hanger is advantageous at locations subject to appreciable movement with thermal changes. Hangers of this type should be selected so that their travel range exceeds expected movements.

(c) Means shall be provided to prevent overstressing spring hangers due to excessive deflections. It is recommended that all spring hangers be provided with position indicators.

321.2.4 Counterweight Supports. Counterweights shall be provided with stops to limit travel. Weights shall be positively secured. Chains, cables, hangers, rocker arms, or other devices used to attach the counterweight load to the piping shall be subject to the requirements of para. 321.2.2.

321.2.5 Hydraulic Supports. An arrangement utilizing a hydraulic cylinder may be used to give a constant supporting force. Safety devices and stops shall be provided to support the load in case of hydraulic failure.

321.3 Structural Attachments

External and internal attachments to piping shall be designed so that they will not cause undue flattening of the pipe, excessive localized bending stresses, or harmful thermal gradients in the pipe wall. It is important that attachments be designed to minimize stress concentration, particularly in cyclic services.

321.3.1 Nonintegral Attachments. Nonintegral attachments, in which the reaction between the piping and the attachment is by contact, include clamps, slings, cradles, U-bolts, saddles, straps, and clevises. If the weight of a vertical pipe is supported by a clamp, it is recommended to prevent slippage that the clamp be located below a flange, fitting, or support lugs welded to the pipe.

321.3.2 Integral Attachments. Integral attachments include plugs, ears, shoes, plates, and angle clips, cast on or welded to the piping. The material for integral attachments attached by welding shall be of good weldable quality. [See para. 321.1.4(e) for material requirements.] Preheating, welding, and heat treatment

[10] Various types of inextensible (solid) and resilient supports are illustrated in MSS SP-58.

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shall be in accordance with Chapter V. Consideration shall be given to the localized stresses induced in the piping component by welding the integral attachment.

(a) Integral reinforcement, complete encirclement reinforcement, or intermediate pads of suitable alloy and design may be used to reduce contamination or undesirable heat effects in alloy piping.

(b) Intermediate pads, integral reinforcement, complete encirclement reinforcement, or other means of reinforcement may be used to distribute stresses.

321.4 Structural Connections

The load from piping and pipe supporting elements (including restraints and braces) shall be suitably transmitted to a pressure vessel, building, platform, support structure, foundation, or to other piping capable of bearing the load without deleterious effects.

PART 6
SYSTEMS

322 SPECIFIC PIPING SYSTEMS

322.3 Instrument Piping

322.3.1 Definition. Instrument piping within the scope of this Code includes all piping and piping components used to connect instruments to other piping or equipment, and control piping used to connect air or hydraulically operated control apparatus. It does not include instruments, or permanently sealed fluid-filled tubing systems furnished with instruments as temperature or pressure responsive devices.

322.3.2 Requirements. Instrument piping shall meet the applicable requirements of the Code and the following.

(a) The design pressure and temperature for instrument piping shall be determined in accordance with para. 301. If more severe conditions are experienced during blowdown of the piping, they may be treated as occasional variations in accordance with para. 302.2.4.

(b) Consideration shall be given to the mechanical strength (including fatigue) of small instrument connections to piping or apparatus (see para. 304.3.5).

(c) Instrument piping containing fluids which are normally static and subject to freezing shall be protected by heat tracing or other heating methods, and insulation.

(d) If it will be necessary to blow down (or bleed) instrument piping containing toxic or flammable fluids, consideration shall be given to safe disposal.

322.6 Pressure Relieving Systems

Pressure relieving systems within the scope of this Code shall conform to the following requirements. See also Appendix F, para. F322.6.

322.6.1 Stop Valves in Pressure Relief Piping. If one or more stop valves are installed between the piping being protected and its protective device or devices, or between the protective device or devices and the point of discharge, they shall meet the requirements of (a) and either (b) or (c), below.

(a) A full-area stop valve may be installed on the inlet side of a pressure relieving device. A full area stop valve may be placed on the discharge side of a pressure relieving device when its discharge is connected to a common header with other discharge lines from other pressure relieving devices. Stop valves of less than full area may be used on both the inlet side and discharge side of pressure relieving devices as outlined herein if the stop valves are of such type and size that the increase in pressure drop will not reduce the relieving capacity below that required, nor adversely affect the proper operation of the pressure relieving device.

(b) Stop valves to be used in pressure relief piping shall be so constructed or positively controlled that the closing of the maximum number of block valves possible at one time will not reduce the pressure relieving capacity provided by the unaffected relieving devices below the required relieving capacity.

(c) As an alternative to (b) above, stop valves shall be so constructed and arranged that they can be locked or sealed in either the open or closed position. See Appendix F, para. F322.6.

322.6.2 Pressure Relief Discharge Piping. Discharge lines from pressure relieving safety devices shall be designed to facilitate drainage. When discharging directly to the atmosphere, discharge shall not impinge on other piping or equipment and shall be directed away from platforms and other areas used by personnel. Reactions on the piping system due to actuation of safety relief devices shall be considered, and adequate strength shall be provided to withstand these reactions.

322.6.3 Pressure Relieving Devices

(a) Pressure relieving devices required by para. 301.2.2(a) shall be in accordance with the BPV Code, Section VIII, Division 1, UG-125(c), UG-126 through UG-128, and UG-132 through UG-136, excluding UG-

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CHAPTER III
MATERIALS

323 GENERAL REQUIREMENTS

Chapter III states limitations and required qualifications for materials based on their inherent properties. Their use in piping is also subject to requirements and limitations in other parts of this Code [see para. 300(d)]. See also para. 321.1.4 for support materials, and Appendix F, para. F323, for precautionary considerations.

323.1 Materials and Specifications

323.1.1 Listed Materials. Any material used in pressure containing piping components shall conform to a listed specification except as provided in para. 323.1.2.

323.1.2 Unlisted Materials. Unlisted materials may be used provided they conform to a published specification covering chemistry, physical and mechanical properties, method and process of manufacture, heat treatment, and quality control, and otherwise meet the requirements of this Code. Allowable stresses shall be determined in accordance with the applicable allowable stress basis of this Code or a more conservative basis.

323.1.3 Unknown Materials. Materials of unknown specification shall not be used for pressure-containing piping components.

323.1.4 Reclaimed Materials. Reclaimed pipe and other piping components may be used, provided they are properly identified as conforming to a listed or published specification (para. 323.1.1 or 323.1.2) and otherwise meet the requirements of this Code. Sufficient cleaning and inspection shall be made to determine minimum wall thickness and freedom from imperfections which would be unacceptable in the intended service.

323.2 Temperature Limitations

The designer shall verify that materials which meet other requirements of the Code are suitable for service throughout the operating temperature range. Attention is directed to Note (7) in Appendix A, which explains the means used to set both cautionary and restrictive temperature limits in Tables A-1 and A-2.

323.2.1 Upper Temperature Limits, Listed Materials. A listed material may be used at a temperature above the maximum for which a stress value or rating is shown, only if:

(a) there is no prohibition in Appendix A or elsewhere in the Code; and

(b) the designer verifies the serviceability of the material in accordance with para. 323.2.4.

323.2.2 Lower Temperature Limits, Listed Materials A00

(a) A listed material may be used at any temperature not lower than the minimum shown in Table A-1, provided that the base metal, weld deposits, and heat-affected zone (HAZ) are qualified as required by the applicable entry in Column A of Table 323.2.2.

(b) For carbon steels with a letter designation in the Min. Temp. column of Table A-1, the minimum temperature is defined by the applicable curve and Notes in Fig. 323.2.2A. If a design minimum metal temperature-thickness combination is on or above the curve, impact testing is not required.

(c) A listed material may be used at a temperature lower than the minimum shown in Table A-1 or Fig. 323.2.2A (including Notes), unless prohibited in Table 323.2.2, Table A-1, or elsewhere in the Code, and provided that the base metal, weld deposits, and HAZ are qualified as required by the applicable entry in Column B of Table 323.2.2.

(d) Where the Stress Ratio defined in Fig. 323.2.2B is less than one, Fig. 323.2.2B provides a further basis for the use of carbon steels covered by paras. 323.2.2(a) and (b), without impact testing.

(1) For design minimum temperatures of −48°C (−55°F) and above, the minimum design metal temperature without impact testing determined in para. 323.2.2(b), for the given material and thickness, may be reduced by the amount of the temperature reduction provided in Fig. 323.2.2B for the applicable Stress Ratio. If the resulting temperature is lower than the minimum design metal temperature, impact testing of

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TABLE 323.2.2
REQUIREMENTS FOR LOW TEMPERATURE TOUGHNESS TESTS FOR METALS
These Toughness Test Requirements Are in Addition to Tests Required by the Material Specification

	Type of Material	Column A Design Minimum Temperature at or Above Min. Temp. in Table A-1 or Fig. 323.2.2A		Column B Design Minimum Temperature Below Min. Temp. in Table A-1 or Fig. 323.2.2A
Listed materials — Materials	1 Gray cast iron	A-1 No additional requirements		B-1 No additional requirements
	2 Malleable and ductile cast iron; carbon steel per Note (1)	A-2 No additional requirements		B-2 Materials designated in Box 2 shall not be used.
		(a) Base Metal	(b) Weld Metal and Heat Affected Zone (HAZ) [Note (2)]	
	3 Other carbon steels; low and intermediate alloy steels; high alloy ferritic steels; duplex stainless steels	A-3 (a) No additional requirements	A-3 (b) Weld metal deposits shall be impact tested per para. 323.3 if design min. temp. < −29°C (−20°F), except as provided in Notes (3) and (5), and except as follows: for materials listed for Curves C and D of Fig. 323.2.2A, where corresponding welding consumables are qualified by impact testing at the design minimum temperature or lower in accordance with the applicable AWS specification, additional testing is not required.	B-3 Except as provided in Notes (3) and (5), heat treat base metal per applicable ASTM specification listed in para. 323.3.2; then impact test base metal, weld deposits, and HAZ per para. 323.3 [see Note (2)]. When materials are used at design min. temp. below the assigned curve as permitted by Notes (2) and (3) of Fig. 323.2.2A, weld deposits and HAZ shall be impact tested [see Note (2)].
	4 Austenitic stainless steels	A-4 (a) If: (1) carbon content by analysis > 0.1%; or (2) material is not in solution heat treated condition; then, impact test per para. 323.3 for design min. temp. < −29°C (−20°F) except as provided in Notes (3) and (6)	A-4 (b) Weld metal deposits shall be impact tested per para. 323.3 if design min. temp. < −29°C (−20°F) except as provided in para. 323.2.2 and in Notes (3) and (6)	B-4 Base metal and weld metal deposits shall be impact tested per para. 323.3. See Notes (2), (3), and (6).
	5 Austenitic ductile iron, ASTM A 571	A-5 (a) No additional requirements	A-5 (b) Welding is not permitted	B-5 Base metal shall be impact tested per para. 323.3. Do not use < −196°C (−320°F). Welding is not permitted.
	6 Aluminum, copper, nickel, and their alloys; unalloyed titanium	A-6 (a) No additional requirements	A-6 (b) No additional requirements unless filler metal composition is outside the range for base metal composition; then test per column B-6	B-6 Designer shall be assured by suitable tests [see Note (4)] that base metal, weld deposits, and HAZ are suitable at the design min. temp.
Unlisted	7 An unlisted material shall conform to a published specification. Where composition, heat treatment, and product form are comparable to those of a listed material, requirements for the corresponding listed material shall be met. Other unlisted materials shall be qualified as required in the applicable section of column B.			

Notes to this Table follow on next page

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TABLE 323.2.2 (CONT'D)

NOTES:
(1) Carbon steels conforming to the following are subject to the limitations in Box B-2; plates per ASTM A 36, A 283, and A 570; pipe per ASTM A 134 when made from these plates; and pipe per ASTM A 53 Type F and API 5L Gr. A25 buttweld.
(2) Impact tests that meet the requirements of Table 323.3.1, which are performed as part of the weld procedure qualification, will satisfy all requirements of para. 323.2.2, and need not be repeated for production welds.
(3) Impact testing is not required if the design minimum temperature is below −29°C (−20°F) but at or above −104°C (−155°F) and the Stress Ratio defined in Fig. 323.2.2B does not exceed 0.3 times S.
(4) Tests may include tensile elongation, sharp-notch tensile strength (to be compared with unnotched tensile strength), and/or other tests, conducted at or below design minimum temperature. See also para. 323.3.4.
(5) Impact tests are not required when the maximum obtainable Charpy specimen has a width along the notch of less than 2.5 mm (0.098 in.). Under these conditions, the design minimum temperature shall not be less than the lower of −48°C (−55°F) or the minimum temperature for the material in Table A-1.
(6) Impact tests are not required when the maximum obtainable Charpy specimen has a width along the notch of less than 2.5 mm (0.098 in.).

the material is not required. Where this is applied, the piping system shall also comply with the following requirements:

(a) The piping shall be subjected to a hydrostatic test at no less than 1½ times the design pressure.

(b) Except for piping with a nominal wall thickness of 13 mm (½ in.) or less, the piping system shall be safeguarded (see Appendix G) from external loads such as maintenance loads, impact loads, and thermal shock.

(2) For design minimum temperatures lower than −48°C (−55°F), impact testing is required for all materials, except as provided by Note (3) of Table 323.2.2.

(e) The allowable stress or component rating at any temperature below the minimum shown in Table A-1 or Fig. 323.2.2A shall not exceed the stress value or rating at the minimum temperature in Table A-1 or the component standard.

(f) Impact testing is not required for the following combinations of weld metals and design minimum temperatures:

(1) for austenitic stainless steel base materials having a carbon content not exceeding 0.10%, welded without filler metal, at design minimum temperatures of −101°C (−150°F) and higher.

(2) for austenitic weld metal:

(a) having a carbon content not exceeding 0.10%, and produced with filler metals conforming to AWS A5.4, A5.9, A5.11, A5.14, or A5.22[1] at design minimum temperatures of −101°C (−150°F) and higher; or

(b) having a carbon content exceeding 0.10%, and produced with filler metals conforming to AWS A5.4, A5.9, A5.11, A5.14, or A5.22[1] at design minimum temperatures of −48°C (−55°F) and higher.

323.2.3 Temperature Limits, Unlisted Materials. An unlisted material, acceptable under para. 323.1.2, shall be qualified for service at all temperatures within a stated range, from design minimum temperature to design (maximum) temperature, in accordance with para. 323.2.4.

323.2.4 Verification of Serviceability

(a) When an unlisted material is to be used, or when a listed material is to be used above the highest temperature for which stress values appear in Appendix A, the designer is responsible for demonstrating the validity of the allowable stresses and other limits used in design and of the approach taken in using the material, including the derivation of stress data and the establishment of temperature limits.

(b) Data for the development of design limits shall be obtained from a sound scientific program carried out in accordance with recognized technology for both the material and the intended service conditions. Factors to be considered include:

(1) applicability and reliability of the data, especially for extremes of the temperature range;

(2) resistance of the material to deleterious effects of the fluid service and of the environment throughout the temperature range; and

(3) determination of allowable stresses in accordance with para. 302.3.

323.3 Impact Testing Methods and Acceptance Criteria

323.3.1 General. When impact testing is required by Table 323.2.2, provisions elsewhere in this Code, or the engineering design, it shall be done in accordance

[1] Titles of referenced AWS standards are as follows: AWS A5.4, Stainless Steel Electrodes for Shielded Metal Arc Welding; AWS A5.9, Bare Stainless Steel Welding Electrodes and Rods; AWS A5.11, Nickel and Nickel Alloy Welding Electrodes for Shielded Metal Arc Welding; AWS A5.14, Nickel and Nickel Alloy Bare Welding Electrodes and Rods; and AWS A5.22, Flux Cored Corrosion-Resisting Chromium and Chromium-Nickel Steel Electrodes.

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with Table 323.3.1 using the testing methods and acceptance criteria described in paras. 323.3.2 through 323.3.5.

323.3.2 Procedure. Impact testing of each product form of material for any specification (including welds in the components) shall be done using procedures and apparatus in accordance with ASTM A 370, and in conformance with impact testing requirements of the following specifications, except that specific requirements of this Code which conflict with requirements of those specifications shall take precedence.

Product Form	ASTM Spec. No.
Pipe	A 333
Tube	A 334
Fittings	A 420
Forgings	A 350
Castings	A 352
Bolting	A 320
Plate	A 20

GENERAL NOTE: Titles of referenced standards not listed in the Specifications Index for Appendix A are: A 20 General Requirements for Steel Plates for Pressure Vessels and A 370 Test Methods and Definitions for Mechanical Testing of Steel Products.

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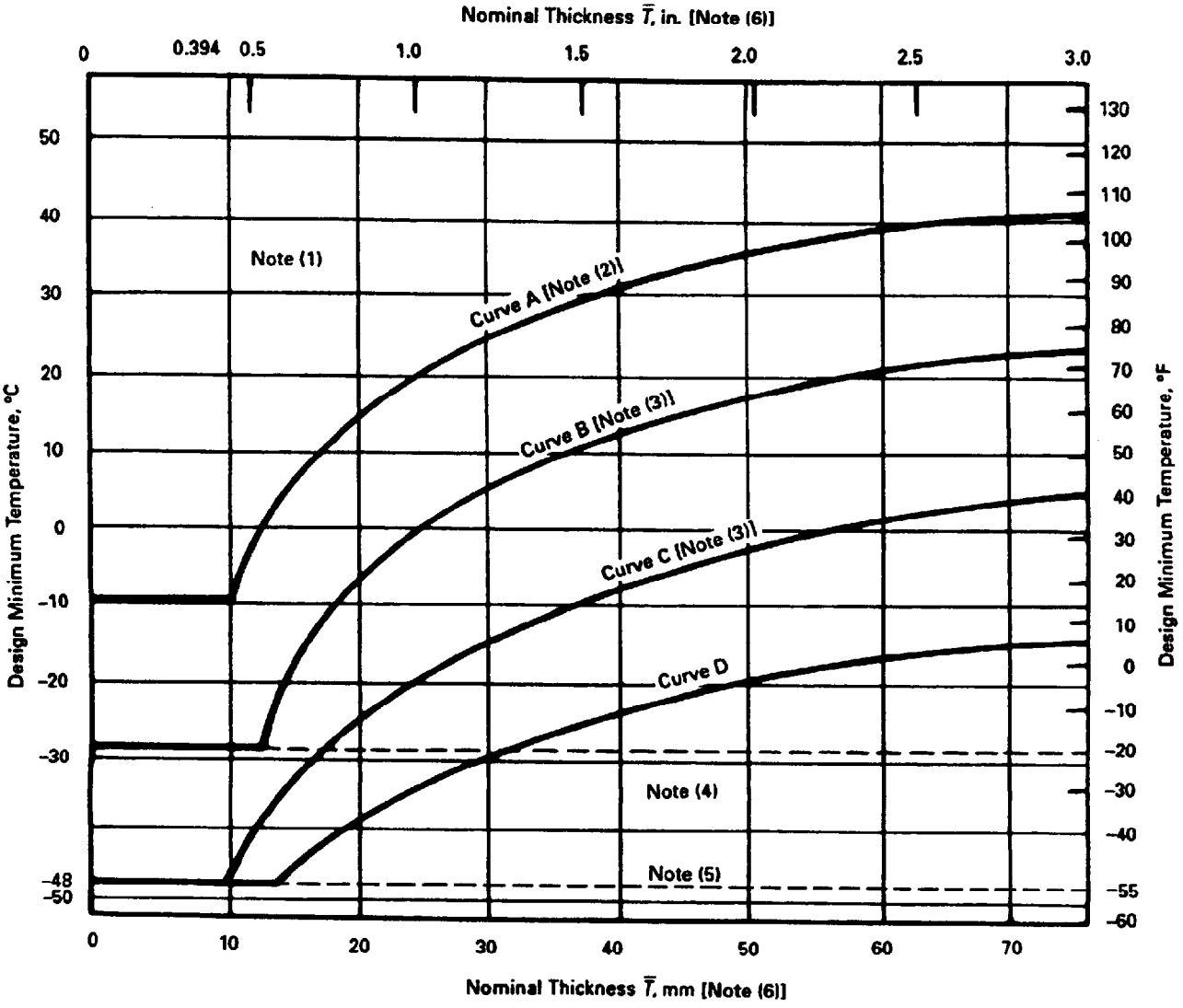
Fig. 323.2.2A



NOTES:
(1) Any carbon steel material may be used to a minimum temperature of -29°C (-20°F) for Category D Fluid Service.
(2) X Grades of API 5L, and ASTM A 381 materials, may be used in accordance with Curve B if normalized or quenched and tempered.
(3) The following materials may be used in accordance with Curve D if normalized:
  (a) ASTM A 516 Plate, all grades;
  (b) ASTM A 671 Pipe, Grades CE55, CE60, and all grades made with A 516 plate;
  (c) ASTM A 672 Pipe, Grades E55, E60, and all grades made with A 516 plate.
(4) A welding procedure for the manufacture of pipe or components shall include impact testing of welds and HAZ for any design minimum temperature below -29°C (-20°F), except as provided in Table 323.2.2, A-3(b).
(5) Impact testing in accordance with para. 323.3 is required for any design minimum temperature below -48°C (-55°F), except as permitted by Note (3) in Table 323.2.2.
(6) For blind flanges and blanks, $\overline{T}$ shall be $^1/_4$ of the flange thickness.

A00 FIG. 323.2.2A MINIMUM TEMPERATURES WITHOUT IMPACT TESTING FOR CARBON STEEL MATERIALS
(See Table A-1 for Designated Curve for a Listed Material)

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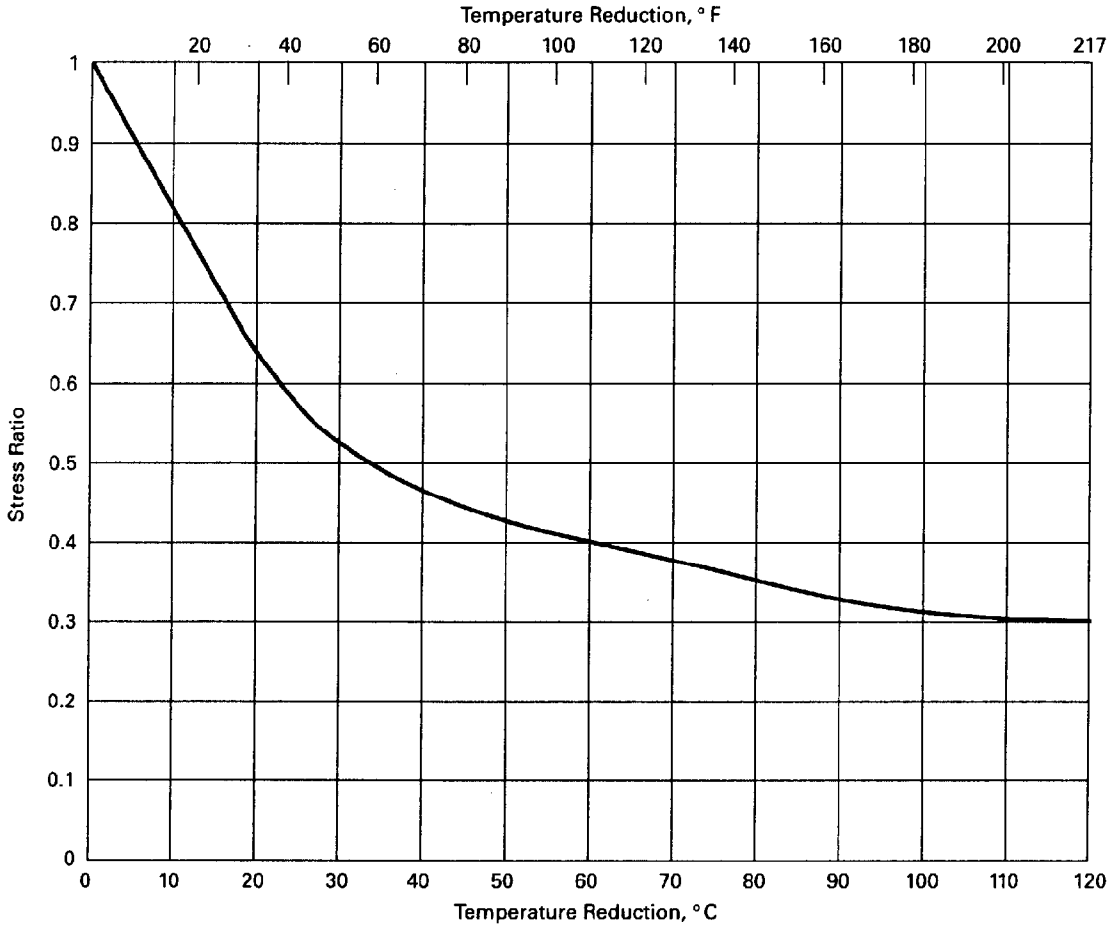

GENERAL NOTES:

(a) The Stress Ratio is defined as the maximum of the following:

(1) nominal pressure stress (based on minimum pipe wall thickness less allowances) divided by S at the design minimum temperature;

(2) for piping components with pressure ratings, the pressure for the condition under consideration divided by the pressure rating at the design minimum temperature;

(3) combined longitudinal stress due to pressure, dead weight, and displacement strain (stress intensification factors are not included in this calculation) divided by S at the design minimum temperature. In calculating longitudinal stress, the forces and moments in the piping system shall be calculated using nominal dimensions and the stresses shall be calculated using section properties based on the nominal dimensions less corrosion, erosion, and mechanical allowances.

(b) Loadings coincident with the metal temperature under consideration shall be used in determining the Stress Ratio as defined above.

A00 FIG. 323.2.2B REDUCTION IN MINIMUM DESIGN METAL TEMPERATURE WITHOUT IMPACT TESTING

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CHAPTER IV
STANDARDS FOR PIPING COMPONENTS

326 DIMENSIONS AND RATINGS OF COMPONENTS

326.1 Dimensional Requirements

326.1.1 Listed Piping Components. Dimensional standards[1] for piping components are listed in Table 326.1. Dimensional requirements contained in specifications listed in Appendix A shall also be considered requirements of this Code.

326.1.2 Unlisted Piping Components. Dimensions of piping components not listed in Table 326.1 or Appendix A shall conform to those of comparable listed components insofar as practicable. In any case, dimensions shall be such as to provide strength and performance equivalent to standard components except as provided in paras. 303 and 304.

326.1.3 Threads. The dimensions of piping connection threads not otherwise covered by a governing component standard or specification shall conform to the requirements of applicable standards listed in Table 326.1 or Appendix A.

[1] It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and address of sponsoring organizations, are shown in Appendix E.

326.2 Ratings of Components

326.2.1 Listed Components. The pressure-temperature ratings of components listed in Table 326.1 are accepted for pressure design in accordance with para. 303.

326.2.2 Unlisted Components. The pressure-temperature ratings of unlisted piping components shall conform to the applicable provisions of para. 304.

326.3 Reference Documents

A00

The documents listed in Table 326.1 contain references to codes, standards, and specifications not listed in Table 326.1. Such unlisted codes, standards, and specifications shall be used only in the context of the listed documents in which they appear.

The design, materials, fabrication, assembly, examination, inspection, and testing requirements of this Code are not applicable to components manufactured in accordance with the documents listed in Table 326.1, unless specifically stated in this Code, or the listed document.

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TABLE 326.1
COMPONENT STANDARDS[1]

Standard or Specification	Designation [Note (2)]
Bolting	
Square and Hex Bolts and Screws, Inch Series, Including Hex Cap Screws and Lag Screws	*ASME B18.2.1
Square and Hex Nuts (Inch Series)	*ASME B18.2.2
Metallic Fittings, Valves, and Flanges	
Cast Iron Pipe Flanges and Flanged Fittings	*ASME B16.1
Malleable Iron Threaded Fittings	*ASME B16.3
Gray Iron Threaded Fittings	*ASME B16.4
Pipe Flanges and Flanged Fittings	*ASME B16.5
Factory-Made Wrought Steel Buttwelding Fittings	*ASME B16.9
Face-to-Face and End-To-End Dimensions of Valves	*ASME B16.10
Forged Fittings, Socket-Welding and Threaded	*ASME B16.11
Ferrous Pipe Plugs, Bushings, and Locknuts With Pipe Threads	*ASME B16.14
Cast Bronze Threaded Fittings, Class 125 and 250 [Notes (3), (4)]	*ASME B16.15
Cast Copper Alloy Solder Joint Pressure Fittings	*ASME B16.18
Wrought Copper and Copper Alloy Solder Joint Pressure Fittings	*ASME B16.22
Bronze Pipe Flanges and Flanged Fittings Class 150, 300, 400, 600, 900, 1500, and 2500 and Flanged Fittings, Class 150 and 300	*ASME B16.24
Cast Copper Alloy Fittings for Flared Copper Tubes	*ASME B16.26
Wrought Steel Buttwelding Short Radius Elbows and Returns [Note (5)]	*ASME B16.28
Valves-Flanged, Threaded, and Welding End	*ASME B16.34
Orifice Flanges, Class 300, 600, 900, 1500, and 2500	*ASME B16.36
Malleable Iron Threaded Pipe Unions, Class 150, 250, and 300	*ASME B16.39
Ductile Iron Pipe Flanges and Flanged Fittings, Class 150 and 300	*ASME B16.42
Large Diameter Steel Flanges, NPS 26 Through NPS 60	*ASME B16.47
Flanged Steel Pressure-Relief Valves	API 526
Wafer and Wafer-Lug Check Valves	*API 594
Metal Plug Valves—Flanged and Welding Ends	API 599
Steel Gate Valves — Flanged and Buttwelding Ends, Bolted and Pressure Seal Bonnets	API 600
Compact Steel Gate Valves — Flanged, Threaded, Welding and Extended Body Ends	API 602
Class 150, Cast, Corrosion-Resistant, Flanged-End Gate Valves	*API 603
Metal Ball Valves-Flanged, Threaded, and Welding End	API 608
Lug- and Wafer-Type Butterfly Valves	*API 609
Ductile-Iron and Gray-Iron Fittings, 3 Inch Through 48 Inch (75 mm Through 1200 mm), for Water and Other Liquids	*AWWA C110
Flanged Ductile-Iron with Ductile-Iron or Gray-Iron Threaded Flanges	*AWWA C115
Steel Pipe Flanges for Water works Service, sizes 4 inch Through 144 inch (100 mm Through 3,600 mm)	*AWWA C207
Dimensions for Fabricated Steel Water Pipe Fittings	*AWWA C208
Metal-Seated Gate Valves for Water Supply Service	*AWWA C500
Rubber-Seated Butterfly Valves	*AWWA C504
Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings	MSS SP-6
Spot Facing for Bronze, Iron and Steel Flanges	MSS SP-9
Standard Marking Systems for Valves, Fittings, Flanges, and Unions	MSS SP-25
Class 150 Corrosion-Resistant Gate, Globe, Angle and Check Valves With Flanged and Buttweld Ends	MSS SP-42
Wrought Stainless Steel Buttwelding Fittings	MSS SP-43
Steel Pipe Line Flanges	MSS SP-44

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TABLE 326.1 (CONT'D)
COMPONENT STANDARDS[1]

(99)
A00

Standard or Specification	Designation [Note (2)]
Bypass and Drain Connections	MSS SP-45
Class 150LW Corrosion Resistant Cast Flanges and Flanged Fittings	MSS SP-51
High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets	MSS SP-65
Cast Iron Gate Valves, Flanged and Threaded Ends	MSS SP-70
Cast Iron Swing Check Valves, Flanged and Threaded Ends	MSS SP-71
Ball Valves With Flanged or Buttwelding Ends for General Service	MSS SP-72
Specifications for High Test Wrought Buttwelding Fittings	MSS SP-75
Socket-Welding Reducer Inserts	MSS SP-79
Bronz Gate, Globe, Angle and Check Valves	MSS SP-80
Stainless Steel, Bonnetless, Flanged, Knife Gate Valves	MSS SP-81
Class 3000 Steel Pipe Unions, Socket-Welding and Threaded	MSS SP-83
Cast Iron Globe and Angle Valves, Flanged and Threaded Ends	MSS SP-85
Diaphragm Type Valves	MSS SP-88
Swage (d) Nipples and Bull Plugs	MSS SP-95
Integrally Reinforced Forged Branch Outlet Fittings — Socket Welding, Threaded, and Buttwelding Ends	MSS SP-97
Instrument Valves for Code Applications	MSS SP-105
Belled End Socket Welding Fittings, Stainless Steel and Copper Nickel [Note (7)]	MSS SP-119
Refrigeration Tube Fittings — General Specifications	SAE J513
Hydraulic Tube Fittings	SAE J514
Hydraulic Flanged Tube, Pipe, and Hose Connections, Four-Bolt Split Flanged Type	*SAE J518
Metallic Pipe and Tubes [Note (6)]	
Welded and Seamless Wrought Steel Pipe	*ASME B36.10M
Stainless Steel Pipe	*ASME B36.19M
Flanged Ductile-Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges	*AWWA C115
Thickness Design of Ductile-Iron Pipe	*AWWA C150
Ductile-Iron Pipe, Centrifugally Cast, for Water and Other Liquids	*AWWA C151
Steel Water Pipe 6 inches (150 mm) and Larger	AWWA C200
Miscellaneous	
Unified Inch Screw Threads (UN and UNR Thread Form)	*ASME B1.1
Pipe Threads, General Purpose (Inch)	*ASME B1.20.1
Dryseal Pipe Threads (Inch)	*ASME B1.20.3
Hose Coupling Screw Threads (Inch)	*ASME B1.20.7
Metallic Gaskets for Pipe Flanges—Ring: Joint, Spiral Wound, and Jacketed	*ASME B16.20
Nonmetallic Flat Gaskets for Pipe Flanges	*ASME B16.21
Buttwelding Ends	*ASME B16.25
Surface Texture (Surface Roughness, Waviness, and Lay)	*ASME B46.1
Specification for Threading, Gaging and Thread Inspection of Casing, Tubing, and Line Pipe Threads	API 5B
Rubber Gasket Joints for Ductile-Iron Pressure Pipe and Fittings	*AWWA C111
Pipe Hangers and Supports — Materials, Design, and Manufacture	MSS SP-58
Brazing Joints for Wrought and Cast Copper Alloy Solder Joint Fittings	MSS SP-73
Standard for Fire Hose Connections	NFPA 1963

Notes to this Table follow on next page

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TABLE 326.1 (CONT'D)

NOTES:

(1) It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.

(2) An asterisk (*) preceding the designation indicates that the standard has been approved as an American National Standard by the American National Standards Institute.

(3) This standard allows the use of unlisted materials; see para. 323.1.2.

(4) This standard allows straight pipe threads in sizes ≤ DN 15 (NPS $\frac{1}{2}$); see para. 314.2.1(d).

(5) *Cautionary Note:* Pressure ratings of components manufactured in accordance with editions prior to the 1994 edition of this standard were derated to 80% of equivalent seamless pipe. This derating is no longer required for components manufactured in accordance with the 1994 Edition.

(6) See also Appendix A.

(7) MSS SP-119 includes three classes of fittings: MP, MARINE, and CR. Only the MP class fittings are considered a "Listed Component" for the purpose of this Code. *Cautionary Note:* See MSS SP-119 (Section 6) for special provisions concerning ratings. (In accordance with MSS SP-119, the pressure ratings for MP class fittings are 87.5% of those calculated for straight seamless pipe of *minimum* wall thickness.)

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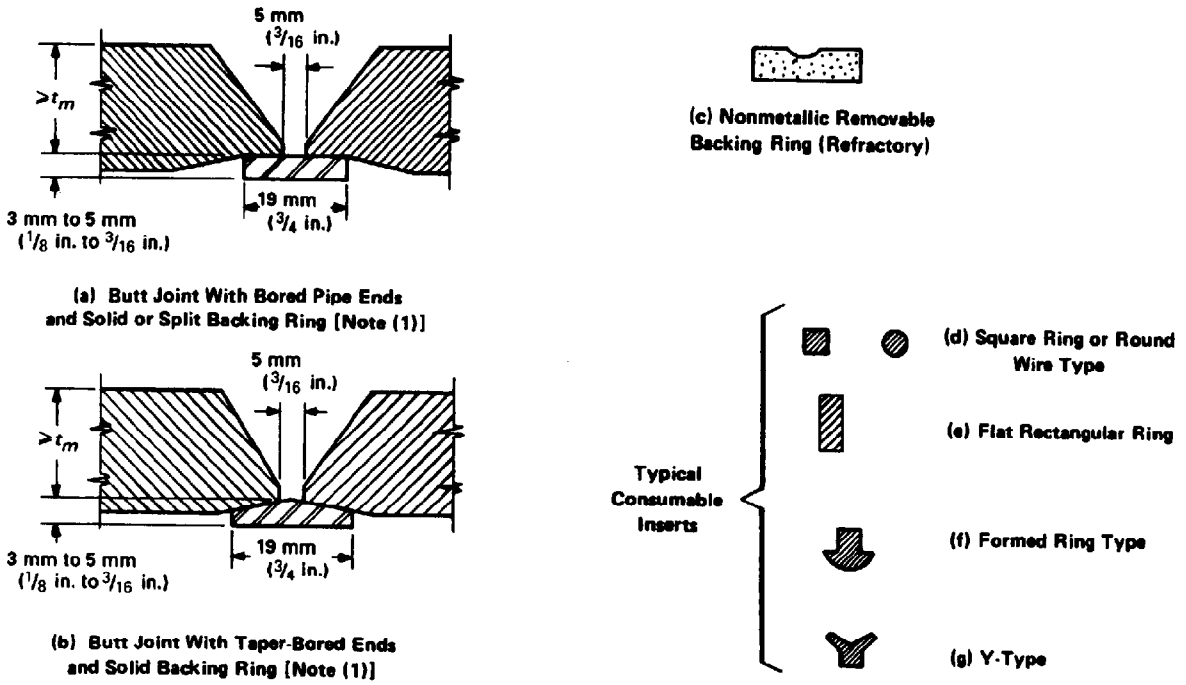

NOTE:
(1) Refer to ASME B16.25 for detailed dimensional information on welding ends.

FIG. 328.3.2 TYPICAL BACKING RINGS AND CONSUMABLE INSERTS

(a) or (b) to correct internal misalignment, such trimming shall not reduce the finished wall thickness below the required minimum wall thickness t_m.

(2) Component ends may be bored to allow for a completely recessed backing ring, provided the remaining net thickness of the finished ends is not less than t_m.

(3) It is permissible to size pipe ends of the same nominal size to improve alignment if wall thickness requirements are maintained.

(4) Where necessary, weld metal may be deposited inside or outside of the component to permit alignment or provide for machining to ensure satisfactory seating of rings or inserts.

(5) When a girth or miter groove weld joins components of unequal wall thickness and one is more than 1½ times the thickness of the other, end preparation and geometry shall be in accordance with acceptable designs for unequal wall thickness in ASME B16.25.

328.4.3 Alignment

(a) Circumferential Welds

(1) Inside surfaces of components at ends to be joined in girth or miter groove welds shall be aligned within the dimensional limits in the WPS and the engineering design.

(2) If the external surfaces of the components are not aligned, the weld shall be tapered between them.

(b) Longitudinal Welds. Alignment of longitudinal groove welds (not made in accordance with a standard listed in Table A-1 or Table 326.1) shall conform to the requirements of para. 328.4.3(a).

(c) Branch Connection Welds

(1) Branch connections which abut the outside surface of the run pipe shall be contoured for groove welds which meet the WPS requirements [see Fig. 328.4.4 sketches (a) and (b)].

(2) Branch connections which are inserted through a run opening shall be inserted at least as far as the inside surface of the run pipe at all points [see Fig. 328.4.4 sketch (c)] and shall otherwise conform to para. 328.4.3(c)(1).

(3) Run openings for branch connections shall not deviate from the required contour more than the dimension m in Fig. 328.4.4. In no case shall deviations

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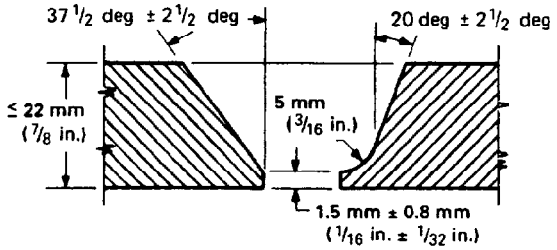
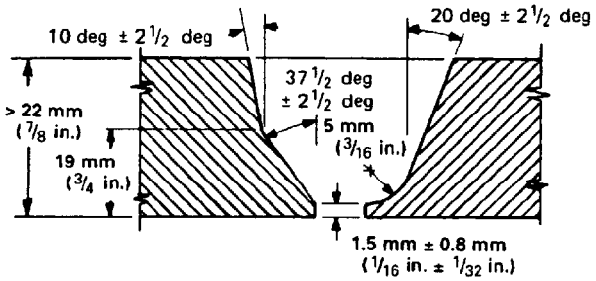
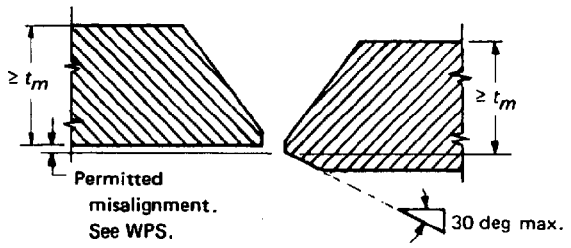


(a) Wall Thickness 6 mm to 22 mm, Inclusive (3/16 in. to 7/8 in.)

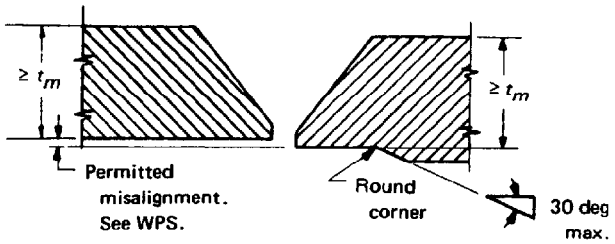


(b) Wall Thickness Over 22 mm (7/8 in.)

FIG. 328.4.2 TYPICAL BUTT WELD END PREPARATION



(a) Thicker Pipe Taper-Bored to Align



(b) Thicker Pipe Bored for Alignment

FIG. 328.4.3 TRIMMING AND PERMITTED MISALIGNMENT

of the shape of the opening cause the root spacing tolerance limits in the WPS to be exceeded. Weld metal may be added and refinished if necessary for compliance.

(d) Spacing. The root opening of the joint shall be within the tolerance limits in the WPS.

328.5 Welding Requirements

328.5.1 General

(a) Welds, including addition of weld metal for alignment [paras. 328.4.2(b)(4) and 328.4.3(c)(3)], shall be made in accordance with a qualified procedure and by qualified welders or welding operators.

(b) Each qualified welder and welding operator shall be assigned an identification symbol. Unless otherwise specified in the engineering design, each pressure containing weld or adjacent area shall be marked with the identification symbol of the welder or welding operator. In lieu of marking the weld, appropriate records shall be filed.

(c) Tack welds at the root of the joint shall be made with filler metal equivalent to that used in the root pass. Tack welds shall be made by a qualified welder or welding operator. Tack welds shall be fused with the root pass weld, except that those which have cracked shall be removed. Bridge tacks (above the weld) shall be removed.

(d) Peening is prohibited on the root pass and final pass of a weld.

(e) No welding shall be done if there is impingement on the weld area of rain, snow, sleet, or excessive wind, or if the weld area is frosted or wet.

(f) Welding End Valves. The welding sequence and procedure and any heat treatment for a welding end valve shall be such as to preserve the seat tightness of the valve.

328.5.2 Fillet and Socket Welds. Fillet welds (including socket welds) may vary from convex to concave. The size of a fillet weld is determined as shown in Fig. 328.5.2A.

(a) Typical weld details for slip-on and socket welding flanges are shown in Fig. 328.5.2B; minimum welding dimensions for other socket welding components are shown in Fig. 328.5.2C or MSS SP-119. A00

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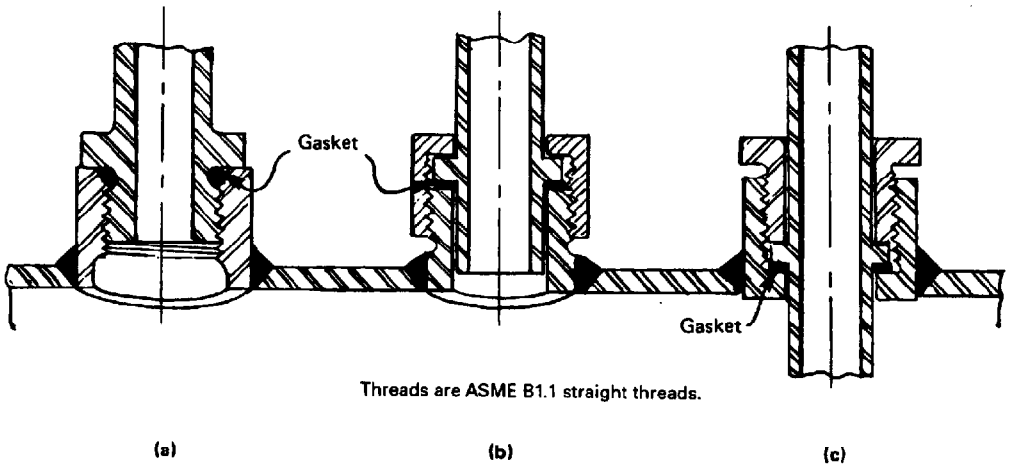

FIG. 335.3.3 TYPICAL THREADED JOINTS USING STRAIGHT THREADS A00

335.2.2 Bolting Torque

(a) In assembling flanged joints, the gasket shall be uniformly compressed to the proper design loading.

(b) Special care shall be used in assembling flanged joints in which the flanges have widely differing mechanical properties. Tightening to a predetermined torque is recommended.

335.2.3 Bolt Length. Bolts should extend completely through their nuts. Any which fail to do so are considered acceptably engaged if the lack of complete engagement is not more than one thread.

335.2.4 Gaskets. No more than one gasket shall be used between contact faces in assembling a flanged joint.

335.3 Threaded Joints

335.3.1 Thread Compound or Lubricant. Any compound or lubricant used on threads shall be suitable for the service conditions and shall not react unfavorably with either the service fluid or the piping material.

335.3.2 Joints for Seal Welding. A threaded joint to be seal welded shall be made up without thread compound. A joint containing thread compound which leaks during leak testing may be seal welded in accordance with para. 328.5.3, provided all compound is removed from exposed threads.

335.3.3 Straight Threaded Joints. Typical joints using straight threads, with sealing at a surface other than the threads, are shown in Fig. 335.3.3 sketches (a), (b), and (c). Care shall be taken to avoid distorting the seat when incorporating such joints into piping assemblies by welding, brazing, or bonding.

335.4 Tubing Joints

335.4.1 Flared Tubing Joints. The sealing surface of the flare shall be examined for imperfections before assembly and any flare having imperfections shall be rejected.

335.4.2 Flareless and Compression Tubing Joints. Where the manufacturer's instructions call for a specified number of turns of the nut, these shall be counted from the point at which the nut becomes finger tight.

335.5 Caulked Joints

Caulked joints shall be installed and assembled in accordance with the manufacturer's instructions, as modified by the engineering design. Care shall be taken to ensure adequate engagement of joint members.

335.6 Expanded Joints and Special Joints

335.6.1 General. Expanded joints and special joints (as defined in para. 318) shall be installed and assembled in accordance with the manufacturer's instructions, as modified by the engineering design. Care shall be taken to ensure adequate engagement of joint members.

335.6.2 Packed Joints. Where a packed joint is used to absorb thermal expansion, proper clearance shall be provided at the bottom of the socket to permit this movement.

335.9 Cleaning of Piping

See Appendix F, para. F335.9.

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(a) date of test
(b) identification of piping system tested
(c) test fluid
(d) test pressure
(e) certification of results by examiner

These records need not be retained after completion of the test if a certification by the Inspector that the piping has satisfactorily passed pressure testing as required by this Code is retained.

345.3 Preparation for Leak Test

345.3.1 Joints Exposed. All joints, including welds and bonds, are to be left uninsulated and exposed for examination during leak testing, except that joints previously tested in accordance with this Code may be insulated or covered. All joints may be primed and painted prior to leak testing unless a sensitive leak test (para. 345.8) is required.

345.3.2 Temporary Supports. Piping designed for vapor or gas shall be provided with additional temporary supports, if necessary, to support the weight of test liquid.

A00 **345.3.3 Piping With Expansion Joints**

(a) An expansion joint that depends on external main anchors to restrain pressure end load shall be tested in place in the piping system.

(b) A self-restrained expansion joint previously shop-tested by the manufacturer [see Appendix X, para. X302.2.3(a)] may be excluded from the system under test, except that such expansion joints shall be installed in the system when a sensitive leak test in accordance with para. 345.8 is required.

(c) A piping system containing expansion joints shall be leak tested without temporary joint or anchor restraint at the lesser of:

(1) 150 % of design pressure for a bellows-type expansion joint; or

(2) the system test pressure determined in accordance with para. 345.

In no case shall a bellows-type expansion joint be subjected to a test pressure greater than the manufacturer's test pressure.

(d) When a system leak test at a pressure greater than the minimum test pressure specified in (c), or greater than 150% of the design pressure within the limitations of para. 345.2.1(a) is required, bellows-type expansion joints shall be removed from the piping system or temporary restraints shall be added to limit main anchor loads if necessary.

345.3.4 Limits of Tested Piping. Equipment which is not to be tested shall be either disconnected from the piping or isolated by blinds or other means during the test. A valve may be used provided the valve (including its closure mechanism) is suitable for the test pressure.

345.4 Hydrostatic Leak Test

345.4.1 Test Fluid. The fluid shall be water unless there is the possibility of damage due to freezing or to adverse effects of water on the piping or the process. In that case another suitable nontoxic liquid may be used. If the liquid is flammable, its flash point shall be at least 49°C (120°F), and consideration shall be given to the test environment.

345.4.2 Test Pressure. Except as provided in para. 345.4.3, the hydrostatic test pressure at any point in a metallic piping system shall be as follows:

(a) not less than $1\frac{1}{2}$ times the design pressure;

(b) for design temperature above the test temperature, the minimum test pressure shall be calculated by Eq. (24), except that the value of S_T/S shall not exceed 6.5:

$$P_T = \frac{1.5\ PS_T}{S} \qquad (24)$$

where

P_T = minimum test gage pressure
P = internal design gage pressure
S_T = stress value at test temperature
S = stress value at design temperature (see Table A-1)

(c) if the test pressure as defined above would produce a nominal pressure stress or longitudinal stress in excess of the yield strength at test temperature, the test pressure may be reduced to the maximum pressure that will not exceed the yield strength at test temperature. [See paras. 302.3.2(e) and (f).] For metallic bellows expansion joints, see Appendix X, para. X302.2.3(a).

345.4.3 Hydrostatic Test of Piping With Vessels[4] as a System

(a) Where the test pressure of piping attached to a vessel is the same as or less than the test pressure for the vessel, the piping may be tested with the vessel at the piping test pressure.

[4] The provisions of para. 345.4.3 do not affect the pressure test requirements of any applicable vessel code.

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(b) Where the test pressure of the piping exceeds the vessel test pressure, and it is not considered practicable to isolate the piping from the vessel, the piping and the vessel may be tested together at the vessel test pressure, provided the owner approves and the vessel test pressure is not less than 77% of the piping test pressure calculated in accordance with para. 345.4.2(b).

345.5 Pneumatic Leak Test

345.5.1 Precautions. Pneumatic testing involves the hazard of released energy stored in compressed gas. Particular care must therefore be taken to minimize the chance of brittle failure during a pneumatic leak

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test. Test temperature is important in this regard and must be considered when the designer chooses the material of construction. See para. 345.2.2(c) and Appendix F, para. F323.4.

345.5.2 Pressure Relief Device. A pressure relief device shall be provided, having a set pressure not higher than the test pressure plus the lesser of 345 kPa (50 psi) or 10% of the test pressure.

345.5.3 Test Fluid. The gas used as test fluid, if not air, shall be nonflammable and nontoxic.

345.5.4 Test Pressure. The test pressure shall be 110% of design pressure.

345.5.5 Procedure. The pressure shall be gradually increased until a gage pressure which is the lesser of one-half the test pressure or 170 kPa (25 psi) is attained, at which time a preliminary check shall be made, including examination of joints in accordance with para. 341.4.1(a). Thereafter, the pressure shall be gradually increased in steps until the test pressure is reached, holding the pressure at each step long enough to equalize piping strains. The pressure shall then be reduced to the design pressure before examining for leakage in accordance with para. 345.2.2(a).

345.6 Hydrostatic-Pneumatic Leak Test

If a combination hydrostatic-pneumatic leak test is used, the requirements of para. 345.5 shall be met, and the pressure in the liquid filled part of the piping shall not exceed the limits stated in para. 345.4.2.

345.7 Initial Service Leak Test

This test is applicable only to piping in Category D Fluid Service, at the owner's option. See para. 345.1(a).

345.7.1 Test Fluid. The test fluid is the service fluid.

345.7.2 Procedure. During or prior to initial operation, the pressure shall be gradually increased in steps until the operating pressure is reached, holding the pressure at each step long enough to equalize piping strains. A preliminary check shall be made as described in para. 345.5.5 if the service fluid is a gas or vapor.

345.7.3 Examination for Leaks. In lieu of para. 345.2.2(a), it is permissible to omit examination for leakage of any joints and connections previously tested in accordance with this Code.

345.8 Sensitive Leak Test

The test shall be in accordance with the Gas and Bubble Test method specified in the BPV Code, Section V, Article 10, or by another method demonstrated to have equal sensitivity. Sensitivity of the test shall be not less than 10^{-3} atm·ml/sec under test conditions.

(a) The test pressure shall be at least the lesser of 105 kPa (15 psi) gage, or 25% or the design pressure.

(b) The pressure shall be gradually increased until a gage pressure the lesser of one-half the test pressure or 170 kPa (25 psi) is attained, at which time a preliminary check shall be made. Then the pressure shall be gradually increased in steps until the test pressure is reached, the pressure being held long enough at each step to equalize piping strains.

345.9 Alternative Leak Test

The following procedures and leak test method may be used only under the conditions stated in para. 345.1(c).

345.9.1 Examination of Welds. Welds, including those used in the manufacture of welded pipe and fittings, which have not been subjected to hydrostatic or pneumatic leak tests in accordance with this Code, shall be examined as follows.

(a) Circumferential, longitudinal, and spiral groove welds shall be 100% radiographed in accordance with para. 344.5.

(b) All welds, including structural attachment welds, not covered in (a) above, shall be examined using the liquid penetrant method (para. 344.4) or, for magnetic materials, the magnetic particle method (para. 344.3).

345.9.2 Flexibility Analysis. A flexibility analysis of the piping system shall have been made in accordance with the requirements of para. 319.4.2 (b), if applicable, or (c) and (d).

345.9.3 Test Method. The system shall be subjected to a sensitive leak test in accordance with para. 345.8.

346 RECORDS

346.2 Responsibility

It is the responsibility of the piping designer, the manufacturer, the fabricator, and the erector, as applicable, to prepare the records required by this Code and by the engineering design.

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PART 8
PIPING COMPONENTS, STANDARDS

A326 DIMENSIONS AND RATINGS OF COMPONENTS

A326.1 Requirements

Paragraph 326 applies in its entirety except that references to Table A326.1 and Appendix B replace references to Table 326.1 and Appendix A, respectively.

A00 **A326.4 Abbreviations in Table A326.1 and Appendix B**

The abbreviations tabulated below are used in this Chapter to replace lengthy phrases in the text and in the titles of standards in Table A326.1 and the Specifications Index for Appendix B. Those marked with an asterisk (*) are in accordance with ASTM D 1600, Terminology Relating to Abbreviations, Acronyms, and Codes for Terms Relating to Plastics.

Abbreviation	Term
*ABS	Acrylonitrile-Butadiene-Styrene
*CAB	Cellulose Acetate-Butyrate
CP	Chlorinated Polyether
*CPVC	Chlorinated Poly (Vinyl Chloride)
ECTFE	Ethylene-Chlorotrifluoroethylene
ETFE	Ethylene-Tetrafluoroethylene
*FEP	Perfluoro (Ethylene-Propylene) copolymer
PB	Polybutylene
*PE	Polyethylene
PFA	Perfluoro (Alkoxyalkane) copolymer
*POM	Polyacetal, Poly (Oxymethylene)
POP	Poly (Phenylene Oxide)
*PP	Polypropylene
*PPS	Poly (Phenylene Sulfide)
PR	Pressure Rated
*PTFE	Polytetrafluoroethylene
*PVC	Poly (Vinyl Chloride)
*PVDC	Poly (Vinylidene Chloride)
*PVDF	Poly (Vinylidene Fluoride)
RPM	Reinforced Plastic Mortar
RTR	Reinforced Thermosetting Resin
SDR	Standard Dimensional Ratio

PART 9
FABRICATION, ASSEMBLY, AND ERECTION

A327 GENERAL

Piping materials and components are prepared for assembly and erection by one or more of the fabrication processes in paras. A328, A329, A332, and A334. When any of these processes is used in assembly and erection, requirements are the same as for fabrication.

A328 BONDING OF PLASTICS

Paragraph A328 applies only to joints in thermoplastic, RTR, and RPM piping. Bonding shall conform to paras. A328.1 through A328.7 and the applicable requirements of para. A311.

A328.1 Bonding Responsibility

Each employer is responsible for the bonding done by personnel of his organization and, except as provided in paras. A328.2.2 and A328.2.3, shall conduct the required performance qualification tests to qualify bonding procedure specifications (BPS) and bonders or bonding operators.

A328.2 Bonding Qualifications

A328.2.1 Qualification Requirements

(a) Qualification of the BPS to be used, and of the performance of bonders and bonding operators, is required. To qualify a BPS, all tests and examinations specified therein and in para. A328.2.5 shall be completed successfully.

(b) In addition to the procedure for making the bonds, the BPS shall specify at least the following:

(1) all materials and supplies (including storage requirements);

(2) tools and fixtures (including proper care and handling);

(3) environmental requirements (e.g., temperature, humidity, and methods of measurement);

(4) joint preparation;

(5) dimensional requirements and tolerances;

(6) cure time;

(7) protection of work;

(8) tests and examinations other than those required by para. A328.2.5; and

(9) acceptance criteria for the completed test assembly.

A328.2.2 Procedure Qualification by Others. Subject to the specific approval of the Inspector, a BPS qualified by others may be used provided that:

(a) the Inspector satisfies himself that the proposed qualified BPS has been prepared and executed by a responsible recognized organization with expertise in the field of bonding;

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(99)

TABLE A326.1
COMPONENT STANDARDS[1]

Standard or Specification	Designation [Note (2)]
Nonmetallic Fittings	
Process Glass Pipe and Fittings	ASTM C 599
Threaded PVC Plastic Pipe Fittings, Sch 80	ASTM D 2464
PVC Plastic Pipe Fittings, Sch 40	ASTM D 2466
Socket-Type PVC Plastic Pipe Fittings, Sch 80	ASTM D 2467
Socket-Type ABS Plastic Pipe Fittings, Sch 40	ASTM D 2468
Thermoplastic Gas Pressure Pipe, Tubing, and Fittings	ASTM D 2513
Reinforced Epoxy Resin Gas Pressure Pipe and Fittings	ASTM D 2517
Plastic Insert Fittings for PE Plastic Pipe	ASTM D 2609
Socket-Type PE Fittings for Outside Diameter-Controlled PE Pipe and Tubing	ASTM D 2683
CPVC Plastic Hot and Cold Water Distribution Systems	ASTM D 2846
Butt Heat Fusion PE Plastic Fittings for PE Plastic Pipe and Tubing	ASTM D 3261
PB Plastic Hot-Water Distribution Systems	ASTM D 3309
Fiberglass RTR Pipe Fittings for Nonpressure Applications [Note (3)]	ASTM D 3840
RTR Flanges	ASTM D 4024
Contact Molded Fiberglass RTR Flanges [Note (3)]	ASTM D 5421
PTFE Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 423
Threaded CPVC Plastic Pipe Fittings, Sch 80	ASTM F 437
Socket-Type CPVC Plastic Pipe Fittings, Sch 40	ASTM F 438
Socket-Type CPVC Plastic Pipe Fittings, Sch 80	ASTM F 439
PVDF Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 491
Propylene and PP Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 492
FEP Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 546
PVDC Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 599
PFA Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 781
Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing	ASTM F 1055
Plastic-Lined Ferrous Metal Pipe, Fittings, and Flanges [Note (4), (5)]	ASTM F 1545
Nonmetallic Pipes and Tubes	
PE Line Pipe	API 15LE
Thermoplastic Line Pipe (PVC and CPVC)	API 15LP
Low Pressure Fiberglass Line Pipe	API 15LR
Reinforced Concrete Low-Head Pressure Pipe	ASTM C 361
Process Glass Pipe and Fittings	ASTM C 599
ABS Plastic Pipe, Sch 40 and 80	ASTM D 1527
PVC Plastic Pipe, Sch 40, 80 and 120	ASTM D 1785
PE Plastic Pipe, Sch 40	ASTM D 2104
PE Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter	ASTM D 2239
PVC Plastic Pressure-Rated Pipe (SDR Series)	ASTM D 2241
ABS Plastic Pipe (SDR-PR)	ASTM D 2282
Classification for Machine-Made RTR Pipe	ASTM D 2310
PE Plastic Pipe, Sch 40 & 80, Based on Outside Diameter	ASTM D 2447
Thermoplastic Gas Pressure Pipe, Tubing, and Fittings	ASTM D 2513
Reinforced Epoxy Resin Gas Pressure Pipe and Fittings	ASTM D 2517
PB Plastic Pipe (SDR-PR)	ASTM D 2662
PB Plastic Tubing	ASTM D 2666

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TABLE A326.1 (CONT'D)
COMPONENT STANDARDS[1]

Standard or Specification	Designation [Note (2)]
Bell End PVC Plastic Pipe	ASTM D 2672
PE Plastic Tubing	ASTM D 2737
CPVC Plastic Hot and Cold Water Distribution System	ASTM D 2846
Filament-Wound Fiberglass RTR Pipe [Note (3)]	ASTM D 2996
Centrifugally Cast RTR Pipe	ASTM D 2997
PB Plastic Pipe (SDR-PR) Based on Outside Diameter	ASTM D 3000
PE Plastic Pipe (SDR-PR) Based on Controlled Outside Diameter	ASTM D 3035
PB Plastic Hot-Water Distribution Systems	ASTM D 3309
Fiberglass RTR Pressure Pipe [Note (3)]	ASTM D 3517
Fiberglass RTR Sewer and Industrial Pressure Pipe [Note (3)]	ASTM D 3754
PTFE Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 423
CPVC Plastic Pipe	ASTM F 441
CPVC Plastic Pipe (SDR-PR)	ASTM F 442
PVDF Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 491
Propylene and PP Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 492
FEP Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 546
PVDC Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 599
PFA Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 781
Plastic-Lined Ferrous Metal Pipe, Fittings, and Flanges [Notes (4), (5)]	ASTM F 1545
Reinforced Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids	AWWA C300
Prestressed Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids	AWWA C301
Reinforced Concrete Pressure Pipe, Noncylinder Type, for Water and Other Liquids	AWWA C302
PVC Pressure Pipe, 4-inch through 12-inch, for Water	AWWA C900
Glass-Fiber-Reinforced Thermosetting Resin Pressure Pipe	*AWWA C950
Miscellaneous	
Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion Resistant Equipment	ASTM C 582
Threads for Fiberglass RTR Pipe (60 deg stub) [Note (3)]	ASTM D 1694
Solvent Cements for ABS Plastic Pipe and Fittings	ASTM D 2235
Solvent Cements for PVC Plastic Pipe and Fittings	ASTM D 2564
Bell End PVC Plastic Pipe	ASTM D 2672
Joints for Plastic Pressure Pipes using Flexible Elastomeric Seals	ASTM D 3139
Fiberglass RTR Pipe Joints Using Flexible Elastomeric Seals [Note (3)]	ASTM D 4161
Design and Construction of Nonmetallic Enveloped Gaskets for Corrosive Service	ASTM F 336
Solvent Cements for CPVC Plastic Pipe and Fittings	ASTM F 493

NOTES:
(1) It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.
(2) An asterisk (*) preceding the designation indicates that the standard has been approved as an American National Standard by the American National Standards Institute.
(3) The term *fiberglass RTR* takes the place of the ASTM designation: "*fiberglass*" (*glass-fiber-reinforced thermosetting resin*).
(4) This Standard allows the use of unlisted materials; see para. 323.1.2.
(5) This Standard contains no pressure-temperature ratings.

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(b) by signature, the employer accepts both the BPS and procedure qualification record (PQR) as his own; and

(c) the employer has at least one currently employed bonder who, while in his employ, has satisfactorily passed a performance qualification test using the proposed qualified BPS.

A328.2.3 Performance Qualification by Others. Without the Inspector's specific approval, an employer shall not accept a performance qualification test made by a bonder or bonding operator for another employer. If approval is given, it is limited to work on piping using the same or equivalent BPS. An employer accepting such performance qualification tests shall obtain a copy of the performance qualification test record from the previous employer showing the name of the employer by whom the bonder or bonding operator was qualified, the date of such qualification, and the date the bonder or bonding operator last bonded pressure piping under such performance qualification.

A328.2.4 Qualification Records. The employer shall maintain a self-certified record, available to the owner or owner's agent and to the Inspector, of the BPS used and the bonders or bonding operators employed by him, and showing the dates and results of BPS qualifications and bonding performance qualifications.

A328.2.5 Qualification Tests. Tests, as specified in para. A328.2.1(a), shall be performed to qualify each BPS and the performance of each bonder and bonding operator. Test assemblies shall conform to (a) below and the test method shall be in accordance with either (b) or (c).

(a) Test Assembly. The assembly shall be fabricated in one pipe size in accordance with the BPS and shall contain at least one of each different type of joint identified in the BPS. More than one test assembly may be prepared if necessary to accommodate all of the joint types or to assure that at least one of each joint type is loaded in both circumferential and longitudinal directions. The size of pipe and fittings in the assembly shall be as follows.

(1) When the largest size to be joined is 110 mm (NPS 4) or smaller, the test assembly shall be the largest size to be joined.

(2) When the largest size to be joined is greater than 110 mm, the size of the test assembly shall be either 110 mm or 25% of the largest piping size to be joined, whichever is greater.

(b) Burst Test Method. The test assembly shall be subjected to a burst test in accordance with the applicable sections of ASTM D 1599.[5] The time to burst in this standard may be extended. The test is successful if failure initiates outside of any bonded joint.

(c) Hydrostatic Test Method. The test assembly shall be subjected to hydrostatic pressure of at least P_T for not less than 1 hr with no leakage or separation of joints.

(1) For thermoplastics, P_T shall be determined in accordance with Eq. (27):

$$P_T = 0.80\overline{T}\left(\frac{(S_S + S_H)}{D - \overline{T}}\right) \quad (27)$$

where

D = outside diameter of pipe
$\overline{T}$ = nominal thickness of pipe
S_S = mean short term burst stress in accordance with ASTM D 1599,[5] from Table B-1 if listed, otherwise from manufacturer's data.
S_H = mean long term hydrostatic strength (LTHS) in accordance with ASTM D 2837. Use twice the 23°C (73°F) HDB design stress from Table B-1 if listed; or use manufacturer's data.

(2) For RTR (laminated and filament-wound) and RPM, P_T shall be three times the manufacturer's allowable pressure for the components being joined.

(3) The test shall be conducted so that the joint is loaded in both the circumferential and longitudinal directions.

A328.2.6 Performance Requalification. Renewal of a bonding performance qualification is required when:

(a) a bonder or bonding operator has not used the specific bonding process for a period of 6 months or more; or (99) A00

(b) there is specific reason to question the individual's ability to make bonds that meet the BPS.

A328.3 Bonding Materials and Equipment

A328.3.1 Materials. Bonding materials that have deteriorated by exposure to air or prolonged storage, or will not spread smoothly, shall not be used in making joints.

A328.3.2 Equipment. Fixtures and tools used in making joints shall be in such condition as to perform their functions satisfactorily.

[5] Titles of referenced standards and specifications are listed in Table A326.1, except ASTM D 1599 and ASTM D 2855, Practice for Making Solvent-Cemented Joints with PVC Pipe and Fittings.

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CHAPTER VIII
PIPING FOR CATEGORY M FLUID SERVICE

M300 GENERAL STATEMENTS

(a) Chapter VIII pertains to piping designated by the owner as being in Category M Fluid Service. See also Appendix M.

(b) The organization, content, and paragraph designations of this Chapter correspond to those of the base Code (Chapters I through VI) and Chapter VII. The prefix M is used.

(c) Provisions and requirements of the base Code and Chapter VII apply only as stated in this Chapter.

(d) Consideration shall be given to the possible need for engineered safeguards (see Appendix G, para. G300.3) in addition to the safeguards already provided (paras. G300.1 and G300.2).

(e) This Chapter makes no provision for piping to be used under severe cyclic conditions. The occurrence of such conditions can ordinarily be circumvented by piping layout, component selection, and other means. If this is not feasible, the engineering design shall specify any necessary provisions in accordance with para. 300(c)(5).

(f) Chapter I applies in its entirety.

PART 1
CONDITIONS AND CRITERIA

M301 DESIGN CONDITIONS

Paragraph 301 applies in its entirety, with the exceptions of paras. 301.3 and 301.5. See paras. M301.3 and M301.5.

M301.3 Design Temperature, Metallic Piping

Use of any temperature other than the fluid temperature as the design temperature shall be substantiated by heat transfer calculations confirmed by tests or by experimental measurements.

M301.5 Dynamic Effects

Paragraph 301.5 applies with the exception of paras. 301.5.1 and 301.5.4. See paras. M301.5.1 and M301.5.4.

M301.5.1 Impact. Design, layout, and operation of piping shall be conducted so as to minimize impact and shock loads. In the event that such loadings are unavoidable, para. 301.5.1 applies.

M301.5.4 Vibration. Suitable dynamic analysis, such as computer simulation, shall be made where necessary to avoid or minimize conditions which lead to detrimental vibration, pulsation, or resonance effects in the piping.

M302 DESIGN CRITERIA

M302.1 General

Paragraph M302 pertains to pressure-temperature ratings, stress criteria, design allowances, and minimum design values, together with permissible variations of these factors as applied to piping design.

Paragraph 302 applies in its entirety, with the exception of paras. 302.2 and 302.3. See paras. M302.2 and M302.3.

M302.2 Pressure-Temperature Design Criteria

Paragraph 302.2 applies in its entirety, with the exception of paras. 302.2.4 and 302.2.5. See paras. M302.2.4 and M302.2.5.

M302.2.4 Allowance for Pressure and Temperature Variations, Metallic Piping. Use of allowances in para. 302.2.4 is not permitted. Design temperature and pressure shall be based on coincident pressure-temperature conditions requiring the greatest wall thickness or the highest component rating.

M302.2.5 Ratings at Junction of Different Services, Metallic Piping. When two services that operate at different pressure-temperature conditions are connected, the valve segregating the services shall be rated for the more severe service condition.

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M302.3 Allowable Stresses and Other Stress Limits for Metallic Piping

Paragraph 302.3 applies in its entirety, with the exception of para. 302.3.2. See para. M302.3.2.

M302.3.2 Bases for Allowable Stresses. The designer shall fully document the basis for using any stress limit not in accordance with the stress Tables in Appendix A.

M302.4 Allowances

Paragraph 302.4 applies in its entirety.

PART 2
PRESSURE DESIGN OF METALLIC PIPING COMPONENTS

M303 GENERAL

Paragraph 303 applies in its entirety.

M304 PRESSURE DESIGN OF METALLIC COMPONENTS

Paragraph 304 applies in its entirety.

PART 3
FLUID SERVICE REQUIREMENTS FOR METALLIC PIPING COMPONENTS

M305 PIPE

M305.1 General

Listed pipe may be used in accordance with para. M305.2. Unlisted pipe may be used only as provided in para. 302.2.3.

M305.2 Specific Requirements for Metallic Pipe

Pipe listed in para. 305.2.2 shall not be used. The provision for severe cyclic conditions in para. 305.2.3 does not apply [see para. M300(e)].

M306 METALLIC FITTINGS, BENDS, MITERS, LAPS, AND BRANCH CONNECTIONS

General. Fittings, bends, miters, laps, and branch connections may be used in accordance with paras. M306.1 through M306.6. Pipe and other materials used in such components shall be suitable for the manufacturing process and the fluid service.

M306.1 Pipe Fittings

Paragraph 306.1 applies in its entirety, with the exception of para. 306.1.3. See para. M306.1.3 below. The provision for severe cyclic conditions in para. 306.1.4 does not apply [see para. M300(e)].

M306.1.3 Specific Fittings. The following shall not be used:

(a) fittings conforming to MSS SP-43 and MSS SP-119; A00

(b) proprietary "Type C" lap-joint stub-end butt welding fittings.

M306.2 Pipe Bends

Paragraph 306.2 applies, except that bends in accordance with para. 306.2.2 shall not be used and para. 306.2.3 does not apply [see para. M300(e)].

M306.3 Miter Bends

A miter bend shall conform to para. 306.3.1 and shall not make a change in direction at a single joint (angle α in Fig. 304.2.3) greater than 22.5 deg. Paragraph 306.3.3 does not apply [see para. M300(e)].

M306.4 Fabricated or Flared Laps

M306.4.1 General. The following requirements do not apply to fittings conforming to para. M306.1, nor to laps integrally forged on pipe ends. Paragraph 306.4.1 applies.

M306.4.2 Flared Laps. A flared lap shall meet the requirements of para. 306.4.2. In addition:

(a) pipe size shall be $\leq$ DN 100 (NPS 4), with wall thickness before flaring $\geq$ the value of T for Schedule 10S;

(b) pressure-temperature rating shall be $\leq$ that of an ASME B16.5 PN 20 (Class 150) Group 1.1 flange; and

(c) service temperature shall be $\leq$ 204°C (400°F).

M306.5 Fabricated Branch Connections

The following requirements do not apply to fittings conforming to para. M306.1. Paragraph 306.5.1 applies, with the following exceptions.

(a) Of the methods listed in para. 304.3.1(a), the one in subpara. (3) may be used only if those in (1) and (2) are unavailable.

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(b) Of the branch connections described in paras. 304.3.2(b) and (c), those having threaded outlets are permitted only in accordance with para. M314 and those having socket welding outlets are permitted only in accordance with para. M311.2.

M306.6 Closures

The following requirements do not apply to blind flanges or to fittings conforming to para. M306.1. Of the closures described in para. 304.4, flat closures in accordance with the BPV Code, Section VIII, Division 1, UG-34 and UW-13, and conical closures without transition knuckles [UG-32(g) and UG-33(f)], may be used only if others are not available. The requirements in M306.5 apply to openings in closures [see also para. 304.4.2(b)].

M307 METALLIC VALVES AND SPECIALTY COMPONENTS

The following requirements for valves shall also be met as applicable by other pressure containing piping components, such as strainers and separators. See also Appendix F, para. F307.

M307.1 General

Paragraph 307.1 applies, subject to the requirements in para. M307.2.

M307.2 Specific Requirements

(a) Valves having threaded bonnet joints (other than union joints) shall not be used.

(b) Only metallic valves conforming to the following requirements may be used.

(1) Special consideration shall be given to valve design to prevent stem leakage to the environment.

(2) Bonnet or cover plate closures shall be: flanged, secured by at least four bolts with gasketing conforming to para. 308.4; or proprietary, attached by bolts, lugs, or other substantial means, and having a gasket design that increases gasket compression as fluid pressure increases; or secured with a full penetration weld made in accordance with para. M311; or secured by a straight thread sufficient for mechanical strength, a metal-to-metal seat, and a seal weld made in accordance with para. M311, all acting in series.

(3) Body joints, other than bonnet or cover plate joints, shall conform to para. M307.2(b)(2).

M308 FLANGES, BLANKS, FLANGE FACINGS, AND GASKETS

Paragraph 308.1 applies in its entirety.

M308.2 Specific Requirements for Metallic Flanges

Paragraph 308.2.4 does not apply [see para. M300(e)]. The following shall not be used:

(a) single-welded slip-on flanges;

(b) expanded-joint flanges; A00

(c) slip-on flanges used as lapped flanges unless the requirements in para. 308.2.1(c) are met;

(d) threaded metallic flanges, except those employing lens rings or similar gaskets and those used in lined pipe where the liner extends over the gasket face.

M308.3 Flange Facings

Paragraph 308.3 applies.

M308.4 Gaskets

Paragraph 308.4 applies.

M308.5 Blanks

All blanks shall be marked with material, rating, and size.

M309 BOLTING

Paragraph 309 applies, except for para. 309.2.4 [see para. M300(e)].

PART 4
FLUID SERVICE REQUIREMENTS FOR METALLIC PIPING JOINTS

M310 METALLIC PIPING, GENERAL

Paragraph 310 applies in its entirety.

M311 WELDED JOINTS IN METALLIC PIPING

Welded joints may be made in any metal for which it is possible to qualify welding procedures, welders, and welding operators in accordance with para. M328.

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M311.1 General

Paragraph 311.1 applies with the following exceptions.

(a) Split backing rings shall not be used.

(b) Socket welded joints greater than DN 50 (NPS 2) are not permitted.

(c) Examination shall be in accordance with para. M341.4.

M311.2 Specific Requirements

Paragraphs 311.2.3(a), 311.2.4(a), (b), and (d), 311.2.5, and 311.2.6 apply.

M312 FLANGED JOINTS IN METALLIC PIPING

Paragraph 312 applies in its entirety.

M313 EXPANDED JOINTS IN METALLIC PIPING

Expanded joints shall not be used.

M314 THREADED JOINTS IN METALLIC PIPING

M314.1 General

Paragraphs 314.1(a), (b), and (c) apply.

M314.2 Specific Requirements

M314.2.1 Taper-Threaded Joints. Paragraph 314.2.1 applies except that only components suitable for Normal Fluid Service in sizes 8 ≤ DN ≤ 25 (¼ ≤ NPS ≤ 1) are permitted (see Table 314.2.1). Sizes smaller than DN 20 (NPS ¾) shall be safeguarded (see Appendix G).

A00 **M314.2.2 Straight-Threaded Joints.** Paragraph 314.2.2 applies. In addition, components shall have adequate mechanical strength and the joint shall have a confined seating surface not subject to relative rotation as or after the joint is tightened. [See Fig. 335.3.3 sketches (b) and (c) for acceptable construction.]

M315 TUBING JOINTS IN METALLIC PIPING

Paragraph 315 applies, except for para. 315.2(b).

M316 CAULKED JOINTS

Caulked joints shall not be used.

M317 SOLDERED AND BRAZED JOINTS

Soldered, brazed, and braze welded joints shall not be used.

M318 SPECIAL JOINTS IN METALLIC PIPING

Paragraph 318 applies, with the exception that adhesive joints and bell type joints shall not be used.

PART 5
FLEXIBILITY AND SUPPORT OF METALLIC PIPING

M319 FLEXIBILITY OF METALLIC PIPING

Paragraph 319 applies, with the exception that the simplified rules in para. 319.4.1(c) do not apply.

M321 PIPING SUPPORT

Paragraph 321 applies, except that supporting elements shall be of listed material.

PART 6
SYSTEMS

M322 SPECIFIC PIPING SYSTEMS

M322.3 Instrument Piping

Paragraph 322.3 applies, with the exception that, for signal lines in contact with process fluids and process temperature–pressure conditions:

(a) tubing shall be not larger than 16 mm (⅝ in.) O.D. and shall be suitable for the service; A00

(b) an accessible block valve shall be provided to isolate the tubing from the pipeline;

(c) joining methods shall conform to the requirements of paras. 315.1 and 315.2.

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M322.6 Pressure Relieving Systems

Paragraph 322.6 applies, except for para. 322.6.3. See para. M322.6.3.

M322.6.3 Overpressure Protection. For metallic piping, the design pressure may be exceeded by no more than 10% during operation of a pressure relieving system.

PART 7
METALLIC MATERIALS

M323 GENERAL REQUIREMENTS

M323.1 Materials and Specifications

Paragraphs 323.1.1 and 323.1.2 apply. See paras. M323.1.3 and M323.1.4.

M323.1.3 Unknown Materials. Materials of unknown specification shall not be used.

M323.1.4 Reclaimed Metallic Materials. Reclaimed materials may be used when the material certification records are available for the specific materials employed, and the designer is assured that the material is sound and free from harmful defects.

M323.2 Temperature Limitations

Paragraph 323.2 applies with the exception that, in regard to lower temperature limits, the relaxation of minimum temperature limits stated in Note (3) of Table 323.2.2 is not permitted.

M323.3 Impact Testing Methods and Acceptance Criteria

Paragraph 323.3 applies in its entirety.

M323.4 Fluid Service Requirements for Metallic Materials

Paragraph 323.4.1 applies.

M323.4.2 Specific Requirements. Paragraph 323.4.2 applies, except that cast irons other than ductile iron shall not be used for pressure-containing parts, and lead and tin shall be used only as linings.

M323.4.3 Metallic Cladding and Lining Materials. In addition to the requirements of para. 323.4.3, where materials covered in paras. 323.4.2(c)(2) and 323.4.3 are used as cladding or lining in which the cladding or lining also serves as a gasket or as part of the flange facing, consideration shall be given to the design of the flanged joint to prevent leakage to the environment.

M323.5 Deterioration of Materials in Service

Paragraph 323.5 applies in its entirety.

M325 MATERIALS — MISCELLANEOUS

M325.1 Joining and Auxiliary Materials

In applying para. 325, materials such as solvents, brazes, and solders shall not be used. Nonmetallic materials used as gaskets and packing materials shall be suitable for the fluid service.

PART 8
STANDARDS FOR PIPING COMPONENTS

M326 DIMENSIONS AND RATINGS OF COMPONENTS

Paragraph 326.1.3 applies.

M326.1 Dimensional Requirements

M326.1.1 Listed Piping Components. Except for prohibitions and restrictions stated elsewhere in Chapter VIII, components made in accordance with standards and specifications listed in Table 326.1 may be used in Category M service.

M326.1.2 Unlisted Piping Components. Dimensions of unlisted components shall be governed by requirements in paras. 303 and 304.

M326.2 Ratings of Components

Paragraph 326.2 applies in its entirety.

M326.3 Reference Documents A00

Paragraph 326.3 applies in its entirety.

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PART 9
FABRICATION, ASSEMBLY, AND ERECTION OF METALLIC PIPING

M327 GENERAL

Metallic piping materials and components are prepared for assembly and erection by one or more of the fabrication processes in paras. M328, M330, M331,

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and M332. When any of these processes is used in assembly and erection, requirements are the same as for fabrication.

M328 WELDING OF METALS

Welding shall be in accordance with paras. M311.1 and 328, except see para. M328.3.

M328.3 Welding Materials

Paragraph 328.3 applies in its entirety, except that split backing rings shall not be used, and removable backing rings and consumable inserts may be used only where their suitability has been demonstrated by procedure qualification.

M330 PREHEATING OF METALS

Paragraph 330 applies in its entirety.

M331 HEAT TREATMENT OF METALS

Paragraph 331 applies in its entirety, with the exception that no requirements less stringent than those of Table 331.1.1 shall be specified.

M332 BENDING AND FORMING OF METALS

Paragraph 332 applies in its entirety, except that bending which conforms to para. 332.2.3 is not permitted.

M335 ASSEMBLY AND ERECTION OF METALLIC PIPING

M335.1 General

M335.1.1 Alignment. In addition to the requirements of para. 335.1.1, any bending or forming required for alignment and fit-up shall be heat treated if required by para. 332.4.

M335.2 Flanged Joints

Paragraph 335.2 applies in its entirety.

M335.3 Threaded Joints

Paragraphs 335.3.1 and 335.3.2 apply. See paras. M335.3.3 and M335.3.4.

M335.3.3 Straight-Threaded Joints. The requirements of para. 335.3.3 are subject to the limitations in para. M322.

M335.3.4 Condition of Threads. Taper-threaded components and threaded ends permitted under para. M314.2.1 shall be examined before assembly for cleanliness and continuity of threads and shall be rejected if not in conformance with ASME B1.20.1 or other applicable standards.

M335.4 Tubing Joints

M335.4.1 Flared Tubing Joints. The requirements of para. 335.4.1 apply; however, see para. M322 for limitations associated with specific piping systems. (99)

M335.4.2 Flareless and Compression Tubing Joints. The requirements of para. 335.4.2 apply; however, see para. M322 for limitations associated with specific piping systems. (99)

M335.6 Special Joints

Special joints shall be in accordance with paras. M318 and 335.6.1.

M335.9 Cleaning of Piping

See Appendix F, para. F335.9.

PART 10
INSPECTION, EXAMINATION, TESTING, AND RECORDS OF METALLIC PIPING

M340 INSPECTION

Paragraph 340 applies in its entirety.

M341 EXAMINATION

Paragraphs 341.1, 341.2, 341.3, and 341.5 apply in their entirety. See para. M341.4.

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CHAPTER IX
HIGH PRESSURE PIPING

K300 GENERAL STATEMENTS

(a) Applicability. This Chapter pertains to piping designated by the owner as being in High Pressure Fluid Service. Its requirements are to be applied in full to piping so designated. High pressure is considered herein to be pressure in excess of that allowed by the ASME B16.5 PN 420 (Class 2500) rating for the specified design temperature and material group. However, there are no specified pressure limitations for the application of these rules.

(b) Responsibilities. In addition to the responsibilities stated in para. 300(b):

(1) for each piping system designated as being in High Pressure Fluid Service, the owner shall provide all information necessary to perform the analyses and testing required by this Chapter;

(2) the designer shall make a written report to the owner summarizing the design calculations and certifying that the design has been performed in accordance with this Chapter.

(c) The identification, intent, and Code requirements in paras. 300(a), (c), (d), (e), and (f) apply.

(d) The organization, content, and, wherever possible, paragraph designations of this Chapter correspond to those of the first six Chapters (the base Code). The prefix K is used.

(e) Provisions and requirements of the base Code apply only as stated in this Chapter.

K300.1 Scope

K300.1.1 Content and Coverage. Paragraph 300.1.1 applies with the exceptions stated in paras. K300.1.3 and K300.1.4.

K300.1.2 Packaged Equipment Piping. Interconnecting piping as described in para. 300.1.2 shall conform to the requirements of this Chapter.

K300.1.3 Exclusions. In addition to the exclusions stated in para. 300.1.3, this Chapter excludes nonmetallic and nonmetallic-lined piping.

K300.1.4 Category M Fluid Service. This Chapter makes no provision for piping in Category M Fluid Service. If such piping is required by the owner, the engineering design shall be developed as provided in para. 300(c)(5).

K300.2 Definitions

Paragraph 300.2 applies except for terms relating only to nonmetals and severe cyclic conditions.

The term allowable stress is used in lieu of basic allowable stress.

The term safeguarding and other terms characterizing hazardous fluid services are not used in this Chapter but should be taken into account in design.

K300.3 Nomenclature

Paragraph 300.3 applies.

K300.4 Status of Appendices A00

Paragraph 300.4 and Table 300.4 apply, except for Appendices A, B, H, L, V, and X.

PART 1
CONDITIONS AND CRITERIA

K301 DESIGN CONDITIONS

Paragraph 301 applies with the exceptions of paras. 301.1, 301.2, 301.3, and 301.5.

K301.1 General

Paragraph 301.1 applies but refer to para. K301 instead of para. 301.

K301.2 Design Pressure

K301.2.1 General. Paragraph 301.2.1(a) applies except that reference to para. 302.2.4 is not applicable. Paragraphs 301.2.1(b) and (c) apply, but refer to para. K304 instead of para. 304.

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K301.2.2 Required Pressure Containment or Relief. Paragraphs 301.2.2(a) and (b) apply, but refer to para. K322.6.3 instead of para. 322.6.3. Paragraph 301.2.2(c) is not applicable.

K301.3 Design Temperature

Paragraph 301.3 applies with the exceptions of paras. 301.3.1 and 301.3.2 and the following exceptions in the text.

(a) Refer to para. K301.2 instead of para. 301.2.

(b) Refer to para. K301.3.2 instead of para. 301.3.2.

K301.3.1 Design Minimum Temperature. Paragraph 301.3.1 applies, but refer to para. K323.2.2 instead of para. 323.2.2.

K301.3.2 Uninsulated Components. The fluid temperature shall be used as the component temperature.

K301.5 Dynamic Effects

Paragraph 301.5 applies with the exception of para. 301.5.4.

K301.5.4 Vibration. Suitable dynamic analysis shall be made where necessary, to avoid or minimize conditions which lead to detrimental vibration, pulsation, or resonance effects in the piping.

K302 DESIGN CRITERIA

K302.1 General

In para. K302, pressure-temperature ratings, stress criteria, design allowances, and minimum design values are stated, and permissible variations of these factors as applied to design of high pressure piping systems are formulated.

The designer shall be satisfied as to the adequacy of the design, and of materials and their manufacture, considering at least the following:

(a) tensile, compressive, flexural, and shear strength at design temperature;

(b) fatigue strength;

(c) design stress and its basis;

(d) ductility and toughness;

(e) possible deterioration of mechanical properties in service;

(f) thermal properties;

(g) temperature limits;

(h) resistance to corrosion and erosion;

(i) fabrication methods;

(j) examination and testing methods;

(k) hydrostatic test conditions; and

(l) bore imperfections.

K302.2 Pressure-Temperature Design Criteria

K302.2.1 Listed Components Having Established Ratings. Pressure-temperature ratings for certain piping components have been established and are contained in some of the standards in Table K326.1. Unless limited elsewhere in this Chapter, those ratings are acceptable for design pressures and temperatures under this Chapter. With the owner's approval, the rules and limits of this Chapter may be used to extend the pressure-temperature ratings of a component beyond the ratings of the listed standard, but not beyond the limits stated in para. K323.2.

K302.2.2 Listed Components Not Having Specific Ratings

(a) Piping components for which design stresses have been developed in accordance with para. K302.3, but which do not have specific pressure-temperature ratings, shall be rated by rules for pressure design in para. K304, within the range of temperatures for which stresses are shown in Table K-1, modified as applicable by other rules of this Chapter.

(b) Piping components which do not have allowable stresses or pressure-temperature ratings shall be qualified for pressure design as required by para. K304.7.2.

K302.2.3 Unlisted Components

(a) Piping components not listed in Table K326.1 or Table K-1, but which conform to a published specification or standard, may be used subject to the following requirements:

(1) the designer shall determine that composition, mechanical properties, method of manufacture, and quality control are comparable to the corresponding characteristics of listed components; and

(2) pressure design shall be verified in accordance with para. K304, including the fatigue analysis required by para. K304.8.

(b) Other unlisted components shall be qualified for pressure design as required by para. K304.7.2.

K302.2.4 Allowance for Pressure and Temperature Variations. Variations in pressure above the design pressure at the coincident temperature, except for accumulation during pressure relieving (see para. K322.6.3), are not permitted for any piping system.

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quality factor E_c = 1.00, with examination and acceptance criteria in accordance with para. K302.3.3. All welds shall have a weld quality factor E_j = 1.00, with examination and acceptance criteria in accordance with paras. K341 through K344. Listed fittings may be used in accordance with para. K303. Unlisted fittings may be used only in accordance with para. K302.2.3.

K306.1.2 Specific Fittings

(a) Socket welding fittings are not permitted.

(b) Threaded fittings are permitted only in accordance with para. K314.

(c) Branch connection fittings (see para. 300.2) whose design has been performance tested successfully as required by para. K304.7.2(b) may be used within their established ratings.

K306.2 Pipe Bends

K306.2.1 General. A bend made in accordance with para. K332.2 and verified for pressure design in accordance with para. K304.2.1 shall be suitable for the same service as the pipe from which it is made.

K306.2.2 Corrugated and Other Bends. Bends of other design (such as creased or corrugated) are not permitted.

K306.3 Miter Bends

Miter bends are not permitted.

K306.4 Fabricated or Flared Laps

Only forged laps are permitted.

K306.5 Fabricated Branch Connections

Fabricated branch connections constructed by welding shall be fabricated in accordance with para. K328.5.4 and examined in accordance with para. K341.4.

K307 VALVES AND SPECIALTY COMPONENTS

The following requirements for valves shall also be met, as applicable, by other pressure containing piping components, such as traps, strainers, and separators.

K307.1 General

Pressure design of unlisted valves shall be qualified as required by para. K304.7.2.

K308 FLANGES, BLANKS, FLANGE FACINGS, AND GASKETS

K308.1 General

Pressure design of unlisted flanges shall be verified in accordance with para. K304.5.1 or qualified as required by para. K304.7.2.

K308.2 Specific Flanges

K308.2.1 Threaded Flanges. Threaded flanges may be used only within the limitations on threaded joints in para. K314.

K308.2.2 Other Flange Types. Slip-on, socket welding, and expanded joint flanges, and flanges for flared laps, are not permitted.

K308.3 Flange Facings

The flange facing shall be suitable for the service and for the gasket and bolting employed.

K308.4 Gaskets

Gaskets shall be selected so that the required seating load is compatible with the flange rating and facing, the strength of the flange, and its bolting. Materials shall be suitable for the service conditions. Mode of gasket failure shall be considered in gasket selection and joint design.

K308.5 Blanks

Blanks shall have a marking identifying material, pressure-temperature rating, and size, which is visible after installation.

K309 BOLTING

Bolting, including bolts, bolt studs, studs, cap screws, nuts, and washers, shall meet the requirements of the BPV Code, Section VIII, Division 2, Article M-5. See also Appendix F, para. F309, of this Code.

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PART 4
FLUID SERVICE REQUIREMENTS FOR PIPING JOINTS

K310 GENERAL

Joints shall be suitable for the fluid handled, and for the pressure-temperature and other mechanical loadings expected in service.

K311 WELDED JOINTS

K311.1 General

Welds shall conform to the following.

(a) Welding shall be in accordance with para. K328.

(b) Preheating and heat treatment shall be in accordance with paras. K330 and K331, respectively.

(c) Examination shall be in accordance with para. K341.4, with acceptance criteria as shown in Table K341.3.2.

K311.2 Specific Requirements

K311.2.1 Backing Rings and Consumable Inserts. Backing rings shall not be used. Consumable inserts shall not be used in butt welded joints except when specified by the engineering design.

K311.2.2 Fillet Welds. Fillet welds may be used only for structural attachments in accordance with the requirements of paras. K321 and K328.5.2.

K311.2.3 Other Weld Types. Socket welds and seal welds are not permitted.

K312 FLANGED JOINTS

Flanged joints shall be selected for leak tightness, considering the requirements of para. K308, flange facing finish, and method of attachment. See also para. F312.

K312.1 Joints Using Flanges of Different Ratings

Paragraph 312.1 applies.

K313 EXPANDED JOINTS

Expanded joints are not permitted.

K314 THREADED JOINTS

K314.1 General

Except as provided in paras. K314.2 and K314.3, threaded joints are not permitted as pipeline assembly joints.

(a) Layout of piping should be such as to minimize strain on threaded joints which could adversely affect sealing.

(b) Supports shall be designed to control or minimize strain and vibration on threaded joints and seals.

K314.2 Special Threaded Joints

Special threaded joints may be used to attach flanges or fittings for joints in which the pipe end projects through the flange or fitting and is machined to form the sealing surface with a lens ring, cone ring, the mating pipe end, or other similar sealing device.

K314.3 Other Threaded Joints

Threaded joints not in accordance with para. K314.2 shall be used only for instrumentation, vents, drains, and similar purposes, and shall be not larger than DN 15 (NPS ½). Such joints shall not be subject to bending or vibration loads.

K314.3.1 Taper-Threaded Joints. For mechanical strength, male-threaded components shall be at least Schedule 160 in nominal wall thickness. The nominal thickness of Schedule 160 piping is listed in ASME B36.10M for DN 15 (NPS ½) and in ASME B16.11 for sizes smaller than DN 15 (NPS ½). A00

K314.3.2 Straight-Threaded Joints. Threaded joints in which the tightness of the joint is provided by a seating surface other than the threads (e.g., construction shown in Fig. 335.3.3) shall be qualified as required by para. K304.7.2.

K315 TUBING JOINTS

Tubing joints of the flared, flareless, and compression type are not permitted.

K316 CAULKED JOINTS

Caulked joints are not permitted.

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K317 SOLDERED AND BRAZED JOINTS

K317.1 Soldered Joints

Soldered joints are not permitted.

K317.2 Brazed Joints

(a) Braze welded joints and fillet joints made with brazing filler metal are not permitted.

(b) Brazed joints shall be made in accordance with para. K333 and shall be qualified as required by para. K304.7.2. Such application is the owner's responsibility. The melting point of brazing alloys shall be considered when exposure to fire is possible.

K318 SPECIAL JOINTS

Special joints include coupling, mechanical, and gland nut and collar types of joints.

K318.1 General

Joints may be used in accordance with para. 318.2 and the requirements for materials and components in this Chapter.

K318.2 Specific Requirements

K318.2.1 Prototype Tests. A prototype joint shall have been subjected to performance tests in accordance with para. K304.7.2(b) to determine the safety of the joint under test conditions simulating all expected service conditions. Testing shall include cyclic simulation.

K318.2.2 Prohibited Joints. Bell type and adhesive joints are not permitted.

PART 5
FLEXIBILITY AND SUPPORT

K319 FLEXIBILITY

Flexibility analysis shall be performed for each piping system. Paragraphs 319.1 through 319.7 apply, except for paras. 319.4.1(c) and 319.4.5. The computed displacement stress range shall be within the allowable displacement stress range in para. K302.3.5 and shall also be included in the fatigue analysis in accordance with para. K304.8.

K321 PIPING SUPPORT

Piping supports and methods of attachment shall be in accordance with para. 321 except as modified below, and shall be detailed in the engineering design.

K321.1.1 Objectives. Paragraph 321.1.1 applies, but substitute "Chapter" for "Code" in (1).

K321.1.4 Materials. Paragraph 321.1.4 applies, but replace (e) with the following:

(e) Attachments welded to the piping shall be of a material compatible with the piping and the service. Other requirements are specified in paras. K321.3.2 and K323.4.2(b).

K321.3.2 Integral Attachments. Paragraph 321.3.2 applies, but substitute "K321.1.4(e)" for "321.1.4(e)" and "Chapter IX" for "Chapter V."

PART 6
SYSTEMS

K322 SPECIFIC PIPING SYSTEMS

K322.3 Instrument Piping

K322.3.1 Definition. Instrument piping within the scope of this Chapter includes all piping and piping components used to connect instruments to high pressure piping or equipment. Instruments, permanently sealed fluid-filled tubing systems furnished with instruments as temperature- or pressure-responsive devices, and control piping for air or hydraulically operated control apparatus (not connected directly to the high pressure piping or equipment) are not within the scope of this Chapter.

K322.3.2 Requirements. Instrument piping within the scope of this Chapter shall be in accordance with para. 322.3.2 except that the design pressure and temperature shall be determined in accordance with para. K301, and the requirements of para. K310 shall apply. Instruments, and control piping not within the scope of this Chapter, shall be designed in accordance with para. 322.3.

K322.6 Pressure Relieving Systems

Paragraph 322.6 applies, except for para. 322.6.3.

K322.6.3 Overpressure Protection. Overpressure protection for high pressure piping systems shall conform to the following.

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(a) The cumulative capacity of the pressure relieving devices shall be sufficient to prevent the pressure from rising more than 10% above the piping design pressure at the operating temperature during the relieving condition for a single relieving device or more than 16% above the design pressure when more than one device is provided, except as provided in (c) below.

(b) System protection must include one relief device set at or below the design pressure at the operating temperature for the relieving condition, with no device set to operate at a pressure greater than 105% of the design pressure, except as provided in (c) below.

(c) Supplementary pressure relieving devices provided for protection against overpressure due to fire or other unexpected sources of external heat shall be set to operate at a pressure not greater than 110% of the design pressure of the piping system and shall be capable of limiting the maximum pressure during relief to no more than 121% of the design pressure.

PART 7
MATERIALS

K323 GENERAL REQUIREMENTS

(a) Paragraph K323 states limitations and required qualifications for materials based on their inherent properties. Their use is also subject to requirements elsewhere in Chapter IX and in Table K-1.

(b) Specific attention should be given to the manufacturing process to ensure uniformity of properties throughout each piping component.

(c) See para. K321.1.4 for support materials.

K323.1 Materials and Specifications

K323.1.1 Listed Materials. Any material used in a pressure-containing piping component shall conform to a listed specification, except as provided in para. K323.1.2.

K323.1.2 Unlisted Materials. An unlisted material may be used, provided it conforms to a published specification covering chemistry, physical and mechanical properties, method and process of manufacture, heat treatment, and quality control, and otherwise meets the requirements of this Chapter. Allowable stresses shall be determined in accordance with the applicable allowable stress basis of this Chapter or a more conservative basis.

K323.1.3 Unknown Materials. Materials of unknown specification, type, or grade are not permitted.

K323.1.4 Reclaimed Materials. Reclaimed pipe and other piping components may be used provided they are properly identified as conforming to a listed specification, have documented service history for the material and fatigue life evaluation, and otherwise meet the requirements of this Chapter. Sufficient cleaning and inspection shall be made to determine minimum wall thickness and freedom from defects which would be unacceptable in the intended service.

K323.1.5 Product Analysis. Conformance of materials to the product analysis chemical requirements of the applicable specification shall be verified, and certification shall be supplied. Requirements for product analysis are defined in the applicable materials specification.

K323.1.6 Repair of Materials by Welding. A material defect may be repaired by welding, provided that all of the following criteria are met.

(a) The material specification provides for weld repair.

(b) The welding procedure and welders or welding operators are qualified as required by para. K328.2.

(c) The repair and its examination are performed in accordance with the material specification and with the owner's approval.

K323.2 Temperature Limitations A00

The designer shall verify that materials which meet other requirements of this Chapter are suitable for service throughout the operating temperature range. Attention is directed to Note (4) in Appendix K, and para. K323.2.1 following. [Note (7) of Appendix A explains the means used to set both cautionary and restrictive temperature limits for materials.]

K323.2.1 Upper Temperature Limits, Listed Materials. A00 A listed material may be used at a temperature above the maximum for which a stress value is shown in Table K-1, but only if:

(a) there is no prohibition in Appendix K or elsewhere in this Chapter;

(b) the designer verifies the serviceability of the material in accordance with para. K323.2.4; and

(c) the upper temperature limit shall be less than the temperature for which an allowable stress determined in accordance with para. 302.3.2 is governed by the creep or stress rupture provisions of that paragraph.

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A00 **K323.2.2 Lower Temperature Limits, Listed Materials**

(a) The lowest permitted service temperature for a component or weld shall be the impact test temperature determined in accordance with para. K323.3.4(a), except as provided in (b) or (c) below.

(b) For a component or weld subjected to a longitudinal or circumferential stress ≤ 41 MPa (6 ksi), the lowest service temperature shall be the lower of −46°C (−50°F) or the impact test temperature determined in para. K323.3.4(a).

(c) For materials exempted from Charpy testing by Note (6) of Table K323.3.1, the service temperature shall not be lower than −46°C (−50°F).

A00 **K323.2.3 Temperature Limits, Unlisted Materials.** An unlisted material acceptable under para. K323.1.2 shall be qualified for service at all temperatures within a stated range from design minimum temperature to design (maximum) temperature, in accordance with para. K323.2.4. The requirements of para. K323.2.1(c) also apply.

K323.2.4 Verification of Serviceability

(a) When an unlisted material is used, the designer is responsible for demonstrating the validity of the allowable stresses and other design limits, and of the approach taken in using the material, including the derivation of stress data and the establishment of temperature limits.

(b) Paragraph 323.2.4(b) applies except that allowable stress values shall be determined in accordance with para. K302.3.

K323.3 Impact Testing Methods and Acceptance Criteria

K323.3.1 General. Impact testing shall be performed in accordance with Table K323.3.1 on representative samples using the testing methods described in paras. K323.3.2, K323.3.3, and K323.3.4. Acceptance criteria are described in para. K323.3.5.

K323.3.2 Procedure. Paragraph 323.3.2 applies.

K323.3.3 Test Specimens

(a) Each set of impact test specimens shall consist of three specimen bars. Impact tests shall be made using standard 10 mm (0.394 in.) square cross section Charpy V-notch specimen bars oriented in the transverse direction.

(b) Where component size and/or shape does not permit specimens as specified in (a) above, standard 10 mm square cross-section longitudinal Charpy specimens may be prepared.

(c) Where component size and/or shape does not permit specimens as specified in (a) or (b) above, subsize longitudinal Charpy specimens may be prepared. Test temperature shall be reduced in accordance with Table 323.3.4. See also Table K323.3.1, Note (6).

(d) If necessary in (a), (b), or (c) above, corners of specimens parallel to and on the side opposite the notch may be as shown in Fig. K323.3.3.

K323.3.4 Test Temperatures. For all Charpy impact tests, the test temperature criteria in (a) or (b) below shall be observed.

(a) Charpy impact tests shall be conducted at a temperature no higher than the lowest metal temperature at which a piping component or weld will be subjected to a stress greater than 41 MPa (6 ksi). In specifying the required test temperature, the following shall be considered:

(1) range of operating conditions;

(2) upset conditions;

(3) ambient temperature extremes; and

(4) required leak test temperature.

(b) Where the largest possible test specimen has a width along the notch less than the lesser of 80% of the material thickness or 8 mm (0.315 in.), the test shall be conducted at a reduced temperature in accordance with Table 323.3.4, considering the temperature as reduced below the test temperature required by (a) above.

K323.3.5 Acceptance Criteria

(a) Minimum Energy Requirements for Materials Other Than Bolting. The applicable minimum impact energy requirements for materials shall be those shown in Table K323.3.5. Lateral expansion shall be measured in accordance with ASTM A 370 (for title see para. 323.3.2). The results shall be included in the impact test report.

(b) Minimum Energy Requirements for Bolting Materials. The applicable minimum energy requirements shall be those shown in Table K323.3.5 except as provided in Table K323.3.1.

(c) Weld Impact Test Requirements. Where two base metals having different required impact energy values are joined by welding, the impact test energy requirements shall equal or exceed the requirements of the base material having the lower required impact energy.

(d) Retests

(1) Retest for Absorbed Energy Criteria. When the average value of the three specimens equals or

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exceeds the minimum value permitted for a single specimen, and the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, a retest of three additional specimens shall be made. The value for each of these retest specimens shall equal or exceed the required average value.

(2) Retest for Erratic Test Results. When an erratic result is caused by a defective specimen or uncertainty in the test, a retest will be allowed. The report giving

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TABLE K323.3.1
IMPACT TESTING REQUIREMENTS

	Test Characteristics	Column A Pipe, Tubes, and Components Made From Pipe or Tubes	Column B Other Components, Fittings, Etc.	Column C Bolts
Tests on Materials	Number of tests	As required by the material specification, or one test set per lot [see Note (1)], whichever is greater, except as permitted by Note (6).		
	Location and orientation of specimens [see Note (2)]	(a) Transverse to the longitudinal axis, with notch parallel to axis. [See Note (3).] (b) Where component size and/or shape does not permit specimens as specified in (a) above, paras. K323.3.3(b), (c), and (d) apply as needed.	(a) Transverse to the direction of maximum elongation during rolling or to direction of major working during forging. Notch shall be oriented parallel to direction of maximum elongation or major working. (b) If there is no single identifiable axis, e.g., for castings or triaxial forgings, specimens shall either meet the longitudinal values of Table K323.3.5, or three sets of orthogonal specimens shall be prepared, and the lowest impact values obtained from any set shall meet the transverse values of Table K323.3.5. (c) Where component size and/or shape does not permit specimens as specified in (a) or (b) above, paras. K323.3.3(c) and (d) apply as needed.	(a) Bolts ≤ 52 mm (2 in.) nominal size made in accordance with ASTM A 320 shall meet the impact requirements of that specification. (b) For all other bolts, longitudinal specimens shall be taken. The impact values obtained shall meet the transverse values of Table K323.3.5.
Tests on Welds in Fabrication or Assembly	Test pieces [see Note (5)]	Test pieces for preparation of impact specimens shall be made for each welder, welding procedure, type of electrode, or filler metal (i.e., AWS E-XXXX classification) and each flux to be used. All test pieces shall be subject to heat treatment, including cooling rates and aggregate time at temperature or temperatures, essentially the same as the heat treatment which the finished component will have received.		
	Number of test pieces [see Note (4)]	(1) One test piece with a thickness T for each range of material thicknesses which can vary from $\frac{1}{2}T$ to $T + 6$ mm ($\frac{1}{4}$ in.). (2) Unless otherwise specified in this Chapter [see Note (3)] or the engineering design, test pieces need not be made from individual material lots, or from material for each job, provided welds in other certified material of the same thickness ranges and to the same specification (type and grade, not heat or lot) have been tested as required and the records of those tests are made available.		
	Location and orientation of specimens	(1) Weld metal impact specimens shall be taken across the weld with the notch in the weld metal. Each specimen shall be oriented so that the notch axis is normal to the surface of the material and one face of the specimen shall be within 1.5 mm ($\frac{1}{16}$ in.) of the surface of the material. (2) Heat affected zone impact specimens shall be taken across the weld and have sufficient length to locate the notch in the heat affected zone, after etching. The notch shall be cut approximately normal to the material surface in such a manner as to include as much heat affected zone material as possible in the resulting fracture. (3) The impact values obtained from both the weld metal and heat affected zone specimens shall be compared to the transverse values in Table K323.3.5 for the determination of acceptance criteria.		

Notes to this Table follow on next page

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TABLE K323.3.1 (CONT'D)

NOTES:

(1) A lot shall consist of pipe or components of the same nominal size, made from the same heat of material, and heat treated together. If a continuous type furnace is used, pipe or components may be considered to have been heat treated together if they are processed during a single continuous time period at the same furnace conditions.

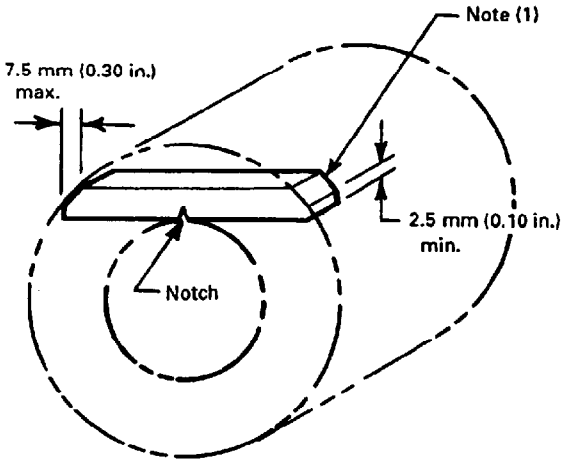
(2) Impact tests shall be performed on a representative sample of material after completion of all heat treatment and forming operations involving plastic deformation, except that cold bends made in accordance with para. K304.2.1 need not be tested after bending.

(3) For longitudinally welded pipe, specimens shall be taken from the base metal, weld metal, and the heat affected zone.

(4) The test piece shall be large enough to permit preparing the number of specimens required by para. K323.3. If this is not possible, additional test pieces shall be prepared.

(5) For welds in the fabrication or assembly of piping or components, including repair welds.

(6) Impact tests are not required when the maximum obtainable longitudinal Charpy specimen has a width along the notch less than 2.5 mm (0.098 in.). See para. K323.2.2(c).



GENERAL NOTE: This Figure illustrates how an acceptable transverse Charpy specimen can be obtained from a tubing or component shape too small for a full length standard specimen in accordance with ASTM A 370. The corners of a longitudinal specimen parallel to and on the side opposite the notch may be as shown.

NOTE:

(1) Corners of the Charpy specimen [see para. K323.3.3(d)] may follow the contour of the component within the dimension limits shown.

FIG. K323.3.3 EXAMPLE OF AN ACCEPTABLE IMPACT TEST SPECIMEN

test results shall specifically state why the original specimen was considered defective or which step of the test procedure was carried out incorrectly.

K323.4 Requirements for Materials

K323.4.1 General. Requirements in para. K323.4 apply to pressure-containing parts, not to materials used as supports, gaskets, packing, or bolting. See also Appendix F, para. F323.4.

K323.4.2 Specific Requirements

(a) Ductile iron and other cast irons are not permitted.

(b) Zinc-coated materials are not permitted for pressure containing components and may not be attached to pressure-containing components by welding.

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TABLE K323.3.5
MINIMUM REQUIRED CHARPY V-NOTCH IMPACT VALUES

Specimen Orientation	Pipe Wall or Component Thickness, mm (in.)	No. of Specimens [Note (1)]	Energy, J (ft-lbf) [Note (2)] Specified Minimum Yield Strength, MPa (ksi) ≤ 932 (≤ 135)	> 932 (> 135)
Transverse	≤ 25 (≤ 1)	Average for 3	27 (20)	34 (25)
		Minimum for 1	20 (15)	27 (20)
	> 25 and ≤ 51 (> 1 and ≤ 2)	Average for 3	34 (25)	41 (30)
		Minimum for 1	27 (20)	33 (24)
	> 51 (> 2)	Average for 3	41 (30)	47 (35)
		Minimum for 1	33 (24)	38 (28)
Longitudinal	≤ 25 (≤ 1)	Average for 3	54 (40)	68 (50)
		Minimum for 1	41 (30)	54 (40)
	> 25 and ≤ 51 (> 1 and ≤ 2)	Average for 3	68 (50)	81 (60)
		Minimum for 1	54 (40)	65 (48)
	> 51 (> 2)	Average for 3	81 (60)	95 (70)
		Minimum for 1	65 (48)	76 (56)

NOTES:
(1) See para. K323.3.5(c) for permissible retests.
(2) Energy values in this Table are for standard size specimens. For subsize specimens, these values shall be multiplied by the ratio of the actual specimen width to that of a full-size specimen, 10 mm (0.394 in.).

K323.4.3 Metallic Clad and Lined Materials. Materials with metallic cladding or lining may be used in accordance with the following provisions.

(a) For metallic clad or lined piping components, the base metal shall be an acceptable material as defined in para. K323, and the thickness used in pressure design in accordance with para. K304 shall not include the thickness of the cladding or lining. The allowable stress used shall be that for the base metal at the design temperature. For such components, the cladding or lining may be any material that, in the judgment of the user, is suitable for the intended service and for the method of manufacture and assembly of the piping component.

(b) Fabrication by welding of clad or lined piping components and the inspection and testing of such components shall be done in accordance with applicable provisions of the BPV Code, Section VIII, Division 1, UCL-30 through UCL-52, and the provisions of this Chapter.

(c) If a metallic liner also serves as a gasket or as part of the flange facing, the requirements and limitations in para. K308.4 apply.

K323.5 Deterioration of Materials in Service

Paragraph 323.5 applies.

K325 MISCELLANEOUS MATERIALS

Paragraph 325 applies.

PART 8
STANDARDS FOR PIPING COMPONENTS

K326 DIMENSIONS AND RATINGS OF COMPONENTS (99) A00

Paragraph 326 applies in its entirety, except as follows:

(a) Refer to Table K326.1 instead of Table 326.1.
(b) Refer to Appendix K instead of Appendix A.
(c) Refer to para. K303 instead of para. 303.
(d) Refer to para. K304 instead of para. 304.

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TABLE K326.1
COMPONENT STANDARDS[1]

Standard or Specification	Designation [Note (3)]
Bolting	
Square and Hex Bolts and Screws, Inch Series; Including Hex Cap Screws and Lag Screws	*ASME B18.2.1
Square and Hex Nuts (Inch Series)	*ASME B18.2.2
Metallic Fittings, Valves, and Flanges	
Pipe Flanges and Flanged Fittings [Note (2)]	*ASME B16.5
Factory Made Wrought Steel Buttwelding Fittings [Note (2)]	*ASME B16.9
Forged Fittings, Socket Welding and Threaded [Note (2)]	*ASME B16.11
Valves—Flanged, Threaded, and Welding End [Note (2)]	*ASME B16.34
Standard Marking System for Valves, Fittings, Flanges, and Unions	MSS SP-25
High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets	MSS SP-65
Metallic Pipe and Tubes	
Welded and Seamless Wrought Steel Pipe [Note (2)]	*ASME B36.10M
Stainless Steel Pipe [Note (2)]	*ASME B36.19M
Miscellaneous	
Unified Inch Screw Threads (UN and UNR Thread Form)	*ASME B1.1
Specification for Threading, Gaging and Thread Inspection of Casing, Tubing, and Line Pipe Threads	API 5B
Metallic Gaskets for Pipe Flanges	*ASME B16.20
Buttwelding Ends	*ASME B16.25
Surface Texture (Surface Roughness, Waviness, and Lay)	*ASME B46.1

NOTES:
(1) It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.
(2) The use of components made in accordance with these standards is permissible provided they meet all of the requirements of this Chapter.
(3) An asterisk (*) preceding the designation indicates that the standard has been approved as an American National Standard by the American National Standards Institute.

PART 9
FABRICATION, ASSEMBLY, AND ERECTION

K327 GENERAL

Piping materials and components are prepared for assembly and erection by one or more of the fabrication processes covered in paras. K328, K330, K331, K332, and K333. When any of these processes is used in assembly or erection, requirements are the same as for fabrication.

K328 WELDING

Welding which conforms to the requirements of para. K328 may be used in accordance with para. K311.

K328.1 Welding Responsibility

Each employer is responsible for the welding done by the personnel of his organization and shall conduct the tests required to qualify welding procedures, and to qualify and as necessary requalify welders and welding operators.

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K328.2 Welding Qualifications

K328.2.1 Qualification Requirements. Qualification of the welding procedures to be used and of the performance of welders and welding operators shall comply with the requirements of the BPV Code, Section IX, except as modified herein.

(a) Impact tests shall be performed for all procedure and performance qualifications in accordance with para. K323.3.

(b) Test weldments shall be made using the same specification and type or grade of base metal(s), and the same specification and classification of filler metal(s) as will be used in production welding.

(c) Test weldments shall be subjected to essentially the same heat treatment, including cooling rate and cumulative time at temperature, as the production welds.

(d) When tensile specimens are required by Section IX, the yield strength shall also be determined, using the method required for the base metal. The yield strength of each test specimen shall be not less than the specified minimum yield strength (SMYS) for the base metals joined. Where two base metals having different SMYS values are joined by welding, the yield strength of each test specimen shall be not less than the lower of the two SMYS values.

(e) Mechanical testing is required for all performance qualification tests.

(f) Qualification on pipe or tubing shall also qualify for plate, but qualification on plate does not qualify for pipe or tubing.

(g) For thickness greater than 51 mm (2 in.), the procedure test coupon shall be at least 75% as thick as the thickest joint to be welded in production.

(h) Paragraph 328.2.1(f) applies.

K328.2.2 Procedure Qualification by Others. Qualification of welding procedures by others is not permitted.

K328.2.3 Performance Qualification by Others. Welding performance qualification by others is not permitted.

K328.2.4 Qualification Records. Paragraph 328.2.4 applies.

K328.2.5 Performance Requalification. Requalification of welders and welding operators is required in accordance with para. K328.2.1 when:

(a) welder or welding operator has not used the specific process for a period of 3 months or more; or

(b) there is specific reason to question the individual's ability to produce welds that meet the requirements of this Chapter.

K328.3 Materials

K328.3.1 Filler Metal. Filler metal shall be specified in the engineering design and shall conform to the requirements of the BPV Code, Section IX. A filler metal not yet incorporated in Section IX may be used with the owner's approval if a procedure qualification test, including an all-weld-metal test, is first successfully made.

K328.3.2 Weld Backing Material. Backing rings shall not be used.

K328.3.3 Consumable Inserts. Paragraph 328.3.3 applies, except that procedures shall be qualified as required by para. K328.2.

K328.4 Preparation for Welding

K328.4.1 Cleaning. Paragraph 328.4.1 applies.

K328.4.2 End Preparation

(a) General

(1) Butt weld end preparation is acceptable only if the surface is machined or ground to bright metal.

(2) Butt welding end preparation contained in ASME B16.25 or any other end preparation which meets the procedure qualification is acceptable. [For convenience, the basic bevel angles taken from B16.25, with some additional J-bevel angles, are shown in Fig. 328.4.2 sketches (a) and (b).]

(b) Circumferential Welds

(1) If components ends are trimmed as shown in Fig. 328.4.2 sketch (a) or (b) to accommodate consumable inserts, or as shown in Fig. K328.4.3 to correct internal misalignment, such trimming shall not result in a finished wall thickness before welding less than the required minimum wall thickness t_m.

(2) It is permissible to size pipe ends of the same nominal size to improve alignment, if wall thickness requirements are maintained.

(3) Where necessary, weld metal may be deposited on the inside or outside of the component to permit alignment or provide for machining to ensure satisfactory seating of inserts.

(4) When a butt weld joins sections of unequal wall thickness and the thicker wall is more than $1\frac{1}{2}$ times the thickness of the other, end preparation and geometry shall be in accordance with acceptable designs for unequal wall thickness in ASME B16.5.

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SPECIFICATION INDEX FOR APPENDIX A

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Spec. No.	Title
ASTM	
A 36	Structural Steel
A 47	Ferritic Malleable Iron Castings
A 48	Gray Iron Castings
A 53	Pipe, Steel, Black and Hot-Dipped, Zinc Coated, Welded and Seamless
A 105	Forgings, Carbon Steel, for Piping Components
A 106	Seamless Carbon Steel Pipe for High-Temperature Service
A 126	Gray Cast Iron Castings for Valves, Flanges, and Pipe Fittings
A 134	Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)
A 135	Electric-Resistance-Welded Steel Pipe
A 139	Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over)
A 167	Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet and Strip
A 179	Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes
A 181	Forgings, Carbon Steel For General Purpose Piping
A 182	Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
A 197	Cupola Malleable Iron
A 202	Pressure Vessel Plates, Alloy Steel, Chromium-Manganese-Silicon
A 203	Pressure Vessel Plates, Alloy Steel, Nickel
A 204	Pressure Vessel Plates, Alloy Steel, Molybdenum
A 216	Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service
A 217	Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts Suitable forHigh-Temperature Service
A 234	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures
A 240	Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Pressure Vessels
A 268	Seamless and Welded Ferritic Stainless Steel Tubing for General Service
A 269	Seamless and Welded Austenitic Stainless Steel Tubing for General Service
A 278	Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F
A 283	Low and Intermediate Tensile Strength Carbon Steel Plates, Shapes and Bars
A 285	Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
A 299	Pressure Vessel Plates, Carbon Steel, Manganese-Silicon
ASTM (Cont'd)	
A 302	Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel
A 312	Seamless and Welded Austenitic Stainless Steel Pipe
A 333	Seamless and Welded Steel Pipe for Low-Temperature Service
A 334	Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service
A 335	Seamless Ferritic Alloy Steel Pipe for High-Temperature Service
A 350	Forgings, Carbon and Low-Alloy Steel Requiring Notch Toughness Testing for Piping Components
A 351	Steel Castings, Austenitic, Austenitic-Ferritic (Duplex) for Pressure-Containing Parts
A 352	Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts Suitable for Low-Temperature Service
A 353	Pressure Vessel Plates, Alloy Steel, 9 Percent Nickel, Double Normalized and Tempered
A 358	Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High-Temperature Service
A 369	Carbon Steel and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service
A 376	Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service
A 381	Metal-Arc-Welded Steel Pipe for Use with High-Pressure Transmission Systems
A 387	Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum
A 395	Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures
A 403	Wrought Austenitic Stainless Steel Piping Fittings
A 409	Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service
A 420	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service
A 426	Centrifugally Cast Ferritic Alloy Steel Pipe for High-Temperature Service
A 451	Centrifugally Cast Austenitic Steel Pipe for High-Temperature Service
A 479	Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
A 487	Steel Castings Suitable for Pressure Service
A 494	Castings, Nickel and Nickel Alloy
A 515	Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
A 516	Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
A 524	Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures
A 537	Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel

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SPECIFICATION INDEX FOR APPENDIX A

Spec. No.	Title
ASTM (Cont'd)	
A 553	Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 8 and 9 Percent Nickel
A 570	Hot-Rolled Carbon Steel Sheet and Strip, Structural Quality
A 571	Austenitic Ductile Iron Castings for Pressure-Containing Parts Suitable for Low-Temperature Service
A 587	Electric-Welded Low-Carbon Steel Pipe for the Chemical Industry
A 645	Pressure Vessel Plates, 5 Percent Nickel Alloy Steel, Specially Heat Treated
A 671	Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures
A 672	Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures
A 691	Carbon and Alloy Steel Pipe, Electric Fusion-Welded for High-Pressure Service at High Temperatures
A 789	Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service
A 790	Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe
A 815	Wrought Ferritic, Ferritic/Austenitic and Martensitic Stainless Steel Fittings
B 21	Naval Brass Rod, Bar, and Shapes
B 26	Aluminum-Alloy Sand Castings
B 42	Seamless Copper Pipe, Standard Sizes
B 43	Seamless Red Brass Pipe, Standard Sizes
B 61	Steam or Valve Bronze Castings
B 62	Composition Bronze or Ounce Metal Castings
B 68	Seamless Copper Tube, Bright Annealed
B 75	Seamless Copper Tube
B 88	Seamless Copper Water Tube
B 96	Copper-Silicon Alloy Plate, Sheet, Strip, and Rolled Bar for General Purposes and Pressure Vessels
B 98	Copper-Silicon Alloy Rod, Bar and Shapes
B 127	Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip
B 133	Copper Rod, Bar and Shapes
B 148	Aluminum-Bronze Castings
B 150	Aluminum-Bronze Rod, Bar and Shapes
B 152	Copper Sheet, Strip, Plate and Rolled Bar
B 160	Nickel Rod and Bar
B 161	Nickel Seamless Pipe and Tube
B 162	Nickel Plate, Sheet and Strip
B 164	Nickel-Copper Alloy Rod, Bar and Wire
B 165	Nickel-Copper Alloy (UNS N04400) Seamless Pipe and Tube
B 166	Nickel-Chromium-Iron Alloy (UNS N06600) Rod, Bar and Wire
ASTM (Cont'd)	
B 167	Nickel-Chromium-Iron Alloy (UNS N06600-N06690) Seamless Pipe and Tube
B 168	Nickel-Chromium-Iron Alloy (UNS N06600-N06690) Plate, Sheet and Strip
B 169	Aluminum Bronze Plate, Sheet, Strip, and Rolled Bar
B 171	Copper-Alloy Condenser Tube Plates
B 187	Copper Bar, Bus Bar, Rod, and Shapes
B 209	Aluminum and Aluminum-Alloy Sheet and Plate
B 210	Aluminum-Alloy Drawn Seamless Tubes
B 211	Aluminum-Alloy Bars, Rods and Wire
B 221	Aluminum-Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes
B 241	Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube
B 247	Aluminum-Alloy Die, Hand and Rolled Ring Forgings
B 280	Seamless Copper Tube for Air Conditioning and Refrigeration Fluid Service
B 283	Copper and Copper-Alloy Die Forgings (Hot-Pressed)
B 265	Titanium and Titanium Alloy Strip, Sheet, and Plate
B 333	Nickel-Molybdenum Alloy Plate, Sheet, and Strip
B 335	Nickel-Molybdenum Alloy Rod
B 337	Seamless and Welded Titanium and Titanium Alloy Pipe
B 345	Aluminum-Alloy Seamless Extruded Tube and Seamless Pipe for Gas and Oil Transmission and Distribution Piping Systems
B 361	Factory-Made Wrought Aluminum and Aluminum-Alloy Welding Fittings
B 366	Factory-Made Wrought Nickel and Nickel-Alloy Welding Fittings
B 381	Titanium and Titanium Alloy Forgings
B 407	Nickel-Iron-Chromium Alloy Seamless Pipe and Tube
B 409	Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip
B 435	UNS N06022, UNS N06230, and UNS R30556 Plate, Sheet, and Strip
B 443	Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Plate, Sheet and Strip
B 444	Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Seamless Pipe and Tube
B 446	Nickel-Chromium-Molybdenum-Columbium Alloy (UNS 06625) Rod and Bar
B 462	Forged or Rolled UNS N08020, UNS N08024, UNS N08026, and UNS N08367 Alloy Pipe Fittings, and Valves and Parts for Corrosive High-Temperature Service
B 463	Forged or Rolled UNS N08020, UNS N08026, UNS N08024 Alloy Plate, Sheet, and Strip
B 464	Welded Chromium-Nickel-Iron-Molybdenum-Copper-Columbium Stabilized Alloy (UNS N08020) Pipe

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Spec. No.	Title
ASTM (Cont'd)	
B 466	Seamless Copper-Nickel Pipe and Tube
B 467	Welded Copper-Nickel Pipe
B 491	Aluminum and Aluminum Alloy Extruded Round Tubes for General-Purpose Applications
B 493	Zirconium and Zirconium Alloy Forgings
B 514	Welded Nickel-Iron-Chromium Alloy Pipe
B 517	Welded Nickel-Chromium-Iron UNS N06800 Pipe
B 523	Seamless and Welded Zirconium and Zirconium Alloy Tubes for Condensers and Heat Exchangers
B 550	Zirconium and Zirconium Alloy Bar and Wire
B 551	Zirconium and Zirconium Alloy Strip, Sheet, and Plate
B 564	Nickel Alloy Forgings
B 574	Low-Carbon Nickel-Molybdenum-Chromium Alloy Rod
B 575	Low-Carbon Nickel-Molybdenum-Chromium Alloy Plate, Sheet and Strip
B 581	Nickel-Chromium-Iron-Molybdenum-Copper Alloy Rod
B 582	Nickel-Chromium-Iron-Molybdenum-Copper Alloy Plate, Sheet and Strip
B 584	Copper Alloy Sand Castings for General Applications
B 619	Welded Nickel and Nickel-Cobalt Alloy Pipe
B 620	Nickel-Iron-Chromium-Molybdenum Alloy (UNS N08320) Plate, Sheet and Strip
B 621	Nickel-Iron-Chromium-Molybdenum Alloy (UNS N08320) Rod
B 622	Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube
B 625	Nickel Alloy Plate and Sheet
B 649	Ni-Fe-Cr-Mo-Cu Low Carbon Alloy (UNS N08904) and Ni-Fe-Cr-Mo-Cu-N Low Carbon Alloy UNS N08925, UNS N08031, and UNS N08926) Bar and Wire
B 658	Zirconium and Zirconium Alloy Seamless and Welded Pipe
B 675	UNS N08366 and UNS N08367 Welded Pipe
B 688	Chromium-Nickel-Molybdenum-Iron (UNS N08366 and UNS N08367) Plate, Sheet, and Strip
B 690	Iron-Nickel-Chromium-Molybdenum Alloys (UNS N08366 and UNS N08367) Seamless Pipe and Tube
B 705	Nickel-Alloy (UNS N06625 and N08825) Welded Pipe
B 725	Welded Nickel (UNS N02200/UNS N02201) and Nickel-Copper Alloy (UNS N04400) Pipe
B 729	Seamless UNS N08020, UNS N08026, UNS N08024 Nickel-Alloy Pipe and Tube
B 804	UNS N08367 Welded Pipe
E 112	Methods for Determining Average Grain Size
API	
5L	Line Pipe

GENERAL NOTE: It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.

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NOTES FOR APPENDIX A TABLES

GENERAL NOTES:

(a) The allowable stress values, P-Number or S-Number assignments, weld joint and casting quality factors, and minimum temperatures in Tables A-1, A-1A, A-1B and A-2, together with the referenced Notes and single or double bars in the stress Tables, are requirements of this Code.

(b) Notes (1) through (7) are referenced in Table headings and in headings for material type and product form; Notes (8) and following are referenced in the Notes column for specific materials. Notes marked with an asterisk (*) restate requirements found in the text of the Code.

(c) At this time, metric equivalents have not been provided in Appendix A Tables. To convert stress values in Table A-1 to MPa at a given temperature in °C, determine the equivalent temperature in °F and interpolate to calculate the stress value in ksi at the given temperature. Multiply that value by 6.895 to determine basic allowable stress S in MPa at the given temperature.

NOTES:

(1) *The stress values in Table A-1 and the design stress values in Table A-2 are basic allowable stresses in tension in accordance with para. 302.3.1(a). For pressure design, the stress values from Table A-1 are multiplied by the appropriate quality factor E (E_c from Table A-1A or E_j from Table A-1B). Stress values in shear and bearing are stated in para. 302.3.1(b); those in compression in para. 302.3.1(c).

(2) *The quality factors for castings E_c in Table A-1A are basic factors in accordance with para. 302.3.3(b). The quality factors for longitudinal weld joints E_j in Table A-1B are basic factors in accordance with para. 302.3.4(a). See paras. 302.3.3(c) and 302.3.4(b) for enhancement of quality factors. See also para. 302.3.1(a), footnote 1.

(3) The stress values for austenitic stainless steels in these Tables may not be applicable if the material has been given a final heat treatment other than that required by the material specification or by reference to Note (30) or (31).

(4) *Stress values printed in *italics* exceed two-thirds of the expected yield strength at temperature. Stress values in **boldface** are equal to 90% of expected yield strength at temperature. See paras. 302.3.2(d)(3) and (e).

(5) *See para. 328.2.1(f) for description of P-Number and S-Number groupings. P-Numbers are indicated by number or by a number followed by a letter (e.g., 8, or 5B, or 11A). S-Numbers are preceded by an S (e.g., S-1).

A00 (6) *The minimum temperature shown is that design minimum temperature for which the material is normally suitable without impact testing other than that required by the material specification. However, the use of a material at a design minimum temperature below −29°C (−20°F) is established by rules elsewhere in this Code, including para. 323.2.2(a) and other impact test requirements. For carbon steels with a letter designation in the Min. Temp. column, see para. 323.2.2(b) and the applicable curve and Notes in Fig. 323.2.2A.

(7) *A single bar (|) adjacent to a stress value indicates that use of the material above (if the bar is to the right) or (if the bar is to the left) below the corresponding temperature is affected as described in a referenced Note. A single bar adjacent to the "Min. Temp." value has the same significance. A double bar (‖) adjacent to a stress value indicates that use of a material is prohibited above the corresponding temperature or above some lower temperature, depending on location (as described above) and on the referenced Note. A double bar to the left of "Min. Temp." indicates prohibition below that temperature. Where no stress values are listed, a material may be used in accordance with para. 323.2 unless prohibited by a double bar.

(8) *There are restrictions on the use of this material in the text of the Code as follows.
- (a) See para. 305.2.1; temperature limits are −29°C to 186°C (−20°F to 366°F).
- (b) See para. 305.2.2; pipe shall be safeguarded when used outside the temperature limits in Note (8a).
- (c) See Table 323.2.2, Section B-2.
- (d) See para. 323.4.2(a).
- (e) See para. 323.4.2(b).
- (f) See para. 309.2.1.
- (g) See para. 309.2.2.

(9) *For pressure-temperature ratings of components made in accordance with standards listed in Table 326.1, see para. 326.2.1. Stress values in Table A-1 may be used to calculate ratings for unlisted components, and special ratings for listed components, as permitted by para. 303.

(9a) Component standards listed in Table 326.1 impose the following restrictions on this material when used as a forging: composition, properties, heat treatment, and grain size shall conform to this specification: manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

(10) *This casting quality factor is applicable only when proper supplementary examination has been performed (see para. 302.3.3).

(11) *For use under this Code, radiography shall be performed after heat treatment.

(12) *Certain forms of this material, as stated in Table 323.2.2, must be impact tested to qualify for service below −29°C (−20°F). Alternatively, if provisions for impact testing are included in the material specification as supplementary requirements and are invoked, the material may be used down to the temperature at which the test was conducted in accordance with the specification.

(13) Properties of this material vary with thickness or size. Stress values are based on minimum properties for the thickness listed.

(14) For use in Code piping at the stated stress values, the required minimum tensile and yield properties must be verified by tensile test. If such tests are not required by the material specification, they shall be specified in the purchase order.

(15) These stress values are established from a consideration of strength only and will be satisfactory for average service. For bolted joints where freedom from leakage over a long period of time without retightening is required, lower stress values may be necessary as determined from the flexibility of the flange and bolts and corresponding relaxation properties.

(16) An E_j factor of 1.00 may be applied only if all welds, including welds in the base material, have passed 100% radiographic examination. Substitution of ultrasonic examination for radiography is not permitted for the purpose of obtaining an E_j of 1.00.

(17) Filler metal shall not be used in the manufacture of this pipe or tube.

(18) *This specification does not include requirements for 100% radiographic inspection. If this higher joint factor is to be used, the material shall be purchased to the special requirements of Table 341.3.2 for longitudinal butt welds with 100% radiography in accordance with Table 302.3.4.

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(19) *This specification includes requirements for random radiographic inspection for mill quality control. If the 0.90 joint factor is to be used, the welds shall meet the requirements of Table 341.3.2 for longitudinal butt welds with spot radiography in accordance with Table 302.3.4. This shall be a matter of special agreement between purchaser and manufacturer.

(20) For pipe sizes ≥ DN 200 (NPS 8) with wall thicknesses ≥ Sch 140, the specified minimum tensile strength is 483 MPa (70 ksi).

(21) For material thickness > 127 mm (5 in.), the specified minimum tensile strength is 483 MPa (70 ksi).

(21a) For material thickness > 127 mm (5 in.), the specified minimum tensile strength is 448 MPa (65 ksi).

(22) The minimum tensile strength for weld (qualification) and stress values shown shall be multiplied by 0.90 for pipe having an outside diameter less than 51 mm (2 in.) and a D/t value less than 15. This requirement may be waived if it can be shown that the welding procedure to be used will consistently produce welds that meet the listed minimum tensile strength of 165 MPa (24 ksi).

(23) Light-weight aluminum alloy welded fittings conforming to dimensions in MSS SP-43 shall have full penetration welds.

(24) Yield strength is not stated in the material specification. The value shown is based on yield strengths of materials with similar characteristics.

(25) This steel may develop embrittlement after service at approximately 316°C (600°F) and higher temperature.

(26) This unstabilized grade of stainless steel increasingly tends to precipitate intergranular carbides as the carbon content increases above 0.03%. See also para. F323.4(c)(2).

(27) For temperatures above 427°C (800 °F), these stress values apply only when the carbon content is 0.04% or higher.

(28) For temperatures above 538°C (1000°F), these stress values apply only when the carbon content is 0.04% or higher.

(29) The stress values above 538°C (1000°F) listed here shall be used only when the steel's austenitic micrograin size, as defined in ASTM E 112, is No. 6 or less (coarser grain). Otherwise, the lower stress values listed for the same material, specification, and grade shall be used.

(30) For temperatures above 538°C (1000°F), these stress values may be used only if the material has been heat treated at a temperature of 1093°C (2000°F) minimum.

(31) For temperatures above 538°C (1000°F), these stress values may be used only if the material has been heat treated by heating to a minimum temperature of 1038°C (1900°F) and quenching in water or rapidly cooling by other means.

(32) Stress values shown are for the lowest strength base material permitted by the specification to be used in the manufacture of this grade of fitting. If a higher strength base material is used, the higher stress values for that material may be used in design.

(33) For welded construction with work hardened grades, use the stress values for annealed material; for welded construction with precipitation hardened grades, use the special stress values for welded construction given in the Tables.

(34) If material is welded, brazed, or soldered, the allowable stress values for the annealed condition shall be used.

(35) This steel is intended for use at high temperatures; it may have low ductility and/or low impact properties at room temperature, however, after being used above the temperature indicated by the single bar (|). See also para. F323.4(c)(4).

(36) The specification permits this material to be furnished without solution heat treatment or with other than a solution heat treatment. When the material has not been solution heat treated, the minimum temperature shall be −29°C (−20°F) unless the material is impact tested per para. 323.3.

(37) Impact requirements for seamless fittings shall be governed by those listed in this Table for the particular base material specification in the grades permitted (A 312, A 240, and A 182). When A 276 materials are used in the manufacture of these fittings, the Notes, minimum temperatures, and allowable stresses for comparable grades of A 240 materials shall apply.

Note (38) Deleted A00

(39) This material when used below −29°C (−20°F) shall be impact tested if the carbon content is above 0.10%.

(40) *This casting quality factor can be enhanced by supplementary examination in accordance with para. 302.3.3(c) and Table 302.3.3C. The higher factor from Table 302.3.3C may be substituted for this factor in pressure design equations.

(41) Design stresses for the cold drawn temper are based on hot rolled properties until required data on cold drawn are submitted.

(42) This is a product specification. No design stresses are necessary. Limitations on metal temperature for materials covered by this specification are: A00

Grade(s)	Metal Temperature, °C (°F)
1	−29 to 482 (−20 to 900)
2, 2H, and 2HM	−48 to 593 (−55 to 1100)
3	−29 to 593 (−20 to 1100)
4 [see Note (42a)]	−101 to 593 (−150 to 1100)
6	−29 to 427 (−20 to 800)
7 and 7M [see Note (42a)]	−101 to 593 (−150 to 1100)
8FA [see Note (39)]	−29 to 427 (−20 to 800)
8MA and 8TA	−198 to 816 (−325 to 1500)
8, 8A, and 8CA	−254 to 816 (−425 to 1500)

(42a) When used below −46°C (−50°F), this material shall be impact tested as required by A 320 for Grade L7.

(42b) This is a product specification. No design stresses are necessary. For limitations on usage, see paras. 309.2.1 and 309.2.2.

(43) *The stress values given for this material are not applicable when either welding or thermal cutting is employed [see para. 323.4.2(c)].

(44) This material shall not be welded.

(45) Stress values shown are applicable for "die" forgings only.

(46) The letter "a" indicates alloys which are not recommended for welding and which, if welded, must be individually qualified. The letter "b" indicates copper base alloys which must be individually qualified.

(47) If no welding is employed in fabrication of piping from these materials, the stress values may be increased to 230 MPa (33.3 ksi).

(48) The stress value to be used for this gray cast iron material at its upper temperature limit of 232°C (450°F) is the same as that shown in the 204°C (400°F) column.

(49) If the chemical composition of this Grade is such as to render it hardenable, qualification under P-No. 6 is required.

(50) This material is grouped in P-No. 7 because its hardenability is low.

(51) This material may require special consideration for welding qualification. See the BPV Code, Section IX, QW/QB-422. For use in this Code, a qualified WPS is required for each strength level of material.

(52) Copper-silicon alloys are not always suitable when exposed to certain media and high temperature, particularly above 100°C (212°F). The user should satisfy himself that the alloy selected is satisfactory for the service for which it is to be used.

(53) Stress relief heat treatment is required for service above 232°C (450°F).

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(54) The maximum operating temperature is arbitrarily set at 260°C (500°F) because hard temper adversely affects design stress in the creep rupture temperature ranges.

(55) Pipe produced to this specification is not intended for high temperature service. The stress values apply to either nonexpanded or cold expanded material in the as-rolled, normalized, or normalized and tempered condition.

(56) Because of thermal instability, this material is not recommended for service above 427°C (800°F).

(57) Conversion of carbides to graphite may occur after prolonged exposure to temperatures over 427°C (800°F). See para. F323.4(b)(2).

(58) Conversion of carbides to graphite may occur after prolonged exposure to temperatures over 468°C (875°F). See para. F323.4(b)(3).

(59) For temperatures above 482°C (900°F), consider the advantages of killed steel. See para. F323.4(b)(4).

(60) For all design temperatures, the maximum hardness shall be Rockwell C35 immediately under the thread roots. The hardness shall be taken on a flat area at least 3 mm ($\frac{1}{8}$ in.) across, prepared by removing threads. No more material than necessary shall be removed to prepare the area. Hardness determination shall be made at the same frequency as tensile tests.

(61) Annealed at approximately 982°C (1800°F).

(62) Annealed at approximately 1121°C (2050°F).

(63) For stress relieved tempers (T351, T3510, T3511, T451, T4510, T4511, T651, T6510, T6511), stress values for material in the listed temper shall be used.

(64) The minimum tensile strength of the reduced section tensile specimen in accordance with the BPV Code, Section IX, QW-462.1, shall not be less than 758 MPa (110.0 ksi).

(65) The minimum temperature shown is for the heaviest wall permissible by the specification. The minimum temperature for lighter walls shall be as shown in the following tabulation:

Impact Test Temp. (°C) for Plate Thicknesses Shown

Spec. No. & Grade	25 mm Max.	51 mm Max.	Over 51 to 76 mm
A 203 A	−68	−68	−59
A 203 B	−68	−68	−59
A 203 D	−101	−101	−87
A 203 E	−101	−101	−87

Impact Test Temp. (°F) for Plate Thicknesses Shown

Spec. No. & Grade	1 in. Max.	2 in. Max.	Over 2 in. to 3 in.
A 203 A	−90	−90	−75
A 203 B	−90	−90	−75
A 203 D	−150	−150	−125
A 203 E	−150	−150	−125

(66) Stress values shown are 90% of those for the corresponding core material.

(67) For use under this Code, the heat treatment requirements for pipe manufactured to A 671, A 672, and A 691 shall be as required by para. 331 for the particular material being used. **A00**

(68) The tension test specimen from plate 12.7 mm ($\frac{1}{2}$ in.) and thicker is machined from the core and does not include the cladding alloy; therefore, the stress values listed are those for materials less than 12.7 mm.

(69) This material may be used only in nonpressure applications.

(70) Alloy 625 (UNS N06625) in the annealed condition is subject to severe loss of impact strength at room temperature after exposure in the range of 538°C to 760°C (1000°F to 1400°F).

(71) These materials are normally microalloyed with Cb, V, and/or Ti. Supplemental specifications agreed to by manufacturer and purchaser commonly establish chemistry more restrictive than the base specification, as well as plate rolling specifications and requirements for weldability (i.e., C-equivalent) and toughness.

(72) For service temperature > 454°C (850°F), weld metal shall have a carbon content > 0.05%.

(73) Heat treatment is required after welding for all products of zirconium Grade R60705. See Table 331.1.1.

(74) Mechanical properties of fittings made from forging stock shall meet the requirements of one of the bar, forging, or rod specifications listed in Table 1 of B 366.

(75) Stress values shown are for materials in the normalized and tempered condition, or when the heat treatment is unknown. If material is annealed, use the following values above 510°C (950°F):

Temp., °F	1000	1050	1100	1150	1200
S, ksi	8.0	5.7	3.8	2.4	1.4

(76) Hydrostatic testing is an option (not required) in this specification. For use under this Code, hydrostatic testing is required.

(77) The pipe grades listed below, produced in accordance with CSA (Canadian Standards Association) Z245.1, shall be considered as equivalents to API 5L and treated as listed materials. **(99) A00**

Grade Equivalents

API 5L	CSA Z245.1
A25	172
A	207
B	241
X42	290
X46	317
X52	359
X56	386
X60	414
X65	448
X70	483
X80	550

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)														
400	500	600	650	700	750	800	850	900	950	1000	1050	1100	Grade	Spec. No.
													Carbon Steel (Cont'd) Pipes and Tubes (2) (Cont'd)	
20.0	18.9	17.3	17.0	16.5	13.0	10.8	8.7	6.5	4.5	2.5	1.6	1.0	B	A 53
													B	A 106
													6	A 333
													6	A 334
													FPB	A 369
													Y35	A 381
													B	API 5L
...	...	...	...	...	...	...	...	...	...	...	...	...	C	A 139
20.0	...	...	...	...	...	...	...	...	...	...	...	...	D	A 139
20.0	...	...	...	...	...	...	...	...	...	...	...	...	X42	API 5L
17.8	16.9	16.0	15.5	...	...	...	...	...	...	...	...	...	Y42	A 381
21.0	...	...	...	...	...	...	...	...	...	...	...	...	X46	API 5L
21.0	...	...	...	...	...	...	...	...	...	...	...	...	Y46	A 381
18.4	17.4	16.5	16.0	...	...	...	...	...	...	...	...	...	Y50	A 381
20.0	18.9	17.3	17.0	16.8	13.9	11.4	9.0	6.5	4.5	2.5	...	...	CC65	A 671
20.0	18.9	17.3	17.0	16.8	13.9	11.4	9.0	6.5	4.5	2.5	1.6	1.0	CB65	A 671
													B65	A 672
													C65	A 672
...	...	...	...	...	...	...	...	...	...	...	...	...	E	A 139
22.0	...	...	...	...	...	...	...	...	...	...	...	...	X52	API 5L
22.0	...	...	...	...	...	...	...	...	...	...	...	...	Y52	A 381
21.7	20.5	18.7	18.4	18.3	14.8	12.0	9.3	6.5	4.5	2.5	...	...	CC70	A 671
21.7	20.5	18.7	18.4	18.3	14.8	12.0	9.3	6.5	4.5	2.5	1.6	1.0	CB70	A 671
													B70	A 672
													C70	A 672
22.9	21.6	19.7	19.4	19.2	14.8	12.0	...	...	...	...	...	...	C	A 106
22.9	22.9	22.6	22.0	21.4	...	...	...	...	...	...	...	...	CD70	A 671
													D70	A 672
													CMSH70	A 691
23.7	...	...	...	...	...	...	...	...	...	...	...	...	X56	API 5L
23.7	...	...	...	...	...	...	...	...	...	...	...	...	Y56	A 381

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200	300
						Tensile	Yield			
Carbon Steel (Cont'd)										
Pipes and Tubes (2) (Cont'd)										
A 299 (> 1 in. thick)	A 671	1	CK75							
A 299 (> 1 in. thick)	A 672	1	N75	(57)(67)	A	75	40	25.0	24.4	23.7
A 299 (> 1 in. thick)	A 691	1	CMS75							
A 299 (≤ 1 in. thick)	A 671	1	CK75							
A 299 (≤ 1 in. thick)	A 672	1	N75	(57)(67)	A	75	42	25.0	25.0	24.8
A 299 (≤ 1 in. thick)	A 691	1	CMS75							
...	API 5L	S-1	X60	(51)(55)(71)(77)	A	75	60	25.0	25.0	25.0
...	API 5L	S-1	X65	(51)(55)(71)	A	77	65	25.7	25.7	25.7
...	API 5L	S-1	X70	(51)(55)(71)	A	82	70	27.3	27.3	27.3
...	API 5L	S-1	X80	(51)(55)(71)	A	90	80	30.0	30.0	30.0
...	A 381	S-1	Y60	(51)(71)	A	75	60	25.0	25.0	25.0
Pipes (Structural Grade) (2)										
A 283 Gr. A	A 134	1	...	(8a)(8c)	−20	45	24	13.7	13.0	12.4
A 570 Gr. 30	A 134	S-1	...	(8a)(8c)	−20	49	30	15.0	15.0	15.0
A 283 Gr. B	A 134	1	...	(8a)(8c)	−20	50	27	15.3	14.4	13.9
A 570 Gr. 33	A 134	S-1	...	(8a)(8c)	−20	52	33	15.9	15.9	15.9
A 570 Gr. 36	A 134	S-1	...	(8a)(8c)	−20	53	36	16.3	16.3	16.3
A 570 Gr. 40	A 134	1	...	(8a)(8c)	−20	55	40	16.9	16.9	16.9
A 36	A 134	1	...	(8a)(8c)	−20	58	36	17.6	16.8	16.8
A 283 Gr. D	A 134	1	...	(8a)(8c)	−20	60	33	18.4	17.4	16.6
A 570 Gr. 45	A 134	S-1	...	(8a)(8c)	−20	60	45	18.4	18.4	18.4
A 570 Gr. 50	A 134	1	...	(8a)(8c)	−20	65	50	19.9	19.9	19.9

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)														
400	500	600	650	700	750	800	850	900	950	1000	1050	1100	Grade	Spec. No.
													Carbon Steel (Cont'd) Pipes and Tubes (2) (Cont'd)	
22.9	21.6	19.7	19.4	19.2	15.7	12.6	9.5	6.5	4.5	2.5	1.6	1.0	CK75	A 671
													N75	A 672
													CMS75	A 691
24.0	22.7	20.7	20.4	20.2	...	...	...	...	...	...	...	...	CK75	A 671
													N75	A 672
													CMS75	A 691
25.0	...	...	...	...	...	...	...	...	...	...	...	...	X60	API 5L
25.7	...	...	...	...	...	...	...	...	...	...	...	...	X65	API 5L
27.3	...	...	...	...	...	...	...	...	...	...	...	...	X70	API 5L
30.0	...	...	...	...	...	...	...	...	...	...	...	...	X80	API 5L
25.0	...	...	...	...	...	...	...	...	...	...	...	...	Y60	A 381
													Pipes (Structural Grade) (2)	
11.8	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
15.0	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
...	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
15.9	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
16.3	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
16.9	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
16.8	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
...	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
18.4	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
19.9	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200	300
						Tensile	Yield			
Carbon Steel (Cont'd) Plates and Sheets										
...	A 285	1	A	(57)(59)	B	45	24	15.0	14.6	14.2
...	A 285	1	B	(57)(59)	B	50	27	16.7	16.4	16.0
...	A 516	1	55	(57)	C	55	30	18.3	18.3	17.7
...	A 285	1	C	(57)(59)	A	55	30	18.3	18.3	17.7
...	A 516	1	60	(57)	C	60	32	20.0	19.5	18.9
...	A 515	1	60	(57)	B	60	32	20.0	19.5	18.9
...	A 516	1	65	(57)	B	65	35	21.7	21.3	20.7
...	A 515	1	65	(57)	A	65	35	21.7	21.3	20.7
...	A 516	1	70	(57)	B	70	38	23.3	23.1	22.5
...	A 515	1	70	(57)	A	70	38	23.3	23.1	22.5
($\leq 2\frac{1}{2}$ in. thick)	A 537	1	Cl. 1	...	D	70	50	23.3	23.3	22.9
(> 1 in. thick)	A 299	1	...	(57)	A	75	40	25.0	24.4	23.7
($\leq$ 1 in. thick)	A 299	1	...	(57)	A	75	42	25.0	25.0	24.8
Plates and Sheets (Structural)										
...	A 283	1	A	(8c)(57)	A	45	24	13.8	13.2	12.5
...	A 570	S-1	30	(8c)(57)	A	49	30	15.0	15.0	15.0
...	A 283	1	B	(8c)(57)	A	50	27	15.3	14.6	14.0
...	A 570	S-1	33	(8c)(57)	A	52	33	15.9	15.9	15.9
...	A 570	S-1	36	(8c)(57)	A	53	36	16.3	16.3	16.3
...	A 283	1	C	(8c)(57)	A	55	30	16.9	16.1	15.3
...	A 570	S-1	40	(8c)(57)	A	55	40	16.9	16.9	16.9
...	A 36	1	...	(8c)	A	58	36	17.8	16.9	16.9
...	A 283	1	D	(8c)(57)	A	60	33	18.4	17.5	16.7
...	A 570	S-1	45	(8c)(57)	A	60	45	18.4	18.4	18.4
...	A 570	S-1	50	(8c)(57)	A	65	50	19.9	19.9	19.9

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																	
300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
																Low and Intermediate Alloy Steel Pipes (2)	
17.5	16.9	16.3	15.7	15.4	15.1	13.8	13.5	13.2	12.8	9.2	5.9	...	...	...	...	P2	A 335
18.3	18.3	17.9	17.3	16.9	16.6	13.8	13.8	13.4	12.8	9.2	5.9	...	...	...	...	½Cr	A 691
17.5	16.9	16.3	15.7	15.4	15.1	13.8	13.5	13.2	12.7	8.2	4.8	4.0	2.4	...	...	P1	A 335
17.5	16.9	16.3	15.7	15.4	15.1	13.8	13.5	13.2	12.8	9.2	5.9	4.0	2.4	...	...	FP1	A 369
17.5	16.9	16.3	15.7	15.4	15.1	13.8	13.5	13.2	12.8	9.2	5.9	4.0	2.4	...	...	FP2	A 369
18.3	18.3	17.9	17.3	16.9	16.6	16.3	15.9	15.4	14.0	11.3	7.2	4.5	2.8	1.8	1.1	1Cr	A 691
17.0	16.3	15.6	14.9	14.6	14.2	13.9	13.5	13.2	12.5	10.0	6.3	4.0	2.4	...	...	CP2	A 426
17.6	17.0	16.5	15.9	15.6	15.3	15.0	14.4	13.8	12.5	10.0	6.3	4.0	2.4	...	...	P15	A 335
																CP15	A 426
17.6	17.1	16.5	15.9	15.7	15.4	15.1	14.8	14.2	13.1	11.3	7.2	4.5	2.8	1.8	1.1	CP12	A 426
17.1	16.2	15.4	14.5	14.1	13.7	13.3	12.8	12.4	10.9	9.0	5.5	3.5	2.5	1.8	1.2	CP5b	A 426
17.4	16.8	16.1	15.5	15.2	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	2.7	1.5	CP21	A 426
18.2	17.3	16.4	15.5	15.0	...	...	...	...	...	...	...	...	...	...	...	4	A 333
17.5	16.4	16.3	15.7	15.4	15.1	13.9	13.5	13.1	12.5	10.0	6.2	4.2	2.6	1.4	1.0	FP3b	A 369
18.0	17.5	17.2	16.7	16.2	15.6	15.2	15.0	14.5	12.8	11.3	7.2	4.5	2.8	1.8	1.1	P12	A 335
																FP12	A 369
18.0	17.5	17.2	16.7	16.2	15.6	15.2	15.0	14.5	12.8	9.3	6.3	4.2	2.8	1.9	1.2	P11	A 335
																FP11	A 369
20.0	19.7	18.9	18.3	18.0	17.6	17.3	16.8	16.3	15.0	9.9	6.3	4.2	2.8	1.9	1.2	1¼Cr	A 691
17.4	17.2	17.1	16.8	16.6	16.3	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.8	2.0	1.3	5Cr	A 691
17.4	17.2	17.1	16.8	16.6	16.3	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	P5	A 335
																P5b	A 335
																P5c	A 335
																FP5	A 369
17.4	17.2	17.1	16.8	16.6	16.3	13.2	12.8	12.1	11.4	10.6	7.4	5.0	3.3	2.2	1.5	F9	A 335
																FP9	A 369
																9Cr	A 691

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200
						Tensile	Yield		
Low and Intermediate Alloy Steel (Cont'd)									
Pipes (2) (Cont'd)									
3Cr-1Mo	A 335	5A	P21						
3Cr-1Mo	A 369	5A	FP21	...	−20	60	30	20.0	18.7
3Cr-1Mo A 387 Gr. 21 Cl. 1	A 691	5A	3Cr	(11)(67)	−20	60	30	20.0	18.5
2¼Cr-1Mo A 387 Gr. 22 Cl. 1	A 691	5A	2¼Cr	(11)(67) (72)(75)					
2¼Cr-1Mo	A 369	5A	FP22	(72)(75)	−20	60	30	20.0	18.5
2¼Cr-1Mo	A 335	5A	P22	(72)(75)					
2Ni-1Cu	A 333								
2Ni-1Cu	A 334	9A	9	...	−100	63	46	21.0	...
2¼Ni	A 333								
2¼Ni	A 334	9A	7	...	−100	65	35	21.7	19.6
3½Ni	A 333								
3½Ni	A 334	9B	3	...	−150	65	35	21.7	19.6
C-½Mo	A 426	3	CP1	(10)(58)	−20	65	35	21.7	21.7
C-Mo A 204 Gr. A	A 672	3	L65						
C-Mo A 204 Gr. A	A 691	3	CM65	(11)(58)(67)	−20	65	37	21.7	21.7
2¼Ni A 203 Gr. B	A 671	9A	CF70						
3½Ni A 203 Gr. E	A 671	9B	CF71	(11)(65)(67)	−20	70	40	23.3	...
C-Mo A 204 Gr. B	A 672	3	L70						
C-Mo A 204 Gr. B	A 691	3	CM70	(11)(58)(67)	−20	70	40	23.3	23.3
1¼Cr-½Mo	A 426	4	CP11	(10)	−20	70	40	23.3	23.3
2¼Cr-1Mo	A 426	5A	CP22	(10)(72)	−20	70	40	23.3	23.3
C-Mo A 204 Gr. C	A 672	3	L75						
C-Mo A 204 Gr. C	A 691	3	CM75	(11)(58)(67)	−20	75	43	25.0	25.0
9Cr-1Mo-V ≤ 3 in. thick	A 335								
9Cr-1Mo-V ≤ 3 in. thick	A 691	5B	P91	...	−20	85	60	28.3	28.3
5Cr-½Mo	A 426	5B	CP5	(10)	−20	90	60	30.0	28.0
9Cr-1Mo	A 426	5B	CP9	(10)	−20	90	60	30.0	22.5
9Ni	A 333	11A	8	(47)					
9Ni	A 334	11A	8	...	−320	100	75	31.7	31.7

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																	
300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
																Low and Intermediate Alloy Steel (Cont'd) Pipes (2) (Cont'd)	
18.0	17.5	17.2	16.7	16.2	15.6	15.2	15.0	14.0	12.0	9.0	7.0	5.5	4.0	2.7	1.5	P21	A 335
																FP21	A 369
18.1	17.9	17.9	17.9	17.9	17.9	17.9	17.8	14.0	12.0	9.0	7.0	5.5	4.0	2.7	1.5	3Cr	A 691
18.0	17.9	17.9	17.9	17.9	17.9	17.9	17.8	14.5	12.8	10.8	7.8	5.1	3.2	2.0	1.6	2¼Cr	A 691
																FP22	A 369
																P22	A 335
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9	A 333, A 334
19.6	18.7	17.6	16.8	16.3	15.5	13.9	11.4	9.0	6.5	4.5	2.5	1.6	1.0	...	...	7	A 333, A 334
19.6	18.7	17.8	16.8	16.3	15.5	13.9	11.4	9.0	6.5	4.5	2.5	1.6	1.0	...	...	3	A 333, A 334
21.7	21.7	21.3	20.7	20.4	20.0	16.3	15.7	14.4	12.5	10.0	6.3	4.0	2.4	...	...	CP1	A 426
21.7	20.7	20.0	19.3	19.0	18.6	16.3	15.8	15.3	13.7	8.2	4.8	4.0	2.4	...	...	L65	A 672
																CM65	A 691
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CF70	A 671
																CF71	A 671
23.3	22.5	21.7	20.9	20.5	20.1	17.5	17.5	17.1	13.7	8.2	4.8	4.0	2.4	...	...	L70	A 672
																CM70	A 691
23.3	23.3	22.9	22.3	21.6	20.9	15.5	15.0	14.4	13.7	9.3	6.3	4.2	2.8	1.9	1.2	CP11	A 426
23.3	23.3	22.9	22.3	21.6	20.9	17.5	17.5	16.0	14.0	11.0	7.8	5.1	3.2	2.0	1.2	CP22	A 426
25.0	24.1	23.3	22.5	22.1	21.7	18.8	18.8	18.3	13.7	8.2	4.8	4.0	2.4	...	...	L75	A 672
																CM75	A 691
28.3	28.2	28.1	27.7	27.3	26.7	25.9	24.9	23.7	22.3	20.7	18.0	14.0	10.3	7.0	4.3	P91	A 335, A 691
26.1	24.1	22.1	20.1	19.0	17.5	16.0	14.5	12.8	10.4	7.6	5.6	4.2	3.1	1.8	1.0	CP5	A 426
22.5	22.5	22.5	22.5	22.5	22.0	21.0	19.4	17.3	15.0	10.7	8.5	5.5	3.3	2.2	1.5	CP9	A 426
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8	A 333
																8	A 334

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200
						Tensile	Yield		
Low and Intermediate Alloy Steel (Cont'd)									
Plates									
½Cr-½Mo	A 387	3	Gr. 2 Cl. 1	...	−20	55	33	18.3	18.3
1Cr-½Mo	A 387	4	Gr. 12 Cl. 1	...	−20	55	33	18.3	18.3
9Cr-1Mo	A 387	5	Gr. 9 Cl. 1	...	−20	60	30	20.0	18.1
1¼Cr-½Mo	A 387	4	Gr. 11 Cl. 1	...	−20	60	35	20.0	20.0
5Cr-½Mo	A 387	5B	Gr. 5 Cl. 1	...	−20	60	30	20.0	18.1
3Cr-1Mo	A 387	5A	Gr. 21 Cl. 1	...	−20	60	30	20.0	18.5
2¼Cr-1Mo	A 387	5A	Gr. 22 Cl. 1	(72)	−20	60	30	20.0	18.5
2¼Ni	A 203	9A	A	(12)(65)	−20	65	37	21.7	19.6
3½Ni	A 203	9B	D						
C-½Mo	A 204	3	A	(58)	−20	65	37	21.7	21.7
1Cr-½Mo	A 387	4	Gr. 12 Cl. 2	...	−20	65	40	21.7	21.7
2¼Ni	A 203	9A	B	(12)(65)	−20	70	40	23.3	21.1
3½Ni	A 203	9B	E						
½Cr-½Mo	A 387	3	Gr. 2 Cl. 2	...	−20	70	45	23.3	17.5
C-½Mo	A 204	3	B	(58)	−20	70	40	23.3	23.3
Cr-n-Si	A 202	4	A	...	−20	75	45	25.0	23.9
Mn-Mo	A 302	3	A	...	−20	75	45	25.0	25.0
C-½Mo	A 204	3	C	(58)	−20	75	43	25.0	25.0
1¼Cr-½Mo	A 387	4	Gr. 11 Cl. 2	...	−20	75	45	25.0	25.0
5Cr-½Mo	A 387	5B	Gr. 5 Cl. 2	...	−20	75	45	25.0	24.9
3Cr-½Mo	A 387	5A	Gr. 21 Cl. 2	...	−20	75	45	25.0	25.0
2¼Cr-1Mo	A 387	5A	Gr. 22 Cl. 2	(72)	−20	75	45	25.0	25.0
Mn-Mo	A 302	3	B	...	−20	80	50	26.7	26.7
Mn-Mo-Ni	A 302	3	C						
Mn-Mo-Ni	A 302	3	D						
Cr-n-Si	A 202	4	B	...	−20	85	47	28.4	27.1
9Cr-1Mo-V ≤ 3 in. thick	A 387	5B	91 Cl. 2	...	−20	85	60	28.3	28.3
8Ni	A 553	11A	Type II	(47)	−275	100	85	31.7	...
5Ni	A 645	11A	...	...	−275	95	65	31.7	31.6
9Ni	A 553	11A	Type I	(47)	−320	100	85	31.7	31.7
9Ni	A 353	11A	...	(47)	−320	100	75		

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																	
300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
																Low and Intermediate Alloy Steel (Cont'd) Forgings and Fittings (2) (Cont'd)	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	WPL8	A 420
																Castings (2)	
20.5	19.7	18.9	18.3	18.0	17.6	...	...	...	...	...	...	...	...	...	...	LC1	A 352
20.5	19.7	18.9	18.3	18.0	17.6	16.2	15.8	15.3	13.7	8.2	4.8	4.0	2.4	...	...	WC1	A 352
17.5	17.5	17.5	17.5	17.5	...	...	...	...	...	...	...	...	...	...	...	LC2	A 352
																LC3	A 352
23.3	22.5	21.7	20.9	20.5	20.1	17.5	17.5	17.1	15.0	9.2	5.9	...	...	...	...	WC4	A 217
23.3	22.5	21.7	20.9	20.5	20.1	17.5	17.5	17.1	16.3	11.0	6.9	4.6	2.8	...	...	WC5	A 217
23.3	22.5	21.7	20.9	20.5	20.1	19.7	19.2	18.7	14.5	11.0	6.9	4.6	2.8	2.5	1.3	WC6	A 217
23.1	22.5	22.4	22.4	22.2	21.9	21.5	21.0	19.8	17.0	11.4	7.8	5.1	3.2	2.0	1.2	WC9	A 217
29.1	28.9	28.7	28.3	27.9	27.3	19.8	19.1	14.3	10.9	8.0	5.8	4.2	2.9	1.8	1.0	C5	A 217
29.1	28.9	28.7	28.3	27.9	27.3	19.8	19.1	18.2	16.5	11.0	7.4	5.0	3.3	2.2	1.5	C12	A 217

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi Tensile	Yield	Min. Temp. to 100	200	300	400	500	600
Stainless Steel (3) (4) Pipes and Tubes (2)													
18Cr-10Ni-Ti pipe smls > 3/8 in. thick	A 312												
18Cr-10Ni-Ti pipe > 3/8 in. thick	A 376	8	TP321	(30)(36)	−425	70	25	16.7	*16.7*	*16.7*	16.7	16.1	15.2
18Cr-8Ni tube	A 269	8	TP304L	(14)(36)	−425								
18Cr-8Ni pipe	A 312	8	TP304L	...	−425	70	25	16.7	*16.7*	*16.7*	15.8	14.8	14.0
Type 304L A 240	A 358	8	304L	(36)	−425								
16Cr-12Ni-2Mo tube	A 269	8	TP316L	(14)(36)	−425								
16Cr-12Ni-2Mo pipe	A 312	8	TP316L	...	−425	70	25	16.7	*16.7*	*16.7*	15.5	14.4	13.5
Type 316L A 240	A 358	8	316L	(36)	−425								
18Cr-10Ni-Ti pipe smls > 3/8 in. thick	A 312												
18Cr-10Ni-Ti pipe > 3/8 in. thick	A 376	8	TP321	(28)(30)(36)	−425								
18Cr-10Ni-i pipe smls > 3/8 in. thick	A 312	8	TP321H	(30)(36)	−325	70	25	16.7	*16.7*	*16.7*	16.7	16.1	15.2
18Cr-10Ni-Ti pipe > 3/8 in. thick	A 376	8	TP321H	...	−325								
23Cr-13Ni	A 451	8	CPH8	(26)(28)(35)	−325	65	28	18.7	*18.7*	*18.7*	*18.7*	*18.7*	18.0
25Cr-20Ni	A 451	8	CPK20	(12)(28)(35)(39)	−325	65	28	18.7	*18.7*	*18.7*	*18.7*	*18.7*	18.0
11Cr-Ti tube	A 268	7	TP409	(35)	−20	60	30	20.0	...	...	...	...	...
18Cr-i tube	A 268	7	TP430Ti	(35)(49)	−20	60	40	20.0	...	...	...	...	...
15Cr-13Ni-2Mo-Cb	A 451	S-8	CPF10MC	(28)	−325	70	30	20.0	...	...	...	...	...
16Cr-8Ni-2Mo pipe	A 376	8	16-8-2H	(26)(31)(35)	−325	75	30	20.0	...	...	...	...	...
12Cr-Al tube	A 268	7	TP405	(35)	−20	60	30	20.0	18.4	17.7	17.4	17.2	16.8
13Cr tube	A 268	6	TP410	(35)	−20	60	30	20.0	18.4	17.7	17.4	17.2	16.8
16Cr tube	A 268	7	TP430	(35)(49)	−20	60	35	20.0	20.0	19.6	19.2	19.0	18.5
18Cr-13Ni-3Mo pipe	A 312	8	TP317L	...	−325	75	30	20.0	*20.0*	*20.0*	18.9	17.7	16.8
25Cr-20Ni pipe	A 312	8	TP310	(28)(35)(39)									
Type 310S A 240	A 358	8	310S	(28)(31)(35)(36)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	20.0	19.2
25Cr-20Ni pipe	A 409	8	TP310	(28)(31)(35)(36)(39)									
18Cr-10Ni-Ti pipe smls ≤ 3/8 in. thk & wld	A 312	8	TP321	(30)									
18Cr-10Ni-Ti pipe	A 358	8	321										
18Cr-10Ni-Ti pipe ≤ 3/8 in. thick	A 376			(30)(36)	−425	75	30	20.0	*20.0*	*20.0*	*20.0*	19.3	18.3
18Cr-10Ni-Ti pipe	A 409	8	TP321										
23Cr-12Ni pipe	A 312	8	TP309	(28)(35)(39)	−325								
Type 309S A 240	A 358	8	309S	(28)(31)(35)(36)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
23Cr-12Ni pipe	A 409	8	TP309	(28)(31)(35)(36)(39)	−325								
18Cr-8Ni	A 451	8	CPF8	(26)(28)	−425	70	30	20.0	*20.0*	*19.8*	17.5	16.4	15.7

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																			
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Grade	Spec. No.
																		Stainless Steel (3) (4) Pipes and Tubes (2)	
14.9	14.6	14.3	14.1	14.0	13.8	13.6	13.5	9.6	6.9	5.0	3.6	2.6	1.7	1.1	0.8	0.5	0.3	TP321	A 312 A 376
13.7	13.5	13.3	13.0	12.8	*11.9*	*9.9*	7.8	6.3	5.1	4.0	3.2	2.6	2.1	1.7	1.1	1.0	0.9	TP304L TP304L 304L	A 269 A 312 A 358
13.2	12.9	12.6	12.4	12.1	11.8	11.5	11.2	10.8	*10.2*	*8.8*	6.4	4.7	3.5	2.5	1.8	1.3	1.0	TP316L TP316L 316L	A 269 A 312 A 358
14.9	14.6	14.3	14.1	14.0	13.8	13.6	13.5	11.7	9.1	6.9	5.4	4.1	3.2	2.5	1.9	1.5	1.1	TP321 TP321 TP321H TP321H	A 312 A 376 A 312 A 376
17.4	17.1	16.8	16.3	*12.8*	*12.4*	*11.8*	10.4	8.4	6.4	5.0	3.7	2.9	2.3	1.7	1.3	0.9	0.8	CPH8	A 451
17.4	17.1	16.8	16.3	*12.8*	*12.4*	*11.9*	11.0	9.8	8.4	7.2	6.0	4.8	3.4	2.3	1.5	1.1	0.8	CPK20	A 451
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	TP409	A 268
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	TP430Ti	A 268
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CPF10MC	A 451
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	16-8-2H	A 376
16.5	16.2	15.7	15.1	10.4	9.7	8.4	4.0	...	...	...	...	...	...	...	...	...	...	TP405	A 268
16.5	16.2	15.7	15.1	10.4	9.7	8.4	6.4	4.4	2.9	1.8	1.0	...	...	...	...	...	...	TP410	A 268
18.2	17.6	17.1	16.4	10.4	9.7	8.5	6.5	4.5	3.2	2.4	1.8	...	...	...	...	...	...	TP430	A 268
16.6	16.2	15.8	15.5	15.2	...	...	...	...	...	...	...	...	...	...	...	...	...	TP317L	A312
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	11.0	7.1	5.0	3.6	2.5	1.5	0.8	0.5	0.4	0.3	0.2	TP310 310S TP310	A 312 A 358 A 409
17.9	17.5	17.2	16.9	16.7	16.6	16.4	16.2	9.6	6.9	5.0	3.6	2.6	1.7	1.1	0.8	0.5	0.3	TP321 321 TP321 TP321	A 312 A 358 A 376 A 409
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	10.5	8.5	6.5	5.0	3.8	2.9	2.3	1.8	1.3	0.9	0.7	TP309 309S TP309	A 312 A 358 A 409
15.3	15.1	14.9	14.8	*12.9*	*12.7*	*12.3*	*10.8*	9.5	7.4	5.8	4.4	3.2	2.4	1.8	1.3	1.0	0.8	CPF8	A 451

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200	300	400	500	600
						Tensile	Yield						
Stainless Steel (3) (4) (Cont'd)													
Pipes and Tubes (2) (Cont'd)													
18Cr-10Ni-Cb pipe	A 312	8	TP347	...	−425								
Type 347 A 240	A 358	8	347	(30)(36)	−425								
18Cr-10Ni-Cb pipe	A 376	8	TP347	(30)(36)	−425								
18Cr-10Ni-Cb pipe	A 409	8	TP347	(30)(36)	−425	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-10Ni-Cb pipe	A 312	8	TP348	...	−325								
Type 348 A 240	A 358	8	348	(30)(36)	−325								
18Cr-10Ni-b pipe	A 376	8	TP348	(30)(36)	−325								
18Cr-10Ni-Cb pipe	A 409	8	TP348	(30)(36)	−325								
23Cr-13Ni	A 451	8	CPH10 or CPH20	(12)(14)(28)(35)(39)	−325	70	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
25Cr-20Ni pipe	A 312	8	TP310	(28)(29)(35)(39)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
Type 310S A 240	A 358	8	310S	(28)(29)(31)(35)(36)									
18Cr-10Ni-Cb	A 451	8	CPF8C	(28)	−325	70	30	20.0	*20.0*	*20.0*	*20.0*	19.3	18.3
18Cr-10Ni-Ti pipe smls ≤ 3/8 in. thk; wld	A 312	8	TP321	(28)(30)									
Type 321 A 240	A 358	8	321										
18Cr-10Ni-Ti pipe ≤ 3/8 in. thick	A 376	8	TP321	(28)(30)(36)	−425	75	30	20.0	*20.0*	*20.0*	*20.0*	19.3	18.3
18Cr-10Ni-Ti pipe	A 409												
18Cr-10Ni-Ti pipe ≤ 3/8 in. thick	A 376	8	TP321H	(30)(36)	−325								
18Cr-10Ni-Ti pipe smls ≤ 3/8 in. thk; wld	A 312	8	TP321H	...	−325								
16Cr-12Ni-Mo tube	A 269	8	TP316	(14)(26)(28)(31)(36)	−425								
16Cr-12Ni-2Mo pipe	A 312	8	TP316	(26)(28)	−425								
Type 316 A 240	A 358	8	316	(26)(28)(31)(36)	−425								
16Cr-12Ni-2Mo pipe	A 376	8	TP316	(26)(28)(31)(36)	−425	75	30	20.0	*20.0*	*20.0*	19.3	17.9	17.0
16Cr-12Ni-2Mo pipe	A 409	8	TP316	(26)(28)(31)(36)	−425								
18Cr-3Ni-3Mo pipe	A 312	8	TP317	(26)(28)	−325								
18Cr-3Ni-3Mo pipe	A 409	8	TP317	(26)(28)(31)(36)	−325								
16Cr-12Ni-2Mo pipe	A 376	8	TP316H	(26)(31)(36)	−325								
16Cr-12Ni-2Mo pipe	A 312	8	TP316H	(26)	−325	75	30	20.0	*20.0*	*20.0*	19.3	17.9	17.0
18Cr-10Ni-Cb pipe	A 376	8	TP347H	(30)(36)	−325								
18Cr-0Ni-Cb pipe	A 312	8	TP347	(28)	−425								
Type 347 A 240	A 358	8	347	(28)(30)(36)	−425								
18Cr-10Ni-Cb pipe	A 376	8	TP347	(28)(30)(36)	−425								
18Cr-10Nib pipe	A 409	8	TP347	(28)(30)(36)	−425	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-10Ni-b pipe	A 312	8	TP348	(28)	−325								
Type 348 A 240	A 358	8	348	(28)(30)(36)	−325								
18Cr-10Ni-Cb pipe	A 376	8	TP348	(28)(30)(36)	−325								
18Cr-10Ni-Cb pipe	A 409	8	TP348	(28)(30)(36)	−325								
18Cr-10Ni-Cb pipe	A 312	8	TP347H	...	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-10Ni-Cb pipe	A 312	8	TP348H										

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																		Grade	Spec. No.
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500		
																		Stainless Steel (3) (4) (Cont'd) Pipes and Tubes (2) (Cont'd)	
19.0	18.6	18.5	18.4	*18.2*	*18.1*	*18.1*	*18.0*	*12.1*	9.1	6.1	4.4	3.3	2.2	1.5	1.2	0.9	0.8	TP347	A 312
																		347	A 358
																		TP347	A 376
																		TP347	A 409
																		TP348	A 312
																		348	A 358
																		TP348	A 376
																		TP348	A 409
18.8	18.3	18.0	17.4	*13.5*	*13.3*	*12.4*	10.5	8.4	6.4	5.0	3.7	2.9	2.3	1.7	1.3	0.9	0.8	CPH10 or CPH20	A 451
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	11.0	9.8	8.5	7.3	6.0	4.8	3.5	2.3	1.6	1.1	0.8	TP310	A 312
																		310S	A 358
18.0	17.5	17.2	17.1	*14.0*	*13.9*	*13.7*	*13.4*	*13.0*	*10.8*	8.0	5.0	3.5	2.7	2.0	1.4	1.1	1.0	CPF8C	A 451
17.9	17.5	17.2	16.9	*16.7*	*16.6*	*16.4*	*16.2*	*11.7*	9.1	6.9	5.4	4.1	3.2	2.5	1.9	1.5	1.1	TP321	A 312
																		321	A 358
																		TP321	A 376
																		TP321	A 409
																		TP321H	A 376
																		TP321H	A 312
16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	*14.5*	*12.4*	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	TP316	A 269
																		TP316	A 312
																		316	A 358
																		TP316	A 376
																		TP316	A 409
																		TP317	A 312
																		TP317	A 409
																		TP316H	A 376
16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	*14.5*	*12.4*	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	TP316H	A 312
19.0	18.6	18.5	18.4	18.2	18.1	18.1	18.0	*17.1*	*14.2*	10.5	7.9	5.9	4.4	3.2	2.5	1.8	1.3	TP347H	A 376
																		TP347	A 312
																		347	A 358
																		TP347	A 376
																		TP347	A 409
																		TP348	A 312
																		348	A 358
																		TP348	A 376
																		TP348	A 409
19.0	18.6	18.5	18.4	18.2	18.1	18.1	18.0	*17.1*	*14.2*	10.5	7.9	5.9	4.4	3.2	2.5	1.8	1.3	TP347H	A 312
																		TP348H	A 312

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200	300	400	500	600
						Tensile	Yield						
Stainless Steel (3) (4) (Cont'd) Pipes and Tubes (2) (Cont'd)													
18Cr-8Ni tube	A 269	8	TP304	(14)(26)(28)(31)(36)	−425								
18Cr-8Ni pipe	A 312	8	TP304	(26)(28)	−425								
Type 304 A 240	A 358	8	304	(26)(28)(31)(36)	−425	75	30	20.0	*20.0*	*20.0*	18.7	17.5	16.4
18Cr-8Ni pipe	A 376	8	TP304	(20)(26)(28)(31)(36)	−425								
18Cr-8Ni pipe	A 376	8	TP304H	(26)(31)(36)	−325								
18Cr-8Ni pipe	A 409	8	TP304	(26)(28)(31)(36)	−425								
18Cr-8Ni pipe	A 312	8	TP304H	(26)	−325	75	30	20.0	*20.0*	*20.0*	18.7	17.5	16.4
18Cr-10Ni-Mo	A 451	8	CPF8M	(26)(28)	−425	70	30	20.0	*20.0*	*20.0*	19.4	18.1	17.1
20Cr-Cu tube	A 268	10	TP443										
27Cr tube	A 268	10I	TP446	(35)	−20	70	40	23.3	23.3	21.4	20.4	19.4	18.4
25-10Ni-N	A 451	8	CPE20N	(35)(39)	−325	80	40	26.7	26.2	24.9	23.3	22.0	21.4
23Cr-4Ni-N	A 789												
23Cr-4Ni-N	A 790	10H	S32304	(25)	−60	87	58	29.0	27.9	26.3	25.3	24.9	24.5
12¾Cr	A 426	6	CPCA-15	(10)(35)	−20	90	65	30.0	...	...	...	...	...
22Cr-5Ni-3Mo	A 789												
22Cr-5Ni-3Mo	A 790	10H	S31803	(25)	−60	90	65	30.0	30.0	28.9	27.9	27.2	26.9
26Cr-4Ni-Mo	A 789												
26Cr-4Ni-Mo	A 790	10H	S32900	(25)	−20	90	70	30.0	...	...	...	...	...
25Cr-8Ni-3Mo-W-Cu-N	A 789												
25Cr-8Ni-3Mo-W-Cu-N	A 790	S-10H	S32760	(25)	−60	109	80	36.3	34.4	34.0	34.0	34.0	...
25Cr-7Ni-4Mo-N	A 789												
25Cr-7Ni-4Mo-N	A 790	10H	S32750	(25)	−20	116	80	38.7	35.0	33.1	31.9	31.4	31.2
Plates and Sheets													
18Cr-10Ni	A 240	8	305	(26)(36)(39)	−325	70	25	16.7	...	...	...	...	...
12Cr-Al	A 240	7	405	(35)	−20	60	25	16.7	15.3	14.8	14.5	14.3	14.0
18Cr-8Ni	A 240	8	304L	(36)	−425	70	25	16.7	*16.7*	*16.7*	15.6	14.8	14.0
16Cr-12Ni-2Mo	A 240	8	316L	(36)	−425	70	25	16.7	*16.7*	*16.7*	15.5	14.4	13.5
18Cr-Ti-Al	A 240	...	X8M	(35)	−20	65	30	20.0	...	...	...	...	...
18Cr-8Ni	A 167	S-8	302B	(26)(28)(31)(36)(39)	−325	75	30	20.0	*20.0*	*20.0*	18.7	17.4	16.4
18Cr-Ni	A 240	8	302	(26)(36)	−325	75	30	20.0	*20.0*	*20.0*	18.7	17.4	16.4

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress S, ksi (1), at Metal Temperature, °F (7)																			
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Grade	Spec. No.
																		Stainless Steel (3) (4) (Cont'd) Pipes and Tubes (2) (Cont'd)	
																		TP304	A 269
																		TP304	A 312
16.2	16.0	15.6	15.2	14.9	*14.6*	*14.4*	*13.8*	*12.2*	9.7	7.7	6.0	4.7	3.7	2.9	2.3	1.8	1.4	304	A 358
																		TP304	A 376
																		TP304H	A 376
																		TP304	A 409
16.2	16.0	15.6	15.2	14.9	*14.6*	*14.4*	*13.8*	*12.2*	9.7	7.7	6.0	4.7	3.7	2.9	2.3	1.8	1.4	TP304H	A 312
16.7	16.2	15.8	15.5	*14.7*	*14.4*	*14.0*	*13.4*	11.4	9.3	8.0	6.8	5.3	4.0	3.0	2.3	1.9	1.4	CPF8M	A 451
																		TP443	A 268
18.0	17.5	16.9	16.2	15.1	13.0	6.9	4.5	...	...	...	...	...	...	...	...	...	...	TP446	A 268
21.3	21.2	21.1	21.0	20.8	20.5	...	...	...	...	...	...	...	...	...	...	...	...	CPE20N	A 451
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S32304	A 789, A 790
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CPCA-15	A 426
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S31803	A 789, A 790
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S32900	A 789, A 790
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S32760	A 789, A 790
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S32750	A 789, A 790
																		Plates and Sheets	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	305	A 240
13.8	13.5	11.6	11.1	10.4	9.6	8.4	4.0	...	...	...	...	...	...	...	...	...	...	405	A 240
13.7	13.5	13.3	13.0	12.8	*11.9*	*9.9*	7.8	6.3	5.1	4.0	3.2	2.6	2.1	1.7	1.1	1.0	0.9	304L	A 240
13.2	12.9	12.6	12.4	12.1	11.8	11.5	11.2	10.8	*10.2*	*8.8*	6.4	4.7	3.5	2.5	1.8	1.3	1.0	316L	A 240
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	X8M	A 240
16.1	15.9	15.6	15.2	14.9	14.3	*13.7*	...	...	...	...	...	...	...	...	...	...	...	302B	A 167
16.1	15.9	15.6	15.2	14.9	14.6	14.3	*13.7*	...	...	...	...	...	...	...	...	...	...	302	A 240

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200	300	400	500	600
						Tensile	Yield						
Stainless Steel (3) (4) (Cont'd) Plates and Sheets (Cont'd)													
13Cr	A 240	7	410S	(35)(50)	−20	60	30	20.0	18.4	17.7	17.4	17.2	16.8
13Cr	A 240	6	410	(35)	−20	65	30	20.0	18.4	17.7	17.4	17.2	16.8
15Cr	A 240	6	429										
17Cr	A 240	7	420	(35)	−20	65	30	20.0	18.4	17.7	17.4	17.2	16.8
18Cr-13Ni-3Mo	A 240	8	317L	(36)	−325	75	30	20.0	*20.0*	*20.0*	18.9	17.7	16.8
25Cr-20Ni	A 167	S-8	310	(28)(35)(36)(39)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
25Cr-20Ni	A 240	8	310S	(28)(35)(36)									
18Cr-10Ni-Ti	A 240	8	321	(30)(36)	−325	75	30	20.0	*20.0*	*20.0*	20.0	19.3	18.3
20Cr-10Ni	A 167	S-8	308	(6)(26)(31)(39)	−325	75	30	20.0	16.7	15.0	13.6	12.5	11.6
23Cr-12Ni	A 167	S-8	309	(12)(28)(31)(35)(36)(39)									
23Cr-12Ni	A 240	8	309S	(28)(35)(36)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
18Cr-10Ni-Cb	A 240	8	347	(36)	−425	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-10Ni-Cb	A 240	8	348	(36)	−325								
25Cr-20Ni	A 167	S-8	310	(28)(29)(35)(36)(39)									
25Cr-20Ni	A 240	8	310S	(28)(29)(35)(36)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
18Cr-10Ni-Ti	A 240	8	321	(28)(30)(36)									
18Cr-10Ni-Ti	A 240	8	321H	(36)	−325	75	30	20.0	*20.0*	*20.0*	20.0	19.3	18.3
16Cr-12Ni-2Mo	A 240	8	316	(26)(28)(36)	−425								
18Cr-13Ni-3Mo	A 240	8	317	(26)(28)(36)	−325	75	30	20.0	*20.0*	*20.0*	19.3	17.9	17.0
18Cr-10Ni-Cb	A 167	8	347	(28)(30)(36)									
18Cr-10Ni-Cb	A 240	8	347	(28)(36)	−425								
18Cr-10Ni-Cb	A 167	8	348	(28)(30)(36)		75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-10Ni-Cb	A 240	8	348	(28)(36)	−325								
18Cr-8Ni	A 240	8	304	(26)(28)(36)	−426	75	30	20.0	*20.0*	*20.0*	18.7	17.5	16.4
25Cr-8Ni-3Mo-W-Cu-N	A 240	S-10H	S32760	(25)	−60	109	80	36.3	35.9	34.4	34.0	34.0	34.0

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																		Grade	Spec. No.
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500		
																		Stainless Steel (3) (4) (Cont'd) Plates and Sheets (Cont'd)	
16.5	16.2	15.7	15.1	10.4	9.6	8.4	6.4	4.4	2.9	1.7	1.0	...	...	...	...	...	...	410S	A 240
16.5	16.2	15.7	15.1	11.2	10.4	8.8	6.4	4.4	2.9	1.7	1.0	...	...	...	...	...	...	410	A 240
16.5	16.2	15.7	15.1	11.2	10.4	9.2	9.5	4.5	3.2	2.4	1.7	...	...	...	...	...	...	429	A 240
																		430	A 240
16.6	16.2	15.8	15.5	15.2	...	...	...	...	...	...	...	...	...	...	...	...	...	317L	A 240
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	11.0	7.1	5.0	3.6	2.5	1.5	0.8	0.5	0.4	0.3	0.2	310	A 167
																		310S	A 240
17.9	17.5	17.2	16.9	16.7	16.6	16.4	*16.2*	9.6	6.9	5.0	3.6	2.6	1.7	1.1	0.8	0.5	0.3	321	A 240
11.2	10.8	10.4	10.0	9.7	9.4	9.1	8.8	8.5	7.5	5.7	4.5	3.2	2.4	1.8	1.4	1.0	0.7	308	A 167
																		309	A 167
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	10.5	8.5	6.5	5.0	3.8	2.9	2.3	1.8	1.3	0.9	0.7	309S	A 240
19.0	18.6	18.5	18.4	*18.2*	*18.1*	*18.1*	*13.0*	*12.1*	9.1	6.1	4.4	3.3	2.2	1.5	1.2	0.9	0.8	347	A 240
																		348	A 240
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	11.0	9.8	8.5	7.3	6.0	4.8	3.5	2.3	1.6	1.1	0.8	310	A 167
																		310S	A 240
17.9	17.5	17.2	16.9	16.7	16.6	16.4	*16.2*	*11.7*	9.1	6.9	5.4	4.1	3.2	2.5	1.9	1.5	1.1	321	A 240
																		321H	A 240
16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	*14.5*	*12.4*	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	316	A 240
																		317	A 240
19.0	18.6	18.5	18.4	18.2	18.1	18.1	18.0	17.1	14.2	10.5	7.9	5.9	4.9	3.2	2.5	1.8	1.3	347	A 167
																		347	A 240
																		348	A 167
																		348	A 240
16.2	16.0	15.6	15.2	14.9	14.6	14.4	*13.8*	*12.2*	9.7	7.7	6.0	4.7	3.7	2.9	2.3	1.8	1.4	304	A 240
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S32760	A 240

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi: Tensile	Yield	Min. Temp. to 100	200	300	400	500	600
Stainless Steel (3) (4) (Cont'd) Forgings and Fittings (2)													
18Cr-13Ni-3Mo ≤ 5 in. thk.	A 182	8	F317L	(9)(21a)	−325	70	25	16.7	*16.7*	16.0	15.6	14.8	14.0
18Cr-8Ni	A 182	8	F304L	(9)(21a)	−425	70	25	16.7	*16.7*	*16.7*	15.8	14.8	14.0
18Cr-8Ni	A 403	8	WP304L	(32)(37)	−425								
16Cr-12Ni-2Mo	A 182	8	F316L	(9)(21a)	−425	70	25	16.7	*16.7*	*16.7*	15.5	14.4	13.5
16Cr-12Ni-2Mo	A 403	8	WP316L	(32)(37)	−425								
20Ni-8Cr	A 182	8	F10	(26)(28)(39)	−325	80	30	20.0	...	...	...	...	...
18Cr-13Ni-3Mo	A 403	8	WP317L	(32)(37)	−325	75	30	20.0	*20.0*	*20.0*	18.9	17.7	16.8
25Cr-20Ni	A 182	8	F310	(9)(21)(28)(35) (39)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
25Cr-20Ni	A 403	8	WP310	(28)(32)(35)(37) (39)	−325								
18Cr-10Ni-Ti	A 182	8	F321	(9)(21)	−325	75	30	20.0	*20.0*	*20.0*	20.0	19.3	18.3
18Cr-10Ni-Ti	A 403	8	WP321	(32)(37)	−325								
23Cr-12Ni	A 403	8	WP309	(28)(32)(35)(37) (39)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
25Cr-20Ni	A 182	8	F310	(9)(21)(28)(29) (35)(39)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
25Cr-20Ni	A 403	8	WP310	(28)(29)(32)(35) (37)(39)	−325								
18Cr-10Ni-Cb	A 182	8	F347	(9)(21)	−425	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-10Ni-Cb	A 403	8	WP347	(32)(37)	−425								
18Cr-10Ni-Cb	A 182	8	F348	(9)(21)	−325								
18Cr-10Ni-Cb	A 403	8	WP348	(32)(37)	−325								
18Cr-10Ni-Ti	A 182	8	F321	(9)(21)(28)(30)	−325	75	30	20.0	*20.0*	*20.0*	20.0	19.3	18.3
18Cr-10Ni-Ti	A 182	8	F321H	(9)(21)									
18Cr-10Ni-Ti	A 403	8	WP321	(28)(30)(32)(37)									
18Cr-10Ni-Ti	A 403	8	WP321H	(32)(37)	−325								
16Cr-12Ni-2Mo	A 403	8	WP316H	(26)(32)(37)	−325	75	30	20.0	*20.0*	*20.0*	19.3	17.9	17.0
16Cr-12Ni-2Mo	A 182	8	F316	(9)(21)(26)	−325	75	30	20.0	*20.0*	*20.0*	19.3	17.9	17.0
18Cr-10Ni-Cb	A 403	8	WP347H	(32)(37)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-10Ni-Cb	A 182	8	F347	(9)(21)(28)	−425								
18Cr-10Ni-Cb	A 403	8	WP347	(28)(32)(37)	−425								
18Cr-10Ni-Cb	A 182	8	F348	(9)(21)(28)	−325								
18Cr-10Ni-Cb	A 403	8	WP348	(28)(32)(37)	−325								
18Cr-10Ni-Cb	A 182	8	F347H	(9)(21)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	*19.3*
18Cr-10Ni-Cb	A 182	8	F348H										

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																			
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Grade	Spec. No.
																		Stainless Steel (3) (4) (Cont'd) Forgings and Fittings (2) (Cont'd)	
16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	*14.5*	*12.4*	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	F316	A 182
																		WP316	A 403
																		WP317	A 403
16.2	16.0	15.6	15.2	14.9	14.6	14.4	13.8	*12.2*	9.7	7.7	6.0	4.7	3.7	2.9	2.3	1.8	1.4	F304	A 182
																		WP304	A 403
16.2	16.0	15.6	15.2	14.9	14.6	14.4	*13.8*	*12.2*	9.7	7.7	6.0	4.7	3.7	2.9	2.3	1.8	1.4	WP304H	A 403
																		F304H	A 182
21.1	20.6	19.9	19.1	11.2	10.4	8.8	6.4	...	...	...	...	...	...	...	...	...	...	F6a Cl. 1	A 182
25.7	25.0	24.4	23.2	14.4	12.3	8.8	6.4	4.4	2.9	1.8	1.0	...	...	...	...	...	...	F6a Cl. 2	A 182
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S32760	A 182
																		S32760	A 815
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	F6a Cl. 3	A 182
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	F6b	A 182
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	F6a Cl. 4	A 182
																			Bar
16.2	16.0	15.6	15.2	14.9	14.7	14.4	14.1	12.4	9.8	7.7	6.1	4.7	3.7	2.9	2.3	1.8	1.4	304	A 479
																			Castings (2)
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CN7M	A 351
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	HT30	A 351
18.0	17.1	16.7	16.4	*12.7*	*12.5*	*11.7*	10.5	8.5	6.5	5.5	3.7	2.9	2.0	1.7	1.2	0.9	0.7	CH8	A 351
17.5	17.1	16.7	16.4	*12.7*	*12.5*	*11.9*	11.0	9.7	8.5	7.2	6.0	4.7	3.5	2.4	1.6	1.1	0.7	CK20	A 351
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CF10MC	A 351
15.2	15.1	14.9	14.7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CF3	A 351
15.0	14.6	14.4	14.0	13.2	...	...	...	...	...	...	...	...	...	...	...	...	...	CF3M	A 351
16.1	15.9	15.5	15.1	*14.4*	*14.2*	*13.9*	*12.2*	9.5	7.5	6.0	4.8	3.9	3.3	2.7	2.3	2.0	1.7	CF8	A 351
18.7	18.2	18.0	17.5	*13.6*	*13.2*	*12.5*	10.5	8.5	8.5	5.0	3.7	2.9	2.0	1.7	1.2	0.9	0.7	CH10	A 351
																		CH20	A 351
18.4	18.2	18.2	18.2	*18.1*	*18.1*	*18.1*	*18.0*	*17.1*	*14.2*	10.5	7.9	5.4	4.4	3.2	2.5	1.8	1.3	CF8C	A 351
16.7	16.2	15.7	15.6	*14.7*	*14.5*	*14.0*	*13.1*	11.5	9.4	8.0	6.7	5.2	4.0	3.0	2.4	1.9	1.5	CF8M	A 351
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	HK40	A 351
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	HK30	A 351
18.9	17.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CF3A	A 351
21.3	21.2	21.1	21.0	20.8	20.5	...	...	...	...	...	...	...	...	...	...	...	...	CF8A	A 351
																		CE20N	A 351
18.4	18.1	17.5	16.8	14.9	11.0	7.6	5.0	3.3	2.3	1.5	1.0	...	...	...	...	...	...	CA15	A 217
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CE8MN	A 351
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CD3M-W-Cu-N	A 351
33.2	32.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CA6NM Cl.A	A 487

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)(46)	Class	Temper	Size Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.	
								Tensile	Yield	to 100	150
Cooper and Copper Alloy Pipes and Tubes (2)											
Cu pipe	B 42	31	C10200, C12000, C12200	061	...	...					
Cu tube	B 75	31	C10200, C12000, C12200	050, 060	...	...					
Cu tube	B 68										
Cu tube	B 88	S-31	C12200	050, 060	...	(24)	-452	30	9	6.0	5.1
Cu tube	B 280	S-31	C12200	060	...	(24)					
Red brass pipe	B 43	32	C23000	061	...	...	-452	40	12	8.0	8.0
90Cu-10Ni	B 467	34	C70600	W050, W061	> 4.5 O.D.						
90Cu-10Ni	B 466	34	C70600	Annealed	...	(14)	-452	38	13	8.7	8.4
90Cu-10Ni	B 467	34	C70600	W050, W061	≤ 4.5 O.D.	(14)	-452	40	15	10.0	9.7
70Cu-30Ni	B 467	34	C71500	W050, W061	> 4.5 O.D.	(14)	-452	45	15	10.0	9.6
80Cu-20Ni	B 466	34	C71000	Annealed	≤ 4.5 O.D.	(14)	-452	45	16	10.7	10.6
Cu pipe	B 42	31	C10200, C12000, C12200	H55	NPS 2 1/2 thru 12						
Cu tube	B 75	31	C10200, C12000, C12200	H58	...	(14)(34)	-452	36	30	12.0	12.0
Cu tube	B 88	S-31	C12200	H	...	(14)(24)(34)					
70Cu-30Ni	B 466	34	C71500	060	...	(14)	-452	52	18	12.0	11.6
70Cu-30Ni	B 467	34	C71500	W050, W061	≤ 4.5 O.D.	(14)	-452	50	20	13.3	12.7
Cu pipe	B 42	31	C10200, C12000, C12200	H80	NPS 1/8 thru 2						
Cu tube	B 75	31	C10200, C12000, C12200	H80	...	(14)(34)	-452	45	40	15.0	15.0
Plates and Sheets											
Cu	B 152	31	C10200, C10400, C10500, C10700 C12200, C12300	025	...	(14)(24)	-452	30	10	6.7	5.8
90Cu-10Ni	B 171	34	C70600	...	≤ 2.5 thk.	(14)	-452	40	15	10.0	9.7
Cu-Si	B 96	33	C65500	061	...	...	-452	52	18	12.0	12.0
70Cu-30Ni	B 171	34	C71500	...	≤ 2.5 thk.	(14)	-452	50	20	13.3	12.7
Al-bronze	B 169	35	C61400	025, 060	≤ 2.0 thk.	(13)	-452	70	30	20.0	20.0

Symbols in Temper Column

025 = hot-rolled, annealed
050 = light annealed
060 = soft annealed
061 = annealed
W050 = welded, annealed
W061 = welded, fully finished, annealed
H = drawn
H55 = light drawn
H58 = drawn, general purpose
H80 = hard drawn

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)												
200	250	300	350	400	450	500	550	600	650	700	Class	Spec. No.
											Copper and Copper Alloy Pipes and Tubes (2)	
4.8	4.8	4.7	4.0	3.0	1.5	0.8	...	...	...	...	C10200, C12000, C12200	B 42
											C10200, C12000, C12200	B 75
											C12200	B 68
											C12200	B 88
											C12200	B 280
8.0	8.0	8.0	7.0	5.0	2.0	...	...	...	...	...	C23000	B 43
8.3	8.0	7.8	7.7	7.6	7.5	7.3	7.0	6.0	...	...	C70600	B 467
9.5	9.3	9.0	8.7	8.7	8.6	8.0	7.0	6.0	...	...	C70600	B 466
9.5	9.2	9.1	8.8	8.6	8.4	8.2	8.1	8.0	7.9	7.8	C70600	B 467
10.5	10.4	10.3	10.1	9.9	9.6	9.3	8.9	8.4	7.7	7.0	C71500	B 467
											C71000	B 466
12.0	12.0	11.6	11.4	10.5	...	...	...	...	...	...	C10200, C12000, C12200	B 42
											C10200, C12000, C12200	B 75
											C12200	B 88
11.3	11.0	10.8	10.6	10.3	10.1	9.9	9.8	9.6	9.5	9.4	C71500	B 466
12.3	12.1	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	10.4	C71500	B 467
15.0	15.0	14.7	13.7	4.3	...	...	...	...	...	...	C10200, C12000, C12200	B 42
											C10200, C12000, C12200	B 75
											Plates and Sheets	
5.5	5.2	5.1	4.0	3.0	1.5	0.8	...	...	...	...	C10200, C10400, C10500, C10700, C12200, C12300	B 152
9.5	9.3	9.0	8.7	8.7	8.6	8.0	7.0	6.0	...	...	C70600	B 171
11.9	11.7	10.0	5.0	...	...	...	...	...	...	...	C65500	B 96
12.3	12.1	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	10.4	C71500	B 171
19.9	19.8	19.6	19.4	19.2	19.1	19.0	...	...	...	...	C61400	B 169

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)(46)	Class	Temper	Size Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.	
								Tensile	Yield	to 100	150
Copper and Copper Alloy (Cont'd)											
Forgings											
Cu	B 283	S-31	C11000	...	...	(14)	−452	33	11	7.3	6.7
High Si bronze (A)	B 283	S-33	C65500	...	...	(14)	−452	52	18	12.0	10.0
Forging brass	B 283	a	C37700	...	...	(14)	−325	58	23	15.3	12.5
Leaded naval brass	B 283	a	C48500	...	...	(14)	−325	62	24	16.0	15.2
Naval brass	B 283	S-32	C46400	...	...	(14)	−425	64	26	17.3	15.8
Mn-bronze (A)	B 283	S-32	C67500	...	...	(14)	−325	72	34	22.7	12.9
Castings(2)											
Composition bronze	B 62	a	C83600	...	...	(9)	−325	30	14	9.4	9.4
Leaded Ni-bronze	B 584	a	C97300	...	...	...	−325	30	15	10.0	...
Leaded Ni-bronze	B 584	a	C97600	...	...	...	−325	40	17	10.0	7.5
Leaded Sn-bronze	B 584	a	C92300	...	...	...	−325	36	16	10.6	9.0
Leaded Sn-bronze	B 584	a	C92200	...	...	...	−325	34	16	10.6	10.6
Steam bronze	B 61	a	C92200	...	...	(9)	−325	34	16	10.6	10.6
Sn-bronze	B 584	b	C90300	...	...	...	−325	40	18	12.0	10.0
Sn-bronze	B 584	b	C90500	...	...	...	−325	40	18	12.0	12.0
Leaded Mn-bronze	B 584	a	C86400	...	...	(9)	−325	60	20	13.3	12.8
Leaded Ni-bronze	B 584	a	C97800	...	...	...	−325	50	22	14.6	10.4
No. 1 Mn-bronze	B 584	b	C86500	...	...	...	−325	65	25	16.6	14.8
Al-bronze	B 148	S-35	C95200	...	...	(9)					
Al-bronze	B 148	S-35	C95300	...	...	...	−425	65	25	16.3	15.7
Si-Al-bronze	B 148	S-35	C95600	...	...	...	−325	60	28	18.8	...
Al-bronze	B 148	S-35	C95400	...	...	...	−325	75	30	20.0	18.8
Mn-bronze	B 584	a	C86700	...	...	...	−325	80	32	21.3	17.5
Al-bronze	B 148	S-35	C95500	...	...	...	−452	90	40	26.6	22.5
High strength Mn-bronze	B 584	b	C86200	...	...	...	−325	90	45	30.0	19.5
High strength Mn-bronze	B 584	b	C86300	...	...	...	−325	110	60	36.6	23.3

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)												
200	250	300	350	400	450	500	550	600	650	700	Class	Spec. No.
											Copper and Copper Alloy (Cont'd) Forgings	
6.5	6.3	5.0	3.8	2.5	1.5	0.8	...	...	...	...	C11000	B 283
10.0	10.0	10.0	5.0	2.0	...	...	...	...	...	...	C65500	B 283
12.0	11.2	10.5	7.5	2.0	...	...	...	...	...	...	C37700	B 283
15.0	14.1	13.0	8.5	2.0	...	...	...	...	...	...	C48500	B 283
15.3	14.2	13.0	9.0	2.0	...	...	...	...	...	...	C46400	B 283
12.0	11.2	10.5	7.5	2.0	...	...	...	...	...	...	C67500	B 283
												Castings (2)
9.4	9.4	9.1	8.9	8.6	8.5	...	...	...	...	...	C83600	B 62
...	...	...	...	...	...	...	...	...	...	...	C97300	B 584
7.3	6.9	6.3	...	...	...	...	...	...	...	...	C97600	B 584
9.0	9.0	8.5	8.0	7.0	...	...	...	...	...	...	C92300	B 584
10.6	10.6	10.6	10.6	10.3	...	...	...	...	...	...	C92200	B 584
10.6	10.6	10.6	10.6	10.3	9.6	9.0	6.3	...	...	...	C92200	B 61
9.5	9.3	8.5	8.0	7.0	...	...	...	...	...	...	C90300	B 584
12.0	12.0	12.0	11.9	11.0	...	...	...	...	...	...	C90500	B 584
12.0	11.3	10.5	7.5	...	...	...	...	...	...	...	C86400	B 584
9.4	8.5	7.5	7.0	...	...	...	...	...	...	...	C97800	B 584
13.4	12.0	10.5	7.5	...	...	...	...	...	...	...	C86500	B 584
15.2	14.7	14.5	14.2	14.2	14.2	14.2	11.7	7.4	...	...	C95200	B 148
											C95300	B 148
...	...	...	...	...	...	...	...	...	...	...	C95600	B 148
18.0	17.3	16.3	15.6	14.8	12.9	11.0	...	...	...	...	C95400	B 148
15.3	12.9	10.5	7.5	...	...		...	...	...	...	C86700	B 584
21.0	19.5	18.0	16.5	15.0	13.5	12.0	...	...	...	...	C95500	B 148
17.3	16.5	10.5	7.5	...	...	...	...	...	...	...	C86200	B 584
19.0	14.8	10.5	7.5	...	...	...	...	...	...	...	C86300	B 584

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	UNS No.	Class	Size Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200	300	400	500	600	650	700	750
								Tensile	Yield									
Nickel and Nickel Alloy (4) Pipes and Tubes (2)																		
Low C Ni	B 161	41																
Low C Ni	B 725	S41	N02201	Annealed	> 5 O.D.	...	−325	50	10	6.7	6.4	6.3	6.2	6.2	6.2	6.2	6.2	6.1
Ni	B 161	41																
Ni	B 725	S41	N02200	Annealed	> 5 O.D.	...	−325	55	12	8.0	8.0	8.0	8.0	8.0	8.0	...	...	...
Low C Ni	B 161	41																
Low C Ni	B 725	S41	N02201	Annealed	≤ 5 O.D.	...	−325	50	12	8.0	7.7	7.5	7.5	7.5	7.5	7.5	7.4	7.3
Ni	B 161	41																
Ni	B 725	S41	N02200	Annealed	≤ 5 O.D.	...	−325	55	15	10.0	10.0	10.0	10.0	10.0	10.0	...	...	...
Ni-Cu	B 165	42																
Ni-Cu	B 725	S42	N04400	Annealed	> 5 O.D.	...	−325	70	25	16.7	14.7	13.7	13.2	13.2	13.2	13.2	13.2	13.0
Ni-Fe-Cr	B 407	45	N08800	H.F. or H.F. ann.	...	(76)	−325	65	25	16.7	*16.7*	*16.7*	*15.8*	*14.9*	*14.6*	*14.4*	*14.3*	*14.2*
Ni-Cr-Fe	B 167	43	N06600	H.F. or H.F. ann.	> 5 O.D.	...	−325	75	25	16.7	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*
Ni-Fe-Cr	B 407	45	N08810	C.D. sol. ann. or H.F. ann.	...	(62)(76)												
Ni-Fe-Cr	B 514	45	N08810	Annealed	...	(62)(76)	−325	65	25	16.7	16.7	16.7	16.7	16.7	16.5	16.0	15.7	15.4
Ni-Fe-Cr	B 407	45	N08811	C.D. sol. ann. or H.F. ann.	...	(62)(76)	−325	65	25	16.7	16.7	16.7	16.7	16.7	16.5	16.0	15.7	15.4
Ni-Cu	B 165	42																
Ni-Cu	B 725	S42	N04400	Annealed	≤ 5 O.D.	...	−325	70	28	18.7	16.4	15.4	14.8	14.8	14.8	14.8	14.8	14.6
Ni-Fe-Cr-Mo	B 619	45	N08320	Sol. ann.	...	(76)												
Ni-Fe-Cr-Mo	B 622	45	N08320	Sol. ann.	...	...	−325	75	28	18.7	*18.7*	*18.6*	*17.9*	*17.6*	*17.5*	*17.5*	*17.5*	*17.4*
Low C Ni	B 161	41																
Low C Ni	B 725	S41	N02201	Str. rel.	...	...	−325	60	30	20.0	15.0	15.0	14.8	14.7	14.2	...	...	...
Ni-Fe-Cr	B 514	45	N08800	Annealed	...	(76)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
Ni-Cr-Fe	B 167	43	N06600	H.F. or H.F. ann.	≤ 5 O.D.													
Ni-Cr-Fe	B 167	43	N06600	C.D. ann.	> 5 O.D.	...	−325	80	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
Ni-Fe-Cr	B 407	45	N08800	C.D. ann.	...	(61)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	20.0	20.0
Ni	B 161																	
Ni	B 725	41	N02200	Str. rel.	...	...	−325	65	40	21.6	16.3	16.3	16.3	16.0	15.4	...	...	...
Ci-Ni-Fe-Mo-Cu -Cb	B 464																	
Cr-Ni-Fe-Mo-Cu -Cb	B 729	45	N08020	Annealed	...	(76)	−325	80	35	23.3	*20.0*	*19.8*	*19.4*	*19.3*	*19.3*	19.2	19.2	19.2
Ni-Cr-Fe-Mo-Cu	B 619	45	N06007	Sol. ann.	...	(76)	−325	90	35	23.3	*23.3*	*23.3*	*23.3*	*23.3*	22.7	22.5	22.3	22.0
Ni-Cr-Fe-Mo-Cu	B 622	45	N06007	Sol. ann.	...	...	−325	90	35	23.3	*23.3*	*23.3*	*23.3*	*23.3*	22.7	22.5	22.3	22.0
Ni-Cr-Fe	B 167	43	N06600	C.D. ann.	≤ 5 O.D.	...												
Ni-Cr-Fe	B 517	43	N06600	C.D. ann.	...	(76)	−325	80	35	23.3	23.3	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*
Ni-Mo-Cr	B 619	44	N06455	Sol. ann.	...	(76)	−325	100	40	26.7	*24.9*	*24.9*	*24.9*	*24.7*	*24.4*	*24.2*	*24.0*	*23.8*

Abbreviations in Class Column:

ann	annealed	H.R.	hot rolled	sol.	solution
C.D.	cold worked	plt.	plate	str.	stress
forg.	forged	R.	rolled		
H.F.	hot worked	rel.	relieved		

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Spec. No.	P-No. or S-No. (5)	Grade	Temper	Size or Thickness Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Basic Allowable Stress S, ksi (1), at Metal Temperature, °F (7)						
							Tensile	Yield	Min. Temp. to 100	150	200	250	300	350	400
Aluminum Alloy (Cont'd)															
Seamless Pipes and Tubes (Cont'd)															
B 241	22	5652	0, H112	...	(33)	−452	25	10	6.7	6.7	6.7	6.2	5.6	4.1	2.3
B 210	23	6061	T4	...	(33)	−452	30	16	10.0	10.0	10.0	9.8	9.2	7.9	5.6
B 241	23														
B 345	S-23	6061	T4	...	(33)(63)	−452	26	16	8.7	8.7	8.7	8.5	8.0	7.9	5.6
B 210	23	6061	T6	...	(33)	−452	42	35	14.0	14.0	14.0	13.2	11.3	7.9	5.6
B 241	23	6061	T6	...	(33)(63)	−452	38	35	12.7	12.7	12.7	12.1	10.6	7.9	5.6
B 345	S-23														
B 210, B 241	23	6061	T4, T6 wld.	...	(22)(63)	−452	24	...	8.0	8.0	8.0	7.9	7.4	6.1	4.3
B 345	S-23														
B 210	23	6063	T4	...	(33)	−452	22	10							
B 241	23														
B 345	S-23	6063	T4	≤ 0.500	(33)	−452	19	10	6.7	6.7	6.7	6.7	6.7	3.4	2.0
B 241	23														
B 345	S-23	6063	T5	≤ 0.500	(33)	−452	22	16	7.3	7.3	7.2	6.8	6.1	3.4	2.0
B 210	23	6063	T6	...	(33)	−452	33	28	11.0	11.0	10.5	9.5	7.0	3.4	2.0
B 241	23														
B 345	S-23	6063	T6	...	(33)	−452	30	25	10.0	10.0	9.8	9.0	6.6	3.4	2.0
B 210, B 241	23	6063	T4, T5, T6 wld.	...	...	−452	17	...	5.7	5.7	5.7	5.6	5.2	3.0	2.0
B 345	S-23														
Structural Tubes															
B 221	21	1060	0, H112	...	(33)(69)	−452	8.5	2.5	1.7	1.7	1.6	1.5	1.3	1.1	0.8
B 221	21	1100	0, H112	...	(33)(69)	−452	11	3	2.0	2.0	2.0	1.9	1.7	1.3	1.0
B 221	21	3003	0, H112	...	(33)(69)	−452	14	5	3.3	3.3	3.3	3.1	2.4	1.8	1.4
B 221	21	Alclad 3003	0, H112	...	(33)(69)	−452	13	4.5	3.0	3.0	3.0	2.8	2.2	1.6	1.3
B 221	22	5052	0	...	(69)	−452	25	10	6.7	6.7	6.7	6.2	5.6	4.1	2.3
B 221	25	5083	0	...	(69)	−452	39	16	10.7	10.7	...	...	...	...	...
B 221	25	5086	0	...	(69)	−452	35	14	9.3	9.3	...	...	...	...	...
B 221	22	5154	0	...	(69)	−452	30	11	7.3	7.3	...	...	...	...	...
B 221	22	5454	0	...	(69)	−452	31	12	8.0	8.0	8.0	7.4	5.5	4.1	3.0
B 221	25	5456	0	...	(69)	−452	41	19	12.7	12.7	...	...	...	...	...
B 221	23	6061	T4	...	(33)(63)(69)	−452	26	16	8.7	8.7	8.7	8.5	8.0	7.7	5.3
B 221	23	6061	T6	...	(33)(63)(69)	−452	38	35	12.7	12.7	12.7	12.1	10.6	7.9	5.6
B 221	23	6061	T4, T6 wld.	...	(22)(63)(69)	−452	24	...	8.0	8.0	8.0	7.9	7.4	6.1	4.3

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Spec. No.	P-No. or S-No. (5)	Grade	Temper	Size or Thickness Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Basic Allowable Stress S, ksi (1), at Metal Temperature, °F (7)						
							Tensile	Yield	Min. Temp. to 100	150	200	250	300	350	400
Aluminum Alloy (Cont'd)															
Structural Tubes (Cont'd)															
B 221	23	6063	T4	≤ 0.500	(13)(33)(69)	−452	19	10	6.4	6.4	6.4	6.4	6.4	3.4	2.0
B 221	23	6063	T5	≤ 0.500	(13)(33)(69)	−452	22	16	7.3	7.3	7.2	6.8	6.1	3.4	2.0
B 221	23	6063	T6	...	(33)(69)	−452	30	25	10.0	10.0	9.8	9.0	6.6	3.4	2.0
B 221	23	6063	T4, T5, T6 wld.	...	(69)	−452	17	...	5.7	5.7	5.7	5.6	5.2	3.0	2.0
Plates and Sheets															
B 209	21	1060	0	...	...	−452	8	2.5	1.7	1.7	1.6	1.5	1.3	1.1	0.8
B 209	21	1060	H112	0.500–1.000	(13)(33)	−452	10	5	3.3	3.2	2.9	1.9	1.7	1.4	1.0
B 209	21	1060	H12	...	(33)	−452	11	9	3.7	3.7	3.4	2.3	2.0	1.8	1.1
B 209	21	1060	H14	...	(33)	−452	12	10	4.0	4.0	4.0	3.0	2.6	1.8	1.1
B 209	21	1100	0	...	...	−452	11	3.5	2.3	2.3	2.3	2.3	1.7	1.3	1.0
B 209	21	1100	H112	0.500–2.000	(13)(33)	−452	12	5	3.3	3.3	3.3	2.5	2.2	1.7	1.0
B 209	21	1100	H12	...	(33)	−452	14	11	4.7	4.7	4.7	3.2	2.8	1.9	1.1
B 209	21	1100	H14	...	(33)	−452	16	14	5.3	5.3	5.3	3.7	2.8	1.9	1.1
B 209	21	3003	0	...	...	−452	14	5	3.3	3.3	3.3	3.1	2.4	1.8	1.4
B 209	21	3003	H112	0.500–2.000	(13)(33)	−452	15	6	4.0	4.0	3.9	3.1	2.4	1.8	1.4
B 209	21	3003	H12	...	(33)	−452	17	12	5.7	5.7	5.7	4.0	3.6	3.0	2.3
B 209	21	3003	H14	...	(33)	−452	20	17	6.7	6.7	6.7	4.8	4.3	3.0	2.3
B 209	21	Alclad 3003	0	0.006–0.499	(66)	−452	13	4.5							
B 209	21	Alclad 3003	0	0.500–3.000	(68)	−452	14	5	3.0	3.0	3.0	2.8	2.2	1.6	1.3
B 209	21	Alclad 3003	H112	0.500–2.000	(33)(66)	−452	15	6	3.6	3.6	3.5	2.8	2.2	1.6	1.3
B 209	21	Alclad 3003	H12	0.017–0.499	(33)(66)	−452	16	11							
B 209	21	Alclad 3003	H12	0.500–2.000	(33)(68)	−452	17	12	5.1	5.1	5.1	3.6	3.2	2.7	2.1
B 209	21	Alclad 3003	H14	0.009–0.499	(33)(66)	−452	19	16							
B 209	21	Alclad 3003	H14	0.500–1.000	(33)(68)	−452	20	17	6.0	6.0	6.0	4.3	3.9	2.7	2.1
B 209	22	3004	0	...	...	−452	22	8.5	5.7	5.7	5.7	5.7	5.7	3.8	2.3
B 209	22	3004	H112	...	(33)	−452	23	9	6.0	6.0	6.0	6.0	5.8	3.8	2.3
B 209	22	3004	H32	...	(33)	−452	28	21	9.3	9.3	9.3	7.0	5.8	3.8	2.3
B 209	22	3004	H34	...	(33)	−452	32	25	10.7	10.7	10.7	8.0	5.8	3.8	2.3

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Spec. No.	P-No. or S-No. (5)	Grade	Temper	Size or Thickness Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)						
							Tensile	Yield	Min. Temp. to 100	150	200	250	300	350	400
Aluminum Alloy (Cont'd)															
Forgings and Fittings (2) (Cont'd)															
B 361	S-21	WP1100	O, H112	...	(13)(14)(23)(32)(33)	−452	11	3	2.0	2.0	2.0	1.9	1.7	1.3	1.0
B 361	S-21	WP3003	O, H112	...	(13)(14)(23)(32)(33)	−452	14	5	3.3	3.3	3.3	3.1	2.4	1.8	1.4
B 361	S-21	WP Alclad 3003	O, H112	...	(13)(14)(23)(32)(33)(66)	−452	13	4.5	3.0	3.0	3.0	2.8	2.2	1.6	1.3
B 361	S-25	WP5083	O, H112	...	(13)(23)(32)(33)	−452	39	16	10.7	10.7	...	...	...	...	...
B 361	S-22	WP5154	O, H112	...	(23)(32)(33)	−452	30	11	7.3	7.3	...	...	...	...	...
B 361	S-23	WP6061	T4	...	(13)(23)(32)(33)(63)	−452	26	16	8.7	8.7	8.7	8.5	8.0	7.7	5.6
B 361	S-23	WP6061	T6	...	(13)(23)(32)(33)(63)	−452	38	35	12.7	12.7	12.7	12.1	10.6	7.9	5.6
B 361	S-23	WP6061	T4, T6 wld.	...	(22)(23)(32)(63)	−452	24	...	8.0	8.0	8.0	7.9	7.4	6.1	4.3
B 361	S-23	WP6063	T4	...	(13)(23)(32)(33)	−452	18	9	6.0	6.0	6.0	6.0	6.0	3.4	2.0
B 361	S-23	WP6063	T6	...	(13)(23)(32)(33)	−452	30	25	10.0	10.0	9.8	9.0	6.6	3.4	2.0
B 361	S-23	WP6063	T4, T6 wld.	...	(23)(32)	−452	17	...	5.7	5.7	5.7	5.6	5.2	3.0	2.0
Castings (2)															
B 26	...	443.0	F	...	(9)(43)	−452	17	6	4.0	4.0	4.0	4.0	4.0	4.0	3.0
B 26	...	356.0	T6	...	(9)(43)	−452	30	20	10.0	10.0	10.0	8.4	...	...	...
B 26	...	356.0	T71	...	(9)(43)	−452	25	18	8.3	8.3	8.3	8.1	7.3	5.5	2.4

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TABLE A-1A
BASIC CASTING QUALITY FACTORS E_c

These quality factors are determined in accordance with para. 302.3.3(b). See also para. 302.3.3(c) and Table 302.3.3C for increased quality factors applicable in special cases. Specifications are ASTM.

Spec. No.	Description	E_c (2)	Appendix A Notes
Iron			
A 47	Malleable iron castings	1.00	(9)
A 48	Gray iron castings	1.00	(9)
A 126	Gray iron castings	1.00	(9)
A 197	Cupola malleable iron castings	1.00	(9)
A 278	Gray iron castings	1.00	(9)
A 395	Ductile and ferritic ductile iron castings	0.80	(9)(40)
A 571	Austenitic ductile iron castings	0.80	(9)(40)
Carbon Steel			
A 216	Carbon steel castings	0.80	(9)(40)
A 352	Ferritic steel castings	0.80	(9)(40)
Low and Intermediate Alloy Steel			
A 217	Martensitic stainless and alloy castings	0.80	(9)(40)
A 352	Ferritic steel castings	0.80	(9)(40)
A 426	Centrifugally cast pipe	1.00	(10)
Stainless Steel			
A 351	Austenitic steel castings	0.80	(9)(40)
A 451	Centrifugally cast pipe	0.90	(10)(40)
A 487	Steel castings	0.80	(9)(40)
Copper and Copper Alloy			
B 61	Steam bronze castings	0.80	(9)(40)
B 62	Composition bronze castings	0.80	(9)(40)
B 148	Al-Bronze and Si-Al-Bronze castings	0.80	(9)(40)
B 584	Copper alloy castings	0.80	(9)(40)
Nickel and Nickel Alloy			
A 494	Nickel and nickel alloy castings	0.80	(9)(40)
Aluminum Alloy			
B 26, Temper F	Aluminum alloy castings	1.00	(9)(10)
B 26, Temper T6, T71	Aluminum alloy castings	0.80	(9)(40)

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TABLE A-1B

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BASIC QUALITY FACTORS FOR LONGITUDINAL WELD JOINTS IN PIPES, TUBES, AND FITTINGS E_j

These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

Spec. No.	Class (or Type)	Description	E_j (2)	Appendix A Notes
Carbon Steel				
API 5L	...	Seamless pipe	1.00	...
	...	Electric resistance welded pipe	0.85	...
	...	Electric fusion welded pipe, double butt, straight or spiral seam	0.95	...
	...	Furnace butt welded	0.60	...
A 53	Type S	Seamless pipe	1.00	...
	Type E	Electric resistance welded pipe	0.85	...
	Type F	Furnace butt welded pipe	0.60	...
A 105	...	Forgings and fittings	1.00	(9)
A 106	...	Seamless pipe	1.00	...
A 134	...	Electric fusion welded pipe, single butt, straight or spiral seam	0.80	...
A 135	...	Electric resistance welded pipe	0.85	...
A 139	...	Electric fusion welded pipe, straight or spiral seam	0.80	...
A 179	...	Seamless tube	1.00	...
A 181	...	Forgings and fittings	1.00	(9)
A 234	...	Seamless and welded fittings	1.00	(16)
A 333	...	Seamless pipe	1.00	...
	...	Electric resistance welded pipe	0.85	...
A 334	...	Seamless tube	1.00	...
A 350	...	Forgings and fittings	1.00	(9)
A 369	...	Seamless pipe	1.00	...
A 381	...	Electric fusion welded pipe, 100% radiographed	1.00	(18)
	...	Electric fusion welded pipe, spot radiographed	0.90	(19)
	...	Electric fusion welded pipe, as manufactured	0.85	...
A 420	...	Welded fittings, 100% radiographed	1.00	(16)
A 524	...	Seamless pipe	1.00	...
A 587	...	Electric resistance welded pipe	0.85	...
A 671	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...
A 672	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...
A 691	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...

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TABLE A-1B (CONT'D)
BASIC QUALITY FACTORS FOR LONGITUDINAL WELD JOINTS IN PIPES, TUBES, AND FITTINGS E_j

These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

Spec. No.	Class (or Type)	Description	E_j (2)	Appendix A Notes
Low and Intermediate Alloy Steel				
A 182	...	Forgings and fittings	1.00	(9)
A 234	...	Seamless and welded fittings	1.00	(16)
A 333	...	Seamless pipe	1.00	...
	...	Electric resistance welded pipe	0.85	...
A 334	...	Seamless tube	1.00	...
A 335	...	Seamless pipe	1.00	...
A 350	...	Forgings and fittings	1.00	...
A 369	...	Seamless pipe	1.00	...
A 420	...	Welded fittings, 100% radiographed	1.00	(16)
A 671	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...
A 672	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...
A 691	12, 22, 32, 42, 52	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23, 33, 43, 53	Electric fusion welded pipe, double butt seam	0.85	...
Stainless Steel				
A 182	...	Forgings and fittings	1.00	...
A 268	...	Seamless tube	1.00	...
	...	Electric fusion welded tube, double butt seam	0.85	...
	...	Electric fusion welded tube, single butt seam	0.80	...
A 269	...	Seamless tube	1.00	...
	...	Electric fusion welded tube, double butt seam	0.85	...
	...	Electric fusion welded tube, single butt seam	0.80	...
A 312	...	Seamless tube	1.00	...
	...	Electric fusion welded tube, double butt seam	0.85	...
	...	Electric fusion welded tube, single butt seam	0.80	...
A 358	1, 3, 4	Electric fusion welded pipe, 100% radiographed	1.00	...
	5	Electric fusion welded pipe, spot radiographed	0.90	...
	2	Electric fusion welded pipe, double butt seam	0.85	...
A 376	...	Seamless pipe	1.00	...
A 403	...	Seamless fittings	1.00	...
	...	Welded fitting, 100% radiographed	1.00	(16)
	...	Welded fitting, double butt seam	0.85	...
	...	Welded fitting, single butt seam	0.80	...

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TABLE A-1B (CONT'D)

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BASIC QUALITY FACTORS FOR LONGITUDINAL WELD JOINTS IN PIPES, TUBES, AND FITTINGS E_j

These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

Spec. No.	Class (or Type)	Description	E_j (2)	Appendix A Notes
Stainless Steel (Cont'd)				
A 409	...	Electric fusion welded pipe, double butt seam	0.85	...
	...	Electric fusion welded pipe, single butt seam	0.80	...
A 487	...	Steel castings	0.80	(9)(40)
A 789	...	Seamless tube	1.00	...
	...	Electric fusion welded, 100% radiographed	1.00	...
	...	Electric fusion welded, double butt	0.85	...
	...	Electric fusion welded, single butt	0.80	...
A 790	...	Seamless pipe	1.00	...
	...	Electric fusion welded, 100% radiographed	1.00	...
	...	Electric fusion welded, double butt	0.85	...
	...	Electric fusion welded, single butt	0.80	...
A 815	...	Seamless fittings	1.00	...
	...	Welded fittings, 100% radiographed	1.00	(16)
	...	Welded fittings, double butt seam	0.85	...
	...	Welded fittings, single butt seam	0.80	...
Copper and Copper Alloy				
B 42	...	Seamless pipe	1.00	...
B 43	...	Seamless pipe	1.00	...
B 68	...	Seamless tube	1.00	...
B 75	...	Seamless tube	1.00	...
B 88	...	Seamless water tube	1.00	...
B 280	...	Seamless tube	1.00	...
B 466	...	Seamless pipe and tube	1.00	...
B 467	...	Electric resistance welded pipe	0.85	...
	...	Electric fusion welded pipe, double butt seam	0.85	...
	...	Electric fusion welded pipe, single butt seam	0.80	...
Nickel and Nickel Alloy				
B 160	...	Forgings and fittings	1.00	(9)
B 161	...	Seamless pipe and tube	1.00	...
B 164	...	Forgings and fittings	1.00	(9)
B 165	...	Seamless pipe and tube	1.00	...
B 167	...	Seamless pipe and tube	1.00	...
B 366	...	Seamless and welded fittings	1.00	(16)
B 407	...	Seamless pipe and tube	1.00	...
B 444	...	Seamless pipe and tube	1.00	...
B 464	...	Welded pipe	0.80	...
B 514	...	Welded pipe	0.80	...
B 517	...	Welded pipe	0.80	...
B 564	...	Nickel alloy forgings	1.00	(9)

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TABLE A-1B (CONT'D)
BASIC QUALITY FACTORS FOR LONGITUDINAL WELD JOINTS IN PIPES, TUBES, AND FITTINGS E_j

These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

Spec. No.	Class (or Type)	Description	E_j (2)	Appendix A Notes
Nickel and Nickel Alloy (Cont'd)				
B 619	...	Electric resistance welded pipe	0.85	...
	...	Electric fusion welded pipe, double butt seam	0.85	...
	...	Electric fusion welded pipe, single butt seam	0.80	...
B 622	...	Seamless pipe and tube	1.00	...
B 675	All	Welded pipe	0.80	...
B 690	...	Seamless pipe	1.00	...
B 705	...	Welded pipe	0.80	...
B 725	...	Electric fusion welded pipe, double butt seam	0.85	...
	...	Electric fusion welded pipe, single butt seam	0.80	...
B 729	...	Seamless pipe and tube	1.00	...
B 804	1, 3, 5	Welded pipe, 100% radiographed	1.00	...
	2, 4	Welded pipe, double fusion welded	0.85	...
	6	Welded pipe, single fusion welded	0.80	...
Titanium and Titanium Alloy				
B 337	...	Seamless pipe	1.00	...
	...	Electric fusion welded pipe, double butt seam	0.85	...
Zirconium and Zirconium Alloy				
B 523	...	Seamless tube	1.00	...
	...	Electric fusion welded tube	0.80	...
B 658	...	Seamless pipe	1.00	...
	...	Electric fusion welded pipe	0.80	...
Aluminum Alloy				
B 210	...	Seamless tube	1.00	...
B 241	...	Seamless pipe and tube	1.00	...
B 247	...	Forgings and fittings	1.00	(9)
B 345	...	Seamless pipe and tube	1.00	...
B 361	...	Seamless fittings	1.00	...
	...	Welded fittings, 100% radiograph	1.00	(18)(23)
	...	Welded fittings, double butt	0.85	(23)
	...	Welded fittings, single butt	0.80	(23)

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Table A-2 begins on the next page

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TABLE A-2
DESIGN STRESS VALUES FOR BOLTING MATERIALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM

Material	Spec. No.	Grade	Size Range, Diam., in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.					
						Tensile	Yield	to 100	200	300	400	500	600
Carbon Steel													
...	A 675	45	...	(8f)(8g)	−20	45	22.5	11.2	11.2	11.2	11.2	11.2	11.2
...	A 675	50	...	(8f)(8g)	−20	50	25	12.5	12.5	12.5	12.5	12.5	12.5
...	A 675	55	...	(8f)(8g)	−20	55	27.5	13.7	13.7	13.7	13.7	13.7	13.7
...	A 307	B	...	(8f)(8g)	−20	60	...	13.7	13.7	13.7	13.7	13.7	...
...	A 675	60	...	(8f)(8g)	−20	60	30	15.0	15.0	15.0	15.0	15.0	15.0
...	A 675	65	...	(8g)	−20	65	32.5	16.2	16.2	16.2	16.2	16.2	16.2
...	A 675	70	...	(8g)	−20	70	35	17.5	17.5	17.5	17.5	17.5	17.5
...	A 325	...	...	(8g)	−20	105	81	19.3	19.3	19.3	19.3	19.3	19.3
...	A 675	80	...	(8g)	−20	80	40	20.0	20.0	20.0	20.0	20.0	20.0
Nuts	A 194	1	...	(42)	−20	...	...	...	...	...	...	...	...
Nuts	A 194	2, 2H	...	(42)	−20	...	...	...	...	...	...	...	...
...	A 194	2HM	...	(42)	−55	...	...	...	...	...	...	...	...
Nuts	A 563	A, Hvy Hex	...	(42b)	−20	...	...	...	...	...	...	...	...
Alloy Steel													
Cr-0.2Mo	A 193	B7M	≤ 4	...	−55	100	80	20.0	20.0	20.0	20.0	20.0	20.0
Cr-0.20Mo	A 320	L7M	≤ 2½	...	−100								
5Cr	A 193	B5	≤ 4	(15)	−20	100	80	20.0	20.0	20.0	20.0	20.0	20.0
Cr-Mo-V	A 193	B16	> 2½, ≤ 4	(15)	−20	110	95	22.0	22.0	22.0	22.0	22.0	22.0
...	A 354	BC	...	(15)	0	115	99	23.0	23.0	23.0	23.0	23.0	23.0
Cr-Mo	A 193	B7	> 2½, ≤ 4	(15)	−40	115	95	23.0	23.0	23.0	23.0	23.0	23.0
Ni-Cr-Mo	A 320	L43	≤ 4	(15)	−150	125	105	25.0	25.0	25.0	25.0	25.0	25.0
Cr-Mo	A 320	L7	≤ 2½										
Cr-Mo	A 320	L7A, L7B, L7C	≤ 2½	(15)	−150	125	105	25.0	25.0	25.0	25.0	25.0	25.0
Cr-Mo	A 193	B7	≤ 2½	...	−55	125	105	25.0	25.0	25.0	25.0	25.0	25.0
Cr-Mo-V	A 193	B16	≤ 2½	(15)	−20	125	105	25.0	25.0	25.0	25.0	25.0	25.0
...	A 354	BD	≤ 2½	(15)	20	150	130	30.0	30.0	30.0	30.0	30.0	30.0
5Cr nuts	A 194	3	...	(42)	−20	...	...	...	...	...	...	...	...
C-Mo nuts	A 194	4	...	(42)	−150								
Cr-Mo nuts	A 194	7	...	(42)	−150								
Cr-Mo nuts	A 194	7M	...	(42)	−150								
Stainless Steel													
316	A 193												
316	A 320	B8M Cl. 2	> 1¼, ≤ 1½	(15)(60)	−325	90	50	18.8	16.2	16.2	16.2	16.2	16.2
304	A 193												
304	A 320	B8 Cl. 2	> 1¼, ≤ 1½	(15)(60)	−325	100	50	18.8	17.2	16.0	15.0	14.0	13.4
321	A 193												
321	A 320	B8C Cl. 2	> 1¼, ≤ 1¼	(15)(60)	−325	100	50	18.8	16.7	16.3	16.3	16.3	16.3
347	A 193												
347	A 320	B8T Cl. 2	> 1¼, ≤ 1½	(15)(60)	−325	100	50	18.8	17.8	16.5	16.3	16.3	16.3
303 sol. trt.	A 320	B8F Cl. 1	...	(8f)(15)(39)	−325	75	30	18.8	13.0	12.0	10.9	10.0	9.3
19Cr-9Ni	A 453	651B	> 3	(15)(35)	−20	95	50						
19Cr-9Ni	A 453	651B	≤ 3	(15)(35)	−20	95	60	19.0	19.0	19.0	19.0	19.0	19.0
19Cr-9Ni	A 453	651A	> 3	(15)(35)	−20	100	60						
19Cr-9Ni	A 453	651A	≤ 3	(15)(35)	−20	100	70	20.0	20.0	20.0	20.0	20.0	20.0

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APPENDIX B
STRESS TABLES AND ALLOWABLE PRESSURE TABLES FOR NONMETALS

The data and Notes in Appendix B are requirements of this Code.

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Table B-2 Listed Specifications for Laminated Reinforced Thermosetting Resin Pipe 235
Table B-3 Listed Specifications for Filament Wound and Centrifugally Cast Reinforced Thermosetting Resin and Reinforced Plastic Mortar Pipe 235
Table B-4 Allowable Pressures and Recommended Temperature Limits for Concrete Pipe 235
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SPECIFICATION INDEX FOR APPENDIX B

Spec. No.	Title [Note (1)]
ASTM	
C 361	Reinforced Concrete Low-Head Pressure Pipe
C 582	Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion Resistant Equipment
C 599	Process Glass Pipe and Fittings
D 1785	PVC Plastic Pipe, Schedules, 40, 80 AND 120
D 2104	PE Plastic Pipe, Schedule 40
D 2239	PE PlasticPipe (SIDR-PR) Based on Controlled Inside Diameter
D 2241	PVC Plastic Pressure-Rated Pipe (SDR Series)
D 2447	PE Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter
D 2513	Thermoplastic Gas Pressure Pipe, Tubing and Fittings
D 2517	Reinforced Epoxy Resin Gas Pressure Pipe and Fittings
D 2662	PB Plastic Pipe (SDR-PR)
D 2666	PB Plastic Tubing
D 2672	Bell-End PVC Pipe
D 2737	PE Plastic Tubing
D 2846	CPVC Plastic Hot- and Cold-Water Distribution Systems
D 2996	Filament-Wound Fiberglass RTR Pipe [Note (2)]
D 2997	Centrifugally Cast RIR Pipe
D 3000	PB Plastic Pipe (SDR-PR), Based on Outside Diameter
D 3035	PE Plastic Pipe (SDR-PR), Based on Controlled Outside Diameter
D 3309	PB Plastic Hot-Water Distribution Systems
D 3517	Fiberglass RTR Pressure Pipe [Note (2)]
D 3754	Fiberglass RTR Sewer and Industrial Pressure Pipe [Note (2)]
F 441	CPVC Plastic Pipe
F 442	CPVC Plastic Pipe, (SDR-PR)
AWWA	
C300	Reinforced Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids
C301	Prestressed Concrete Pressure, Pipe Steel Cylinder Type, for Water and Other Liquids
C302	Reinforced Concrete Pressure Pipe, Steel Non-Cylinder Type, for Water and Other Liquids
C950	Glass-Fiber-Reinforced Thermosetting-Resin Pressure Pipe

GENERAL NOTE: It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.

NOTES:

(1) For names of plastics identified only by abbreviation, see para. A326.3.

(2) The term *fiberglass RTR* takes the place of the ASTM designation: "*fiberglass*" *(glass-fiber-reinforced thermosetting resin).*

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APPENDIX E
REFERENCE STANDARDS[1, 2]

(99)
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Standards incorporated in this Code by reference, and the names and addresses of the sponsoring organizations are shown in this Appendix. It is not practical to refer to a specific edition of each standard throughout the Code text; instead, the specific edition reference dates are shown here. Subsequent issues and revisions of these referenced standards and any new standards incorporated in the Code by reference in Code Addenda will be listed (after review and acceptance by the Code Committee) in revisions of this Appendix E.

A component ordinarily is not marked to indicate the edition date of the standard to which it is manufactured. It is therefore possible that an item taken from inventory was produced in accordance with a superseded edition, or an edition not yet approved by the Code (because it is of later date than that listed and is in use). If compliance with a specific edition is a requirement of the intended service, it usually will be necessary to state the specific requirement in the purchase specification and to maintain identification of the component until it is put in service.

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F 439-97
F 441/441M-97
F 442/F 442M-97
F 491-95
F 492-95
F 493-97

F 546-95
F 599-95
F 781-95
F 1055-95a
F 1290-93

F 1545-97

ASCE Standard

ASCE 7-95

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REFERENCE STANDARDS (CONT'D)

ASME Codes

ASME Boiler and PressureVessel Code, 1995 Ed. (A1997)
* Section II, Part D
* Section V
* Section VIII, Div. 1, 1998 Ed.
* Section VIII, Div. 2, 1998 Ed.
* Section VIII, Div. 3, 1998 Ed. (A1999)
* Section IX

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B1.20.7-1991

* B16.1-1989
* B16.3-1992
* B16.4-1992
* B16.5-1996
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* B16.14-1991
* B16.15-1985 (R1994)
* B16.20-1993

* B16.21-1992
* B16.22-1995
* B16.24-1991
* B16.25-1997
* B16.26-1988
* B16.28-1994
* B16.34-1996
* B16.36-1996
* B16.39-1986 (R1994)

* B16.42-1987
* B16.47-1996

* B18.2.1-1996
* B18.2.2-1987 (R1993)

* B36.10M-1996
* B36.19M-1985 (R1994)

* B46.1-1995

*American National Standards

A21.14-1984
A21.52-1982

B16.18-1984 (R1994)

B93.11-1981

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5B, 1996
5L, 41st Ed., 1995
15LE, 3rd Ed., 1995
15LP, 5th Ed., 1981
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API Standards

* 526, 1995
594, 4th Ed., 1991
599, 1994
600, 1997

602, 6th Ed., 1993
603, 5th Ed., 1991

608, 1995
609, 4th Ed., 1997

API Recommended Practice

RP 941, 5th Ed., 1997

ASNT Standard

SNT TC-1A-1996

AWS Standards

* A3.0-1994
* A5.1-1992
* A5.4-1992
* A5.5-1996
A5.9-1993
A5.11-1990
A5.14-1989
A5.22-1995

AWWA Standards

* C110-1993
* C111-1995
* C115-1994
* C150-1996
* C151-1996
* C200-1991
* C207-1994
C208-1996
* C300-1997
* C301-1992

AWWA Standards (Cont'd)

* C302-1995
* C500-1993

* C504-1994
* C900-1989
* C950-1995

CDA Publication

Copper Tube Handbook, 1980

CGA Publication

G-4.1-1996

CSA Publication

Z245.1-1998

EJMA Publication

EJMA Standards, 7th Ed.

ICBO Publication

Uniform Building Code, 1997 Edition

MSS Standard Practices

SP-6-1996
SP-9-1997
SP-25-1993

SP-42-1990 (R1995)
SP-43-1991 (R1996)
SP-44-1996
SP-45-1992
SP-51-1991 (R1995)
SP-53-1995
SP-55-1996
* SP-58-1993
SP-65-1994
SP-70-1990

SP-71-1997
SP-72-1992
SP-73-1991 (R1996)

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REFERENCE STANDARDS (CONT'D)

MSS Standard Practices (Cont'd)

SP-75-1993
SP-79-1992
SP-80-1997
SP-81-1995
SP-83-1995
SP-85-1994
SP-88-1993
SP-95-1986 (R1991)
SP-97-1995
SP-105-1990
SP-119-1996

NACE Publication

Corrosion Data Survey, 1985
MR 0175-97
RP 0170-93 (R1997)
RP 0472-95

NBS Publication

NFPA Specification

* 1963-1993

PFI Standard

ES-7-1994

PPI Technical Report

TR-21-1974

SAE Specifications

* J 513-1996
* J 514-1996
* J 518-1993

NOTES:
(1) The issue date shown immediately following the hyphen after the number of the standard (e.g., B16.9-1978, C207-1978, and A 47-77) is the effective date of the issue (edition) of the standard. Any additional number shown following the issue date and prefixed by the letter "R" is the latest date of reaffirmation [e.g., C101-1967 (R1977)]. Any edition number prefixed by the letter "A" is the date of the latest addenda accepted [e.g., B16.36-1975 (A1979)].
(2) * Indicates that the standard has been approved as an American National Standard by the American National Standards Institute.

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Specifications and standards of the following organizations, appear in Appendix E:

API American Petroleum Institute
Publications and Distribution Section
1220 L Street, NW
Washington, DC 20005-4070
202 682-8375
www.api.org

ASCE The American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia 20191-4400
703 295-6300 or 800 548-2723
www.asce.org

ASME ASME International
Three Park Avenue
New York, New York 10016-5990
212 591-8500 or 800 843-2763
www.asme.org

ASME Order Department
22 Law Drive
Box 2900
Fairfield, New Jersey 07007-2300
973 882-1170 or 800 843-2763

ASNT American Society for Nondestructive Testing, Inc.
P.O. Box 28518
1711 Arlingate Lane
Columbus, Ohio 43228-0518
614 274-6003 or 800 222-2768
www.asnt.org

ASTM American Society for Testing and Materials
100 Barr Harbor Drive
West Conshohocken, Pennsylvania
19428-2959
610 832-9500
www.astm.org

AWWA American Water Works Association
6666 W. Quincy Avenue
Denver, Colorado 80235
303 794-7711 or 800 926-7337
www.awwa.org

AWS American Welding Society
550 NW LeJeune Road
Miami, Florida 33126
305 443-9353 or 800 443-9353
www.aws.org

CDA Copper Development Association, Inc.
260 Madison Avenue, 16th Floor
New York, New York 10016
212 251-7200 or 800 232-3282
www.copper.org

CGA Compressed Gas Association, Inc.
1725 Jefferson Davis Highway; Suite 1004
Arlington, Virginia 22202-4102
703 412-0900
www.cganet.com

CSA CSA International
178 Rexdale Boulevard
Etobicoke (Toronto), Ontario
M9W 1R3, Canada
416 747-2620 or 800 463-6727
www.csa-international.org

EJMA Expansion Joint Manufacturers Association
25 North Broadway
Tarrytown, New York 10591
914 332-0040
www.ejma.org

ICBO International Conference of Building Officials
5360 Workman Mill Road
Whittier, California 90601-2298
562 692-4226 or 800 284-4406
www.icbo.org

MSS Manufacturers Standardization Society ofthe Valve and Fittings Industry, Inc.
127 Park Street, NE
Vienna, Virginia 22180-4602
703 281-6613
www.mss-hq.com

NACE NACE International
1440 S. Creek Drive
Houston, Texas 77084
281 228-6200
www.nace.org

NFPA National Fire Protection Association
1 Batterymarch Park
Quincy, Massachusetts 02269
617 770-3000 or 800 344-3555
www.nfpa.org

NIST National Institute of Standards and Technology
Publications available from
Superintendent of Documents
United States Government Printing Office
Washington, DC 20402-9325
202 512-1800
www.nist.gov

PFI Pipe Fabrication Institute
655-32nd Avenue, Suite 201
Lachine, Quebec H8T3G6
Canada
514 634-3434
www.pfi-institute.org

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PPI Plastics Pipe Institute
1801 K Street NW; Suite 600K
Washington, DC 20006-1301
202 974-5318 or 800 541-0736
www.plasticpipe.org

SAE Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, Pennsylvania 15096-0001
724 776-4970 or 800 832-6723
www.sae.org

GENERAL NOTE TO LIST OF ORGANIZATIONS: Some of the organizations listed above publish standards that have been approved as American National Standards. Copies of these standards may also be obtained from:

ANSI American National Standards Institute, Inc.
11 West 42nd Street
New York, New York 10036
212 642-4900
www.ansi.org

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STD.ASME B31.3A-ENGL 2000 ■ 0759670 0617628 284 ■

APPENDIX F
PRECAUTIONARY CONSIDERATIONS

F300 GENERAL

This Appendix provides guidance for the designer in the form of precautionary considerations relating to particular fluid services and piping applications. These are not Code requirements but should be taken into account as applicable in the engineering design. Further information on these subjects can be found in the literature.

A00 **F301 DESIGN CONDITIONS**

Selection of pressures, temperatures, various forces, and other conditions that may apply to the design of piping can be influenced by unusual requirements which should be considered when they occur. These include but are not limited to the following.

F301.4 Ambient Effects

Where fluids can be trapped (e.g., in double seated valves) and subjected to heating and consequent expansion, means of pressure relief should be considered to avoid excessive pressure buildup.

F301.5 Dynamic Effects

geysering: an effect that can occur in piping handling fluids at or near their boiling temperatures under conditions when rapid evolution of vapor within the piping causes rapid expulsion of liquid. In such cases a pressure surge can be generated that may be destructive to the piping. (Geysering usually is associated with vertical pipelines but may occur in inclined lines under certain conditions.)

F301.7 Thermal Expansion and Contraction Effects

bowing during cooldown: an effect that can occur, usually in horizontal piping, on introduction of a fluid at or near its boiling temperature and at a flow rate that allows stratified two-phase flow, causing largecircumferential temperature gradients and possibly unacceptable stresses at anchors, supports, guides, and within pipe walls. (Two-phase flow can also generate excessive pressure oscillations and surges that may damage the piping.)

F304 PRESSURE DESIGN

F304.7 Pressure Design of Other Metallic Components

F304.7.4 Expansion Joints. The following are specific considerations to be evaluated by the designer when specifying expansion joint requirements, in addition to the guidelines given in EJMA Standards:

(a) susceptibility to stress corrosion cracking of the materials of construction, considering specific alloy content, method of manufacture, and final heat treated condition;

(b) consideration of not only the properties of the flowing medium but also the environment external to the expansion joint and the possibility of condensation or ice formation due to the operation of the bellows at a reduced temperature;

(c) consideration of specifying a minimum bellows or ply thickness. The designer is cautioned that requiring excessive bellows thickness may reduce the fatigue life of the expansion joint and increase end reactions.

(d) accessibility of the expansion joint for maintenance and inspection;

(e) need for leak tightness criteria for mechanical seals on slip type joints;

(f) specification of installation procedures and shipping or preset bars so that the expansion joint will not be extended, compressed, or offset to compensate for improper alignment of piping, other than the intentional offset specified by the piping designer;

(g) need to request data from the expansion joint manufacturer, including:

(1) effective thrust area;

(2) lateral, axial, and rotational stiffness (spring constant);

(3) calculated design cycle life under specified design conditions;

(4) friction force in hinges, tie rods, etc.;

(5) installed length and weight;

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(6) requirements for additional support or restraint in the piping;

(7) expansion joint elements that are designed to be uninsulated during operation;

(8) certification of pressure containing and/or restraining materials of construction;

(9) maximum test pressure;

(10) design calculations.

F307 VALVES

(a) Extended bonnet valves are recommended where necessary to establish a temperature differential between the valve stem packing and the fluid in the piping, to avoid packing leakage and external icing or other heat flux problems. The valve should be positioned to provide this temperature differential. Consideration should be given to possible packing shrinkage in low temperature fluid service.

(b) The effect of external loads on valve operability and leak tightness should be considered.

F308 FLANGES AND GASKETS

F308.2 Specific Flanges

Slip-On Flanges. The need for venting the space between the welds in double-welded slip-on flanges should be considered for fluid services (including vacuum) that require leak testing of the inner fillet weld, or when fluid handled can diffuse into the enclosed space, resulting in possible failure.

F308.4 Gaskets

(a) Gasket materials not subject to cold flow should be considered for use with raised face flanges for fluid services at elevated pressures with temperatures significantly above or below ambient.

(b) Use of full face gaskets with flat faced flanges should be considered when using gasket materials subject to cold flow for low pressure and vacuum services at moderate temperatures. When such gasket materials are used in other fluid services, the use of tongue-and-groove or other gasket-confining flange facings should be considered.

(c) The effect of flange facing finish should be considered in gasket material selection.

F309 BOLTING

F309.1 General

The use of controlled bolting procedures should be considered in high, low, and cycling temperature services, and under conditions involving vibration or fatigue, to reduce:

(a) the potential for joint leakage due to differential thermal expansion;

(b) the possibility of stress relaxation and loss of bolt tension.

F312 FLANGED JOINTS

F312.1 General

Three distinct elements of a flanged joint must act together to provide a leak-free joint: the flanges, the gasket, and the bolting. Factors that affect performance include:

(a) Selection and Design

(1) consideration of service conditions (including external loads, bending moments, and application of thermal insulation);

(2) flange rating, type, material, facing, and facing finish (see para. F308.2);

(3) gasket type, material, thickness, and design (see para. F308.4);

(4) bolt material, strength (cold and at temperature), and specifications for tightening of bolts (see para. F309.1); and

(5) design for access to the joint.

(b) Installation

(1) condition of flange mating surfaces;

(2) joint alignment and gasket placement before boltup; and

(3) implementation of specified bolting procedures.

F322 DESIGN CONSIDERATIONS FOR SPECIFIC SYSTEMS

F322.6 Pressure Relief Piping

Stop Valves in Pressure Relief Piping. If stop valves are located in pressure relief piping in accordance with para. 322.6.1(a), and if any of these stop valves are to be closed while the equipment is in operation, an authorized person should be present. The authorized person should remain in attendance at a location where

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Symbol	Definition	Units [Note (2)] SI	Units [Note (2)] U.S.	Reference Paragraph	Reference Table/Fig./App.	Reference Equation
P_m	Maximum allowable internal pressure for miter bends	kPa	psi	304.2.3	...	(4a) (4b) (4c)
$P_{max.}$	Maximum allowable gage pressure for continuous operation of component at maximum design temperature	kPa	psi	V303.1.1	...	(V1)
P_S	Limiting design pressure based on column instability, for convoluted U-shaped bellows	kPa	psi	X302.2.3	...	(X3)
P_T	Minimum test gage pressure	kPa	psi	345.4.2 A382.2.5 X302.2.3	...	(24) (27) (X2)
r_i	Ratio of a lesser computed displacement stress range S_i to maximum computed stress range S_{Ei} ($i = 1, 2, \ldots$)	...	...	302.3.5	...	(1d)
r_2	Mean radius of pipe using nominal wall thickness $\overline{T}$	mm	in.	304.2.3 319.4.4	304.2.3 D300	(4a) (4b) (4c) (21)
r_x	External contour radius of extruded outlet	mm	in.	304.3.4	304.3.4 D300	(12)
R	Range of reaction forces or moments in flexibility analysis	N or N-mm	lbf or in.-lbf	319.5 319.5.1	...	(22)
R_a	Estimated instantaneous reaction force or moment at installation temperature	N or N-mm	lbf or in.-lbf	319.5.1	...	...
R_m	Estimated instantaneous maximum reaction force or moment at maximum or minimum metal temperature	N or N-mm	lbf or in.-lbf	319.5.1	...	(22)
$R_{min.}$	Minimum ratio of stress ranges (see para. X3.1.3 for further details)	...	...	X302.1.3	...	(X1) (X2)
A00 R_T	Ratio of the average temperature dependent trend curve value of tensile strength to the room temperature tensile strength	...	...	302.3.2(d)(8)	...	...
00 R_Y	Ratio of the average temperature dependent trend curve value of yield strength to the room temperature yield strength	...	...	302.3.2(d)(8)	...	...
R_1	Effective radius of miter bend	mm	in.	304.2.3	304.2.3	(4b) (5)
(99) R_1	Bend radius of welding elbow or pipe bend	mm	in.	304.2.1	D300	(3f)(3g)
s	Miter spacing at pipe center line	mm	in.	...	D300	...
S	Basic allowable stress for metals	MPa	ksi	300.2 302.3.1 304.1.1 304.1.2 304.1.3 304.2.3	A-1 K-1	(3a) (3b) (3c) (4a) (4b) (4c) (15) (24) (34a) (34b) (35a) (35b) (37)

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Symbol	Definition	Units [Note (2)] SI	Units [Note (2)] U.S.	Reference Paragraph	Reference Table/Fig./App.	Reference Equation
S	Basic allowable stress for metals (Cont'd)			304.3.3 304.4.1 304.5.1 304.5.2 304.5.3 319.3.4 345.4.2 H300 K304.1.1 K304.1.2 K304.8.4 K345.4.2		
S	Bolt design stress	MPa	ksi	300.2 302.3.1	A-2	...
S	Design stress for nonmetals	...	...	A304.1.1 A304.1.2 A304.5.1 A304.5.2	B-1	(26)
S_a	Bolt design stress at atmospheric temperature	MPa	ksi	304.5.1 A304.5.1	...	...
S_b	Bolt design stress at design temperature	MPa	ksi	304.5.1 A304.5.1	...	...
S_b	Resultant bending stress	Mpa	ksi	319.4.4	...	(17) (18) (19) (20)
S_c	Basic allowable stress at minimum metal temperature expected during the displacement cycle under analysis	MPa	ksi	302.3.5 K302.3.5	...	(1a) (1b) (32)
S_d	Allowable stress from Table A-1 for the material at design temperature	MPa	ksi	V303.1.1	...	(V1)
S_f	Allowable stress for flange material or pipe	MPa	ksi	304.5.1 304.5.2	...	...
S_h	Basic allowable stress at maximum metal temperature expected during the displacement cycle under analysis	MPa	ksi	302.3.5 319.5.1 K302.3.5	...	(1a) (1b) (23) (32)
S_i	A computed displacement stress range smaller than S_E ($i = 1, 2, ...$)	MPa	ksi	302.3.5	...	(1d)
S_i	Equivalent stress during service condition i (the higher of S_{pi} and S_L)	MPa	ksi	V303.1.1 V303.1.2	...	...
S_{pi}	Equivalent stress for pressure during service condition i	MPa	ksi	V303.1.1	...	(V1)
S_t	Torsional stress	MPa	ksi	319.4.4	...	(17)
S_t	Total stress range for design fatigue curves applying to austenitic stainless steel expansion joints	...	psi	X302.1.3	X302.1.3	...

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	Symbol	Definition	Units [Note (2)] SI	Units [Note (2)] U.S.	Reference Paragraph	Reference Table/Fig./App.	Reference Equation
	S_y	Yield stress (BPV Code)	MPa	ksi	302.2.4	...	...
	S_A	Allowable stress range for displacement stress	MPa	ksi	300.2 302.3.5 319.2.3 319.3.4 319.4.4	...	(1a) (1b) (32)
	S_A	Allowable stress range for displacement stress (Cont'd)			319.4.5 K302.3.5		
	S_E	Computed displacement stress range	MPa	ksi	300.2 302.3.5 319.2.3 319.4.4 319.4.5 319.5.1	...	(17) (23)
	S_H	Mean long term hydrostatic strength (LTHS)	kPa	psi	A328.2.5	...	(27)
	S_L	Sum of longitudinal stresses	MPa	ksi	302.3.5 302.3.6 K302.3.5 K302.3.6	...	(1b)
	S_S	Mean short term burst stress	kPa	psi	A328.2.5	...	(27)
A00	S_T	Specified minimum tensile strength at room temperature	MPa	ksi	302.3.2	...	...
	S_T	Allowable stress at test temperature	MPa	ksi	345.4.2 K345.4.2	...	(24) (38)
A00	S_Y	Specified minimum yield strength at room temperature	MPa	ksi	302.3.2	...	...
	t	Pressure design thickness	mm	in.	304.1.1 304.1.2 304.1.3 304.3.3 304.4.1 304.5.2 A304.1.1 A304.1.2 A304.1.3 K304.1.1 K304.1.2 K304.1.3 k304.5.2	304.1.1 328.5.2C	(2) (3a) (3b) (3c) (3d) (13) (14) (25) (26) (33) (34a) (36)
	t_b	Pressure design thickness of branch	mm	in.	304.3.3 304.3.4 H300	304.3.3 304.3.4	(8) (11)
	t_c	Throat thickness of cover fillet weld	mm	in.	328.5.4 331.1.3 H300	328.5.4	...

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Symbol	Definition	Units [Note (2)] SI	Units [Note (2)] U.S.	Reference Paragraph	Reference Table/Fig./App.	Reference Equation
t_h	Pressure design thickness of header	mm	in.	304.3.3 304.3.4 H300	304.3.3 304.3.4	(6) (7) (9) (10)
t_i	Total duration of service condition i, at pressure P_i and temperature T_i	hr	hr	V303.2	...	(V4)
t_m	Minimum required thickness, including mechanical, corrosion, and erosion allowances	mm	in.	304.1.1 304.2.1 304.4.1 304.5.2 304.5.3 328.4.2 A304.1.1 A304.2.1 K304.1.1 K304.2.1 K304.5.2 K328.4.2	328.3.2 328.4.3 K328.4.2 K341.3.2	(2) (13) (14) (15) (25) (33) (36)
$t_{min.}$	For branch, the smaller of $\overline{T}_b$ or $\overline{T}_r$	mm	in.	328.5.4	328.5.4	...
t_{ri}	Rupture life of a component subjected to repeated service conditions i and stress S_i	hr	hr	V303.1.4 V303.2	...	(V3) (V4)
T	Pipe wall thickness (measured or minimum per purchase specification)	mm	in.	304.1.1 304.2.3 306.4.2 A304.1.1 A328.2.5 K304.1.1 K304.1.2	323.3.1 328.5.2B K323.3.1	(4a) (4b) (4c) (35a) (35b) (27)
T_b	Branch pipe wall thickness (measured or minimum per purchase specification)	mm	in.	304.3.3 304.3.4 H300	304.3.3 304.3.4	(8) (11) (12)
T_c	Crotch thickness of tees	mm	in.	...	D300	...
T_h	Header pipe wall thickness (measured or minimum per purchase specification)	mm	in.	304.3.3 304.3.4 H300	304.3.3 304.3.4	(7) (10)
T_i	Actual temperature during sevice condition i	°C	°F	V303.1.4	...	(V3)
T_r	Minimum thickness of reinforcing ring or saddle made from pipe (nominal thickness if made from plate)	mm	in.	304.3.3 H300	304.3.3	...
T_s	Effective branch wall thickness	mm	in.	319.4.4	...	(21)
T_x	Corroded finished thickness of extruded outlet	mm	in.	304.3.4	304.3.4	(12)
A00 T_E	Design temperature during service condition i (temperature corresponding to S_i, Table A-1)	°C	°F	V303.1.2 V303.1.3	...	(V2)

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Symbol	Definition	Units [Note (2)] SI	Units [Note (2)] U.S.	Reference Paragraph	Reference Table/Fig./App.	Reference Equation
T_2	Minimum thickness of fabricated lap	mm	in.	...	328.5.5	...
$\overline{T}$	Nominal wall thickness of pipe	mm	in.	302.3.5	328.5.2B 328.5.5 K302.3.3D D300	...
$\overline{T}_b$	Nominal branch pipe wall thickness	mm	in.	319.4.4 328.5.4 331.1.3	304.3.3 328.5.4D	...
$\overline{T}_h$	Nominal header pipe wall thickness	mm	in.	319.4.4 328.5.4 331.1.3	304.3.3 328.5.4D	...
$\overline{T}_r$	Nominal thickness of reinforcing ring or saddle	mm	in.	328.5.4 331.1.3	328.5.4D D300	...
$\overline{T}_w$	Nominal wall thickness, thinner of components joined by butt weld	mm	in.	344.6.2	341.3.2 K341.3.2	...
u	Creep-rupture usage factor, summed up from individual usage factors, t_i/t_{ri}	...	...	V303.2 V303.3	...	(V4)
U	Straight line distance between anchors	m	ft	319.4.1	...	(16)
X	Factor for modifying the allowable stress range S_t for bellows expansion joint (see para. X302.1.3 for further details	...	...	X302.1.3	...	(X1) (X2)
X_1	Ring reinforcement area	mm^2	$in.^2$	H304		...
X_2	Fillet weld reinforcement area	mm^2	$in.^2$	H304		...
$x_{min.}$	Size of fillet weld to slip-on or socket welding flange	mm	in.	...	328.5.2B	...
y	Resultant of total displacement	mm	in.	319.4.1	...	(16)
Y	Coefficient for effective stressed diameter	...	...	304.1.1 304.1.2	304.1.1	(3a)
Z	Section modulus of pipe	mm^3	$in.^3$	319.4.4	...	(18) (19)
Z_e	Effective section modulus for branch	mm^3	$in.^3$	319.4.4	...	(20) (21)
α	Angle of change in direction at miter joint	deg	deg	304.2.3 306.3.2 306.3.3 M306.3	304.2.3	...
β	Smaller angle between axes of branch and run	deg	deg	304.3.3	304.3.3	(6) (8)
ΔT_n	Range of temperature change for lesser cycle (n = 1, 2, ...)	°C	°F	302.3.5	...	...
ΔT_c	Range of temperature change for full cycle	°C	°F	302.3.5	...	...

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Symbol	Definition	Units [Note (2)] SI	Units [Note (2)] U.S.	Reference Paragraph	Reference Table/Fig./App.	Reference Equation
θ	Angle of miter cut	deg	deg	304.2.3	304.2.3 D300	(4a) (4c) (5)

NOTES:
(1) For Code reference to this Appendix, see para. 300.3.
(2) Note that the use of these units is not required by the Code. They represent sets of consistent units (except where otherwise stated) which may be used in computations, if stress values in ksi and MPa are multiplied by 1000 for use in equations that also involve pressure in psi and kPa values.

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NOTES FOR APPENDIX K TABLES

GENERAL NOTES:

(a) The allowable stress values and P-Number or S-Number assignments in Table K-1, together with the referenced Notes and double bars [see Note (7) of Notes for Appendix A Tables], are requirements of Chapter IX.

(b) Notes (1) through (7) and Notes (17) and (18) are referenced in Table headings and in headings for material type and product form; Notes (8) through (16) and (19) and (20) are referenced in the Notes column for specific materials.

(c) At this time, metric equivalents have not been provided in Table K-1. To convert stress values in Table K-1 to MPa at a given temperature in °C, determine the equivalent temperature in °F and interpolate to calculate the stress value in ksi at the given temperature. Multiply by 6.895 to determine allowable stress in MPa at the given temperature.

NOTES:

(1) The stress values in Table K-1 are allowable stresses in tension in accordance with para. K302.3.1(a). Stress values in shear and bearing are stated in para. K302.3.1(b), those in compression in para. K302.3.1(c).

(2) Samples representative of all piping components, as well as their fabrication welds, shall be impact tested in accordance with para. K323.3.

(3) Material minimum service temperature shall be in accordance with para. K323.2.2.

(4) The temperature limit for materials shall be in accordance with para. K323.2.1. A double bar (‖) after a tabled stress indicates that use of the material is prohibited above that temperature.

(5) Stress values printed in *italics* exceed two-thirds of the expected yield strength at temperature. Stress values in **boldface** are equal to 90% of yield strength at temperature. See para. K302.3.2.

(6) A product analysis of the material shall be performed. See para. K323.1.5.

(7) See para. 328.2.1(f) for a description of P-Number and S-Number groupings. P-Numbers are indicated by number or by a number followed by a letter (e.g., 8, or 5B, or 11A). S-Numbers are preceded by an S (e.g., S-1).

(8) This type or grade is permitted only in the seamless condition.

(9) If this grade is cold expanded, the most severely deformed portion of a representative sample shall be impact tested in accordance with para. K323.3.

(10) This material may require special consideration for welding qualification. See the BPV Code, Section IX, QW/QB-422. For use in this Code, a qualified WPS is required for each strength level of material.

(11) No welding is permitted on this material.

(12) Welds in components shall be of a design that permits fully interpretable radiographic examination; joint quality facter E_j shall be 1.00 per para. K302.3.4.

(13) Pipe furnished to this specification shall be supplied in the solution heat treated condition.

(14) This unstabilized grade of stainless steel increasingly tends to precipitate intergranular carbides as the carbon content increases above 0.03%. See also para. F323.4(c)(2).

(15) Stress values shown are for the lowest strength base material permitted by the specification to be used in the manufacture of this grade of fitting. If a higher strength base material is used, the higher stress values for that material may be used in design.

(16) Galvanized pipe furnished to this specification is not permitted for pressure containing service. See para. K323.4.2(b).

(17) Pipe and tubing shall be examined for longitudinal defects in accordance with Table K305.1.2.

(18) Material defects may be repaired by welding only in accordance with para. K323.1.6.

(19) For material thickness > 127 mm (5 in.), the specified minimum tensile strength is 448 MPa (65 ksi).

(20) For material thickness > 127 mm (5 in.), the specified minimum tensile strength is 483 MPa (70 ksi).

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TABLE K-1
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]

Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	Type or Grade	Notes	Specified Min. Strength, ksi Tensile	Yield
Carbon Steel Pipes and Tubes (17)						
...	A 53	1	B	(8)(16)	60	35
...	A 106	1	B	...		
...	A 333	1	6	(8)		
...	A 334	1	6	(8)		
...	API 5L	S-1	B	(8)(9)		
...	A 210	1	A-1	...	60	37
...	A 106	1	C	...	70	40
...	A 210					
...	API 5L	S-1	X42	(8)(9)	60	42
...	API 5L	S-1	X46	(8)(9)	63	46
...	API 5L	S-1	X52	(8)(9)	66	52
...	API 5L	S-1	X56	(8)(9)(10)	71	56
...	API 5L	S-1	X60	(8)(9)(10)	75	60
...	API 5L	S-1	X65	(8)(9)(10)	77	65
...	API 5L	S-1	X70	(8)(9)(10)	82	70
...	API 5L	S-1	X80	(8)(9)(10)	90	80
Forgings and Fittings						
...	A 234	1	WPB	(8)	60	35
...	A 420	1	WPL6			
...	A 350	1	LF2	...	70	36
...	A 105	1	...			
...	A 234	1	WPC	(8)	70	40
Low and Intermediate Alloy Steel Pipes and Tubes (17)						
C-½Mo	A 335	3	P1	...	55	30
1Cr-½Mo	A 335	4	P12	...	60	32
1¼Cr-½Mo	A 335	4	P11	...	60	30
5Cr-½Mo	A 335	5A	P5	...	60	30
2¼Cr-1Mo	A 335	5A	P22	...	60	30

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TABLE K-1
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]
Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding								Type or Grade	Spec. No.
100	200	300	400	500	600	650	700		
									Carbon Steel Pipes and Tubes (17)
23.3	21.3	20.7	20.0	18.9	17.3	16.9	16.8	B	A 53
								B	A 106
								6	A 333
								6	A 334
								B	API 5L
24.7	22.5	21.9	21.1	20.0	18.3	17.9	17.8	A-1	A 210
26.7	24.3	23.7	22.9	21.6	19.7	19.4	19.2	C	A 106, A 210
28.0	20.0	20.0	20.0	...	...	...	...	X42	API 5L
30.7	21.0	21.0	21.0	...	...	...	...	X46	API 5L
34.7	22.0	22.0	22.0	...	...	...	...	X52	API 5L
37.3	23.7	23.7	23.7	...	...	...	...	X56	API 5L
40.0	25.0	25.0	25.0	...	...	...	...	X60	API 5L
43.3	...	...	...	...	...	...	...	X65	API 5L
46.7	...	...	...	...	...	...	...	X70	API 5L
53.3	...	...	...	...	...	...	...	X80	API 5L
									Forgings and Fittings
23.3	21.3	20.7	20.0	18.9	17.3	16.9	16.8	WPB	A 234
								WPL6	A 420
24.0	21.9	21.3	20.6	19.5	17.7	17.5	17.3	LF2	A 350
26.7	24.3	23.7	22.9	21.6	19.7	19.4	19.2	...	A 105
								WPC	A 234
									Low and Intermediate Alloy Steel Pipes and Tubes (17)
20.0	18.5	17.5	16.9	16.3	15.7	15.4	15.1	P1	A 335
21.3	19.3	18.1	17.3	16.7	16.3	16.1	15.8	P12	A 335
20.0	18.7	17.9	17.5	17.2	16.7	16.2	15.7	P11	A 335
20.0	18.1	17.4	17.2	17.1	16.8	16.6	16.3	P5	A 335
20.0	18.5	18.1	17.9	17.9	17.9	17.9	17.9	P22	A 335

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]

Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	Type or Grade	Notes	Specified Min. Strength, ksi Tensile	Yield
Low and Intermediate Alloy Steel (Cont'd)						
Pipes and Tubes (17) (cont'd)						
3½Ni	A 333	9B	3			
3½Ni	A 334	9B	3	(8)	65	35
9Ni	A 333					
9Ni	A 334	11A	8	(8)	100	75
Forgings and Fittings						
3½Ni	A 420	9B	WPL3	(8)	65	35
3½Ni	A 350	9B	LF3	...	70	37.5
1Cr-½Mo	A 182	4	F12, Cl. 2	...	70	40
1¼Cr-½Mo	A 182	4	F11, Cl. 2	...	70	40
C-½Mo	A 182	3	F1	...	70	40
5Cr-½Mo	A 182	5B	F5	...	70	40
2¼Cr-1Mo	A 182	5A	F22, Cl. 3	...	75	45
9Ni	A 420	11A	WPL8	(8)	110	75
3½Ni-1¾Cr-½Mo	A 508	11A	4N, Cl. 2	...	115	100
Ni-Cr-Mo	A 723	...	1, 2, 3 Cl. 1	(11)	115	100
Ni-Cr-Mo	A 723	...	1, 2, 3 Cl. 2	(11)	135	120
Ni-Cr-Mo	A 723	...	1, 2, 3 Cl. 3	(11)	155	140
Stainless Steel (5)						
Pipes and Tubes (17)						
16Cr-12Ni-2Mo	A 312	8	TP316L	(12)		
316L, A 240	A 358	8	316L, Cl. 1 & 3	(12)(13)	70	25
16Cr-12Ni-2Mo-N	A 312	8	TP316LN	(12)		
316LN, A 240	A 358	8	316LN, Cl. 1 & 3	(12)(13)	75	30
18Cr-8Ni	A 312	8	TP304L	(12)		
304L, A 240	A 358	8	304L, Cl. 1 & 3	(12)(13)	70	25
18Cr-8Ni-N	A 312	8	TP304LN	(12)		
304LN, A 240	A 358	8	304L, Cl. 1 & 3	(12)(13)	75	30

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]
Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

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Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding								Type or Grade	Spec. No.
100	200	300	400	500	600	650	700		
								Low and Intermediate Alloy Steel (Cont'd) Pipes and Tubes (17) (Cont'd)	
23.3	21.3	20.7	20.0	18.9	17.3	17.0	15.7 ‖	3 3	A 333 A 334
50.0	31.7 ‖	...	...	...	...	...	...	8	A 333 A 334
								Forgings and Fittings	
23.3	21.3	19.6	...	...	...	...	...	WPL3	A 420
25.0	22.8	22.1	...	...	...	...	...	LF3	A 350
26.7	24.1	22.7	21.7	20.9	20.3	20.1	19.7 ‖	F12, Cl. 2	A 182
26.7	24.6	23.4	22.5	21.7	20.9	20.5	20.1 ‖	F11, Cl. 2	A 182
26.7	24.6	23.4	22.5	21.7	20.9	20.5	20.1 ‖	F1	A 182
26.7	24.1	23.2	22.9	22.7	22.4	22.1	21.7 ‖	F5	A 182
30.0	27.5	26.1	25.5	24.8	24.3	24.0	23.7 ‖	F22, Cl. 3	A 182
50.0	31.7 ‖	...	...	...	...	...	...	WPL8	A 420
66.7	62.8	60.8	59.5	58.5	57.4	56.7 ‖	...	4N, Cl. 2	A 508
66.7	64.0	62.3	61.3	60.3	59.3	58.5	57.3 ‖	1, 2, 3 Cl. 1	A 723
80.0	76.8	74.8	73.6	72.4	71.2	70.1	68.8 ‖	1, 2, 3 Cl. 2	A 723
93.3	89.6	87.3	85.9	84.5	83.1	81.9	80.3 ‖	1, 2, 3 Cl. 3	A 723
								Stainless Steel (5) Pipes and Tubes (17)	
16.7	*16.7*	*16.7*	15.8	14.8	14.0	13.8	13.5 ‖	TP316L 316L, Cl. 1 & 3	A 312 A 358
20	*20*	*20*	18.9	17.5	16.5	16.0	15.6 ‖	TP316LN 316LN, Cl. 1 & 3	A 312 A 358
16.7	*16.7*	*16.7*	15.8	14.7	14.0	13.7	13.4 ‖	TP304I 304I, Cl. 1 & 3	A 312 A 358
20.0	*20.0*	*20.0*	18.6	17.5	16.4	16.1	15.9 ‖	TP304LN 304LN, Cl. 1 & 3	A 312 A 358

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]

Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	Type or Grade	Notes	Specified Min. Strength, ksi	
					Tensile	Yield
Stainless Steel (5) (Cont'd)						
Pipes and Tubes (17) (Cont'd)						
18Cr-10Ni-Ti smls. > 3/8 in. thick	A 312	8	TP321	...	70	25
18Cr-10Ni-Ti smls. ≤ 3/8 in. thick or wld.	A 312	8	TP321	(12)		
321, A 240	A 358	8	321, Cl. 1 & 3	(12)(13)	75	30
18Cr-8Ni	A 312	8	TP304	(12)(14)		
304, A 240	A 358	8	304, Cl. 1 & 3	(12)(13)(14)	75	30
16Cr-12Ni-2Mo	A 312	8	TP316	(12)(14)		
316, A 240	A 358	8	316, Cl. 1 & 3	(12)(13)(14)	75	30
18Cr-13Ni-3Mo	A 312	8	TP317	(12)(14)		
18Cr-10Ni-Cb	A 312	8	TP347	(12)		
347, A 240	A 358	8	347, Cl. 1 & 3	(12)(13)	75	30
18Cr-8Ni-N	A 312	8	TP304N	(12)(14)		
304N, A 240	A 358	8	304N, Cl. 1 & 3	(12)(13)(14)	80	35
16Cr-12Ni-2Mo-N	A 312	8	TP316N	(12)(14)		
316N, A 240	A 358	8	316N, Cl. 1 & 3	(12)(13)(14)	80	35
Forgings and Fittings						
16Cr-12Ni-2Mo	A 182	8	F316L	(19)		
16Cr-12Ni-2Mo	A 403	8	WP316L, Cl. S & WX	(12)	70	25
16Cr-12Ni-2Mo-N	A 182	8	F316LN	(20)		
16Cr-12Ni-2Mo-N	A 403	8	WP316LN, Cl. S & WX	(12)	75	30
18Cr-8Ni	A 182	8	F304L	(19)		
18Cr-8Ni	A 403	8	WP304L, Cl. S & WX	(12)	70	25
18Cr-8Ni-N	A 182	8	F304LN	(20)		
18Cr-8Ni-N	A 403	8	WP304LN, Cl. S & WX	(12)	75	30

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]
Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

(99)
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Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding								Type or Grade	Spec. No.
100	200	300	400	500	600	650	700		
								Stainless Steel (5) (Cont'd) Pipes and Tubes (17) (Cont'd)	
16.7	*16.7*	*16.7*	*16.7*	16.1	15.2	14.9	14.6	TP321 smls. > 3/8 in. thick	A 312
20.0	*20.0*	*20.0*	*20.0*	19.4	18.3	17.9	17.5	TP321 smls. ≤ 3/8 in. thick & wld. 321, Cl. 1 & 3	A 312 A 358
20.0	*20.0*	*20.0*	18.6	17.5	16.4	16.1	15.9	TP304 304, Cl. 1 & 3	A 312 A 358
20.0	*20.0*	*20.0*	19.3	18.0	17.0	16.7	16.3	TP316 316, Cl. 1 & 3 TP317	A 312 A 358 A 312
20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.4	19.0	18.6	TP347 347, Cl. 1 & 3	A 312 A 358
23.3	*23.3*	22.5	20.3	18.8	17.8	17.6	17.2	TP304N 304N, Cl. 1 & 3	A 312 A 358
23.3	*23.3*	*23.3*	*23.3*	22.2	21.1	20.5	20.1	TP316N 316N, Cl. 1 & 3	A 312 A 358
								Forgings and Fittings	
16.7	*16.7*	*16.7*	15.8	14.8	14.0	13.8	13.5	F316L WP316L, Cl. S & WX	A 182 A 403
20.0	*20.0*	*20.0*	18.9	17.5	16.5	16.0	15.6	F316LN WP316LN, Cl. S & WX	A 182 A 403
16.7	*16.7*	*16.7*	15.8	14.7	14.0	13.7	13.4	F304L WP304L, Cl. S & WX	A 182 A 403
20.0	*20.0*	*20.0*	18.6	17.5	16.4	16.1	15.9	F304LN WP304LN, Cl. S & WX	A 182 A 403

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]

Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	Type or Grade	Notes	Specified Min. Strength, ksi	
					Tensile	Yield
Stainless Steel (5) (Cont'd) Forgings and Fittings (Cont'd)						
18Cr-10Ni-Ti	A 182	8	F321	(20)	75	30
18Cr-10Ni-Ti	A 403	8	WP321, Cl. S & WX	(12)		
18Cr-8Ni	A 182	8	F304	(14)(20)	75	30
18Cr-8Ni	A 403	8	WP304, Cl. S & WX	(12)(14)		
16Cr-12Ni-2Mo	A 182	8	F316	(14)(20)	75	30
16Cr-12Ni-2Mo	A 403	8	WP316, Cl. S & WX	(12)(14)		
18Cr-13Ni-3Mo	A 403	8	WP317, Cl. S & WX	(12)(14)		
18Cr-10Ni-Cb	A 182	8	F347	(20)	75	30
18Cr-10Ni-Cb	A 403	8	WP347, Cl. S & WX	(12)		
18Cr-8Ni-N	A 182	8	F304N	(14)	80	35
18Cr-8Ni-N	A 403	8	WP304N, Cl. S & WX	(12)(14)		
16Cr-12Ni-2Mo-N	A 182	8	F316N	(14)	80	35
16Cr-12Ni-2Mo-N	A 403	8	WP316N, Cl. S & WX	(12)(14)		

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]
Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

(99)
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Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding								Type or Grade	Spec. No.
100	200	300	400	500	600	650	700		
								Stainless Steel (5) (Cont'd) Forgings and Fittings (Cont'd)	
20.0	*20.0*	*20.0*	*20.0*	19.4	18.3	17.9	17.5	F321	A 182
								WP321, Cl. S & WX	A 403
20.0	*20.0*	*20.0*	18.6	17.5	16.4	16.1	15.9	F304	A 182
								WP304, Cl. S & WX	A 403
20.0	*20.0*	*20.0*	19.3	18.0	17.0	16.7	16.3	F316	A 182
								WP316, Cl. S & WX	A 403
								WP317, Cl. S & WX	A 403
20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.4	19.0	18.6	F347	A 182
								WP347, Cl. S & WX	A 403
23.3	*23.3*	22.5	20.3	18.8	17.8	17.6	17.2	F304N	A 182
								WP304N, Cl. S & WX	A 403
23.3	*23.3*	*23.3*	*23.3*	22.2	21.0	20.5	20.1	F316N	A 182
								WP316N, Cl. S & WX	A 403

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]
Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	UNS Number	Condition	Size Range, in.	Notes	Specified Min. Strength, ksi	
							Tensile	Yield
Nickel and Nickel Alloys (5) Pipes and Tubes (17)								
Ni-Cu	B 165	42	N04400	Annealed	> 5 O.D.	...	70	25
Ni-Cr-Fe	B 167	43	N06600	H.W.				
Ni-Cr-Fe	B 167	43	N06600	H.W. ann.	> 5 O.D.	...	75	25
Ni-Cu	B 165	42	N04400	Annealed	≤ 5 O.D.	...	70	28
Ni-Cr-Fe	B 167	43	N06600	H.W.	≤ 5 O.D.	...		
Ni-Cr-Fe	B 167	43	N06600	H.W. ann.	≤ 5 O.D.	...	80	30
Ni-Cr-Fe	B 167	43	N06600	C.W. ann.	> 5 O.D.	...		
Ni-Cr-Fe	B 167	43	N06600	C.W. ann.	≤ 5 O.D.	...	80	35
Ni-Mo-Cr	B 622	44	N10276	...	All	...	100	41
Ni-Cu	B 165	42	N04400	Str. rel.	All	...	85	55
Forgings and Fittings								
Ni-Cu	B 366	S-42	N04400	...	All	(12)(15)		
Ni-Cu	B 564	42	N04400	Annealed	All	...	70	25
Ni-Cr-Fe	B 366	S-43	N06600	...	All	(12)(15)	75	25
Ni-Cr-Fe	B 564	43	N06600	Annealed	All	...	80	35
Ni-Mo-Cr	B 366	44	N10276	...	All	(12)	100	41
Rod and Bar								
Ni-Cu	B 164	42	N04400	Annealed	All	...	70	25
Ni-Cr-Fe	B 166	43	N06600	C.W. ann. & H.W. ann.	All	...	80	35
Ni-Cr-Fe	B 166	43	N06600	H.W., A.W.	sq. rec., & hex.			
Ni-Cr-Fe	B 166	43	N06600	H.W., A.W.	> 3 rd.	...	85	35
Ni-Cu	B 164	42	N04400	H.W.	Rod, sq., & rec. ≤ 12 hex. ≤ $2\frac{1}{8}$	...	80	40
Ni-Cr-Fe	B 166	43	N06600	H.W., A.W.	$\frac{1}{2}$ to 3 rd.	...	90	40
Ni-Mo-Cr	B 574	44	N10276	...	All	...	100	41
Ni-Cr-Fe	B 166	S-43	N06600	H.W., A.W.	$\frac{1}{4}$ to $\frac{1}{2}$ rd.	...	95	45

Abbreviations in Condition and Size Range Columns:

ann.	annealed	rd.	rounds
A.W.	as worked	rec.	rectangle
C.W.	cold worked	rel.	relieved
H.W.	hot worked	sq.	squares
hex.	hexagons	str.	stress
O.D.	outside diameter		

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APPENDIX V
ALLOWABLE VARIATIONS IN ELEVATED TEMPERATURE SERVICE

A00 **V300 APPLICATION**

(a) This Appendix covers application of the Linear Life Fraction Rule, which provides a method for evaluating variations at elevated temperatures above design conditions where material creep properties [see para. V302(c)] control the allowable stress at the temperature of the variation. This Appendix is a Code requirement only when specified by the owner in accordance with the last sentence of para. 302.2.4(f)(1).

(b) Life Fraction analysis addresses only the gross strength of piping components; it does not consider local stress effects. It is the designer's responsibility to provide construction details suitable for elevated temperature design.

V300.1 Definitions

operating condition: any condition of pressure and temperature under which the design conditions are not exceeded

excursion: any condition under which pressure or temperature, or both, exceed the design conditions

service condition: any operating condition or excursion

duration

(a) the extent of any service condition, hours;

(b) the cumulative extent of all repetitions of a given service condition during service life, hours.

service life: the life assigned to a piping system for design purposes, hours

A00 **V301 DESIGN BASIS**

Life Fraction analysis shall be performed in accordance with one of the following design basis options selected by the owner.

(a) All service conditions in the creep range and their durations are included.

(b) To simplify the analysis, less severe service conditions need not be individually evaluated if their durations are included with the duration of a more severe service condition.

V302 CRITERIA

(a) All of the criteria in para. 302.2.4 shall be met.

(b) Only carbon steels, low and intermediate alloy steels, austenitic stainless steels, and high nickel alloys are included.

(c) Service conditions are considered only in the calculation of the usage factors in accordance with para. V303 when the allowable stress at the temperature of those conditions in Table A-1 is based on the creep criteria stated in para. 302.3.2. (99) A00

(d) Creep-fatigue interaction effects shall be considered when the number of cycles exceeds 100.

V303 PROCEDURE

The cumulative effect of all service conditions during the service life of the piping is determined by the Linear Life Fraction Rule in accordance with the following procedure.

V303.1 Calculations for Each Service Condition *i*

The following steps shall be repeated for each service condition considered.

V303.1.1 Equivalent Stress for Pressure

(a) Using Eq. (V1), compute a pressure-based equivalent stress S_{pi}:

$$S_{pi} = S_d P_i / P_{\max.} \qquad \text{(V1)}$$

where

S_{pi} = pressure-based equivalent stress, MPa (ksi)
P_i = gage pressure, kPa (psi), during service condition i
S_d = allowable stress, MPa (ksi) at design temperature, °C (°F)

[1] Footnote 1 deleted. A00

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$P_{max.}$ = maximum allowable gage pressure, kPa (psi), for continuous operation of pipe or component at design temperature

(b) Compute the maximum longitudinal stress S_L during service condition i, in accordance with para. 302.3.5(c).

(c) The equivalent stress S_i for use in para. V303.1.2, is the greater of the values calculated in (a) and (b) above.

A00 **V303.1.2 Effective Temperature.** From Table A-1 find the temperature corresponding to the equivalent stress S_i using linear interpolation if necessary. This temperature T_E is the effective temperature for service condition i.

A00 **V303.1.3 Larson-Miller Parameter.** Compute the LMP for the basic design life for service condition i, using Eq. (V2):

$$\left.\begin{array}{ll} \text{SI metric:} & LMP = (C + 5)(T_E + 273) \\ \text{U.S.:} & LMP = (C + 5)(T_E + 460) \end{array}\right\} \quad \text{(V2)}$$

where

T_E = effective temperature, °C (°F); see para. V303.1.2

C = 20 (carbon, low, and intermediate alloy steels)

C = 15 (austenitic stainless steel and high nickel alloys)

V303.1.4 Rupture Life. Compute the rupture life t_{ri}, hr, using Eq. (V3):

$$t_{ri} = 10^a \quad \text{(V3)}$$

where

$$\text{SI metric:} \quad a = \frac{LMP}{T_i + 273} - C$$

$$\text{U.S.:} \quad a = \frac{LMP}{T_i + 460} - C$$

and

t_{ri} = allowable rupture life, hr, associated with a given service condition i and stress S_i

T_i = actual temperature, °C (°F), during service condition i

LMP and C are as defined in para. V303.1.3

V303.2 Determine Creep-Rupture Usage Factor A00

The usage factor u is the summation of individual usage factors t_i/t_{ri} for all service conditions considered in para. V303.1. See Eq. (V4):

$$u = \sum(t_i/t_{ri}) \quad \text{(V4)}$$

where

i = as a subscript, 1 for the prevalent operating condition; i = 2, 3, etc. for each of the other service conditions considered

t_i = total duration, hr, associated with any service condition i, at pressure P_i and temperature T_i

t_{ri} = as defined in para. V303.1.4

V303.3 Evaluation

The calculated value of u indicates the nominal amount of creep-rupture life expended during the service life of the piping system. If $u \leq 1.0$, the usage factor is acceptable including excursions. If $u > 1.0$, the designer shall either increase the design conditions (selecting piping system components of a higher allowable working pressure if necessary) or reduce the number and/or severity of excursions until the usage factor is acceptable.

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APPENDIX X
METALLIC BELLOWS EXPANSION JOINTS

Design requirements of Appendix X are dependent on and compatible with EJMA standards. There are no metric equivalents and no basis for introducing them at this time.

X300 GENERAL

The intent of this Appendix is to set forth design, manufacturing, and installation requirements and considerations for bellows type expansion joints, supplemented by the EJMA Standards. It is intended that applicable provisions and requirements of Chapters I through VI of this Code shall be met, except as modified herein. This Appendix does not specify design details. The detailed design of all elements of the expansion joint is the responsibility of the manufacturer. This Appendix is not applicable to expansion joints in piping designed in accordance with Chapter IX.

X301 PIPING DESIGNER RESPONSIBILITIES

The piping designer shall specify the design conditions and requirements necessary for the detailed design and manufacture of the expansion joint in accordance with para. X301.1 and the piping layout, anchors, restraints, guides, and supports required by para. X301.2.

X301.1 Expansion Joint Design Conditions

The piping designer shall specify all necessary design conditions including the following.

X301.1.1 Static Design Conditions. The design conditions shall include any possible variations of pressure or temperature, or both, above operating levels. Use of a design metal temperature other than the fluid temperature for any component of the expansion joint shall be verified by computation, using accepted heat transfer procedures, or by test or measurement on similarly designed equipment in service under equivalent operating conditions.

X301.1.2 Cyclic Design Conditions. These conditions shall include coincident pressure, temperature, imposed end displacements and thermal expansion of the expansion joint itself, for cycles during operation. Cycles due to transient conditions (startup, shutdown, and abnormal operation) shall be stated separately. (See EJMA Standards, C-4.1.5.2 on cumulative fatigue analysis, for guidance in defining cycles.)

X301.1.3 Other Loads. Other loads, including dynamic effects (such as wind, thermal shock, vibration, seismic forces, and hydraulic surge); and static loads, such as weight (insulation, snow, ice, etc.), shall be stated.

X301.1.4 Fluid Properties. Properties of the flowing medium pertinent to design requirements, including the owner-designated fluid service category, flow velocity and direction, for internal liners, etc., shall be specified.

X301.1.5 Other Design Conditions. Other conditions that may affect the design of the expansion joint, such as use of shrouds, external or internal insulation, limit stops, other constraints, and connections in the body (e.g., drains or bleeds) shall be stated.

X301.2 Piping Design Requirements

X301.2.1 General. Piping layout, anchorage, restraints, guiding, and support shall be designed to avoid imposing motions and forces on the expansion joint other than those for which it is intended. For example, a bellows expansion joint is not normally designed to absorb torsion. Pipe guides, restraints, and anchorage shall conform to the EJMA Standards. Anchors and guides shall be provided to withstand expansion joint thrust forces when not self-restrained by tie rods, hinge bars, pins, etc. (See para. X302.1.) Column buckling of the piping (e.g., due to internal fluid pressure) shall also be considered.

X301.2.2 Design of Anchors A00

(a) Main Anchors. Main anchors shall be designed to withstand the forces and moments listed in X301.2.2(b),

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and pressure thrust, defined as the product of the effective thrust area of the bellows and the maximum pressure to which the joint will be subjected in operation. Consideration shall be given to the increase of pressure thrust loads on anchors due to unrestrained expansion joints during leak testing if supplemental restraints are not used during the test (see para. 345.3.3). For convoluted, omega, or disk type joints, the effective thrust area recommended by the manufacturer shall be used. If this information is unavailable, the area shall be based on the mean diameter of the bellows.

(b) Intermediate Anchors. Anchors shall be capable of withstanding the following forces and moments:

(1) those required to compress, extend, offset, or rotate the joint by an amount equal to the calculated linear or angular displacement;

(2) static friction of the pipe in moving on its supports between extreme extended and contracted positions (with calculated movement based on the length of pipe between anchor and expansion joint);

(3) operating and transient dynamic forces caused by the flowing medium; and

(4) other piping forces and moments.

X302 EXPANSION JOINT MANUFACTURER RESPONSIBILITIES

The expansion joint manufacturer shall provide the detailed design and fabrication of all elements of the expansion joint in accordance with the requirements of the Code and the engineering design. This includes:

(a) all piping within the end connections of the assembly supplied by the manufacturer, including pipe, flanges, fittings, connections, bellows, and supports or restraints of piping;

(b) specifying the need for supports or restraints external to the assembly as required, and of the data for their design; and

(c) determining design conditions for all components supplied with the expansion joint which are not in contact with the flowing medium.

X302.1 Expansion Joint Design

The design of bellows type expansion joints shall be based on recognized and accepted analysis methods and the design conditions stated in para. X301.1. Convoluted type bellows shall be designed in accordance with the EJMA Standards, except as otherwise required or permitted herein. Design of other types of bellows shall be qualified as required by para. 304.7.2.

X302.1.1 Factors of Safety. The factor of safety on squirm pressure shall be not less than 2.25. The factor of safety on ultimate rupture pressure shall be not less than 3.0.

X302.1.2 Design Stress Limits. For convoluted type bellows, stresses shall be calculated either by the formulas shown in the EJMA Standards or by other methods acceptable to the owner.

(a) The circumferential and meridional membrane stress in the bellows, the tangent end, and reinforcing ring members (including tensile stress in fasteners) due to design pressure shall not exceed the allowable stress values given in Table A-1.

(b) Meridional membrane and bending stresses at design pressure shall be of a magnitude which will not result in permanent deformation of the convolutions at test pressure. Correlation with previous test data may be used to satisfy this requirement.

For an unreinforced bellows, annealed after forming, the meridional membrane plus bending stress in the bellows shall not exceed 1.5 times the allowable stress given in Table A-1.

(c) Direct tensile, bearing, and shear stresses in restraints (tie rods, hinge bars, pins, etc.), in self-restrained expansion joints, and in the attachments of the restraining devices to the pipe or flanges, shall not exceed the allowable stress limits stated in para. 302.3.1. Restraints shall be designed to withstand the full design pressure thrust.

(d) Pressure design of pipe sections, fittings, and flanges shall meet the requirements of paras. 303 and 304.

(e) When the operating metal temperature of the bellows element is in the creep range,[1] the design shall be given special consideration and, in addition to meeting the requirements of this Appendix, shall be qualified as required by para. 304.7.2.

X302.1.3 Fatigue Analysis

(a) A fatigue analysis[1] which takes into account all design cyclic conditions shall be performed and the calculated design cycle life shall be reported. The method of analysis for convoluted U-shaped bellows shall be in accordance with EJMA Standards.

[1] Consideration shall be given to the detrimental effects of creep-fatigue interaction when the operating metal temperature of the bellows element will be in the creep range. Creep-fatigue interaction may become significant at temperatures above 800°F for austenitic stainless steels.

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(b) Material design fatigue curves for as-formed austenitic stainless steel bellows are provided in Fig. X302.1.3. The curves are for use only with the EJMA stress equations. Fatigue testing by individual manufacturers, in accordance with (d) below, is required to qualify use of the pertinent fatigue curve for bellows manufactured by them. Fatigue testing in accordance

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There is a change in the way the Addenda to the 1999 Edition of the ASME B31.3 Process Piping Code are distributed. The 1999 Edition, published March 31, 1999, incorporates the 1999 Addenda revisions, additions, or deletions. There will be no separate 1999 Addenda issued in a replacement page format. Two additional Addenda to the 1999 Edition, in the form of replacement pages, will be issued on March 31, 2000 and March 31, 2001.

The Summary of Changes published with the 1999 Edition lists and describes the revisions that are part of the 1999 Addenda. These changes are identified with a margin note, **99**, denoting the affected area.

The Addenda for 2000 and 2001 will also have a Summary of Changes and identifiers printed on the replacement pages. The revisions, additions, or deletions will be incorporated directly into the affected pages. It is advisable to retain the title sheets and all replaced pages for reference.

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This Edition was approved by the American National Standards Institute and designated ASME B31.3-1999 Edition on March 26, 1999.

The 1999 Edition of this Code is being issued with an automatic update service that includes Addenda, Interpretations, and Cases. The next Edition is scheduled for publication in 2002.

The use of Addenda allows revisions made in response to public review comments or committee actions to be published on a regular basis; revisions published in Addenda will become effective 6 months after the Date of Issuance of the Addenda.

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In this Edition of the Code, SI metric units are given first, with U.S. customary units in parentheses. Appendices H and X, the tables in Appendices A and K, and Tables C-1, C-3, and C-6 in Appendix C are exceptions. Values in metric units are to be regarded as the standard, unless otherwise agreed between the contracting parties. Instructions are given, in those tables that have not been converted for converting tabular data in U.S. units to appropriate SI units.

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FOREWORD

Responding to evident need and at the request of The American Society of Mechanical Engineers, the American Standards Association initiated Project B31 in March 1926, with ASME as sole administrative sponsor. The breadth of the field involved required that membership of the Sectional Committee be drawn from some 40 engineering societies, industries, government bureaus, institutes, and trade associations.

Initial publication in 1935 was as the American Tentative Standard Code for Pressure Piping. Revisions from 1942 through 1955 were published as American Standard Code for Pressure Piping, ASA B31.1. It was then decided to publish as separate documents the various industry Sections, beginning with ASA B31.8-1955, Gas Transmission and Distribution Piping Systems. The first Petroleum Refinery Piping Code Section was designated ASA B31.3-1959. ASA B31.3 revisions were published in 1962 and 1966.

In 1967–1969, the American Standards Association became first the United States of America Standards Institute, then the American National Standards Institute. The Sectional Committee became American National Standards Committee B31 and the Code was renamed the American National Standard Code for Pressure Piping. The next B31.3 revision was designated ANSI B31.3-1973. Addenda were published through 1975.

A draft Code Section for Chemical Plant Piping, prepared by Section Committee B31.6, was ready for approval in 1974. It was decided, rather than have two closely related Code Sections, to merge the Section Committees and develop a joint Code Section, titled Chemical Plant and Petroleum Refinery Piping. The first edition was published as ANSI B31.3-1976.

In this Code, responsibility for piping design was conceptually integrated with that for the overall processing facility, with safeguarding recognized as an effective safety measure. Three categories of Fluid Service were identified, with a separate Chapter for Category M Fluid Service. Coverage for nonmetallic piping was introduced. New concepts were better defined in five Addenda, the last of which added Appendix M, a graphic aid to selection of the proper Fluid Service category.

The Standards Committee was reorganized in 1978 as a Committee operating under ASME procedures with ANSI accreditation. It is now the ASME Code for Pressure Piping, B31 Committee. Section committee structure remains essentially unchanged.

The second edition of Chemical Plant and Petroleum Refinery Piping was compiled from the 1976 Edition and its five Addenda, with nonmetal requirements editorially relocated to a separate Chapter. Its new designation was ANSI/ASME B31.3-1980.

Section Committee B31.10 had a draft Code for Cryogenic Piping ready for approval in 1981. Again, it was decided to merge the two Section Committees and develop a more inclusive Code with the same title. The work of consolidation was partially completed in the ANSI/ASME B31.3-1984 Edition.

Significant changes were made in Addenda to the 1984 Edition: integration of cryogenic requirements was completed; a new stand-alone Chapter on high-pressure piping was added; and coverage of fabrication, inspection, testing, and allowable stresses was reorganized. The new Edition was redesignated as ASME/ANSI B31.3-1987 Edition.

Addenda to subsequent Editions, published at three-year intervals, have been primarily to keep the Code up-to-date. New Appendices have been added, however, on requirements for bellows expansion joints, estimating service life, submittal of Inquiries, and aluminum flanges in the 1990 and 1993 Editions, all designated as ASME B31.3.

In a program to clarify the application of all Sections of the Code for Pressure Piping, changes are being made in the Introduction and Scope statements of B31.3, and its title is changed to Process Piping.

Under direction of ASME Codes and Standards management, metric units of measurement are being emphasized. With certain exceptions, SI metric units are listed first in the 1996 Edition and are designated as the standard. Instructions for conversion are given where metric data are not available. U.S. customary units also are given. By agreement, either system may be used.

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ASME CODE FOR PRESSURE PIPING, B31

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INTRODUCTION

The ASME B31 Code for Pressure Piping consists of a number of individually published Sections, each an American National Standard, under the direction of ASME Committee B31, Code for Pressure Piping.

Rules for each Section reflect the kinds of piping installations considered during its development, as follows:

B31.1 Power Piping: piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems;

B31.3 Process Piping: piping typically found in petroleum refineries, chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants, and related processing plants and terminals;

B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids: piping transporting products which are predominately liquid between plants and terminals and within terminals, pumping, regulating, and metering stations;

B31.5 Refrigeration Piping: piping for refrigerants and secondary coolants;

B31.8 Gas Transportation and Distribution Piping Systems: piping transporting products which are predominately gas between sources and terminals, including compressor, regulating, and metering stations; gas gathering pipelines;

B31.9 Building Services Piping: piping typically found in industrial, institutional, commercial, and public buildings, and in multi-unit residences, which does not require the range of sizes, pressures, and temperatures covered in B31.1;

B31.11 Slurry Transportation Piping Systems: piping transporting aqueous slurries between plants and terminals and within terminals, pumping, and regulating stations.

This is the B31.3 Process Piping Code Section. Hereafter, in this Introduction and in the text of this Code Section B31.3, where the word *Code* is used without specific identification, it means this Code Section.

It is the owner's responsibility to select the Code Section which most nearly applies to a proposed piping installation. Factors to be considered by the owner include: limitations of the Code Section; jurisdictional requirements; and the applicability of other codes and standards. All applicable requirements of the selected Code Section shall be met. For some installations, more than one Code Section may apply to different parts of the installation. The owner is also responsible for imposing requirements supplementary to those of the Code if necessary to assure safe piping for the proposed installation.

Certain piping within a facility may be subject to other codes and standards, including but not limited to:

ANSI Z223.1 National Fuel Gas Code: piping for fuel gas from the point of delivery to the connection of each fuel utilization device;

NEPA Fire Protection Standards: fire protection systems using water, carbon dioxide, halon, foam, dry chemical, and wet chemicals;

NFPA 99 Health Care Facilities: medical and laboratory gas systems;

Building and plumbing codes, as applicable, for potable hot and cold water, and for sewer and drain systems.

The Code sets forth engineering requirements deemed necessary for safe design and construction of pressure piping. While safety is the basic consideration, this factor alone will not necessarily govern the final specifications for any piping installation. The designer is cautioned that the Code is not a design handbook; it does not do away with the need for the designer or for competent engineering judgment.

To the greatest possible extent, Code requirements for design are stated in terms of basic design principles and formulas. These are supplemented, as necessary, with specific requirements to assure uniform application of principles and to guide selection and application of piping elements. The Code prohibits designs and practices known to be unsafe and contains warnings where caution, but not prohibition, is warranted.

This Code Section includes:

(a) references to acceptable material specifications and component standards, including dimensional requirements and pressure–temperature ratings;

(b) requirements for design of components and assemblies, including piping supports;

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(c) requirements and data for evaluation and limitation of stresses, reactions, and movements associated with pressure, temperature changes, and other forces;

(d) guidance and limitations on the selection and application of materials, components, and joining methods;

(e) requirements for the fabrication, assembly, and erection of piping; and

(f) requirements for examination, inspection, and testing of piping.

ASME Committee B31 is organized and operates under procedures of The American Society of Mechanical Engineers which have been accredited by the American National Standards Institute. The Committee is a continuing one, and keeps all Code Sections current with new developments in materials, construction, and industrial practice. Addenda are issued periodically. New editions are published at intervals of 3 years to 5 years.

Code users will note that clauses in the Code are not necessarily numbered consecutively. Such discontinuities result from following a common outline, insofar as practical, for all Code Sections. In this way, corresponding material is correspondingly numbered in most Code Sections, thus facilitating reference by those who have occasion to use more than one Section.

It is intended that this Edition of Code Section B31.3 and any subsequent Addenda not be retroactive. Unless agreement is specifically made between contracting parties to use another issue, or the regulatory body having jurisdiction imposes the use of another issue, the latest Edition and Addenda issued at least 6 months prior to the original contract date for the first phase of activity covering a piping installation shall be the governing document for all design, materials, fabrication, erection, examination, and testing for the piping until the completion of the work and initial operation.

Users of this Code are cautioned against making use of Code revisions without assurance that they are acceptable to the proper authorities in the jurisdiction where the piping is to be installed.

The B31 Committee has established an orderly procedure to consider requests for interpretation and revision of Code requirements. To receive consideration, such request must be in writing and must give full particulars in accordance with Appendix Z.

The approved reply to an inquiry will be sent directly to the inquirer. In addition, the question and reply will be published as part of an Interpretation supplement issued to the applicable Code Section.

A Case is the prescribed form of reply when study indicates that the Code wording needs clarification, or when the reply modifies existing requirements of the Code or grants permission to use new materials or alternative constructions. Proposed Cases are published in *Mechanical Engineering* for public review. In addition, the Case will be published as part of a Case supplement issued to the applicable Code Section.

A Case is normally issued for a limited period. If at the end of that period it has been incorporated in the Code, or if no further use of its provisions is anticipated, it will be allowed to expire. Otherwise, it will be renewed for a limited period.

A request for revision of the Code will be placed on the Committee's agenda. Further information or active participation on the part of the proponent may be requested during consideration of a proposed revision. Approved revisions are published in Addenda to the Code.

Materials ordinarily are listed in the Stress Tables only when sufficient usage in piping within the scope of the Code has been shown. Requests for listing shall include evidence of satisfactory usage and specific data to permit establishment of allowable stresses, maximum and minimum temperature limits, and other restrictions. Additional criteria can be found in the guidelines for addition of new materials in the ASME Boiler and Pressure Vessel Code, Section II and Section VIII, Division 1, Appendix B. (To develop usage and gain experience, unlisted materials may be used in accordance with para. 323.1.2.)

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SUMMARY OF CHANGES

Changes given below are identified on the pages by a margin note, **99,** placed next to the affected area.

Page	*Location*	*Change*
2	300.1.1(c)	Revised
3	Fig. 300.1.1	(1) General Note added (2) Figure caption revised
4, 5, 8	300.2	(1) Definition of *electrofusion joint* added (2) Definitions of *Normal Fluid Service* and *severe cyclic conditions* revised
17	Table 302.3.4	Revised
22	304.3.3(a)	Nomenclature for d_1 revised
26	304.3.4(f)(1)	Equation (10) revised
	304.3.4(f)(2)	Equation (11) revised
	304.3.4(f)(3)	Equation (12) revised
30	306.1.3(a)	Revised
32	308.2	Revised
56, 57	Table 326.1	(1) ANSI A21.14, ANSI A21.52, and ANSI B93.11 deleted (2) MSS SP-105 added
81	341.4.3(a)(3)	Last line revised
102	Table A326.1	ASTM F 1055 added
104	A328.2.6(a)	Second line revised
105–107	A328.5	(1) A328.5.5 and A328.5.6 redesignated as A328.5.6 and A328.5.7, respectively (2) New A328.5.5 added (3) Figures A328.5.5 and A328.5.6 redesignated as Figs. A328.5.6 and A328.5.7, respectively (4) New Fig. A328.5.5 added
118	M335.4.1	Revised
	M335.4.2	Revised
125	K302.3.2(a)	Revised
128	K304.4(b)	Revised

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Page	*Location*	*Change*
128	K304.5.1(b)	Revised
	K304.5.2	Revised
138	K326	Revised
144	K341.4.1(a)(3)	Added
	K341.4.1(a)(4)	Added
153	Specifications Index for Appendix A	B 265 and B 381 added
157	Notes for Appendix A Tables	Note (77) added
160–162, 164	Table A-1	(1) For all API 5L, reference to Note (77) added (2) Allowable Stress values for A53, Type F Grade A pipe revised
170, 171	Table A-1	For 9Cr-1Mo, A 691 added
172–177	Table A-1	Add A 335, A 387, A 182, and A 234, Grade 91
206, 207	Table A-1	(1) B 265 and B 381 added to Titanium entries (2) For B 337, Allowable Stress values revised
209	Table A-1	For B 241 and B 345, entries revised
259–263	Appendix E	Revised
268	F323.4(c)(1)	Revised
283	Appendix J	Nomenclature for R_1 added
295–297	Table K-1	Revised
299	Table K-1	Allowable Stress values for A 182 and A 403, Grade F321 revised
306, 307	L303.1.1	Added
	L303.2.1	Revised
	L303.2.2	Revised
	L303.2.3	Revised
	L305	Added
311	V302(c)	Revised

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CHAPTER I
SCOPE AND DEFINITIONS

300 GENERAL STATEMENTS

(a) Identification. This Process Piping Code is a Section of the American Society of Mechanical Engineers Code for Pressure Piping, ASME B31, an American National Standard. It is published as a separate document for convenience of Code users.

(b) Responsibilities

(1) Owner. The owner of a piping installation shall have overall responsibility for compliance with this Code, and for establishing the requirements for design, construction, examination, inspection, and testing which will govern the entire fluid handling or process installation of which the piping is a part. The owner is also responsible for designating piping in certain fluid services. [See paras. 300(d)(4) and (5) and 300(e).]

(2) Designer. The designer is responsible to the owner for assurance that the engineering design of piping complies with the requirements of this Code and with any additional requirements established by the owner.

(3) Manufacturer, Fabricator, and Erector. The manufacturer, fabricator, and erector of piping are responsible for providing materials, components, and workmanship in compliance with the requirements of this Code and of the engineering design.

(4) Owner's Inspector. The owner's Inspector (see para. 340) is responsible to the owner for ensuring that the requirements of this Code for inspection, examination, and testing are met.

(c) Intent of the Code

(1) It is the intent of this Code to set forth engineering requirements deemed necessary for safe design and construction of piping installations.

(2) This Code is not intended to apply to the operation, examination, inspection, testing, maintenance, or repair of piping that has been placed in service. The provisions of this Code may optionally be applied for those purposes, although other considerations may also be necessary.

(3) Engineering requirements of this Code, while considered necessary and adequate for safe design, generally employ a simplified approach to the subject. A designer capable of applying a more rigorous analysis shall have the latitude to do so, but must be able to demonstrate the validity of that approach.

(4) Piping elements should, insofar as practicable, conform to the specifications and standards listed in this Code. Piping elements neither specifically approved nor specifically prohibited by this Code may be used provided they are qualified for use as set forth in applicable Chapters of this Code.

(5) The engineering design shall specify any unusual requirements for a particular service. Where service requirements necessitate measures beyond those required by this Code, such measures shall be specified by the engineering design. Where so specified, the Code requires that they be accomplished.

(6) Compatibility of materials with the service and hazards from instability of contained fluids are not within the scope of this Code. See para. F323.

(d) Determining Code Requirements

(1) Code requirements for design and construction include fluid service requirements, which affect selection and application of materials, components, and joints. Fluid service requirements include prohibitions, limitations, and conditions, such as temperature limits or a requirement for safeguarding (see para. 300.2 and Appendix G). Code requirements for a piping system are the most restrictive of those which apply to any of its elements.

(2) For metallic piping not in Category M or high pressure fluid service, Code requirements are found in Chapters I through VI (the base Code), and fluid service requirements are found in:

(a) Chapter III for materials;

(b) Chapter II, Part 3, for components;

(c) Chapter II, Part 4, for joints.

(3) For nonmetallic piping and piping lined with nonmetals, all requirements are found in Chapter VII. (Paragraph designations begin with "A.")

(4) For piping in a fluid service designated by the owner as Category M (see para. 300.2 and Appendix M), all requirements are found in Chapter VIII. (Paragraph designations begin with "M.")

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(5) For piping in a fluid service designated by the owner as Category D (see para. 300.2 and Appendix M), piping elements restricted to Category D Fluid Service in Chapters I through VII, as well as elements suitable for other fluid services, may be used.

(6) Metallic piping elements suitable for Normal Fluid Service in Chapters I through VI may also be used under severe cyclic conditions unless a specific requirement for severe cyclic conditions is stated.

(e) High Pressure Piping. Chapter IX provides alternative rules for design and construction of piping designated by the owner as being in High Pressure Fluid Service.

(1) These rules apply only when specified by the owner, and only as a whole, not in part.

(2) Chapter IX rules do not provide for Category M Fluid Service. See para. K300.1.4.

(3) Paragraph designations begin with "K."

(f) Appendices. Appendices of this Code contain Code requirements, supplementary guidance, or other information. See para. 300.4 for a description of the status of each Appendix.

300.1 Scope

Rules for the Process Piping Code Section B31.3[1] have been developed considering piping typically found in petroleum refineries; chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants; and related processing plants and terminals.

300.1.1 Content and Coverage

(a) This Code prescribes requirements for materials and components, design, fabrication, assembly, erection, examination, inspection, and testing of piping.

(b) This Code applies to piping for all fluids, including:

(1) raw, intermediate, and finished chemicals;

(2) petroleum products;

(3) gas, steam, air, and water;

(4) fluidized solids;

(5) refrigerants; and

(6) cryogenic fluids.

(99) *(c)* See Fig. 300.1.1 for a diagram illustrating the application of B31.3 piping at equipment. The joint connecting piping to equipment is within the scope of B31.3.

[1] B31 references here and elsewhere in this Code are to the ASME B31 Code for Pressure Piping and its various Sections, which are identified and briefly described in the Introduction.

300.1.2 Packaged Equipment Piping.

Also included within the scope of this Code is piping which interconnects pieces or stages within a packaged equipment assembly.

300.1.3 Exclusions.

This Code excludes the following:

(a) piping systems designed for internal gage pressures at or above zero but less than 105 kPa (15 psi), provided the fluid handled is nonflammable, nontoxic, and not damaging to human tissue as defined in 300.2, and its design temperature is from –29°C (–20°F) through 186°C (366°F);

(b) power boilers in accordance with BPV Code[2] Section I and boiler external piping which is required to conform to B31.1;

(c) tubes, tube headers, crossovers, and manifolds of fired heaters, which are internal to the heater enclosure; and

(d) pressure vessels, heat exchangers, pumps, compressors, and other fluid handling or processing equipment, including internal piping and connections for external piping.

300.2 Definitions

Some of the terms relating to piping are defined below. For welding terms not shown here, definitions in accordance with ANSI/AWS Standard A3.0 apply.

air-hardened steel: a steel that hardens during cooling in air from a temperature above its transformation range

anneal heat treatment: see *heat treatment*

arc cutting: a group of cutting processes wherein the severing or removing of metals is effected by melting with the heat of an arc between an electrode and the base metal. (Includes carbon-arc cutting, metal-arc cutting, gas metal-arc cutting, gas tungsten-arc cutting, plasma-arc cutting, and air carbon-arc cutting.) See also *oxygen-arc cutting.*

arc welding (AW): a group of welding processes which produces coalescence of metals by heating them with an arc or arcs, with or without the application of pressure and with or without the use of filler metal

[2] BPV Code references here and elsewhere in this Code are to the ASME Boiler and Pressure Vessel Code and its various Sections as follows:
Section I, Power Boilers
Section II, Materials, Part D
Section V, Nondestructive Examination
Section VIII, Pressure Vessels, Divisions 1 and 2
Section IX, Welding and Brazing Qualifications

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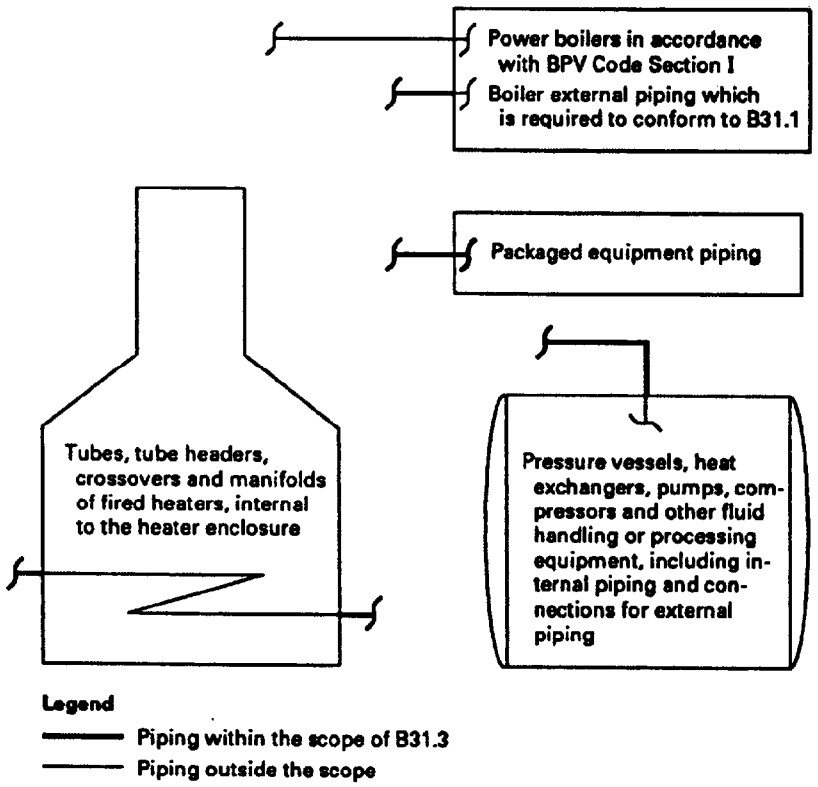

GENERAL NOTE: The means by which piping is attached to equipment is within the scope of the applicable piping code.

FIG. 300.1.1 DIAGRAM ILLUSTRATING APPLICATION OF B31.3 PIPING AT EQUIPMENT (99)

assembly: the joining together of two or more piping components by bolting, welding, bonding, screwing, brazing, soldering, cementing, or use of packing devices as specified by the engineering design

automatic welding: welding with equipment which performs the welding operation without adjustment of the controls by an operator. The equipment may or may not perform the loading and unloading of the work.

backing filler metal: see *consumable insert*

backing ring: material in the form of a ring used to support molten weld metal

balanced piping system: see para. 319.2.2(a)

base material: the material to be brazed, soldered, welded, or otherwise fused

basic allowable stress: see *stress terms frequently used*

bolt design stress: see *stress terms frequently used*

bonded joint: a permanent joint in nonmetallic piping made by one of the following methods:

(a) adhesive joint: a joint made by applying an adhesive to the surfaces to be joined and pressing them together

(b) butt-and-wrapped joint: a joint made by butting together the joining surfaces and wrapping the joint with plies of reinforcing fabric saturated with resin

(c) heat fusion joint: a joint made by heating the surfaces to be joined and pressing them together to achieve fusion

(d) hot gas welded joint: a joint made by simultaneously heating the surfaces to be joined and a filler material with a stream of hot air or hot inert gas, then pressing the surfaces together and applying the filler material to achieve fusion

(e) solvent cemented joint: a joint made by using a solvent cement to soften the surfaces to be joined and pressing them together

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(99) *(f) electrofusion joint:* a joint made by heating the surfaces to be joined using an electrical resistance wire coil, which remains embedded in the joint.

bonder: one who performs a manual or semiautomatic bonding operation

bonding operator: one who operates machine or automatic bonding equipment

bonding procedure: the detailed methods and practices involved in the production of a bonded joint

bonding procedure specification (BPS): the document which lists the parameters to be used in the construction of bonded joints in accordance with the requirements of this Code

branch connection fitting: an integrally reinforced fitting welded to a run pipe and connected to a branch pipe by a buttwelding, socket welding, threaded, or flanged joint; includes a branch outlet fitting conforming to MSS SP-97

braze welding: a welding process using a nonferrous filler metal having a melting point below that of the base metals, but above 427°C (800°F). The filler metal is not distributed in the joint by capillary attraction. (Bronze welding, formerly used, is a misnomer for this term.)

brazing: a metal joining process wherein coalescence is produced by use of a nonferrous filler metal having a melting point above 427°C (800°F), but lower than that of the base metals being joined. The filler metal is distributed between the closely fitted surfaces of the joint by capillary attraction.

butt joint: a joint between two members aligned approximately in the same plane

Category D: see *fluid service*

Category M: see *fluid service*

caulked joint: a joint in which suitable material (or materials) is either poured or compressed by the use of tools into the annular space between a bell (or hub) and spigot (or plain end), thus comprising the joint seal

chemical plant: an industrial plant for the manufacture or processing of chemicals, or of raw materials or intermediates for such chemicals. A chemical plant may include supporting and service facilities, such as storage, utility, and waste treatment units.

cold spring: see para. 319.2.4

connections for external piping: those integral parts of individual pieces of equipment which are designed for attachment of external piping

consumable insert: preplaced filler metal which is completely fused into the root of the joint and becomes part of the weld

damaging to human tissues: for the purposes of this Code, this phrase describes a fluid service in which exposure to the fluid, caused by leakage under expected operating conditions, can harm skin, eyes, or exposed mucous membranes so that irreversible damage may result unless prompt restorative measures are taken. (Restorative measures may include flushing with water, administration of antidotes, or medication.)

design minimum temperature: see para. 301.3.1

design pressure: see para. 301.2

design temperature: see para. 301.3

designer: the person or organization in responsible charge of the engineering design

displacement stress range: see para. 319.2.3

elements: see *piping elements*

engineering design: the detailed design governing a piping system, developed from process and mechanical requirements, conforming to Code requirements, and including all necessary specifications, drawings, and supporting documents

equipment connection: see *connections for external piping*

erection: the complete installation of a piping system in the locations and on the supports designated by the engineering design including any field assembly, fabrication, examination, inspection, and testing of the system as required by this Code

examination, examiner: see paras. 341.1 and 341.2

examination, types of: see para. 344.1.3 for the following:

(a) 100% examination
(b) random examination
(c) spot examination
(d) random spot examination

extruded outlet header: see para. 304.3.4

fabrication: the preparation of piping for assembly, including cutting, threading, grooving, forming, bending,

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and joining of components into subassemblies. Fabrication may be performed in the shop or in the field.

face of weld: the exposed surface of a weld on the side from which the welding was done

filler material: the material to be added in making metallic or nonmetallic joints

fillet weld: a weld of approximately triangular cross section joining two surfaces approximately at right angles to each other in a lap joint, tee joint, or corner joint. (See also *size of weld* and *throat of a fillet weld.*)

flammable: for the purposes of this Code, describes a fluid which under ambient or expected operating conditions is a vapor or produces vapors that can be ignited and continue to burn in air. The term thus may apply, depending on service conditions, to fluids defined for other purposes as *flammable* or *combustible.*

fluid service: a general term concerning the application of a piping system, considering the combination of fluid properties, operating conditions, and other factors which establish the basis for design of the piping system. See Appendix M.

(a) Category D Fluid Service: a fluid service in which all the following apply:

(1) the fluid handled is nonflammable, nontoxic, and not damaging to human tissues as defined in para. 300.2;

(2) the design gage pressure does not exceed 1035 kPA (150 psi); and

(3) the design temperature is from −29°C (−20°F) through 186°C (366°F).

(b) Category M Fluid Service: a fluid service in which the potential for personnel exposure is judged to be significant and in which a single exposure to a very small quantity of a toxic fluid, caused by leakage, can produce serious irreversible harm to persons on breathing or bodily contact, even when prompt restorative measures are taken

(c) High Pressure Fluid Service: a fluid service for which the owner specifies the use of Chapter IX for piping design and construction; see also para. K300

(99) *(d) Normal Fluid Service:* a fluid service pertaining to most piping covered by this Code, i.e., not subject to the rules for Category D, Category M, or High Pressure Fluid Service

full fillet weld: a fillet weld whose size is equal to the thickness of the thinner member joined

fusion: the melting together of filler material and base material, or of base material only, which results in coalescence

gas metal-arc welding (GMAW): an arc-welding process which produces coalescence of metals by heating them with an arc between a continuous filler metal (consumable) electrode and the work. Shielding is obtained entirely from an externally supplied gas, or gas mixture. Some variations of this process are called MIG or CO_2 welding (nonpreferred terms)

gas tungsten-arc welding (GTAW): an arc-welding process which produces coalescence of metals by heating them with an arc between a single tungsten (nonconsumable) electrode and the work. Shielding is obtained from a gas or gas mixture. Pressure may or may not be used and filler metal may or may not be used. (This process has sometimes been called TIG welding.)

gas welding: a group of welding processes wherein coalescence is produced by heating with a gas flame or flames, with or without the application of pressure, and with or without the use of filler material

groove weld: a weld made in the groove between two members to be joined

heat affected zone: that portion of the base material which has not been melted, but whose mechanical properties or microstructure have been altered by the heat of welding, brazing, soldering, forming, or cutting

heat treatment: terms used to describe various types and processes of heat treatment (sometimes called postweld heat treatment) are defined as follows:

(a) annealing: heating to and holding at a suitable temperature and then cooling at a suitable rate for such purposes as: reducing hardness, improving machinability, facilitating cold working, producing a desired microstructure, or obtaining desired mechanical, physical, or other properties

(b) normalizing: a process in which a ferrous metal is heated to a suitable temperature above the transformation range and is subsequently cooled in still air at room temperature

(c) preheating: see *preheating* (separate term)

(d) quenching: rapid cooling of a heated metal

(e) recommended or required heat treatment: the application of heat to a metal section subsequent to a cutting, forming, or welding operation, as provided in para. 331

(f) solution heat treatment: heating an alloy to a suitable temperature, holding at that temperature long

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enough to allow one or more constituents to enter into solid solution, and then cooling rapidly enough to hold the constituents in solution

(g) stress-relief: uniform heating of a structure or portion thereof to a sufficient temperature to relieve the major portion of the residual stresses, followed by uniform cooling slowly enough to minimize development of new residual stresses

(h) tempering: reheating a hardened metal to a temperature below the transformation range to improve toughness

(i) transformation range: a temperature range in which a phase change is initiated and completed

(j) transformation temperature: a temperature at which a phase change occurs

High Pressure Fluid Service: see *fluid service*

indication, linear: in magnetic particle, liquid penetrant or similar examination, a closed surface area marking or denoting a discontinuity requiring evaluation, whose longest dimension is at least three times the width of the indication

indication, rounded: in magnetic particle, liquid penetrant or similar examination, a closed surface area marking or denoting a discontinuity requiring evaluation, whose longest dimension is less than three times the width of the indication

in-process examination: see para. 344.7

inspection, Inspector: see para. 340

joint design: the joint geometry together with the required dimensions of the welded joint

listed: for the purposes of this Code, describes a material or component which conforms to a specification in Appendix A, Appendix B, or Appendix K or to a standard in Table 326.1, A326.1, or K326.1

manual welding: a welding operation performed and controlled completely by hand

may: a term which indicates that a provision is neither required nor prohibited

mechanical joint: a joint for the purpose of mechanical strength or leak resistance, or both, in which the mechanical strength is developed by threaded, grooved, rolled, flared, or flanged pipe ends; or by bolts, pins, toggles, or rings; and the leak resistance is developed by threads and compounds, gaskets, rolled ends, caulking, or machined and mated surfaces

miter: two or more straight sections of pipe matched and joined in a plane bisecting the angle of junction so as to produce a change in direction

nominal: a numerical identification of dimension, capacity, rating, or other characteristic used as a designation, not as an exact measurement

NPS: nominal pipe size (followed, when appropriate, by the specific size designation number without an inch symbol)

Normal Fluid Service: see *fluid service*

normalizing: see *heat treatment*

notch-sensitive: describes a metal subject to reduction in strength in the presence of stress concentration. The degree of notch sensitivity is usually expressed as the strength determined in a notched specimen divided by the strength determined in an unnotched specimen, and can be obtained from either static or dynamic tests.

oxygen-arc cutting (OAC): an oxygen-cutting process that uses an arc between the workpiece and a consumable electrode, through which oxygen is directed to the workpiece. For oxidation-resistant metals, a chemical flux or metal powder is used to facilitate the reaction.

oxygen cutting (OC): a group of thermal cutting processes that severs or removes metal by means of the chemical reaction between oxygen and the base metal at elevated temperature. The necessary temperature is maintained by the heat from an arc, an oxyfuel gas flame, or other source.

oxygen gouging: thermal gouging that uses an oxygen cutting process variation to form a bevel or groove

packaged equipment: an assembly of individual pieces or stages of equipment, complete with inter-connecting piping and connections for external piping. The assembly may be mounted on a skid or other structure prior to delivery.

petroleum refinery: an industrial plant for processing or handling of petroleum and products derived directly from petroleum. Such a plant may be an individual gasoline recovery plant, a treating plant, a gas processing plant (including liquefaction), or an integrated refinery having various process units and attendant facilities.

pipe: a pressure-tight cylinder used to convey a fluid or to transmit a fluid pressure, ordinarily designated *pipe* in applicable material specifications. Materials designated *tube* or *tubing* in the specifications are treated as pipe when intended for pressure service. Types of

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pipe, according to the method of manufacture, are defined as follows:

(a) electric resistance-welded pipe: pipe produced in individual lengths or in continuous lengths from coiled skelp and subsequently cut into individual lengths, having a longitudinal butt joint wherein coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which the pipe is a part, and by the application of pressure

(b) furnace butt welded pipe, continuous welded: pipe produced in continuous lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt joint forge welded by the mechanical pressure developed in passing the hot-formed and edge-heated skelp through a set of round pass welding rolls

(c) electric-fusion welded pipe: pipe having a longitudinal butt joint wherein coalescence is produced in the preformed tube by manual or automatic electric-arc welding. The weld may be single (welded from one side) or double (welded from inside and outside) and may be made with or without the addition of filler metal.

(d) double submerged-arc welded pipe: pipe having a longitudinal butt joint produced by at least two passes, one of which is on the inside of the pipe. Coalescence is produced by heating with an electric arc or arcs between the bare metal electrode or electrodes and the work. The welding is shielded by a blanket of granular fusible material on the work. Pressure is not used and filler metal for the inside and outside welds is obtained from the electrode or electrodes.

(e) seamless pipe: pipe produced by piercing a billet followed by rolling or drawing, or both

(f) spiral welded pipe: pipe having a helical seam with either a butt, lap, or lock-seam joint which is welded using either an electrical resistance, electric fusion or double-submerged arc welding process

pipe-supporting elements: pipe-supporting elements consist of fixtures and structural attachments as follows:

(a) fixtures: fixtures include elements which transfer the load from the pipe or structural attachment to the supporting structure or equipment. They include hanging type fixtures, such as hanger rods, spring hangers, sway braces, counterweights, turnbuckles, struts, chains, guides, and anchors; and bearing type fixtures, such as saddles, bases, rollers, brackets, and sliding supports.

(b) structural attachments: structural attachments include elements which are welded, bolted, or clamped to the pipe, such as clips, lugs, rings, clamps, clevises, straps, and skirts

piping: assemblies of piping components used to convey, distribute, mix, separate, discharge, meter, control, or snub fluid flows. Piping also includes pipe-supporting elements, but does not include support structures, such as building frames, bents, foundations, or any equipment excluded from this Code (see para. 300.1.3).

piping components: mechanical elements suitable for joining or assembly into pressure-tight fluid-containing piping systems. Components include pipe, tubing, fittings, flanges, gaskets, bolting, valves, and devices such as expansion joints, flexible joints, pressure hoses, traps, strainers, in-line portions of instruments, and separators.

piping elements: any material or work required to plan and install a piping system. Elements of piping include design specifications, materials, components, supports, fabrication, examination, inspection, and testing.

piping installation: designed piping systems to which a selected Code Edition and Addenda apply

piping system: interconnected piping subject to the same set or sets of design conditions

plasma arc cutting (PAC): an arc cutting process that uses a constricted arc and removes molten metal with a high velocity jet of ionized gas issuing from the constricting orifice

preheating: the application of heat to the base material immediately before or during a forming, welding, or cutting process. See para. 330.

postweld heat treatment: see *heat treatment*

procedure qualification record (PQR): a document listing all pertinent data, including the essential variables employed and the test results, used in qualifying the procedure specification

process unit: an area whose boundaries are designated by the engineering design within which reactions, separations, and other processes are carried out. Examples of installations which are *not* classified as process units are loading areas or terminals, bulk plants, compounding plants, and tank farms and storage yards.

quench annealing: see *solution heat treatment* under *heat treatment*

quenching: see *heat treatment*

reinforcement: see paras. 304.3 and A304.3. See also *weld reinforcement.*

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root opening: the separation between the members to be joined, at the root of the joint

safeguarding: provision of protective measures of the types outlined in Appendix G, where deemed necessary. See Appendix G for detailed discussion.

seal bond: a bond intended primarily to provide joint tightness against leakage in nonmetallic piping

seal weld: a weld intended primarily to provide joint tightness against leakage in metallic piping

semiautomatic arc welding: arc welding with equipment which controls only the filler metal feed. The advance of the welding is manually controlled.

(99) *severe cyclic conditions:* conditions applying to specific piping components or joints in which S_E computed in accordance with para. 319.4.4 exceeds $0.8S_A$ (as defined in para. 302.3.5), and the equivalent number of cycles (N in para. 302.3.5) exceeds 7000; or other conditions which the designer determines will produce an equivalent effect

shall: a term which indicates that a provision is a Code requirement

shielded metal-arc welding (SMAW): an arc welding process which produces coalescence of metals by heating them with an arc between a covered metal electrode and the work. Shielding is obtained from decomposition of the electrode covering. Pressure is not used and filler metal is obtained from the electrode.

should: a term which indicates that a provision is recommended as good practice but is not a Code requirement

size of weld:

(a) fillet weld: the leg lengths (the leg length for equal-leg welds) of the sides, adjoining the members welded, of the largest triangle that can be inscribed within the weld cross section. For welds between perpendicular members, the definitions in Fig. 328.5.2A apply.

NOTE: When the angle between members exceeds 105 deg, size is of less significance than effective throat (see also *throat of a fillet weld*).

(b) groove weld: the joint penetration (depth of bevel plus the root penetration when specified). The size of a groove weld and its effective throat are the same.

slag inclusion: nonmetallic solid material entrapped in weld metal or between weld metal and base metal

soldering: a metal joining process wherein coalescence is produced by heating to suitable temperatures and by using a nonferrous alloy fusible at temperatures below 427°C (800°F) and having a melting point below that of the base metals being joined. The filler metal is distributed between closely fitted surfaces of the joint by capillary attraction. In general, solders are lead-tin alloys and may contain antimony, bismuth, and other elements.

solution heat treatment: see *heat treatment*

stress relief: see *heat treatment*

stress terms frequently used:

(a) basic allowable stress: this term, symbol S, represents the stress value for any material determined by the appropriate stress basis in para. 302.3.2

(b) bolt design stress: this term represents the design stress used to determine the required cross-sectional area of bolts in a bolted joint

(c) hydrostatic design basis: selected properties of plastic piping materials to be used in accordance with ASTM D 2837 or D 2992 to determine the HDS [see (d) below] for the material

(d) hydrostatic design stress (HDS): the maximum continuous stress due to internal pressure to be used in the design of plastic piping, determined from the hydrostatic design basis by use of a service (design) factor

submerged arc welding (SAW): an arc welding process which produces coalescence of metals by heating them with an arc or arcs between a bare metal electrode or electrodes and the work. The arc is shielded by a blanket of granular, fusible material on the work. Pressure is not used and filler metal is obtained from the electrode and sometimes from a supplemental source (welding rod, flux, or metal granules).

tack weld: a weld made to hold parts of a weldment in proper alignment until the final welds are made

tempering: see *heat treatment*

thermoplastic: a plastic which is capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature

thermosetting resin: a resin capable of being changed into a substantially infusible or insoluble product when cured at room temperature, or by application of heat, or by chemical means

throat of a fillet weld:

(a) theoretical throat: the perpendicular distance

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from the hypotenuse of the largest right triangle that can be inscribed in the weld cross section to the root of the joint

(b) actual throat: the shortest distance from the root of a fillet weld to its face

(c) effective throat: the minimum distance, minus any reinforcement (convexity), between the weld root and the face of a fillet weld

toe of weld: the junction between the face of a weld and the base material

tube: see *pipe*

tungsten electrode: a nonfiller-metal electrode used in arc welding or cutting, made principally of tungsten

unbalanced piping system: see para. 319.2.2(b)

undercut: a groove melted into the base material adjacent to the toe or root of a weld and left unfilled by weld material

visual examination: see para. 344.2.1

weld: a localized coalescence of material wherein coalescence is produced either by heating to suitable temperatures, with or without the application of pressure, or by application of pressure alone, and with or without the use of filler material

weld reinforcement: weld material in excess of the specified weld size

welder: one who performs a manual or semi-automatic welding operation. (This term is sometimes erroneously used to denote a welding machine.)

welding operator: one who operates machine or automatic welding equipment

welding procedure: the detailed methods and practices involved in the production of a weldment

welding procedure specification (WPS): the document which lists the parameters to be used in construction of weldments in accordance with requirements of this Code

weldment: an assembly whose component parts are joined by welding

300.3 Nomenclature

Dimensional and mathematical symbols used in this Code are listed in Appendix J, with definitions and location references to each. Lowercase and uppercase English letters are listed alphabetically, followed by Greek letters.

300.4 Status of Appendices

Table 300.4 indicates for each Appendix of this Code whether it contains Code requirements, guidance, or supplemental information. See the first page of each Appendix for details.

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TABLE 300.4
STATUS OF APPENDICES IN B31.3

Appendix	Title	Status
A	Stress Tables for Metallic Piping and Bolting Materials	Requirements
B	Stress Tables and Allowable Pressure Tables for Nonmetals	Requirements
C	Physical Properties of Piping Materials	Requirements (1)
D	Flexibility and Stress Intensification Factors	Requirements (1)
E	Reference Standards	Requirements
F	Precautionary Considerations	Guidance (2)
G	Safeguarding	Guidance (2)
H	Sample Calculations for Branch Reinforcement	Guidance
J	Nomenclature	Information
K	Allowable Stress for High Pressure Piping	Requirements (3)
L	Aluminum Alloy Pipe Flanges	Specification (5)
M	Guide to Classifying Fluid Services	Guidance (2)
V	Allowable Variations in Elevated Temperature Service	Guidance (2)
X	Metallic Bellows Expansion Joints	Requirements
Z	Preparation of Technical Inquiries	Requirements (4)

NOTES:
(1) Contains default requirements, to be used unless more directly applicable data are available.
(2) Contains no requirements but Code user is responsible for considering applicable items.
(3) Contains requirements applicable only when use of Chapter IX is specified.
(4) Contains administrative requirements.
(5) Contains pressure-temperature ratings, materials, dimensions, and markings of forged aluminum alloy flanges.

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CHAPTER II
DESIGN

PART 1
CONDITIONS AND CRITERIA

301 DESIGN CONDITIONS

See Appendix F, para. F301.

301.1 General

Paragraph 301 defines the temperatures, pressures, and forces applicable to the design of piping, and states the considerations that shall be given to various effects and their consequent loadings.

301.2 Design Pressure

301.2.1 General

(a) The design pressure of each component in a piping system shall be not less than the pressure at the most severe condition of coincident internal or external pressure and temperature (minimum or maximum) expected during service, except as provided in para. 302.2.4.

(b) The most severe condition is that which results in the greatest required component thickness and the highest component rating.

(c) When more than one set of pressure-temperature conditions exist for a piping system, the conditions governing the rating of components conforming to listed standards may differ from the conditions governing the rating of components designed in accordance with para. 304.

301.2.2 Required Pressure Containment or Relief

(a) Provision shall be made to safely contain or relieve (see para. 322.6.3) any pressure to which the piping may be subjected. Piping not protected by a pressure relieving device, or that can be isolated from a pressure relieving device, shall be designed for at least the highest pressure that can be developed.

(b) Sources of pressure to be considered include ambient influences, pressure oscillations and surges, improper operation, and failure of control devices.

(c) The allowances of para. 302.2.4(f) are permitted, provided that the other requirements of para. 302.2.4 are also met.

301.3 Design Temperature

The design temperature of each component in a piping system is the temperature at which, under the coincident pressure, the greatest thickness or highest component rating is required in accordance with para. 301.2. (To satisfy the requirements of para. 301.2, different components in the same piping system may have different design temperatures.)

In establishing design temperatures, consider at least the fluid temperatures, ambient temperatures, solar radiation, heating or cooling medium temperatures, and the applicable provisions of paras. 301.3.2, 301.3.3, and 301.3.4.

301.3.1 Design Minimum Temperature. The design minimum temperature is the lowest component temperature expected in service. This temperature may establish special design requirements and material qualification requirements. See also paras. 301.4.4 and 323.2.2.

301.3.2 Uninsulated Components

(a) For fluid temperatures below 65°C (150°F), the component temperature shall be taken as the fluid temperature unless solar radiation or other effects result in a higher temperature.

(b) For fluid temperatures 65°C (150°F) and above, unless a lower average wall temperature is determined by test or heat transfer calculation, the temperature for uninsulated components shall be no less than the following values:

(1) valves, pipe, lapped ends, welding fittings, and other components having wall thickness comparable to that of the pipe: 95% of the fluid temperature;

(2) flanges (except lap joint) including those on fittings and valves: 90% of the fluid temperature;

(3) lap joint flanges: 85% of the fluid temperature;

(4) bolting: 80% of the fluid temperature.

301.3.3 Externally Insulated Piping. The component design temperature shall be the fluid temperature unless calculations, tests, or service experience based

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on measurements support the use of another temperature. Where piping is heated or cooled by tracing or jacketing, this effect shall be considered in establishing component design temperatures.

301.3.4 Internally Insulated Piping. The component design temperature shall be based on heat transfer calculations or tests.

301.4 Ambient Effects

See Appendix F, para. F301.4.

301.4.1 Cooling: Effects on Pressure. The cooling of a gas or vapor in a piping system may reduce the pressure sufficiently to create an internal vacuum. In such a case, the piping shall be capable of withstanding the external pressure at the lower temperature, or provision shall be made to break the vacuum.

301.4.2 Fluid Expansion Effects. Provision shall be made in the design either to withstand or to relieve increased pressure caused by the heating of static fluid in a piping component. See also para. 322.6.3(b)(2).

301.4.3 Atmospheric Icing. Where the design minimum temperature of a piping system is below 0°C (32°F), the possibility of moisture condensation and buildup of ice shall be considered and provisions made in the design to avoid resultant malfunctions. This applies to surfaces of moving parts of shutoff valves, control valves, pressure relief devices including discharge piping, and other components.

301.4.4 Low Ambient Temperature. Consideration shall be given to low ambient temperature conditions for displacement stress analysis.

301.5 Dynamic Effects

See Appendix F, para. F301.5.

301.5.1 Impact. Impact forces caused by external or internal conditions (including changes in flow rate, hydraulic shock, liquid or solid slugging, flashing, and geysering) shall be taken into account in the design of piping.

301.5.2 Wind. The effect of wind loading shall be taken into account in the design of exposed piping. The method of analysis may be as described in ASCE 7, Minimum Design Loads for Buildings and Other Structures, or the Uniform Building Code.

301.5.3 Earthquake. Piping shall be designed for earthquake-induced horizontal forces. The method of analysis may be as described in ASCE 7-88 or the Uniform Building Code.

301.5.4 Vibration. Piping shall be designed, arranged, and supported so as to eliminate excessive and harmful effects of vibration which may arise from such sources as impact, pressure pulsation, resonance in compressors, and wind loads.

301.5.5 Discharge Reactions. Piping shall be designed, arranged, and supported so as to withstand reaction forces due to let-down or discharge of fluids.

301.6 Weight Effects

The following weight effects, combined with loads and forces from other causes, shall be taken into account in the design of piping.

301.6.1 Live Loads. These loads include the weight of the medium transported or the medium used for test. Snow and ice loads due to both environmental and operating conditions shall be considered.

301.6.2 Dead Loads. These loads consist of the weight of piping components, insulation, and other superimposed permanent loads supported by the piping.

301.7 Thermal Expansion and Contraction Effects

The following thermal effects, combined with loads and forces from other causes, shall be taken into account in the design of piping. See also Appendix F, para. F301.7.

301.7.1 Thermal Loads Due to Restraints. These loads consist of thrusts and moments which arise when free thermal expansion and contraction of the piping are prevented by restraints or anchors.

301.7.2 Loads Due to Temperature Gradients. These loads arise from stresses in pipe walls resulting from large rapid temperature changes or from unequal temperature distribution as may result from a high heat flux through a comparatively thick pipe or stratified two-phase flow causing bowing of the line.

301.7.3 Loads Due to Differences in Expansion Characteristics. These loads result from differences in thermal expansion where materials with different thermal expansion coefficients are combined, as in bimetallic, lined, jacketed, or metallic–nonmetallic piping.

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301.8 Effects of Support, Anchor, and Terminal Movements

The effects of movements of piping supports, anchors, and connected equipment shall be taken into account in the design of piping. These movements may result from the flexibility and/or thermal expansion of equipment, supports, or anchors; and from settlement, tidal movements, or wind sway.

301.9 Reduced Ductility Effects

The harmful effects of reduced ductility shall be taken into account in the design of piping. The effects may, for example, result from welding, heat treatment, forming, bending, or low operating temperatures, including the chilling effect of sudden loss of pressure on highly volatile fluids. Low ambient temperatures expected during operation shall be considered.

301.10 Cyclic Effects

Fatigue due to pressure cycling, thermal cycling, and other cyclic loadings shall be considered in the design of piping.

301.11 Air Condensation Effects

At operating temperatures below −191°C (−312°F) in ambient air, condensation and oxygen enrichment occur. These shall be considered in selecting materials, including insulation, and adequate shielding and/or disposal shall be provided.

302 DESIGN CRITERIA

302.1 General

Paragraph 302 states pressure-temperature ratings, stress criteria, design allowances, and minimum design values together with permissible variations of these factors as applied to the design of piping.

302.2 Pressure-Temperature Design Criteria

302.2.1 Listed Components Having Established Ratings. Except as limited elsewhere in the Code, pressure-temperature ratings contained in standards for piping components listed in Table 326.1 are acceptable for design pressures and temperatures in accordance with this Code. The provisions of this Code may be used at the owner's responsibility to extend the pressure-temperature ratings of a component beyond the ratings of the listed standard.

302.2.2 Listed Components Not Having Specific Ratings. Some of the standards for components in Table 326.1 (e.g., ASME B16.9, B16.11, and B16.28) state that pressure-temperature ratings are based on straight seamless pipe. Except as limited in the standard or elsewhere in this Code, such a component, made of a material having the same allowable stress as the pipe shall be rated using not more than 87.5% of the nominal thickness of seamless pipe corresponding to the schedule, weight, or pressure class of the fitting, less all allowances applied to the pipe (e.g., thread depth and/or corrosion allowance).

302.2.3 Unlisted Components

(a) Components not listed in Table 326.1, but which conform to a published specification or standard, may be used within the following limitations.

(1) The designer shall be satisfied that composition, mechanical properties, method of manufacture, and quality control are comparable to the corresponding characteristics of listed components.

(2) Pressure design shall be verified in accordance with para. 304.

(b) Other unlisted components shall be qualified for pressure design as required by para. 304.7.2.

302.2.4 Allowances for Pressure and Temperature Variations. Occasional variations of pressure and/or temperature may occur in a piping system. Such variations shall be considered in selecting design pressure (para. 301.2) and design temperature (para. 301.3). The most severe coincident pressure and temperature shall determine the design conditions unless all of the following criteria are met.

(a) The piping system shall have no pressure containing components of cast iron or other nonductile metal.

(b) Nominal pressure stresses shall not exceed the yield strength at temperature (see para. 302.3 of this Code and S_y data in BPV Code, Section II, Part D, Table Y-1).

(c) Combined longitudinal stresses shall not exceed the limits established in para. 302.3.6.

(d) The total number of pressure-temperature variations above the design conditions shall not exceed 1000 during the life of the piping system.

(e) In no case shall the increased pressure exceed the test pressure used under para. 345 for the piping system.

(f) Occasional variations above design conditions shall remain within one of the following limits for pressure design.

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(1) Subject to the owner's approval, it is permissible to exceed the pressure rating or the allowable stress for pressure design at the temperature of the increased condition by not more than:

(a) 33% for no more than 10 hr at any one time and no more than 100 hr/yr; or

(b) 20% for no more than 50 hr at any one time and no more than 500 hr/yr.

The effects of such variations shall be determined by the designer to be safe over the service life of the piping system by methods acceptable to the owner. (See Appendix V.)

(2) When the variation is self-limiting (e.g., due to a pressure relieving event), and lasts no more than 50 hr at any one time and not more than 500 hr/year, it is permissible to exceed the pressure rating or the allowable stress for pressure design at the temperature of the increased condition by not more than 20%.

(g) The combined effects of the sustained and cyclic variations on the serviceability of all components in the system shall have been evaluated.

(h) Temperature variations below the minimum temperature shown in Appendix A are not permitted unless the requirements of para. 323.2.2 are met for the lowest temperature during the variation.

(i) The application of pressures exceeding pressure-temperature ratings of valves may under certain conditions cause loss of seat tightness or difficulty of operation. The differential pressure on the valve closure element should not exceed the maximum differential pressure rating established by the valve manufacturer. Such applications are the owner's responsibility.

302.2.5 Ratings at Junction of Different Services. When two services that operate at different pressure-temperature conditions are connected, the valve segregating the two services shall be rated for the more severe service condition. If the valve will operate at a different temperature due to its remoteness from a header or piece of equipment, this valve (and any mating flanges) may be selected on the basis of the different temperature, provided it can withstand the required pressure tests on each side of the valve. For piping on either side of the valve, however, each system shall be designed for the conditions of the service to which it is connected.

302.3 Allowable Stresses and Other Stress Limits

302.3.1 General. The allowable stresses defined in paras. 302.3.1(a), (b), and (c) shall be used in design calculations unless modified by other provisions of this Code.

(a) Tension. Basic allowable stresses S in tension for metals and design stresses S for bolting materials, listed in Tables A-1 and A-2, respectively, are determined in accordance with para. 302.3.2.

In equations elsewhere in the Code where the product SE appears, the value S is multiplied by one of the following quality factors:[1]

(1) casting quality factor E_c as defined in para. 302.3.3 and tabulated for various material specifications in Table A-1A, and for various levels of supplementary examination in Table 302.3.3C; or

(2) longitudinal weld joint factor E_j as defined in 302.3.4 and tabulated for various material specifications and classes in Table A-1B, and for various types of joints and supplementary examinations in Table 302.3.4.

The stress values in Tables A-1 and A-2 are grouped by materials and product forms, and are for stated temperatures up to the limit provided in para. 323.2.1(a). Straight line interpolation between temperatures is permissible. The temperature intended is the design temperature (see para. 301.3).

(b) Shear and Bearing. Allowable stresses in shear shall be 0.80 times the basic allowable stress in tension tabulated in Table A-1 or A-2. Allowable stress in bearing shall be 1.60 times that value.

(c) Compression. Allowable stresses in compression shall be no greater than the basic allowable stresses in tension as tabulated in Appendix A. Consideration shall be given to structural stability.

302.3.2 Bases for Design Stresses.[2] The bases for establishing design stress values for bolting materials and allowable stress values for other metallic materials in this Code are as follows.

(a) Bolting Materials. Design stress values at temper-

[1] If a component is made of castings joined by longitudinal welds, both a casting and a weld joint quality factor shall be applied. The equivalent quality factor E is the product of E_c, Table A-1A, and E_j, Table A-1B.

[2] These bases are the same as those for BPV Code, Section VIII, Division 2, given in Section II, Part D. Stress values in B31.3, Appendix A, at temperatures below the creep range generally are the same as those listed in Section II, Part D, Tables 2A and 2B, and in Table 3 for bolting, corresponding to those bases. They have been adjusted as necessary to exclude casting quality factors and longitudinal weld joint quality factors. Stress values at temperatures in the creep range generally are the same as those in Section II, Part D, Tables 1A and 1B, corresponding to the bases for section VIII, Division 1. Stress values for temperatures above those for which values are listed in the BPV Code, and for materials not listed in the BPV Code, are based on those listed in Appendix A of the 1966 Edition of ASA B31.3. Such values will be revised when reliable mechanical property data for elevated temperatures and/or for additional materials become available to the Committee.

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ature for bolting materials shall not exceed the lowest of the following:

(1) except as provided in (3) below, the lower of one-fourth of specified minimum tensile strength at room temperature (SMTS) and one-fourth of tensile strength at temperature;

(2) except as provided in (3) below, the lower of two-thirds of specified minimum yield strength at room temperature (SMYS) and two-thirds of yield strength at temperature;

(3) at temperatures below the creep range, for bolting materials whose strength has been enhanced by heat treatment or strain hardening, the lower of one-fifth of SMTS and one-fourth of SMYS (unless these values are lower than corresponding values for annealed material, in which case the annealed values shall be used);

(4) two-thirds of the "yield strength at temperature" [see para. 302.3.2(f)];

(5) 100% of the average stress for a creep rate of 0.01% per 1000 hr;

(6) 67% of the average stress for rupture at the end of 100,000 hr;

(7) 80% of minimum stress for rupture at the end of 100,000 hr.

(b) Cast Iron. Basic allowable stress values at temperature for cast iron shall not exceed the lower of the following:

(1) one-tenth of the specified minimum tensile strength at room temperature;

(2) one-tenth of the tensile strength at temperature [see para. 302.3.2(f)].

(c) Malleable Iron. Basic allowable stress values at temperature for malleable iron shall not exceed the lower of the following:

(1) one-fifth of the specified minimum tensile strength at room temperature;

(2) one-fifth of the tensile strength at temperature [see para. 302.3.2(f)].

(d) Other Materials. Basic allowable stress values at temperature for materials other than bolting materials, cast iron, and malleable iron shall not exceed the lowest of the following:

(1) the lower of one-third of SMTS and one-third of tensile strength at temperature;

(2) except as provided in (3) below, the lower of two-thirds of SMYS and two-thirds of yield strength at temperature;

(3) for austenitic stainless steels and nickel alloys having similar stress–strain behavior, the lower of two-thirds of SMYS and 90% of yield strength at temperature [see (e) below];

(4) 100% of the average stress for a creep rate of 0.01% per 1000 hr;

(5) 67% of the average stress for rupture at the end of 100,000 hr;

(6) 80% of the minimum stress for rupture at the end of 100,000 hr;

(7) for structural grade materials, the basic allowable stress shall be 0.92 times the lowest value determined in paras. 302.3.2(d)(1) through (6).

(e) Application Limits. Application of stress values determined in accordance with para. 302.3.2(d)(3) is not recommended for flanged joints and other components in which slight deformation can cause leakage or malfunction. [These values are shown in italics or boldface in Table A-1, as explained in Note (4) to Appendix A Tables.] Instead, either 75% of the stress value in Table A-1 or two-thirds of the yield strength at temperature listed in the BPV Code, Section II, Part D, Table Y-1 should be used.

(f) Unlisted Materials. For a material which conforms to para. 323.1.2, the tensile (yield) strength at temperature shall be derived by multiplying the average expected tensile (yield) strength at temperature by the ratio of SMTS (SMYS) divided by the average expected tensile (yield) strength at room temperature.

302.3.3 Casting Quality Factor E_c

(a) General. The casting quality factors E_c defined herein shall be used for cast components not having pressure-temperature ratings established by standards in Table 326.1.

(b) Basic Quality Factors. Castings of gray and malleable iron, conforming to listed specifications, are assigned a basic casting quality factor E_c of 1.00 (due to their conservative allowable stress basis). For most other metals, static castings which conform to the material specification and have been visually examined as required by MSS SP-55, Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components — Visual Method, are assigned a basic casting quality factor E_c of 0.80. Centrifugal castings which meet specification requirements only for chemical analysis, tensile, hydrostatic, and flattening tests, and visual examination are assigned a basic casting quality factor of 0.80. Basic casting quality factors are tabulated for listed specifications in Table A-1A.

(c) Increased Quality Factors. Casting quality factors may be increased when supplementary examinations are performed on each casting. Table 302.3.3C states the increased casting quality factors E_c which may

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TABLE 302.3.3C[4]
INCREASED CASTING QUALITY FACTORS, E_C

Supplementary Examination in Accordance With Note(s)	Factor, E_C
(1)	0.85
(2)(a) or (2)(b)	0.85
(3)(a) or (3)(b)	0.95
(1) and (2)(a) or (2)(b)	0.90
(1) and (3)(a) or (3)(b)	1.00
(2)(a) or (2)(b) and (3)(a) or (3)(b)	1.00

NOTES:
(1) Machine all surfaces to a finish of 6.3 μm R_a (250 μin. R_a per ASME B46.1), thus increasing the effectiveness of surface examination.
(2) (a) Examine all surfaces of each casting (magnetic material only) by the magnetic particle method in accordance with ASTM E 709. Judge acceptability in accordance with MSS SP-53, using reference photos in ASTM E 125.
(b) Examine all surfaces of each casting by the liquid penetrant method, in accordance with ASTM E 165. Judge acceptability of flaws and weld repairs in accordance with Table 1 of MSS SP-53, using ASTM E 125 as a reference for surface flaws.
(3) (a) Fully examine each casting ultrasonically in accordance with ASTM E 114, accepting a casting only if there is no evidence of depth of defects in excess of 5% of wall thickness.
(b) Fully radiograph each casting in accordance with ASTM E 142. Judge in accordance with the stated acceptance levels in Table 302.3.3D.
(4) Titles of standards referenced in this Table are as follows:
ASTM
E 114 Practice for Ultrasonic Pulse-Echo Straight-Beam Testing by the Contact Method
E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings
E 142 Method for Controlling Quality of Radiographic Testing
E 165 Practice for Liquid Penetrant Inspection Method
E 709 Practice for Magnetic Particle Examination
ASME
B46.1 Surface Texture (Surface Roughness, Waviness and Lay)
MSS
SP-53 Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components—Magnetic Particle Examination Method

TABLE 302.3.3D[1]
ACCEPTANCE LEVELS FOR CASTINGS

Material Examined Thickness, T	Applicable Standard	Acceptance Level (or Class)	Acceptable Discontinuities
Steel $T \le 25$ mm (1 in.)	ASTM E 446	1	Types A, B, C
Steel $T > 25$ mm, ≤ 51 mm (2 in.)	ASTM E 446	2	Types A, B, C
Steel $T > 51$ mm, ≤ 114 mm ($4\frac{1}{2}$ in.)	ASTM E 186	2	Categories A, B, C
Steel $T > 114$ mm, ≤ 305 mm (12 in.)	ASTM E 280	2	Categories A, B, C
Aluminum & magnesium	ASTM E 155	...	Shown in reference radiographs
Copper, Ni–Cu	ASTM E 272	2	Codes A, Ba, Bb
Bronze	ASTM E 310	2	Codes A and B

NOTE:
(1) Titles of standards referenced in this Table are as follows:
ASTM
E 155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings
E 186 Reference Radiographs for Heavy-Walled [2 to $4\frac{1}{2}$-in. (51 to 114-mm)] Steel Castings
E 272 Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Castings
E 280 Reference Radiographs for Heavy-Walled [$4\frac{1}{2}$ to 12-in. (114 to 305-mm)] Steel Castings
E 310 Reference Radiographs for Tin Bronze Castings
E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness

be used for various combinations of supplementary examination. Table 302.3.3D states the acceptance criteria for the examination methods specified in the Notes to Table 302.3.3C. Quality factors higher than those shown in Table 302.3.3C do not result from combining tests 2a and 2b, or 3a and 3b. In no case shall the quality factor exceed 1.00.

Several of the specifications in Appendix A require machining of all surfaces and/or one or more of these supplementary examinations. In such cases, the appropriate increased quality factor is shown in Table A-1A.

302.3.4 Weld Joint Quality Factor, E_j

(a) Basic Quality Factors. The weld joint quality factors E_j tabulated in Table A-1B are basic factors for straight or spiral longitudinal welded joints for pressure-containing components as shown in Table 302.3.4.

(b) Increased Quality Factors. Table 302.3.4 also indicates higher joint quality factors which may be substituted for those in Table A-1B for certain kinds of welds if additional examination is performed beyond that required by the product specification.

302.3.5 Limits of Calculated Stresses Due to Sustained Loads and Displacement Strains

(a) Internal Pressure Stresses. Stresses due to internal pressure shall be considered safe when the wall

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TABLE 302.3.4
LONGITUDINAL WELD JOINT QUALITY FACTOR, E_j

(99)

No.	Type of Joint		Type of Seam	Examination	Factor, E_j
1	Furnace butt weld, continuous weld		Straight	As required by listed specification	0.60 [Note (1)]
2	Electric resistance weld		Straight or spiral	As required by listed specification	0.85 [Note (1)]
3	Electric fusion weld				
	(a) Single butt weld		Straight or spiral	As required by listed specification or this Code	0.80
	(with or without filler metal)			Additionally spot radiographed per para. 341.5.1	0.90
				Additionally 100% radiographed per para. 344.5.1 and Table 341.3.2	1.00
	(b) Double butt weld		Straight or spiral [except as provided in 4(a) below]	As required by listed specification or this Code	0.85
	(with or without filler metal)			Additionally spot radiographed per para. 341.5.1	0.90
				Additionally 100% radiographed per para. 344.5.1 and Table 341.3.2	1.00
4	Per specific specification				
	(a) API 5L	Submerged arc weld (SAW) Gas metal arc weld (GMAW) Combined GMAW, SAW 	Straight with one or two seams Spiral	As required by specification	0.95

NOTE:
(1) It is not permitted to increase the joint quality factor by additional examination for joint 1 or 2.

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thickness of the piping component, including any reinforcement, meets the requirements of para. 304.

(b) External Pressure Stresses. Stresses due to external pressure shall be considered safe when the wall thickness of the piping component, and its means of stiffening, meet the requirements of para. 304.

(c) Longitudinal Stresses S_L. The sum of longitudinal stresses in any component in a piping system, due to pressure, weight, and other sustained loadings S_L shall not exceed S_h in (d) below. The thickness of pipe used in calculating S_L shall be the nominal thickness $\overline{T}$ minus mechanical, corrosion, and erosion allowance c.

(d) Allowable Displacement Stress Range S_A. The computed displacement stress range S_E in a piping system (see para. 319.4.4) shall not exceed the allowable displacement stress range S_A (see paras. 319.2.3 and 319.3.4) calculated by Eq. (1a):

$$S_A = f(1.25S_c + 0.25S_h) \quad (1a)$$

When S_h is greater than S_L, the difference between them may be added to the term $0.25S_h$ in Eq. (1a). In that case, the allowable stress range is calculated by Eq. (1b):

$$S_A = f[1.25(S_c + S_h) - S_L] \quad (1b)$$

In Eqs. (1a) and (1b):

S_c = basic allowable stress[3] at minimum metal temperature expected during the displacement cycle under analysis

S_h = basic allowable stress[3] at maximum metal temperature expected during the displacement cycle under analysis

f = stress range reduction factor,[4] from Table 302.3.5 or calculated by Eq. (1c):[5]

$$f = 6.0(N)^{-0.2} \leq 1.0 \quad (1c)$$

where

TABLE 302.3.5
STRESS-RANGE REDUCTION FACTORS, f

Cycles, N	Factor, f
7,000 and less	1.0
Over 7,000 to 14,000	0.9
Over 14,000 to 22,000	0.8
Over 22,000 to 45,000	0.7
Over 45,000 to 100,000	0.6
Over 100,000 to 200,000	0.5
Over 200,000 to 700,000	0.4
Over 700,000 to 2,000,000	0.3

N = equivalent number of full displacement cycles during the expected service life of the piping system[6]

When the computed stress range varies, whether from thermal expansion or other conditions, S_E is defined as the greatest computed displacement stress range. The value of N in such cases can be calculated by Eq. (1d):

$$N = N_E + \sum(r_i^5 N_i) \text{ for } i = 1, 2, \ldots, n \quad (1d)$$

where

N_E = number of cycles of maximum computed displacement stress range, S_E

r_i = S_i/S_E

S_i = any computed displacement stress range smaller than S_E

N_i = number of cycles associated with displacement stress range S_i

302.3.6 Limits of Calculated Stresses due to Occasional Loads

(a) Operation. The sum of the longitudinal stresses due to pressure, weight, and other sustained loadings S_L and of the stresses produced by occasional loads, such as wind or earthquake, may be as much as 1.33 times the basic allowable stress given in Appendix A. For castings, the basic allowable stress shall be multiplied by the casting quality factor E_c. Where the allowable stress value exceeds two-thirds of yield strength at temperature, the allowable stress value must be reduced as specified in para. 302.3.2(e). Wind and earthquake forces need not be considered as acting concurrently.

(b) Test. Stresses due to test conditions are not subject to the limitations in para. 302.3. It is not necessary to consider other occasional loads, such as

[3] For castings, the basic allowable stress shall be multiplied by the applicable casting quality factor E_c. For longitudinal welds, the basic allowable stress need not be multiplied by the weld quality factor E_j.

[4] Applies to essentially noncorroded piping. Corrosion can sharply decrease cyclic life; therefore, corrosion resistant materials should be considered where a large number of major stress cycles is anticipated.

[5] Equation (1c) does not apply beyond approximately 2×10^6 cycles. Selection of f factors beyond 2×10^6 cycles is the designer's responsibility.

[6] The designer is cautioned that the fatigue life of materials operated at elevated temperature may be reduced.

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wind and earthquake, as occurring concurrently with test loads.

302.4 Allowances

In determining the minimum required thickness of a piping component, allowances shall be included for corrosion, erosion, and thread depth or groove depth. See definition for c in para. 304.1.1(b).

302.4.1 Mechanical Strength. When necessary, the wall thickness shall be increased to prevent overstress, damage, collapse, or buckling due to superimposed loads from supports, ice formation, backfill, or other causes. Where increasing the thickness would excessively increase local stresses or the risk of brittle fracture, or is otherwise impracticable, the required strength may be obtained through additional supports, braces, or other means without an increased wall thickness. Particular consideration should be given to the mechanical strength of small pipe connections to piping or equipment.

PART 2
PRESSURE DESIGN OF PIPING COMPONENTS

303 GENERAL

Components manufactured in accordance with standards listed in Table 326.1 shall be considered suitable for use at pressure-temperature ratings in accordance with para. 302.2.1. The rules in para. 304 are intended for pressure design of components not covered in Table 326.1, but may be used for a special or more rigorous design of such components. Designs shall be checked for adequacy of mechanical strength under applicable loadings enumerated in para. 301.

304 PRESSURE DESIGN OF COMPONENTS

304.1 Straight Pipe

304.1.1 General

(a) The required thickness of straight sections of pipe shall be determined in accordance with Eq. (2):

$$t_m = t + c \qquad (2)$$

The minimum thickness T for the pipe selected, considering manufacturer's minus tolerance, shall be not less than t_m.

TABLE 304.1.1
VALUES OF COEFFICIENT Y
FOR $t < D/6$

Materials	Temperature, °C (°F)					
	≤ 482 (900 & Lower)	510 (950)	538 (1000)	566 (1050)	593 (1100)	≥ 621 (1150 & Up)
Ferritic steels	0.4	0.5	0.7	0.7	0.7	0.7
Austenitic steels	0.4	0.4	0.4	0.4	0.5	0.7
Other ductile metals	0.4	0.4	0.4	0.4	0.4	0.4
Cast iron	0.0	...	...	...	...	...

(b) The following nomenclature is used in the equations for pressure design of straight pipe.

t_m = minimum required thickness, including mechanical, corrosion, and erosion allowances

t = pressure design thickness, as calculated in accordance with para. 304.1.2 for internal pressure or as determined in accordance with para. 304.1.3 for external pressure

c = the sum of the mechanical allowances (thread or groove depth) plus corrosion and erosion allowances. For threaded components, the nominal thread depth (dimension h of ASME B1.20.1, or equivalent) shall apply. For machined surfaces or grooves where the tolerance is not specified, the tolerance shall be assumed to be 0.5 mm (0.02 in.) in addition to the specified depth of the cut.

T = pipe wall thickness (measured or minimum per purchase specification)

d = inside diameter of pipe. For pressure design calculation, the inside diameter of the pipe is the maximum value allowable under the purchase specification.

P = internal design gage pressure

D = outside diameter of pipe as listed in tables of standards or specifications or as measured

E = quality factor from Table A-1A or A-1B

S = stress value for material from Table A-1

Y = coefficient from Table 304.1.1, valid for $t < D/6$ and for materials shown. The value of

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Y may be interpolated for intermediate temperatures.

For $t \geq D/6$,

$$Y = \frac{d + 2c}{D + d + 2c}$$

304.1.2 Straight Pipe Under Internal Pressure

(a) For $t < D/6$, the internal pressure design thickness for straight pipe shall be not less than that calculated in accordance with Eq. (3a):

$$t = \frac{PD}{2(SE + PY)} \quad (3a)$$

Equation (3b), (3c), or (3d) may be used instead of Eq. (3a):

$$t = \frac{PD}{2SE} \quad (3b)$$

$$t = \frac{D}{2}\left(1 - \sqrt{\frac{SE - P}{SE + P}}\right) \quad \text{(Lamé Equation)} \quad (3c)$$

$$t = \frac{P(d + 2c)}{2[SE - P(1 - Y)]} \quad (3d)$$

(b) For t ≥ $D/6$ or for $P/SE > 0.385$, calculation of pressure design thickness for straight pipe requires special consideration of factors such as theory of failure, effects of fatigue, and thermal stress.

304.1.3 Straight Pipe Under External Pressure. To determine wall thickness and stiffening requirements for straight pipe under external pressure, the procedure outlined in the BPV Code, Section VIII, Division 1, UG-28 through UG-30 shall be followed, using as the design length L the running center line length between any two sections stiffened in accordance with UG-29. As an exception, for pipe with $D_o/t < 10$, the value of S to be used in determining P_{a2} shall be the lesser of the following values for pipe material at design temperature:

(a) 1.5 times the stress value from Table A-1 of this Code; or

(b) 0.9 times the yield strength tabulated in Section II, Part D, Table Y-1 for materials listed therein.

(The symbol D_o in Section VIII is equivalent to D in this Code.)

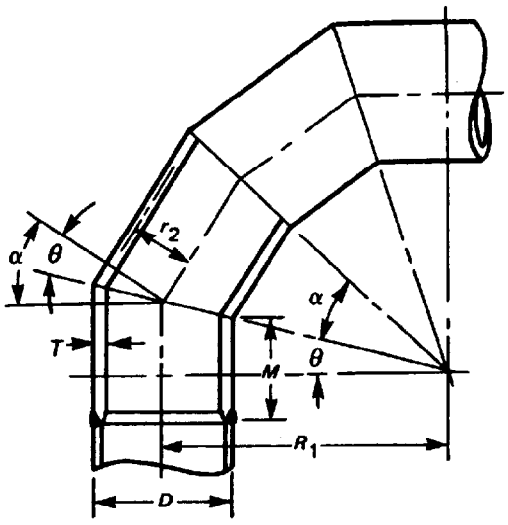

FIG. 304.2.3 NOMENCLATURE FOR MITER BENDS

304.2 Curved and Mitered Segments of Pipe

304.2.1 Pipe Bends. The minimum required thickness t_m of a bend, after bending, shall be determined as for straight pipe in accordance with para. 304.1.

304.2.2 Elbows. Manufactured elbows not in accordance with para. 303 shall be qualified as required by para. 304.7.2.

304.2.3 Miter Bends. An angular offset of 3 deg or less (angle α in Fig. 304.2.3) does not require design consideration as a miter bend. Acceptable methods for pressure design of multiple and single miter bends are given in (a) and (b) below.

(a) Multiple Miter Bends. The maximum allowable internal pressure shall be the lesser value calculated from Eqs. (4a) and (4b). These equations are not applicable when θ exceeds 22.5 deg.

$$P_m = \frac{SE(T - c)}{r_2}\left(\frac{T - c}{(T - c) + 0.643 \tan\theta\sqrt{r_2(T - c)}}\right) \quad (4a)$$

$$P_m = \frac{SE(T - c)}{r_2}\left(\frac{R_1 - r_2}{R_1 - 0.5r_2}\right) \quad (4b)$$

(b) Single Miter Bends

(1) The maximum allowable internal pressure for a single miter bend with angle θ not greater than 22.5 deg shall be calculated by Eq. (4a).

(2) The maximum allowable internal pressure for

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a single miter bend with angle θ greater than 22.5 deg shall be calculated by Eq. (4c):

$$P_m = \frac{SE(T-c)}{r_2}\left(\frac{T-c}{(T-c) + 1.25\tan\theta\sqrt{r_2(T-c)}}\right) \quad (4c)$$

(c) The miter pipe wall thickness T used in Eqs. (4a), (4b), and (4c) shall extend a distance not less than M from the inside crotch of the end miter welds where

M = the larger of $2.5(r_2T)^{0.5}$ or $\tan\theta\,(R_1 - r_2)$

The length of taper at the end of the miter pipe may be included in the distance M.

(d) The following nomenclature is used in Eqs. (4a), (4b), and (4c) for the pressure design of miter bends:

c = same as defined in para. 304.1.1
E = same as defined in para. 304.1.1
P_m = maximum allowable internal pressure for miter bends
r_2 = mean radius of pipe using nominal wall $\overline{T}$
R_1 = effective radius of miter bend, defined as the shortest distance from the pipe center line to the intersection of the planes of adjacent miter joints
S = same as defined in para. 304.1.1
T = miter pipe wall thickness (measured or minimum per purchase specification)
θ = angle of miter cut
α = angle of change in direction at miter joint $= 2\theta$

For compliance with this Code, the value of R_1 shall be not less than that given by Eq. (5):

$$R_1 = \frac{A}{\tan\theta} + \frac{D}{2} \quad (5)$$

where A has the following empirical values:

(1) for SI metric units:

$(T-c)$, mm	A
≤ 13	25
$13 < (T-c) < 22$	$2(T-c)$
≥ 22	$[2(T-c)/3] + 30$

(2) for U.S. customary units:

$(T-c)$, mm	A
≤ 0.5	1.0
$0.5 < (T-c) < 0.88$	$2(T-c)$
≥ 0.88	$[2(T-c)/3] + 1.17$

304.2.4 Curved and Mitered Segments of Pipe Under External Pressure. The wall thickness of curved and mitered segments of pipe subjected to external pressure may be determined as specified for straight pipe in para. 304.1.3.

304.3 Branch Connections

304.3.1 General

(a) Except as provided in (b) below, the requirements in paras. 304.3.2 through 304.3.4 are applicable to branch connections made in accordance with the following methods:

(1) fittings (tees, extruded outlets, branch outlet fittings per MSS SP-97, laterals, crosses);

(2) unlisted cast or forged branch connection fittings (see para. 300.2), and couplings not over DN 80 (NPS 3), attached to the run pipe by welding;

(3) welding the branch pipe directly to the run pipe, with or without added reinforcement, as covered in para. 328.5.4.

(b) The rules in paras. 304.3.2 through 304.3.4 are minimum requirements, valid only for branch connections in which (using the nomenclature of Fig. 304.3.3):

(1) the run pipe diameter-to-thickness ratio (D_h/T_h) is less than 100 and the branch-to-run diameter ratio (D_b/D_h) is not greater than 1.0;

(2) for run pipe with $(D_h/T_h) \ge 100$, the branch diameter D_b is less than one-half the run diameter D_h;

(3) angle β is at least 45 deg;

(4) the axis of the branch intersects the axis of the run.

(c) Where the provisions of (a) and (b) above are not met, pressure design shall be qualified as required by para. 304.7.2.

(d) Other design considerations relating to branch connections are stated in para. 304.3.5.

304.3.2 Strength of Branch Connections. A pipe having a branch connection is weakened by the opening that must be made in it and, unless the wall thickness of the pipe is sufficiently in excess of that required to sustain the pressure, it is necessary to provide added reinforcement. The amount of reinforcement required to sustain the pressure shall be determined in accordance with para. 304.3.3 or 304.3.4. There are, however, certain branch connections which have adequate pressure strength or reinforcement as constructed. It may be assumed without calculation that a branch connection has adequate strength to sustain the internal and external pressure which will be applied to it if:

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(a) the branch connection utilizes a listed fitting in accordance with para. 303;

(b) the branch connection is made by welding a threaded or socket welding coupling or half coupling directly to the run in accordance with para. 328.5.4, provided the size of the branch does not exceed DN 50 (NPS 2) nor one-fourth the nominal size of the run. The minimum wall thickness of the coupling anywhere in the reinforcement zone (if threads are in the zone, wall thickness is measured from root of thread to minimum outside diameter) shall be not less than that of the unthreaded branch pipe. In no case shall a coupling or half coupling have a rating less than Class 2000 per ASME B16.11.

(c) the branch connection utilizes an unlisted branch connection fitting (see para. 300.2), provided the fitting is made from materials listed in Table A-1 and provided that the branch connection is qualified as required by para. 304.7.2.

304.3.3 Reinforcement of Welded Branch Connections. Added reinforcement is required to meet the criteria in paras. 304.3.3(b) and (c) when it is not inherent in the components of the branch connection. Sample problems illustrating the calculations for branch reinforcement are shown in Appendix H.

(99) *(a) Nomenclature.* The nomenclature below is used in the pressure design of branch connections. It is illustrated in Fig. 304.3.3, which does not indicate details for construction or welding. Some of the terms defined in Appendix J are subject to further definitions or variations, as follows:

b = subscript referring to branch

d_1 = effective length removed from pipe at branch. For branch intersections where the branch opening is a projection of the branch pipe inside diameter (e.g., pipe-to-pipe fabricated branch), $d_1 = [D_b - 2(T_b - c)]/\sin\beta$

d_2 = "half width" of reinforcement zone
= d_1 or $(T_b - c) + (T_h - c) + d_1/2$, whichever is greater, but in any case not more than D_h

h = subscript referring to run or header

L_4 = height of reinforcement zone outside of run pipe
= $2.5(T_h - c)$ or $2.5(T_b - c) + T_r$, whichever is less

T_b = branch pipe thickness (measured or minimum per purchase specification) except for branch connection fittings (see para. 300.2). For such connections the value of T_b for use in calculating L_4, d_2, and A_3, is the thickness of the reinforcing barrel (minimum per purchase specification) provided that the barrel thickness is uniform (see Fig. K328.5.4) and extends at least to the L_4 limit (see Fig. 304.3.3).

T_r = minimum thickness of reinforcing ring or saddle made from pipe. (Use nominal thickness if made from plate.)
= 0, if there is no reinforcing ring or saddle

t = pressure design thickness of pipe, according to the appropriate wall thickness equation or procedure in para. 304.1. For welded pipe, when the branch does not intersect the longitudinal weld of the run, the basic allowable stress S for the pipe may be used in determining t_h for the purpose of reinforcement calculation only. When the branch does intersect the longitudinal weld of the run, the product SE (of the stress value S and the appropriate weld joint quality factor E_j from Table A-1B) for the run pipe shall be used in the calculation. The product SE of the branch shall be used in calculating t_b.

β = smaller angle between axes of branch and run

(b) Required Reinforcement Area. The reinforcement area A_1 required for a branch connection under internal pressure is

$$A_1 = t_h d_1 (2 - \sin\beta) \quad (6)$$

For a branch connection under external pressure, area A_1 is one-half the area calculated by Eq. (6), using as t_h the thickness required for external pressure.

(c) Available Area. The area available for reinforcement is defined as

$$A_2 + A_3 + A_4 \geq A_1 \quad (6a)$$

These areas are all within the reinforcement zone and are further defined below.

(1) Area A_2 is the area resulting from excess thickness in the run pipe wall:

$$A_2 = (2d_2 - d_1)(T_h - t_h - c) \quad (7)$$

(2) Area A_3 is the area resulting from excess thickness in the branch pipe wall:

$$A_3 = 2L_4(T_b - t_b - c)/\sin\beta \quad (8)$$

(3) Area A_4 is the area of other metal provided by welds and properly attached reinforcement. [See para. 304.3.3(f).] Weld areas shall be based on the minimum dimensions specified in para. 328.5.4, except

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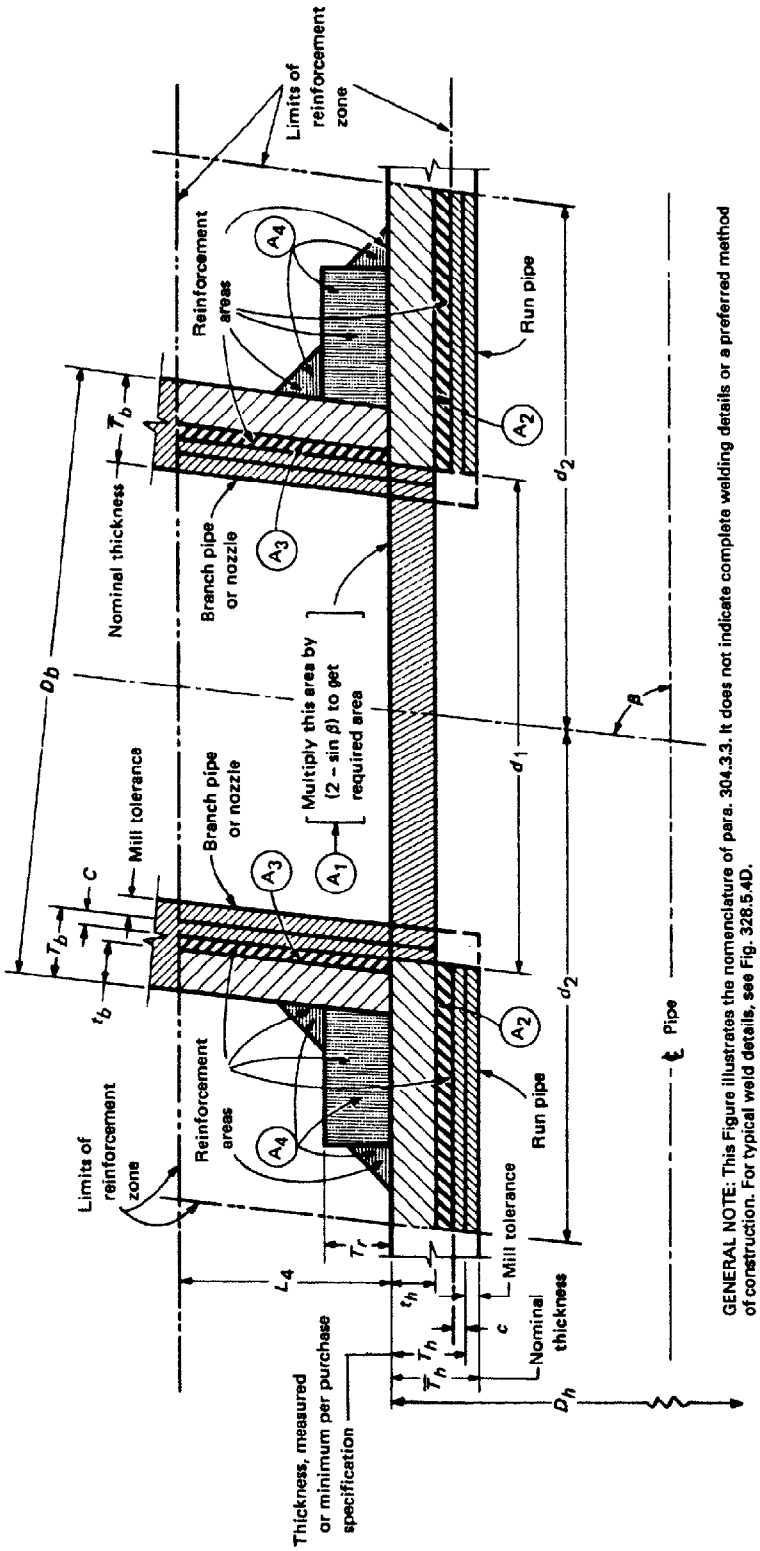

GENERAL NOTE: This Figure illustrates the nomenclature of para. 304.3.3. It does not indicate complete welding details or a preferred method of construction. For typical weld details, see Fig. 328.5.4D.

FIG. 304.3.3 BRANCH CONNECTION NOMENCLATURE

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that larger dimensions may be used if the welder has been specifically instructed to make the welds to those dimensions.

(d) Reinforcement Zone. The reinforcement zone is a parallelogram whose length extends a distance of d_2 on each side of the center line of the branch pipe and whose width starts at the inside surface of the run pipe (in its corroded condition) and extends beyond the outside surface of the run pipe a perpendicular distance L_4.

(e) Multiple Branches. When two or more branch connections are so closely spaced that their reinforcement zones overlap, the distance between centers of the openings should be at least $1\frac{1}{2}$ times their average diameter, and the area of reinforcement between any two openings shall be not less than 50% of the total that both require. Each opening shall have adequate reinforcement in accordance with paras. 304.3.3(b) and (c). No part of the metal cross section may apply to more than one opening or be evaluated more than once in any combined area. (Consult PFI Standard ES-7 for detailed recommendations on spacing of welded nozzles.)

(f) Added Reinforcement

(1) Reinforcement added in the form of a ring or saddle as part of area A_4 shall be of reasonably constant width.

(2) Material used for reinforcement may differ from that of the run pipe provided it is compatible with run and branch pipes with respect to weldability, heat treatment requirements, galvanic corrosion, thermal expansion, etc.

(3) If the allowable stress for the reinforcement material is less than that for the run pipe, its calculated area must be reduced in the ratio of allowable stress values in determining its contribution to area A_4.

(4) No additional credit may be taken for a material having higher allowable stress value than the run pipe.

304.3.4 Reinforcement of Extruded Outlet Headers

(a) The principles of reinforcement stated in para. 304.3.3 are essentially applicable to extruded outlet headers. An extruded outlet header is a length of pipe in which one or more outlets for branch connection have been formed by extrusion, using a die or dies to control the radii of the extrusion. The extruded outlet projects above the surface of the header a distance h_x at least equal to the external radius of the outlet r_x (i.e., $h_x \geq r_x$).

(b) The rules in para. 304.3.4 are minimum requirements, valid only within the limits of geometry shown in Fig. 304.3.4, and only where the axis of the outlet intersects and is perpendicular to the axis of the header. Where these requirements are not met, or where nonintegral material such as a ring, pad, or saddle has been added to the outlet, pressure design shall be qualified as required by para. 304.7.2.

(c) Nomenclature. The nomenclature used herein is illustrated in Fig. 304.3.4. Note the use of subscript x signifying extruded. Refer to para. 304.3.3(a) for nomenclature not listed here.

d_x = the design inside diameter of the extruded outlet, measured at the level of the outside surface of the header. This dimension is taken after removal of all mechanical and corrosion allowances, and all thickness tolerances.

h_x = height of the extruded outlet. This must be equal to or greater than r_x [except as shown in sketch (b) in Fig. 304.3.4].

L_5 = height of reinforcement zone
$= 0.7\sqrt{D_b T_x}$

T_x = corroded finished thickness of extruded outlet, measured at a height equal to r_x above the outside surface of the header

d_2 = half width of reinforcement zone (equal to d_x)

r_x = radius of curvature of external contoured portion of outlet, measured in the plane containing the axes of the header and branch

(d) Limitations on Radius r_x. The external contour radius r_x is subject to the following limitations.

(1) minimum r_x: the lesser of $0.05D_b$ or 38 mm (1.50 in.);

(2) maximum r_x shall not exceed:

(a) for $D_b <$ DN 200 (NPS 8), 32 mm (1.25 in.);

(b) for $D_b \geq$ DN 200, $0.1D_b + 13$ mm (0.50 in.);

(3) for an external contour with multiple radii, the requirements of (1) and (2) above apply, considering the best-fit radius over a 45 deg arc as the maximum radius;

(4) machining shall not be employed in order to meet the above requirements.

(e) Required Reinforcement Area. The required area of reinforcement is defined by

$$A_1 = Kt_h d_x \tag{9}$$

where K is determined as follows.

(1) For $D_b/D_h > 0.60$, $K = 1.00$.

(2) For $0.60 \geq D_b/D_h > 0.15$, $K = 0.6 + \frac{2}{3}(D_b/D_h)$.

(3) For $D_b/D_h \leq 0.15$, $K = 0.70$.

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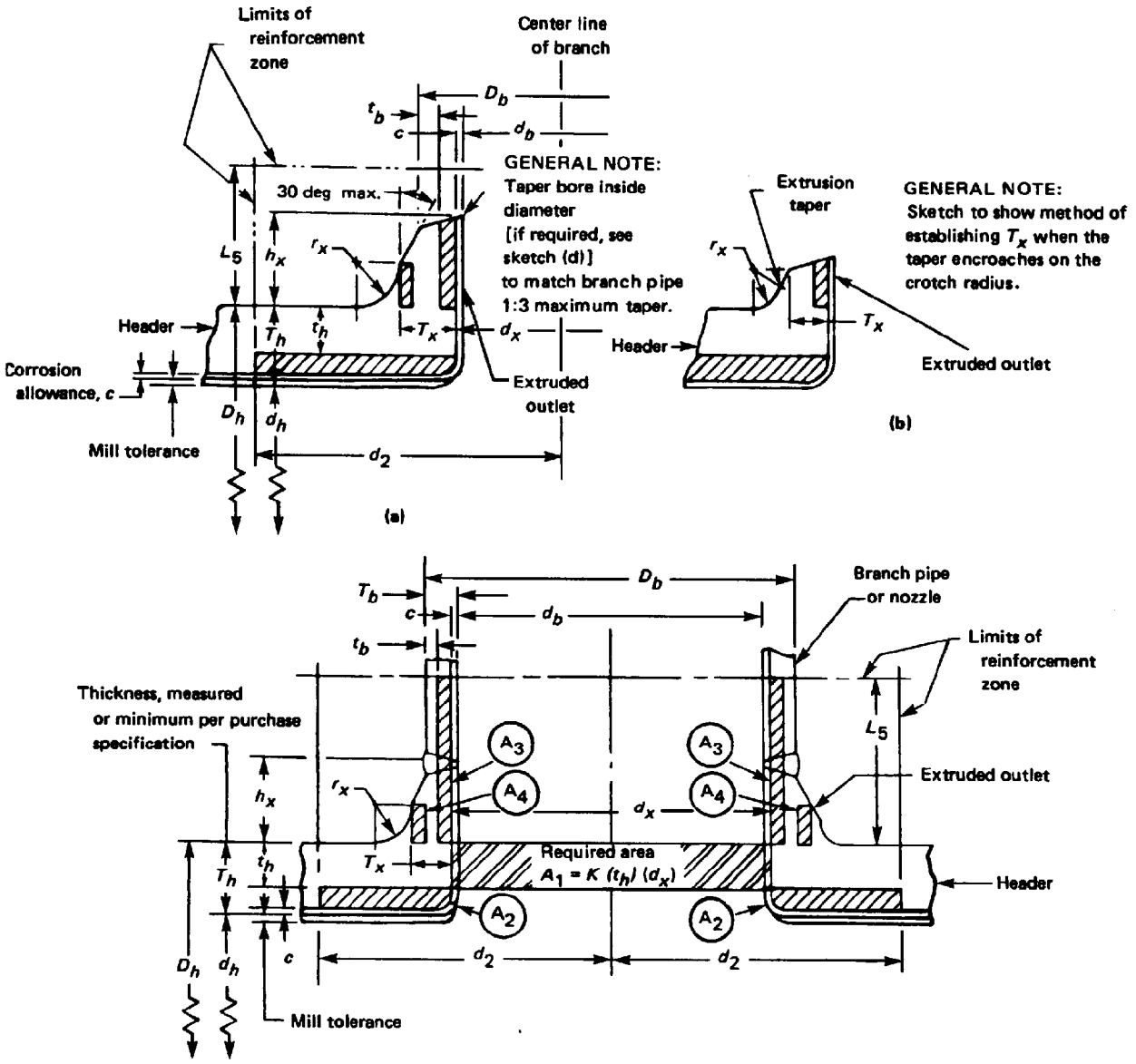

FIG. 304.3.4 EXTRUDED OUTLET HEADER NOMENCLATURE

This Figure illustrates the nomenclature of para. 304.3.4. It does not indicate complete details or a preferred method of construction.

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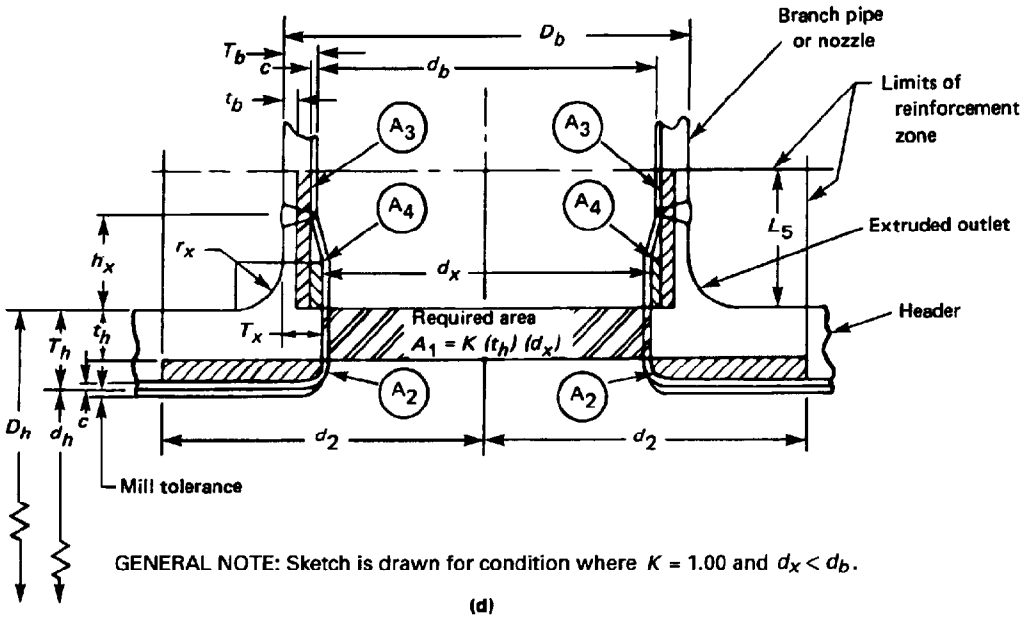

FIG. 304.3.4 EXTRUDED OUTLET HEADER NOMENCLATURE (CONT'D)
This Figure illustrates the nomenclature of para. 304.3.4. It does not indicate complete details or a preferred method of construction.

(f) Available Area. The area available for reinforcement is defined as

$$A_2 + A_3 + A_4 \geq A_1 \quad (9a)$$

These areas are all within the reinforcement zone and are further defined below.

(99) *(1)* Area A_2 is the area resulting from excess thickness in the header wall:

$$A_2 = (2d_2 - d_x)(T_h - t_h - c) \quad (10)$$

(99) *(2)* Area A_3 is the area resulting from excess thickness in the branch pipe wall:

$$A_3 = 2L_5(T_b - t_b - c) \quad (11)$$

(99) *(3)* Area A_4 is the area resulting from excess thickness in the extruded outlet lip:

$$A_4 = 2r_x(T_x - T_b - c) \quad (12)$$

(g) Reinforcement of Multiple Openings. The rules of para. 304.3.3(e) shall be followed except that the required area and reinforcement area shall be as given in para. 304.3.4.

(h) Identification. The manufacturer shall establish the design pressure and temperature for each extruded outlet header and shall mark the header with this information, together with the symbol "B31.3" (indicating the applicable Code Section) and the manufacturer's name or trademark.

304.3.5 Additional Design Considerations. The requirements of paras. 304.3.1 through 304.3.4 are intended to ensure satisfactory performance of a branch connection subject only to pressure. The designer shall also consider the following.

(a) In addition to pressure loadings, external forces and movements are applied to a branch connection by thermal expansion and contraction, dead and live loads, and movement of piping terminals and supports. Special consideration shall be given to the design of a branch connection to withstand these forces and movements.

(b) Branch connections made by welding the branch pipe directly to the run pipe should be avoided under the following circumstances:

(1) when branch size approaches run size, particularly if pipe formed by more than 1.5% cold expansion, or expanded pipe of a material subject to work hardening, is used as the run pipe;

(2) where repetitive stresses may be imposed on the connection by vibration, pulsating pressure, temperature cycling, etc.

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In such cases, it is recommended that the design be conservative and that consideration be given to the use of tee fittings or complete encirclement types of reinforcement.

(c) Adequate flexibility shall be provided in a small line which branches from a large run, to accommodate thermal expansion and other movements of the larger line (see para. 319.6).

(d) If ribs, gussets, or clamps are used to stiffen the branch connection, their areas cannot be counted as contributing to the reinforcement area determined in para. 304.3.3(c) or 304.3.4(f). However, ribs or gussets may be used for pressure-strengthening a branch connection in lieu of reinforcement covered in paras. 304.3.3 and 304.3.4 if the design is qualified as required by para. 304.7.2.

(e) For branch connections which do not meet the requirements of para. 304.3.1(b), integral reinforcement, complete encirclement reinforcement, or other means of reinforcement should be considered.

304.3.6 Branch Connections Under External Pressure. Pressure design for a branch connection subjected to external pressure may be determined in accordance with para. 304.3.1, using the reinforcement area requirement stated in para. 304.3.3(b).

304.4 Closures

304.4.1 General

(a) Closures not in accordance with para. 303 or 304.4.1(b) shall be qualified as required by para. 304.7.2.

(b) For materials and design conditions covered therein, closures may be designed in accordance with the rules in the BPV Code, Section VIII, Division 1, calculated from Eq. (13):

$$t_m = t + c \tag{13}$$

where

t_m = minimum required thickness, including mechanical, corrosion, and erosion allowance

t = pressure design thickness, calculated for the type of closure and direction of loading, shown in Table 304.4.1, except that the symbols used to determine t shall be:

E = same as defined in para. 304.1.1

P = design gage pressure

S = same as defined in para. 304.1.1

c = sum of allowances defined in para. 304.1.1

304.4.2 Openings in Closures

(a) The rules in paras. 304.4.2(b) through (g) apply to openings not larger than one-half the inside diameter of the closure as defined in Section VIII, Division 1, UG-36. A closure with a larger opening should be designed as a reducer in accordance with para. 304.6 or, if the closure is flat, as a flange in accordance with para. 304.5.

TABLE 304.4.1
BPV CODE REFERENCES[1] FOR CLOSURES

Type of Closure	Concave to Pressure	Convex to Pressure
Ellipsoidal	UG-32(d)	UG-33(d)
Torispherical	UG-32(e)	UG-33(e)
Hemispherical	UG-32(f)	UG-33(c)
Conical (no transition to knuckle)	UG-32(g)	UG-33(f)
Toriconical	UG-32(h)	UG-33(f)
Flat (pressure on either side)	UG-34	

NOTE:
(1) Paragraph numbers are from the BPV Code, Section VIII, Division 1.

(b) A closure is weakened by an opening and, unless the thickness of the closure is sufficiently in excess of that required to sustain pressure, it is necessary to provide added reinforcement. The need for and amount of reinforcement required shall be determined in accordance with the subparagraphs below except that it shall be considered that the opening has adequate reinforcement if the outlet connection meets the requirements in para. 304.3.2(b) or (c).

(c) Reinforcement for an opening in a closure shall be so distributed that reinforcement area on each side of an opening (considering any plane through the center of the opening normal to the surface of the closure) will equal at least one-half the required area in that plane.

(d) The total cross-sectional area required for reinforcement in any given plane passing through the center of the opening shall not be less than that defined in UG-37(b), UG-38, and UG-39.

(e) The reinforcement area and reinforcement zone shall be calculated in accordance with para. 304.3.3 or 304.3.4, considering the subscript h and other references to the run or header pipe as applying to the closure. Where the closure is curved, the boundaries of the reinforcement zone shall follow the contour of the closure, and dimensions of the reinforcement zone shall be measured parallel to and perpendicular to the closure surface.

(f) If two or more openings are to be located in a

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closure, the rules in paras. 304.3.3 and 304.3.4 for the reinforcement of multiple openings apply.

(g) The additional design considerations for branch connections discussed in para. 304.3.5 apply equally to openings in closures.

304.5 Pressure Design of Flanges and Blanks

304.5.1 Flanges — General

(a) Flanges not in accordance with para. 303 or 304.5.1(b) or (c) shall be qualified as required by para. 304.7.2.

(b) A flange may be designed in accordance with the BPV Code, Section VIII, Division 1, Appendix 2, using the allowable stresses and temperature limits of the B31.3 Code. Nomenclature shall be as defined in Appendix 2, except as follows:

P = design gage pressure
S_a = bolt design stress at atmospheric temperature
S_b = bolt design stress at design temperature
S_f = product SE (of the stress value S and the appropriate quality factor E from Table A-1A or A-1B) for flange or pipe material. See para. 302.3.2(e).

(c) The rules in (b) above are not applicable to a flanged joint having a gasket which extends outside the bolts (usually to the outside diameter of the flange). For flanges which make solid contact outside the bolts, Section VIII, Division 1, Appendix Y should be used.

(d) See Section VIII, Division 1, Appendix S, for considerations applicable to bolted joint assembly.

304.5.2 Blind Flanges

(a) Blind flanges not in accordance with para. 303 or 304.5.2(b) shall be qualified as required by para. 304.7.2.

(b) A blind flange may be designed in accordance with Eq. (14). The minimum thickness, considering the manufacturer's minus tolerance, shall be not less than t_m:

$$t_m = t + c \tag{14}$$

To calculate t, the rules of Section VIII, Division 1, UG-34 may be used with the following changes in nomenclature:

t = pressure design thickness, as calculated for the given styles of blind flange, using the appropriate equations for bolted flat cover plates in UG-34
c = sum of allowances defined in para. 304.1.1
P = internal or external design gage pressure
S_f = product SE (of the stress value S and the appropriate quality factor E from Table A-1A or A-1B) for flange material. See para. 302.3.2(e).

304.5.3 Blanks. The minimum required thickness of a permanent blank (representative configurations shown in Fig. 304.5.3) shall be calculated in accordance with Eq. (15).

$$t_m = d_g\sqrt{\frac{3P}{16SE}} + c \tag{15}$$

where

d_g = inside diameter of gasket for raised or flat face flanges, or the gasket pitch diameter for ring joint and fully retained gasketed flanges
E = same as defined in para. 304.1.1
P = design gage pressure
S = same as defined in para. 304.1.1
c = sum of allowances defined in para. 304.1.1

304.6 Reducers

304.6.1 Concentric Reducers

(a) Concentric reducers not in accordance with para. 303 or 304.6.1(b) shall be qualified as required by para. 304.7.2.

(b) Concentric reducers made in a conical or reversed curve section, or a combination of such sections, may be designed in accordance with the rules for conical and toriconical closures stated in para. 304.4.1.

304.6.2 Eccentric Reducers. Eccentric reducers not in accordance with para. 303 shall be qualified as required by para. 304.7.2.

304.7 Pressure Design of Other Components

304.7.1 Listed Components. Other pressure containing components manufactured in accordance with standards in Table 326.1 may be utilized in accordance with para. 303.

304.7.2 Unlisted Components and Elements. Pressure design of unlisted components and other piping elements, to which the rules elsewhere in para. 304 do not apply, shall be based on calculations consistent with the design criteria of this Code. These calculations shall be substantiated by one or more of the means stated in paras. 304.7.2(a), (b), (c), and (d), considering applicable dynamic, thermal, and cyclic effects in paras. 301.4 through 301.10, as well as thermal shock. Calculations and documentation showing compliance with

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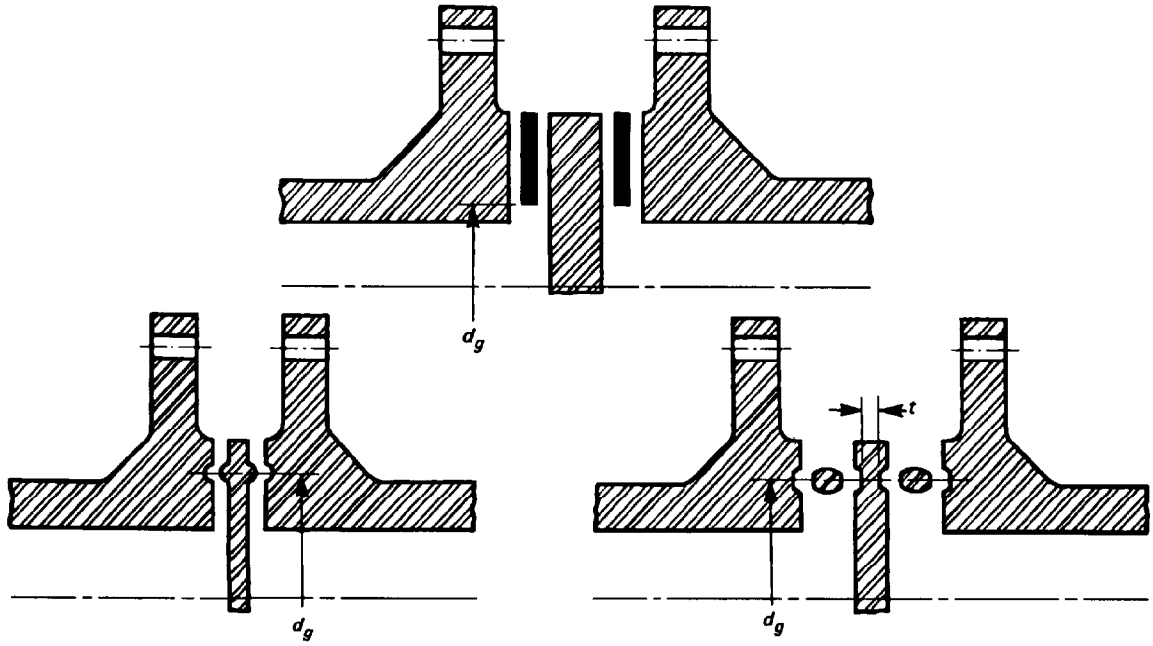

FIG. 304.5.3 BLANKS

paras. 304.7.2(a), (b), (c), or (d), and (e) shall be available for the owner's approval:

(a) extensive, successful service experience under comparable conditions with similarly proportioned components of the same or like material;

(b) experimental stress analysis, such as described in the BPV Code, Section VIII, Division 2, Appendix 6;

(c) proof test in accordance with either ASME B16.9, MSS SP-97, or Section VIII, Division 1, UG-101;

(d) detailed stress analysis (e.g., finite element method) with results evaluated as described in Section VIII, Division 2, Appendix 4, Article 4-1. The basic allowable stress from Table A-1 shall be used in place of S_m in Division 2. At design temperatures in the creep range, additional considerations beyond the scope of Division 2 may be necessary.

(e) For any of the above, the designer may interpolate between sizes, wall thicknesses, and pressure classes, and may determine analogies among related materials.

304.7.3 Metallic Components With Nonmetallic Pressure Parts. Components not covered by standards listed in Table 326.1, in which both metallic and nonmetallic parts contain the pressure, shall be evaluated by applicable requirements of para. A304.7.2 as well as those of para. 304.7.2.

304.7.4 Expansion Joints

(a) Metallic Bellows Expansion Joints. The design of bellows type expansion joints shall be in accordance with Appendix X. See also Appendix F, para. F304.7.4 for further design considerations.

(b) Slip Type Expansion Joints

(1) Pressure containing elements shall be in accordance with para. 318 and other applicable requirements of this Code.

(2) External piping loads shall not impose excessive bending on the joint.

(3) The effective pressure thrust area shall be computed using the outside diameter of the pipe.

(c) Other Types of Expansion Joint. The design of other types of expansion joint shall be qualified as required by para. 304.7.2.

PART 3
FLUID SERVICE REQUIREMENTS FOR PIPING COMPONENTS

305 PIPE

Pipe includes components designated as "tube" or "tubing" in the material specification, when intended for pressure service.

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305.1 General

Listed pipe may be used in Normal Fluid Service except as stated in paras. 305.2.1 and 305.2.2. Unlisted pipe may be used only as provided in para. 302.2.3.

305.2 Specific Requirements

305.2.1 Pipe for Category D Fluid Service. The following carbon steel pipe may be used only for Category D Fluid Service:

API 5L, Furnace Butt-Welded
ASTM A 53, Type F
ASTM A 134 made from other than ASTM A 285 plate

305.2.2 Pipe Requiring Safeguarding. When used for other than Category D Fluid Service, the following carbon steel pipe shall be safeguarded:

ASTM A 134 made from ASTM A 285 plate
ASTM A 139

305.2.3 Pipe for Severe Cyclic Conditions. Only the following pipe[7] may be used under severe cyclic conditions:

(a) Carbon Steel Pipe
API 5L, Grade A or B, seamless
API 5L, Grade A or B, SAW, str. seam, $E_j \geq 0.95$
API 5L, Grade X42, seamless
API 5L, Grade X46, seamless
API 5L, Grade X52, seamless
API 5L, Grade X56, seamless
API 5L, Grade X60, seamless
ASTM A 53, seamless
ASTM A 106
ASTM A 333, seamless
ASTM A 369
ASTM A 381, $E_j \geq 0.90$
ASTM A 524
ASTM A 671, $E_j \geq 0.90$
ASTM A 672, $E_j \geq 0.90$
ASTM A 691, $E_j \geq 0.90$

(b) Low and Intermediate Alloy Steel Pipe
ASTM A 333, seamless
ASTM A 335
ASTM A 369
ASTM A 426, $E_c \geq 0.90$
ASTM A 671, $E_j \geq 0.90$
ASTM A 672, $E_j \geq 0.90$
ASTM A 691, $E_j \geq 0.90$

(c) Stainless Steel Alloy Pipe
ASTM A 268, seamless
ASTM A 312, seamless
ASTM A 358, $E_j \geq 0.90$
ASTM A 376
ASTM A 430
ASTM A 451, $E_c \geq 0.90$

(d) Copper and Copper Alloy Pipe
ASTM B 42
ASTM B 466

(e) Nickel and Nickel Alloy Pipe
ASTM B 161
ASTM B 165
ASTM B 167
ASTM B 407

(f) Aluminum Alloy Pipe
ASTM B 210, Tempers 0 and H112
ASTM B 241, Tempers 0 and H112

306 FITTINGS, BENDS, MITERS, LAPS, AND BRANCH CONNECTIONS

Fittings, bends, miters, laps, and branch connections may be used in accordance with paras. 306.1 through 306.5. Pipe and other materials used in such components shall be suitable for the manufacturing or fabrication process and the fluid service.

306.1 Pipe Fittings

306.1.1 Listed Fittings. Listed fittings may be used in Normal Fluid Service in accordance with para. 303.

306.1.2 Unlisted Fittings. Unlisted fittings may be used only in accordance with para. 302.2.3.

306.1.3 Specific Fittings

(a) Proprietary welding branch outlet fittings which have been design proof tested successfully as prescribed in ASME B16.9, MSS SP-97 or the BPV Code, Section VIII, Division 1, UG-101 may be used within their established ratings. (99)

(b) The lap thickness of a proprietary "Type C" lap-joint stub-end buttwelding fitting shall conform to the requirements of para. 306.4.2 for flared laps.

306.1.4 Fittings for Severe Cyclic Conditions

(a) Only the following fittings may be used under severe cyclic conditions:

(1) forged;

(2) wrought, with factor $E_j \geq 0.90$;[8] or

[7] Casting or joint factors E_c or E_j specified for cast or welded pipe which do not correspond with E factors in Table A-1A or A-1B are established in accordance with paras. 302.3.3 and 302.3.4.

[8] See paras. 302.3.3 and 302.3.4.

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(3) cast, with factor $E_c \geq 0.90$.[8]

(b) Fittings conforming to MSS SP-43 and proprietary "Type C" lap-joint stub-end welding fittings shall not be used under severe cyclic conditions.

306.2 Pipe Bends

306.2.1 General. A pipe bend made in accordance with paras. 332.2.1 and 332.2.2, and verified for pressure design in accordance with para. 304.2.1, is suitable for the same service as the pipe from which it is made.

306.2.2 Corrugated and Other Bends. Bends of other designs (such as creased or corrugated) shall be qualified for pressure design as required by para. 304.7.2.

306.2.3 Bends for Severe Cyclic Conditions. A pipe bend designed as creased or corrugated shall not be used under severe cyclic conditions.

306.3 Miter Bends

306.3.1 General. Except as stated in para. 306.3.2, a miter bend made in accordance with para. 304.2.3 and welded in accordance with para. 311.1 is suitable for use in Normal Fluid Service.

306.3.2 Miter Bends for Category D Fluid Service. A miter bend which makes a change in direction at a single joint (angle α in Fig. 304.2.3) greater than 45 deg, or is welded in accordance with para. 311.2.1, may be used only for Category D Fluid Service.

306.3.3 Miter Bends for Severe Cyclic Conditions. A miter bend to be used under severe cyclic conditions shall be made in accordance with para. 304.2.3 and welded in accordance with para. 311.2.2, and shall have an angle α (see Fig. 304.2.3) $\leq$ 22.5 deg.

306.4 Fabricated or Flared Laps

The following requirements do not apply to fittings conforming to para. 306.1, nor to laps integrally hot-forged on pipe ends.

306.4.1 Fabricated Laps. A fabricated lap is suitable for use in Normal Fluid Service, provided that all of the following conditions are met.

(a) The outside diameter of the lap shall be in accordance with the dimension of an ASME B16.9 lap-joint stub end.

(b) The lap thickness shall be at least equal to the nominal wall thickness of the pipe to which it is attached.

(c) The lap material shall be listed in Table A-1 and shall have an allowable stress at least as great as that of the pipe.

(d) Welding shall be in accordance with para. 311.1 and fabrication shall be in accordance with para. 328.5.5.

306.4.2 Flared Laps. A flared lap is suitable for use in Normal Fluid Service, provided that all of the following conditions are met.

(a) The outside diameter of the lap shall be in accordance with the dimension of an ASME B16.9 lap-joint stub end.

(b) The radius of fillet of the flared lap shall not exceed 3 mm ($\frac{1}{8}$ in.), and the backing flange shall meet the requirements of para. 308.2.5.

(c) The lap thickness, measured at any point, shall be at least 95% of the minimum pipe wall thickness T multiplied by the ratio of the pipe outside radius to the radius at which the lap thickness is measured.

(d) Pressure design shall be qualified as required by para. 304.7.2.

306.4.3 Laps for Severe Cyclic Conditions

(a) A fabricated lap to be used under severe cyclic conditions shall conform to the requirements of para. 306.4.1, except that welding shall be in accordance with para. 311.2.2, with fabrication limited to a detail equivalent to Fig. 328.5.5 sketch (d) or (e).

(b) Flared laps shall not be used under severe cyclic conditions.

306.5 Fabricated Branch Connections

The following requirements do not apply to fittings conforming to para. 306.1.

306.5.1 General. A fabricated branch connection made and verified for pressure design in accordance with para. 304.3, and welded in accordance with para. 311.1, is suitable for use in Normal Fluid Service.

306.5.2 Fabricated Branch Connections for Severe Cyclic Conditions. A fabricated branch connection to be used under severe cyclic conditions shall conform to the requirements of para. 306.5.1, except that welding shall be in accordance with para. 311.2.2, with fabrication limited to a detail equivalent to Fig. 328.5.4D sketch (2) or (4), or to Fig. 328.5.4E.

307 VALVES AND SPECIALTY COMPONENTS

The following requirements for valves shall also be met as applicable by other pressure containing piping

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components, such as traps, strainers, and separators. See also Appendix F, paras. F301.4 and F307.

307.1 General

307.1.1 Listed Valves. A listed valve is suitable for use in Normal Fluid Service, except as stated in para. 307.2.

307.1.2 Unlisted Valves. Unlisted valves may be used only in accordance with para. 302.2.3. Unless pressure-temperature ratings are established by the method set forth in Appendix F to ASME B16.34, pressure design shall be qualified as required by para. 304.7.2.

307.2 Specific Requirements

A bolted bonnet valve whose bonnet is secured to the body by less than four bolts, or by a U-bolt, may be used only for Category D Fluid Service.

308 FLANGES, BLANKS, FLANGE FACINGS, AND GASKETS

308.1 General

308.1.1 Listed Components. A listed flange, blank, or gasket is suitable for use in Normal Fluid Service, except as stated elsewhere in para. 308.

308.1.2 Unlisted Components. Unlisted flanges, blanks, and gaskets may be used only in accordance with para. 302.2.3.

(99) ### 308.2 Specific Requirements for Flanges

See Appendix F, paras. F308.2 and F312.

308.2.1 Slip-On Flanges

(a) A slip-on flange shall be double-welded as shown in Fig. 328.5.2B when the service is:

(1) subject to severe erosion, crevice corrosion, or cyclic loading;

(2) flammable, toxic, or damaging to human tissue;

(3) under severe cyclic conditions;

(4) at temperatures below −101°C (−150°F).

(b) The use of slip-on flanges should be avoided where many large temperature cycles are expected, particularly if the flanges are not insulated.

(c) Slip-on Flanges as Lapped Flanges. A slip-on flange may be used as a lapped flange only as shown in Table 308.2.1 unless pressure design is qualified in accordance with para. 304.5.1. A corner radius or bevel shall conform to one of the following as applicable:

(1) for an ASME B16.9 lap joint stub end or a forged lap (see para. 306.4.3) the corner radius shall be as specified in ASME B16.5, Tables 9 and 12, dimension *r*.

(2) for a fabricated lap, the corner bevel shall be at least half the nominal thickness of the pipe to which the lap is attached (see Fig. 328.5.5).

(3) for a flared lap see para. 308.2.5.

TABLE 308.2.1
PERMISSIBLE SIZES/RATING CLASSES FOR SLIP-ON FLANGES USED AS LAPPED FLANGES[1]

Rating		Maximum Flange Size	
PN	Class	DN	NPS
20	150	300	12
50	300	200	8

NOTE:
(1) Actual thickness of flange at bolt circle shall at least equal minimum required flange thickness in ASME B16.5.

308.2.2 Expanded-Joint Flanges. A flange having an expanded-joint insert is subject to the requirements for expanded joints in para. 313.

308.2.3 Socket Welding and Threaded Flanges. A socket welding flange is subject to the requirements for socket welds in para. 311.2.4. A threaded flange is subject to the requirements for threaded joints in para. 314.4.

308.2.4 Flanges for Severe Cyclic Conditions. Unless it is safeguarded, a flange to be used under severe cyclic conditions shall be welding neck conforming to ASME B16.5 or ASME B16.47, or a similarly proportioned flange designed in accordance with para. 304.5.1.

308.2.5 Flanges for Flared Metallic Laps. For a flange used with a flared metallic lap (para. 306.4.2), the intersection of face and bore shall be beveled or rounded approximately 3 mm ($\frac{1}{8}$ in.). See also para. 308.2.1(c).

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308.3 Flange Facings

The flange facing shall be suitable for the intended service and for the gasket and bolting employed.

308.4 Gaskets

Gaskets shall be selected so that the required seating load is compatible with the flange rating and facing, the strength of the flange, and its bolting. Materials shall be suitable for the service conditions. See also Appendix F, para. F308.4.

309 BOLTING

Bolting includes bolts, bolt studs, studs, cap screws, nuts, and washers. See also Appendix F, para. F309.

309.1 General

309.1.1 Listed Bolting. Listed bolting is suitable for use in Normal Fluid Service, except as stated elsewhere in para. 309.

309.1.2 Unlisted Bolting. Unlisted bolting may be used only in accordance with para. 302.2.3.

309.1.3 Bolting for Components. Bolting for components conforming to a listed standard shall be in accordance with that standard if specified therein.

309.1.4 Selection Criteria. Bolting selected shall be adequate to seat the gasket and maintain joint tightness under all design conditions.

309.2 Specific Bolting

309.2.1 Low Yield Strength Bolting. Bolting having not more than 207 MPa (30 ksi) specified minimum yield strength shall not be used for flanged joints rated ASME B16.5 PN 68 (Class 400) and higher, nor for flanged joints using metallic gaskets, unless calculations have been made showing adequate strength to maintain joint tightness.

309.2.2 Carbon Steel Bolting. Except where limited by other provisions of this Code, carbon steel bolting may be used with nonmetallic gaskets in flanged joints rated ASME B16.5 PN 50 (Class 300) and lower for bolt metal temperatures at −29°C to 204°C (−20°F to 400°F), inclusive. If these bolts are galvanized, heavy hexagon nuts, threaded to suit, shall be used.

309.2.3 Bolting for Metallic Flange Combinations. Any bolting which meets the requirements of para. 309 may be used with any combination of flange material and facing. If either flange is to the ANSI B16.1, ANSI B16.24, MSS SP-42, or MSS SP-51 specification, the bolting material shall be no stronger than low yield strength bolting unless:

(a) both flanges have flat faces and a full face gasket is used; or,

(b) sequence and torque limits for bolt-up are specified, with consideration of sustained loads, displacement strains, and occasional loads (see paras. 302.3.5 and 302.3.6), and strength of the flanges.

309.2.4 Bolting for Severe Cyclic Conditions. Low yield strength bolting (see para. 309.2.1) shall not be used for flanged joints under severe cyclic conditions.

309.3 Tapped Holes

Tapped holes for pressure retaining bolting in metallic piping components shall be of sufficient depth that the thread engagement will be at least seven-eighths times the nominal thread diameter.

PART 4
FLUID SERVICE REQUIREMENTS FOR PIPING JOINTS

310 GENERAL

Piping joints shall be selected to suit the piping material and the fluid service, with consideration of joint tightness and mechanical strength under expected service and test conditions of pressure, temperature, and external loading.

311 WELDED JOINTS

Joints may be made by welding in any material for which it is possible to qualify welding procedures, welders, and welding operators in conformance with the rules in Chapter V.

311.1 General

Except as provided in paras. 311.2.1 and 311.2.2, welds shall conform to the following.

(a) Welding shall be in accordance with para. 328.

(b) Preheating and heat treatment shall be in accordance with paras. 330 and 331, respectively.

(c) Examination shall be in accordance with para. 341.4.1.

(d) Acceptance criteria shall be those in Table 341.3.2 for Normal Fluid Service.

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311.2 Specific Requirements

311.2.1 Welds for Category D Fluid Service. Welds which meet the requirements of para. 311.1, but for which examination is in accordance with para. 341.4.2, and acceptance criteria are those in Table 341.3.2 for Category D Fluid Service, may be used only in that service.

311.2.2 Welds for Severe Cyclic Conditions. Welds for use under severe cyclic conditions shall meet the requirements of para. 311.1 with the exceptions that examination shall be in accordance with para. 341.4.3, and acceptance criteria shall be those in Table 341.3.2 for severe cyclic conditions.

311.2.3 Backing Rings and Consumable Inserts

(a) If a backing ring is used where the resulting crevice is detrimental (e.g., subject to corrosion, vibration, or severe cyclic conditions), it should be removed and the internal joint face ground smooth. When it is impractical to remove the backing ring in such a case, consideration shall be given to welding without backing rings or to the use of consumable inserts or removable nonmetallic backing rings.

(b) Split backing rings shall not be used under severe cyclic conditions.

311.2.4 Socket Welds

(a) Socket welded joints (para. 328.5.2) should be avoided in any service where crevice corrosion or severe erosion may occur.

(b) Socket welded joints shall conform to the following.

(1) Socket dimensions shall conform to ASME B16.5 for flanges and ASME B16.11 for other socket-welding components.

(2) Weld dimensions shall not be less than those shown in Figs. 328.5.2B and 328.5.2C.

(c) Socket welds larger than DN 50 (NPS 2) shall not be used under severe cyclic conditions.

(d) A drain or bypass in a component may be attached by socket welding, provided the socket dimensions conform to Fig. 4 in ASME B16.5.

311.2.5 Fillet Welds

(a) Fillet welds in accordance with para. 328.5.2 may be used as primary welds to attach socket welding components and slip-on flanges.

(b) Fillet welds may also be used to attach reinforcement and structural attachments, to supplement the strength or reduce stress concentration of primary welds, and to prevent disassembly of joints.

311.2.6 Seal Welds. Seal welds (para. 328.5.3) may be used only to prevent leakage of threaded joints and shall not be considered as contributing any strength to the joints.

312 FLANGED JOINTS

312.1 Joints Using Flanges of Different Ratings

Where flanges of different ratings are bolted together, the rating of the joint shall not exceed that of the lower rated flange. Bolting torque shall be limited so that excessive loads will not be imposed on the lower rated flange in obtaining a tight joint.

312.2 Metal to Nonmetal Flanged Joints

Where a metallic flange is bolted to a nonmetallic flange, both should be flat-faced. A full-faced gasket is preferred. If a gasket extending only to the inner edge of the bolts is used, bolting torque shall be limited so that the nonmetallic flange is not overloaded.

313 EXPANDED JOINTS

(a) Expanded joints shall not be used under severe cyclic conditions. For other services, adequate means shall be provided to prevent separation of the joint. If the fluid is toxic or damaging to human tissue, safeguarding is required.

(b) Consideration shall be given to the tightness of expanded joints when subjected to vibration, differential expansion or contraction due to temperature cycling, or external mechanical loads.

314 THREADED JOINTS

314.1 General

Threaded joints are suitable for Normal Fluid Service except as stated elsewhere in para. 314. They may be used under severe cyclic conditions only as provided in paras. 314.2.1(c) and 314.2.2.

(a) Threaded joints should be avoided in any service where crevice corrosion, severe erosion, or cyclic loading may occur.

(b) When threaded joints are intended to be seal welded, thread sealing compound shall not be used.

(c) Layout of piping employing threaded joints should, insofar as possible, minimize stress on joints, giving special consideration to stresses due to thermal expansion and operation of valves (particularly a valve

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TABLE 314.2.1
MINIMUM THICKNESS OF MALE THREADED COMPONENTS[1]

Fluid Service	Notch-Sensitive Material	Size Range [Note (2)] DN	Size Range [Note (2)] NPS	Min. Wall Thickness [Note (3)]
Normal	Yes [Note (4)]	≤ 40	≤ 1½	Sch 80
		50	2	Sch 40
		65–150	2½–6	Sch 40
Normal	No [Note (5)]	≤ 50	≤ 2	Sch 40S
		65–150	2½–6	Sch 40S
Category D	Either	≤ 300	≤ 12	Per para. 304.1.1

NOTES:
(1) Use the greater of para. 304.1.1 or thickness shown in this table.
(2) For sizes > DN 50 (NPS 2), the joint shall be safeguarded (see Appendix G) for a fluid service that is flammable, toxic, or damaging to human tissue.
(3) Nominal wall thicknesses is listed for Sch. 40 and 80 in ASME B36.10M and for Sch. 40S in ASME B36.19M.
(4) For example, carbon steel.
(5) For example, austenitic stainless steel.

at a free end). Provision should be made to counteract forces that would tend to unscrew the joints.

(d) Except for specially designed joints employing lens rings or similar gaskets, threaded flanges in which the pipe ends project through to serve as the gasket surface may be used only for Category D Fluid Service.

314.2 Specific Requirements

314.2.1 Taper-Threaded Joints. Requirements in (a) through (c) below apply to joints in which the threads of both mating components conform to ASME B1.20.1.

(a) Male threaded components may be used in accordance with Table 314.2.1 and its Notes.

(b) Female threaded components shall be at least equivalent in strength and toughness to threaded components listed in Table 326.1 and otherwise suitable for the service.

(c) Threaded components of a specialty nature which are not subject to external moment loading, such as thermometer wells, may be used under severe cyclic conditions.

(d) A coupling having straight threads may be used only for Category D Fluid Service, and only with taper-threaded mating components.

314.2.2 Straight-Threaded Joints. Threaded joints in which the tightness of the joint is provided by a seating surface other than the threads (e.g., a union comprising male and female ends joined with a threaded union nut, or other constructions shown typically in Fig. 335.3.3) may be used. If such joints are used under severe cyclic conditions and are subject to external moment loadings, safeguarding is required.

315 TUBING JOINTS

315.1 General

In selecting and applying flared, flareless, and compression type tubing fittings, the designer shall consider the possible adverse effects on the joints of such factors as assembly and disassembly, cyclic loading, vibration, shock, and thermal expansion and contraction.

315.2 Joints Conforming to Listed Standards

Joints using flared, flareless, or compression type tubing fittings covered by listed standards may be used in Normal Fluid Service provided that:

(a) the fittings and joints are suitable for the tubing with which they are to be used (considering maximum and minimum wall thickness) and are used within the pressure-temperature limitations of the fitting and the joint; and

(b) the joints are safeguarded when used under severe cyclic conditions.

315.3 Joints Not Conforming to Listed Standards

Joints using flared, flareless, or compression type tubing fittings not listed in Table 326.1 may be used in accordance with para. 315.2 provided that the type of fitting selected is also adequate for pressure and other loadings. The design shall be qualified as required by para. 304.7.2.

316 CAULKED JOINTS

Caulked joints such as bell type joints shall be limited to Category D fluid service and to a temperature not over 93°C (200°F). They shall be used within the pressure-temperature limitations of the joint and pipe. Provisions shall be made to prevent disengagement of joints, to prevent buckling of the piping, and to sustain lateral reactions produced by branch connections or other causes.

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317 SOLDERED AND BRAZED JOINTS

317.1 Soldered Joints

Soldered joints shall be made in accordance with the provisions of para. 333 and may be used only in Category D fluid service. Fillet joints made with solder metal are not permitted. The low melting point of solder shall be considered where possible exposure to fire or elevated temperature is involved.

317.2 Brazed and Braze Welded Joints

(a) Brazed and braze welded joints made in accordance with the provisions in para. 333 are suitable for Normal Fluid Service. They shall be safeguarded in fluid services which are flammable, toxic, or damaging to human tissue. They shall not be used under severe cyclic conditions. The melting point of brazing alloys shall be considered where possible exposure to fire is involved.

(b) Fillet joints made with brazing filler metal are not permitted.

318 SPECIAL JOINTS

Special joints are those not covered elsewhere in Chapter II, Part 4, such as bell type and packed gland type joints.

318.1 General

318.1.1 Listed Joints. Joints using listed components are suitable for Normal Fluid Service.

318.1.2 Unlisted Joints. For joints which utilize unlisted components, pressure design shall be qualified as required by para. 304.7.2.

318.2 Specific Requirements

318.2.1 Joint Integrity. Separation of the joint shall be prevented by a means which has sufficient strength to withstand anticipated conditions of service.

318.2.2 Joint Interlocks. Either mechanical or welded interlocks shall be provided to prevent separation of any joint used for a fluid service which is flammable, toxic, or damaging to human tissues, of any joint to be used under severe cyclic conditions, and of any joint exposed to temperatures in the creep range.

318.2.3 Bell and Gland Type Joints. If not covered in para. 316, bell type and gland type joints used under severe cyclic conditions require safeguarding.

PART 5
FLEXIBILITY AND SUPPORT

319 PIPING FLEXIBILITY

319.1 Requirements

319.1.1 Basic Requirements. Piping systems shall have sufficient flexibility to prevent thermal expansion or contraction or movements of piping supports and terminals from causing:

(a) failure of piping or supports from overstress or fatigue;

(b) leakage at joints; or

(c) detrimental stresses or distortion in piping and valves or in connected equipment (pumps and turbines, for example), resulting from excessive thrusts and moments in the piping.

319.1.2 Specific Requirements. In para. 319, concepts, data, and methods are given for determining the requirements for flexibility in a piping system and for assuring that the system meets all of these requirements. In brief, these requirements are:

(a) that the computed stress range at any point due to displacements in the system shall not exceed the allowable stress range established in para. 302.3.5;

(b) that reaction forces computed in para. 319.5 shall not be detrimental to supports or connected equipment; and

(c) that computed movement of the piping shall be within any prescribed limits, and properly accounted for in the flexibility calculations.

If it is determined that a piping system does not have adequate inherent flexibility, means for increasing flexibility shall be provided in accordance with para. 319.7.

319.2 Concepts

Concepts characteristic of piping flexibility analysis are covered in the following paragraphs. Special consideration is given to displacements (strains) in the piping system, and to resultant bending and torsional stresses.

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319.2.1 Displacement Strains

(a) Thermal Displacements. A piping system will undergo dimensional changes with any change in temperature. If it is constrained from free expansion or contraction by connected equipment and restraints such as guides and anchors, it will be displaced from its unrestrained position.

(b) Restraint Flexibility. If restraints are not considered rigid, their flexibility may be considered in determining displacement stress range and reactions.

(c) Externally Imposed Displacements. Externally caused movement of restraints will impose displacements on the piping in addition to those related to thermal effects. Movements may result from tidal changes (dock piping), wind sway (e.g., piping supported from a tall slender tower), or temperature changes in connected equipment.

Movement due to earth settlement, since it is a single cycle effect, will not significantly influence fatigue life. A displacement stress range greater than that permitted by para. 302.3.5(d) may be allowable if due consideration is given to avoidance of excessive localized strain and end reactions.

(d) Total Displacement Strains. Thermal displacements, reaction displacements, and externally imposed displacements all have equivalent effects on the piping system, and shall be considered together in determining the total displacement strains (proportional deformation) in various parts of the piping system.

319.2.2 Displacement Stresses

(a) Elastic Behavior. Stresses may be considered proportional to the total displacement strains in a piping system in which the strains are well-distributed and not excessive at any point (a balanced system). Layout of systems should aim for such a condition, which is assumed in flexibility analysis methods provided in this Code.

(b) Overstrained Behavior. Stresses cannot be considered proportional to displacement strains throughout a piping system in which an excessive amount of strain may occur in localized portions of the system (an unbalanced system). Operation of an unbalanced system in the creep range may aggravate the deleterious effects due to creep strain accumulation in the most susceptible regions of the system. Unbalance may result from one or more of the following:

(1) highly stressed small size pipe runs in series with large or relatively stiff pipe runs;

(2) a local reduction in size or wall thickness, or local use of material having reduced yield strength (for example, girth welds of substantially lower strength than the base metal);

(3) a line configuration in a system of uniform size in which the expansion or contraction must be absorbed largely in a short offset from the major portion of the run;

(4) variation of piping material or temperature in a line. When differences in the elastic modulus within a piping system will significantly affect the stress distribution, the resulting displacement stresses shall be computed based on the actual elastic moduli at the respective operating temperatures for each segment in the system and then multiplied by the ratio of the elastic modulus at ambient temperature to the modulus used in the analysis for each segment.

Unbalance should be avoided or minimized by design and layout of piping systems, particularly those using materials of low ductility. Many of the effects of unbalance can be mitigated by selective use of cold spring. If unbalance cannot be avoided, the designer shall use appropriate analytical methods in accordance with para. 319.4 to assure adequate flexibility as defined in para. 319.1.

319.2.3 Displacement Stress Range

(a) In contrast with stresses from sustained loads, such as internal pressure or weight, displacement stresses may be permitted to attain sufficient magnitude to cause local yielding in various portions of a piping system. When the system is initially operated at the condition of greatest displacement (highest or lowest temperature, or greatest imposed movement) from its installed condition, any yielding or creep brings about a reduction or relaxation of stress. When the system is later returned to its original condition (or a condition of opposite displacement), a reversal and redistribution of stresses occurs which is referred to as self-springing. It is similar to cold springing in its effects.

(b) While stresses resulting from displacement strains diminish with time due to yielding or creep, the algebraic difference between strains in the extreme displacement condition and the original (as-installed) condition (or any anticipated condition with a greater differential effect) remains substantially constant during any one cycle of operation. This difference in strains produces a corresponding stress differential, the displacement stress range, which is used as the criterion in the design of piping for flexibility. See para. 302.3.5(d) for the allowable stress range S_A and para. 319.4.4(a) for the computed stress range S_E.

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(c) Average axial stresses (over the pipe cross section) due to longitudinal forces caused by displacement strains are not normally considered in the determination of displacement stress range, since this stress is not significant in typical piping layouts. In special cases, however, consideration of average axial displacement stress is necessary. Examples include buried lines containing hot fluids, double wall pipes, and parallel lines with different operating temperatures, connected together at more than one point.

319.2.4 Cold Spring. Cold spring is the intentional deformation of piping during assembly to produce a desired initial displacement and stress. Cold spring is beneficial in that it serves to balance the magnitude of stress under initial and extreme displacement conditions. When cold spring is properly applied there is less likelihood of overstrain during initial operation; hence, it is recommended especially for piping materials of limited ductility. There is also less deviation from as-installed dimensions during initial operation, so that hangers will not be displaced as far from their original settings.

Inasmuch as the service life of a piping system is affected more by the range of stress variation than by the magnitude of stress at a given time, no credit for cold spring is permitted in stress range calculations. However, in calculating the thrusts and moments where actual reactions as well as their range of variations are significant, credit is given for cold spring.

319.3 Properties for Flexibility Analysis

The following paragraphs deal with properties of piping materials and their application in piping flexibility stress analysis.

319.3.1 Thermal Expansion Data

(a) Values for Stress Range. Values of thermal displacements to be used in determining total displacement strains for computing the stress range shall be determined from Appendix C as the algebraic difference between the value at maximum metal temperature and that at the minimum metal temperature for the thermal cycle under analysis.

(b) Values for Reactions. Values of thermal displacements to be used in determining total displacement strains for computation of reactions on supports and connected equipment shall be determined as the algebraic difference between the value at maximum (or minimum) temperature for the thermal cycle under analysis and the value at the temperature expected during installation.

319.3.2 Modulus of Elasticity. The reference modulus of elasticity at 21°C (70°F), E_a, and the modulus of elasticity at maximum or minimum temperature, E_m, shall be taken as the values shown in Appendix C for the temperatures determined in para. 319.3.1(a) or (b). For materials not included in Appendix C, reference shall be made to authoritative source data, such as publications of the National Institute of Standards and Technology.

319.3.3 Poisson's Ratio. Poisson's ratio may be taken as 0.3 at all temperatures for all metals. More accurate and authoritative data may be used if available.

319.3.4 Allowable Stresses

(a) The allowable displacement stress range S_A and permissible additive stresses shall be as specified in para. 302.3.5(d) for systems primarily stressed in bending and/or torsion.

(b) The stress intensification factors in Appendix D have been developed from fatigue tests of representative piping components and assemblies manufactured from ductile ferrous materials. The allowable displacement stress range is based on tests of carbon and austenitic stainless steels. Caution should be exercised when using Eqs. (1a) and (1b) (para. 302.3.5) for allowable displacement stress range for some nonferrous materials (e.g., certain copper and aluminum alloys) for other than low cycle applications.

319.3.5 Dimensions. Nominal thicknesses and outside diameters of pipe and fittings shall be used in flexibility calculations.

319.3.6 Flexibility and Stress Intensification Factors. In the absence of more directly applicable data, the flexibility factor k and stress intensification factor i shown in Appendix D shall be used in flexibility calculations in para. 319.4. For piping components or attachments (such as valves, strainers, anchor rings, or bands) not covered in the Table, suitable stress intensification factors may be assumed by comparison of their significant geometry with that of the components shown.

319.4 Flexibility Analysis

319.4.1 Formal Analysis Not Required. No formal analysis of adequate flexibility is required for a piping system which:

(a) duplicates, or replaces without significant change, a system operating with a successful service record;

(b) can readily be judged adequate by comparison with previously analyzed systems;

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(c) is of uniform size, has no more than two points of fixation, no intermediate restraints, and falls within the limitations of empirical Eq. (16):[9]

$$\frac{Dy}{(L-U)^2} \le K_1 \qquad (16)$$

where

D = outside diameter of pipe, mm (in.)
y = resultant of total displacement strains, mm (in.), to be absorbed by the piping system
L = developed length of piping between anchors, m (ft)
U = anchor distance, straight line between anchors, m (ft)
K_1 = 208,000 S_A/E_a, $(mm/m)^2$
= 0.30 S_A/E_a, $(in./ft)^2$

where

S_A = allowable displacement stress range per Eq. (1a), MPa (ksi)
E_a = reference modulus of elasticity at 21°C (70°F), MPa (ksi)

319.4.2 Formal Analysis Requirements

(a) Any piping system which does not meet the criteria in para. 319.4.1 shall be analyzed by a simplified, approximate, or comprehensive method of analysis, as appropriate.

(b) A simplified or approximate method may be applied only if used within the range of configurations for which its adequacy has been demonstrated.

(c) Acceptable comprehensive methods of analysis include analytical and chart methods which provide an evaluation of the forces, moments, and stresses caused by displacement strains (see para. 319.2.1).

(d) Comprehensive analysis shall take into account stress intensification factors for any component other than straight pipe. Credit may be taken for the extra flexibility of such a component.

[9] *WARNING*: No general proof can be offered that this equation will yield accurate or consistently conservative results. It is not applicable to systems used under severe cyclic conditions. It should be used with caution in configurations such as unequal leg U-bends ($L/U > 2.5$) or near-straight "sawtooth" runs, or for large thin-wall pipe ($i \ge 5$), or where extraneous displacements (not in the direction connecting anchor points) constitute a large part of the total displacement. There is no assurance that terminal reactions will be acceptably low, even if a piping system falls within the limitations of Eq. (16).

319.4.3 Basic Assumptions and Requirements. Standard assumptions specified in para. 319.3 shall be followed in all cases. In calculating the flexibility of a piping system between anchor points, the system shall be treated as a whole. The significance of all parts of the line and of all restraints introduced for the purpose of reducing moments and forces on equipment or small branch lines, and also the restraint introduced by support friction, shall be recognized. Consider all displacements, as outlined in para. 319.2.1, over the temperature range defined by para. 319.3.1.

319.4.4 Flexibility Stresses

(a) The range of bending and torsional stresses shall be computed using the reference modulus of elasticity at 21°C (70°F), E_a, except as provided in para. 319.2.2(b)(4), and then combined in accordance with Eq. (17) to determine the computed displacement stress range S_E, which shall not exceed the allowable stress range S_A in para. 302.3.5(d).

$$S_E = \sqrt{S_b^2 + 4S_t^2} \qquad (17)$$

where

S_b = resultant bending stress
S_t = torsional stress
= $M_t/2Z$
M_t = torsional moment
Z = section modulus of pipe

(b) The resultant bending stresses S_b to be used in Eq. (17) for elbows, miter bends, and full size outlet branch connections (Legs 1, 2, and 3) shall be calculated in accordance with Eq. (18), with moments as shown in Figs. 319.4.4A and 319.4.4B.

$$S_b = \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z} \qquad (18)$$

where

S_b = resultant bending stress
i_i = in-plane stress intensification factor from Appendix D
i_o = out-plane stress intensification factor from Appendix D
M_i = in-plane bending moment
M_o = out-plane bending moment
Z = section modulus of pipe

(c) The resultant bending stress S_b to be used in Eq. (17) for reducing outlet branch connections shall be calculated in accordance with Eqs. (19) and (20), with moments as shown in Fig. 319.4.4B.

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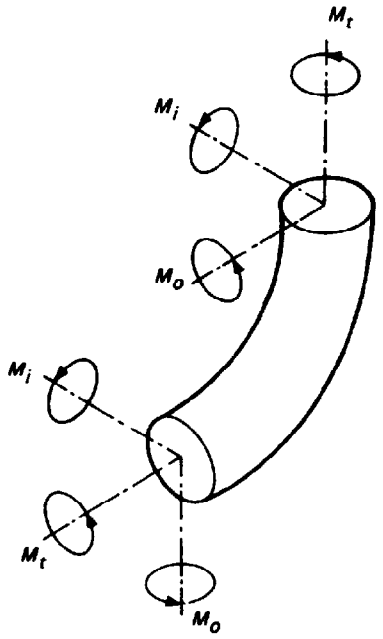

FIG. 319.4.4A MOMENTS IN BENDS

For header (Legs 1 and 2):

$$S_b = \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z} \quad (19)$$

For branch (Leg 3):

$$S_b = \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z_e} \quad (20)$$

where

S_b = resultant bending stress
Z_e = effective section modulus for branch,
$= \pi r_2^2 T_S$ (21)
r_2 = mean branch cross-sectional radius
T_S = effective branch wall thickness, lesser of $\overline{T}_h$ and $(i_i)(\overline{T}_b)$
$\overline{T}_h$ = thickness of pipe matching run of tee or header exclusive of reinforcing elements
$\overline{T}_b$ = thickness of pipe matching branch
i_o = out-plane stress intensification factor (Appendix D)
i_i = in-plane stress intensification factor (Appendix D)

319.4.5 Required Weld Quality Assurance. Any weld at which S_E exceeds $0.8S_A$ (as defined in para. 302.3.5) and the equivalent number of cycles N exceeds 7000 shall be fully examined in accordance with para. 341.4.3.

319.5 Reactions

Reaction forces and moments to be used in design of restraints and supports for a piping system, and in evaluating the effects of piping displacements on connected equipment, shall be based on the reaction range R for the extreme displacement conditions, considering the temperature range defined in para. 319.3.1(b), and using E_a. The designer shall consider instantaneous maximum values of forces and moments in the original and extreme displacement conditions (see para. 319.2.3), as well as the reaction range, in making these evaluations.

319.5.1 Maximum Reactions for Simple Systems. For a two-anchor piping system without intermediate restraints, the maximum instantaneous values of reaction forces and moments may be estimated from Eqs. (22) and (23).

(a) For Extreme Displacement Conditions, R_m. The temperature for this computation is the maximum or minimum metal temperature defined in para. 319.3.1(b), whichever produces the larger reaction:

$$R_m = R\left(1 - \frac{2C}{3}\right)\frac{E_m}{E_a} \quad (22)$$

where

C = cold-spring factor varying from zero for no cold spring to 1.0 for 100% cold spring. (The factor two-thirds is based on experience which shows that specified cold spring cannot be fully assured, even with elaborate precautions.)
E_a = reference modulus of elasticity at 21°C (70°F)
E_m = modulus of elasticity at maximum or minimum metal temperature
R = range of reaction forces or moments (derived from flexibility analysis) corresponding to the full displacement stress range and based on E_a
R_m = estimated instantaneous maximum reaction force or moment at maximum or minimum metal temperature

(b) For Original Condition, R_a. The temperature for

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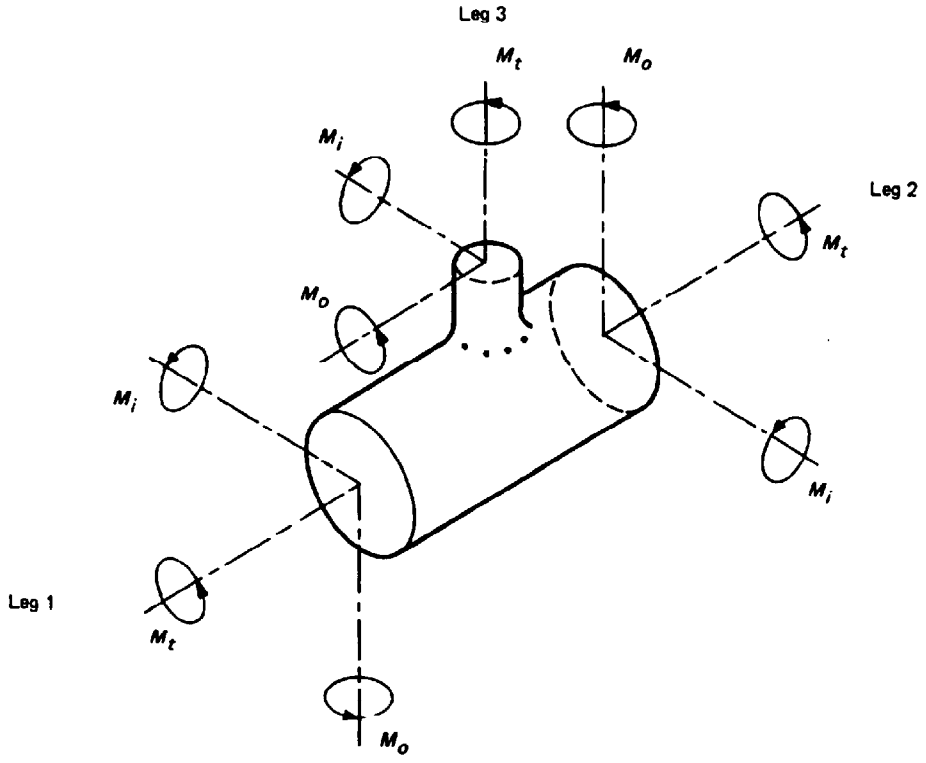

FIG. 319.4.4B MOMENTS IN BRANCH CONNECTIONS

this computation is the expected temperature at which the piping is to be assembled.

R_a = CR or C_1R, whichever is greater

where nomenclature is as in para. 319.5.1(a) and

$$C_1 = 1 - \frac{S_h E_a}{S_E E_m} \quad (23)$$

= estimated self-spring or relaxation factor; use zero if value of C_1 is negative

R_a = estimated instantaneous reaction force or moment at installation temperature

S_E = computed displacement stress range (see para. 319.4.4)

S_h = see definition in para. 302.3.5(d)

319.5.2 Maximum Reactions for Complex Systems. For multianchor piping systems and for two-anchor systems with intermediate restraints, Eqs. (22) and (23) are not applicable. Each case must be studied to estimate location, nature, and extent of local overstrain, and its effect on stress distribution and reactions.

319.6 Calculation of Movements

Calculations of displacements and rotations at specific locations may be required where clearance problems are involved. In cases where small-size branch pipes attached to stiffer run pipes are to be calculated separately, the linear and angular movements of the junction point must be calculated or estimated for proper analysis of the branch.

319.7 Means of Increasing Flexibility

The layout of piping often provides inherent flexibility through changes in direction, so that displacements produce chiefly bending and torsional strains within prescribed limits. The amount of axial tension or compression strain (which produces large reactions) usually is small.

Where the piping lacks built-in changes of direction, or where it is unbalanced [see para. 319.2.2(b)], large reactions or detrimental overstrain may be encountered. The designer should consider adding flexibility by one or more of the following means: bends, loops, or offsets; swivel joints; corrugated pipe; expansion joints

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of the bellows or slip-joint type; or other devices permitting angular, rotational, or axial movement. Suitable anchors, ties, or other devices shall be provided as necessary to resist end forces produced by fluid pressure, frictional resistance to movement, and other causes. When expansion joints or other similar devices are provided, the stiffness of the joint or device should be considered in any flexibility analysis of the piping.

321 PIPING SUPPORT

321.1 General

The design of support structures (not covered by this Code) and of supporting elements (see definitions of piping and pipe supporting elements in para. 300.2) shall be based on all concurrently acting loads transmitted into such supports. These loads, defined in para. 301, include weight effects, loads introduced by service pressures and temperatures, vibration, wind, earthquake, shock, and displacement strain (see para. 319.2.2).

For piping containing gas or vapor, weight calculations need not include the weight of liquid if the designer has taken specific precautions against entrance of liquid into the piping, and if the piping is not to be subjected to hydrostatic testing at initial construction or subsequent inspections.

321.1.1 Objectives. The layout and design of piping and its supporting elements shall be directed toward preventing the following:

(a) piping stresses in excess of those permitted in this Code;

(b) leakage at joints;

(c) excessive thrusts and moments on connected equipment (such as pumps and turbines);

(d) excessive stresses in the supporting (or restraining) elements;

(e) resonance with imposed or fluid-induced vibrations;

(f) excessive interference with thermal expansion and contraction in piping which is otherwise adequately flexible;

(g) unintentional disengagement of piping from its supports;

(h) excessive piping sag in piping requiring drainage slope;

(i) excessive distortion or sag of piping (e.g., thermoplastics) subject to creep under conditions of repeated thermal cycling;

(j) excessive heat flow, exposing supporting elements to temperature extremes outside their design limits.

321.1.2 Analysis. In general, the location and design of pipe supporting elements may be based on simple calculations and engineering judgment. However, when a more refined analysis is required and a piping analysis, which may include support stiffness, is made, the stresses, moments, and reactions determined thereby shall be used in the design of supporting elements.

321.1.3 Stresses for Pipe Supporting Elements. Allowable stresses for materials used for pipe supporting elements, except springs, shall be in accordance with para. 302.3.1. Longitudinal weld joint factors E_j, however, need not be applied to the allowable stresses for welded piping components which are to be used for pipe supporting elements.

321.1.4 Materials

(a) Permanent supports and restraints shall be of material suitable for the service conditions. If steel is cold-formed to a center line radius less than twice its thickness, it shall be annealed or normalized after forming.

(b) Cast, ductile, and malleable iron may be used for rollers, roller bases, anchor bases, and other supporting elements subject chiefly to compressive loading. Cast iron is not recommended if the piping may be subject to impact-type loading resulting from pulsation or vibration. Ductile and malleable iron may be used for pipe and beam clamps, hanger flanges, clips, brackets, and swivel rings.

(c) Steel of an unknown specification may be used for pipe supporting elements that are not welded directly to pressure containing piping components. (Compatible intermediate materials of known specification may be welded directly to such components.) Basic allowable stress in tension or compression shall not exceed 82 MPa (12 ksi) and the support temperature shall be within the range of −29°C to 343°C (−20°F to 650°F). For stress values in shear and bearing, see para. 302.3.1(b).

(d) Wood or other materials may be used for pipe supporting elements, provided the supporting element is properly designed, considering temperature, strength, and durability.

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(e) Attachments welded or bonded to the piping shall be of a material compatible with the piping and service. For other requirements, see para. 321.3.2.

321.1.5 Threads. Screw threads shall conform to ANSI B1.1 unless other threads are required for adjustment under heavy loads. Turnbuckles and adjusting nuts shall have the full length of internal threads engaged. Any threaded adjustment shall be provided with a locknut, unless locked by other means.

321.2 Fixtures

321.2.1 Anchors and Guides

(a) A supporting element used as an anchor shall be designed to maintain an essentially fixed position.

(b) To protect terminal equipment or other (weaker) portions of the system, restraints (such as anchors and guides) shall be provided where necessary to control movement or to direct expansion into those portions of the system which are designed to absorb them. The design, arrangement, and location of restraints shall ensure that expansion joint movements occur in the directions for which the joint is designed. In addition to the other thermal forces and moments, the effects of friction in other supports of the system shall be considered in the design of such anchors and guides.

(c) Piping layout, anchors, restraints, guides, and supports for all types of expansion joints shall be designed in accordance with para. X2.2 of Appendix X.

321.2.2 Inextensible Supports Other Than Anchors and Guides[10]

(a) Supporting elements shall be designed to permit the free movement of piping caused by thermal expansion and contraction.

(b) Hangers include pipe and beam clamps, clips, brackets, rods, straps, chains, and other devices. They shall be proportioned for all required loads. Safe loads for threaded parts shall be based on the root area of the threads.

(c) Sliding Supports. Sliding supports (or shoes) and brackets shall be designed to resist the forces due to friction in addition to the loads imposed by bearing. The dimensions of the support shall provide for the expected movement of the supported piping.

321.2.3 Resilient Supports[10]

(a) Spring supports shall be designed to exert a supporting force, at the point of attachment to the pipe, equal to the load as determined by weight balance calculations. They shall be provided with means to prevent misalignment, buckling, or eccentric loading of the springs, and to prevent unintentional disengagement of the load.

(b) Constant-support spring hangers provide a substantially uniform supporting force throughout the range of travel. The use of this type of spring hanger is advantageous at locations subject to appreciable movement with thermal changes. Hangers of this type should be selected so that their travel range exceeds expected movements.

(c) Means shall be provided to prevent overstressing spring hangers due to excessive deflections. It is recommended that all spring hangers be provided with position indicators.

321.2.4 Counterweight Supports. Counterweights shall be provided with stops to limit travel. Weights shall be positively secured. Chains, cables, hangers, rocker arms, or other devices used to attach the counterweight load to the piping shall be subject to the requirements of para. 321.2.2.

321.2.5 Hydraulic Supports. An arrangement utilizing a hydraulic cylinder may be used to give a constant supporting force. Safety devices and stops shall be provided to support the load in case of hydraulic failure.

321.3 Structural Attachments

External and internal attachments to piping shall be designed so that they will not cause undue flattening of the pipe, excessive localized bending stresses, or harmful thermal gradients in the pipe wall. It is important that attachments be designed to minimize stress concentration, particularly in cyclic services.

321.3.1 Nonintegral Attachments. Nonintegral attachments, in which the reaction between the piping and the attachment is by contact, include clamps, slings, cradles, U-bolts, saddles, straps, and clevises. If the weight of a vertical pipe is supported by a clamp, it is recommended to prevent slippage that the clamp be located below a flange, fitting, or support lugs welded to the pipe.

321.3.2 Integral Attachments. Integral attachments include plugs, ears, shoes, plates, and angle clips, cast on or welded to the piping. The material for integral attachments attached by welding shall be of good weldable quality. [See para. 321.1.4(e) for material requirements.] Preheating, welding, and heat treatment

[10] Various types of inextensible (solid) and resilient supports are illustrated in MSS SP-58.

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shall be in accordance with Chapter V. Consideration shall be given to the localized stresses induced in the piping component by welding the integral attachment.

(a) Integral reinforcement, complete encirclement reinforcement, or intermediate pads of suitable alloy and design may be used to reduce contamination or undesirable heat effects in alloy piping.

(b) Intermediate pads, integral reinforcement, complete encirclement reinforcement, or other means of reinforcement may be used to distribute stresses.

321.4 Structural Connections

The load from piping and pipe supporting elements (including restraints and braces) shall be suitably transmitted to a pressure vessel, building, platform, support structure, foundation, or to other piping capable of bearing the load without deleterious effects.

PART 6
SYSTEMS

322 SPECIFIC PIPING SYSTEMS

322.3 Instrument Piping

322.3.1 Definition. Instrument piping within the scope of this Code includes all piping and piping components used to connect instruments to other piping or equipment, and control piping used to connect air or hydraulically operated control apparatus. It does not include instruments, or permanently sealed fluid-filled tubing systems furnished with instruments as temperature or pressure responsive devices.

322.3.2 Requirements. Instrument piping shall meet the applicable requirements of the Code and the following.

(a) The design pressure and temperature for instrument piping shall be determined in accordance with para. 301. If more severe conditions are experienced during blowdown of the piping, they may be treated as occasional variations in accordance with para. 302.2.4.

(b) Consideration shall be given to the mechanical strength (including fatigue) of small instrument connections to piping or apparatus (see para. 304.3.5).

(c) Instrument piping containing fluids which are normally static and subject to freezing shall be protected by heat tracing or other heating methods, and insulation.

(d) If it will be necessary to blow down (or bleed) instrument piping containing toxic or flammable fluids, consideration shall be given to safe disposal.

322.6 Pressure Relieving Systems

Pressure relieving systems within the scope of this Code shall conform to the following requirements. See also Appendix F, para. F322.6.

322.6.1 Stop Valves in Pressure Relief Piping. If one or more stop valves are installed between the piping being protected and its protective device or devices, or between the protective device or devices and the point of discharge, they shall meet the requirements of (a) and either (b) or (c), below.

(a) A full-area stop valve may be installed on the inlet side of a pressure relieving device. A full area stop valve may be placed on the discharge side of a pressure relieving device when its discharge is connected to a common header with other discharge lines from other pressure relieving devices. Stop valves of less than full area may be used on both the inlet side and discharge side of pressure relieving devices as outlined herein if the stop valves are of such type and size that the increase in pressure drop will not reduce the relieving capacity below that required, nor adversely affect the proper operation of the pressure relieving device.

(b) Stop valves to be used in pressure relief piping shall be so constructed or positively controlled that the closing of the maximum number of block valves possible at one time will not reduce the pressure relieving capacity provided by the unaffected relieving devices below the required relieving capacity.

(c) As an alternative to (b) above, stop valves shall be so constructed and arranged that they can be locked or sealed in either the open or closed position. See Appendix F, para. F322.6.

322.6.2 Pressure Relief Discharge Piping. Discharge lines from pressure relieving safety devices shall be designed to facilitate drainage. When discharging directly to the atmosphere, discharge shall not impinge on other piping or equipment and shall be directed away from platforms and other areas used by personnel. Reactions on the piping system due to actuation of safety relief devices shall be considered, and adequate strength shall be provided to withstand these reactions.

322.6.3 Pressure Relieving Devices

(a) Pressure relieving devices required by para. 301.2.2(a) shall be in accordance with the BPV Code, Section VIII, Division 1, UG-125(c), UG-126 through UG-128, and UG-132 through UG-136, excluding UG-

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135(e) and UG-136(c). The terms "design pressure"[11] and "piping system" shall be substituted for "maximum allowable working pressure" and "vessel," respectively, in these paragraphs. The required relieving capacity of any pressure relieving device shall include consideration of all piping systems which it protects.

(b) Relief set pressure[12] shall be in accordance with Section VIII, Division 1, with the exceptions stated in alternatives (1) and (2), below.

(1) With the owner's approval the set pressure may exceed the limits in Section VIII, Division 1, provided that the limit on maximum relieving pressure stated in (c) below will not be exceeded.

(2) For a liquid thermal expansion relief device which protects only a blocked-in portion of a piping system, the set pressure shall not exceed the lesser of the system test pressure or 120% of design pressure.

(c) The maximum relieving pressure[13] shall be in accordance with Section VIII, Division 1, with the exception that the allowances in para. 302.2.4(f) are permitted, provided that all other requirements of para. 302.2.4 are also met.

[11] The *design pressure* for pressure relief is the maximum design pressure permitted, considering all components in the piping system.

[12] *Set pressure* is the pressure at which the device begins to relieve, e.g., lift pressure of a spring-actuated relief valve, bursting pressure of a rupture disk, or breaking pressure of a breaking pin device.

[13] *Maximum relieving pressure* is the maximum system pressure during a pressure relieving event.

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CHAPTER III
MATERIALS

323 GENERAL REQUIREMENTS

Chapter III states limitations and required qualifications for materials based on their inherent properties. Their use in piping is also subject to requirements and limitations in other parts of this Code [see para. 300(d)]. See also para. 321.1.4 for support materials, and Appendix F, para. F323, for precautionary considerations.

323.1 Materials and Specifications

323.1.1 Listed Materials. Any material used in pressure containing piping components shall conform to a listed specification except as provided in para. 323.1.2.

323.1.2 Unlisted Materials. Unlisted materials may be used provided they conform to a published specification covering chemistry, physical and mechanical properties, method and process of manufacture, heat treatment, and quality control, and otherwise meet the requirements of this Code. Allowable stresses shall be determined in accordance with the applicable allowable stress basis of this Code or a more conservative basis.

323.1.3 Unknown Materials. Materials of unknown specification shall not be used for pressure-containing piping components.

323.1.4 Reclaimed Materials. Reclaimed pipe and other piping components may be used, provided they are properly identified as conforming to a listed or published specification (para. 323.1.1 or 323.1.2) and otherwise meet the requirements of this Code. Sufficient cleaning and inspection shall be made to determine minimum wall thickness and freedom from imperfections which would be unacceptable in the intended service.

323.2 Temperature Limitations

The designer shall verify that materials which meet other requirements of the Code are suitable for service throughout the operating temperature range. Attention is directed to Note (7) in Appendix A, which explains the means used to set both cautionary and restrictive temperature limits in Tables A-1 and A-2.

323.2.1 Upper Temperature Limits, Listed Materials. A listed material may be used at a temperature above the maximum for which a stress value or rating is shown, only if:

(a) there is no prohibition in Appendix A or elsewhere in the Code; and

(b) the designer verifies the serviceability of the material in accordance with para. 323.2.4.

323.2.2 Lower Temperature Limits, Listed Materials

(a) A listed material may be used at any temperature not lower than the minimum shown in Table A-1, provided that the base metal, weld deposits, and heat-affected zone (HAZ) are qualified as required by the applicable entry in Column A of Table 323.2.2.

(b) For carbon steels with a letter designation in the Min. Temp. column of Table A-1, the minimum temperature is defined by the applicable curve and Notes in Fig. 323.2.2. If a design minimum metal temperature-thickness combination is on or above the curve, impact testing is not required.

(c) A listed material may be used at a temperature lower than the minimum shown in Table A-1 or Fig. 323.2.2 (including Notes), unless prohibited in Table 323.2.2, Table A-1, or elsewhere in the Code, and provided that the base metal, weld deposits, and HAZ are qualified as required by the applicable entry in Column B of Table 323.2.2.

(d) The allowable stress or component rating at any temperature below the minimum shown in Table A-1 or Fig. 323.2.2 shall not exceed the stress value or rating at the minimum temperature in Table A-1 or the component standard.

(e) Impact testing is not required for the following combinations of weld metals and design minimum temperatures:

(1) for austenitic stainless steel base materials having a carbon content not exceeding 0.10%, welded without filler metal, at design minimum temperatures of −101°C (−150°F) and higher.

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TABLE 323.2.2
REQUIREMENTS FOR LOW TEMPERATURE TOUGHNESS TESTS FOR METALS
These Toughness Test Requirements Are in Addition to Tests Required by the Material Specification

	Type of Material	Column A Design Minimum Temperature at or Above Min. Temp. in Table A-1 or Fig. 323.2.2		Column B Design Minimum Temperature Below Min. Temp. in Table A-1 or Fig. 323.2.2
Listed materials — Materials	1 Gray cast iron	A-1 No additional requirements		B-1 No additional requirements
	2 Malleable and ductile cast iron; carbon steel per Note (1)	A-2 No additional requirements		B-2 Materials designated in Box 2 shall not be used.
		(a) Base Metal	(b) Weld Metal and Heat Affected Zone (HAZ) [Note (2)]	
	3 Other carbon steels; low and intermediate alloy steels; high alloy ferritic steels; duplex stainless steels	A-3 (a) No additional requirements	A-3 (b) Weld metal deposits shall be impact tested per para. 323.3 if design min. temp. < −29°C (−20°F), except as provided in Notes (3) and (5), and except as follows: for materials listed for Curves C and D of Fig. 323.2.2, where corresponding welding consumables are qualified by impact testing at a temperature of −46°C (−50°F) or lower in accordance with the applicable AWS specification, additional testing is not required.	B-3 Except as provided in Notes (3) and (5), heat treat base metal per applicable ASTM specification listed in para. 323.3.2; then impact test base metal, weld deposits, and HAZ per para. 323.3 [see Note (2)]. When materials are used at design min. temp. below the assigned curve as permitted by Notes (2) and (3) of Fig. 323.2.2, weld deposits and HAZ shall be impact tested [see Note (2)].
	4 Austenitic stainless steels	A-4 (a) If: (1) carbon content by analysis > 0.1%; or (2) material is not in solution heat treated condition; then, impact test per para. 323.3 for design min. temp. < −29°C (−20°F) except as provided in Notes (3) and (6)	A-4 (b) Weld metal deposits shall be impact tested per para. 323.3 if design min. temp. < −29°C (−20°F) except as provided in para. 323.2.2 and in Notes (3) and (6)	B-4 Base metal and weld metal deposits shall be impact tested per para. 323.3. See Notes (2), (3), and (6).
	5 Austenitic ductile iron, ASTM A 571	A-5 (a) No additional requirements	A-5 (b) Welding is not permitted	B-5 Base metal shall be impact tested per para. 323.3. Do not use < −196°C (−320°F). Welding is not permitted.
	6 Aluminum, copper, nickel, and their alloys; unalloyed titanium	A-6 (a) No additional requirements	A-6 (b) No additional requirements unless filler metal composition is outside the range for base metal composition; then test per column B-6	B-6 Designer shall be assured by suitable tests [see Note (4)] that base metal, weld deposits, and HAZ are suitable at the design min. temp.
Unlisted	7 An unlisted material shall conform to a published specification. Where composition, heat treatment, and product form are comparable to those of a listed material, requirements for the corresponding listed material shall be met. Other unlisted materials shall be qualified as required in the applicable section of column B.			

Notes to this Table follow on next page

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TABLE 323.2.2 (CONT'D)

NOTES:
(1) Carbon steels conforming to the following are subject to the limitations in Box B-2; plates per ASTM A 36, A 283, and A 570; pipe per ASTM A 134 when made from these plates; and pipe per ASTM A 53 Type F and API 5L Gr. A25 buttweld.
(2) Impact tests that meet the requirements of Table 323.3.1, which are performed as part of the weld procedure qualification, will satisfy all requirements of para. 323.2.2, and need not be repeated for production welds.
(3) Impact testing is not required if the design temperature is at or above −46°C (−50°F), and the maximum operating pressure of the manufactured components will not exceed 25% of the maximum allowable design pressure at ambient temperature, and the combined longitudinal stress due to pressure, dead weight, and displacement strain (see para. 319.2.1) does not exceed 41 MPa (6 ksi). Use of stress intensification factors when making these calculations is not required.
(4) Tests may include tensile elongation, sharp-notch tensile strength (to be compared with unnotched tensile strength), and/or other tests, conducted at or below design minimum temperature. See also para. 323.3.4.
(5) Impact tests are not required when the maximum obtainable Charpy specimen has a width along the notch of less than 2.5 mm (0.098 in.). Under these conditions, the design minimum temperature shall not be less than the lower of −46°C (−50°F) or the minimum temperature for the material in Table A-1.
(6) Impact tests are not required when the maximum obtainable Charpy specimen has a width along the notch of less than 2.5 mm (0.098 in.).

(2) for austenitic weld metal:

(a) having a carbon content not exceeding 0.10%, and produced with filler metals conforming to AWS A5.4, A5.9, A5.11, A5.14, or A5.22[1] at design minimum temperatures of −101°C (−150°F) and higher; or

(b) having a carbon content exceeding 0.10%, and produced with filler metals conforming to AWS A5.4, A5.9, A5.11, A5.14, or A5.22[1] at design minimum temperatures of −46°C (−50°F) and higher.

323.2.3 Temperature Limits, Unlisted Materials. An unlisted material, acceptable under para. 323.1.2, shall be qualified for service at all temperatures within a stated range, from design minimum temperature to design (maximum) temperature, in accordance with para. 323.2.4.

323.2.4 Verification of Serviceability

(a) When an unlisted material is to be used, or when a listed material is to be used above the highest temperature for which stress values appear in Appendix A, the designer is responsible for demonstrating the validity of the allowable stresses and other limits used in design and of the approach taken in using the material, including the derivation of stress data and the establishment of temperature limits.

(b) Data for the development of design limits shall be obtained from a sound scientific program carried out in accordance with recognized technology for both the material and the intended service conditions. Factors to be considered include:

(1) applicability and reliability of the data, especially for extremes of the temperature range;

(2) resistance of the material to deleterious effects of the fluid service and of the environment throughout the temperature range; and

(3) determination of allowable stresses in accordance with para. 302.3.

323.3 Impact Testing Methods and Acceptance Criteria

323.3.1 General. When impact testing is required by Table 323.2.2, provisions elsewhere in this Code, or the engineering design, it shall be done in accordance with Table 323.3.1 using the testing methods and acceptance criteria described in paras. 323.3.2 through 323.3.5.

323.3.2 Procedure. Impact testing of each product form of material for any specification (including welds in the components) shall be done using procedures and apparatus in accordance with ASTM A 370, and in conformance with impact testing requirements of the following specifications, except that specific requirements of this Code which conflict with requirements of those specifications shall take precedence.

Product Form	ASTM Spec. No.
Pipe	A 333
Tube	A 334
Fittings	A 420
Forgings	A 350
Castings	A 352
Bolting	A 320
Plate	A 20

GENERAL NOTE: Titles of referenced standards not listed in the Specifications Index for Appendix A are: A 20 General Requirements for Steel Plates for Pressure Vessels and A 370 Test Methods and Definitions for Mechanical Testing of Steel Products.

[1] Titles of referenced AWS standards are as follows: AWS A5.4, Stainless Steel Electrodes for Shielded Metal Arc Welding; AWS A5.9, Bare Stainless Steel Welding Electrodes and Rods; AWS A5.11, Nickel and Nickel Alloy Welding Electrodes for Shielded Metal Arc Welding; AWS A5.14, Nickel and Nickel Alloy Bare Welding Electrodes and Rods; and AWS A5.22, Flux Cored Corrosion-Resisting Chromium and Chromium-Nickel Steel Electrodes.

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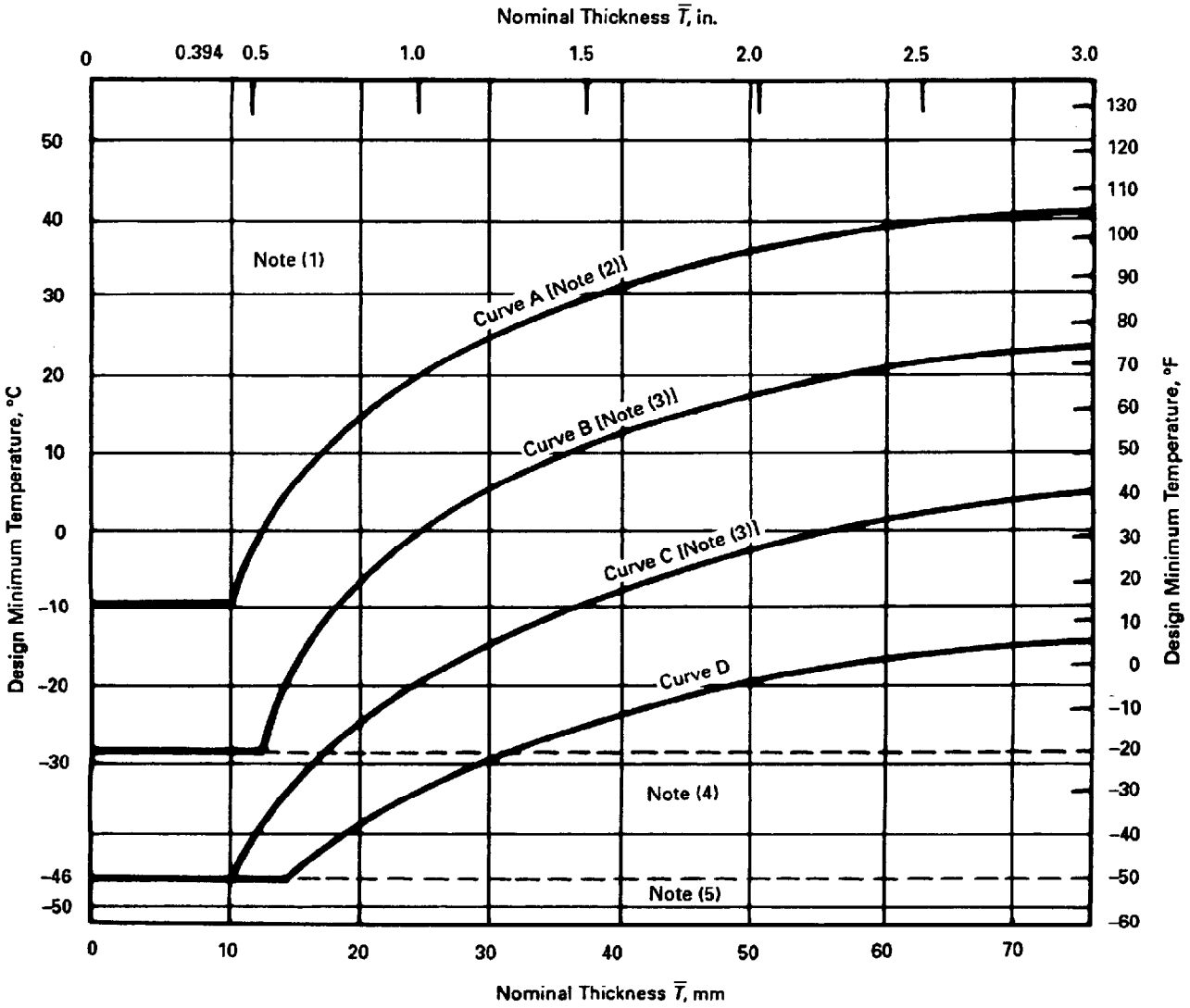

NOTES:

(1) Any carbon steel material may be used to a minimum temperature of -29°C (-20°F) for Category D Fluid Service.

(2) X Grades of API 5L, and ASTM A 381 materials, may be used in accordance with Curve B if normalized or quenched and tempered.

(3) The following materials may be used in accordance with Curve D if normalized:
- (a) ASTM A 516 Plate, all grades;
- (b) ASTM A 671 Pipe, Grades CE55, CE60, and all grades made with A 516 plate;
- (c) ASTM A 672 Pipe, Grades E55, E60, and all grades made with A 516 plate.

(4) A welding procedure for the manufacture of pipe or components shall include impact testing of welds and HAZ for any design minimum temperature below -29°C (-20°F), except as provided in Table 323.2.2, A-3(b).

(5) Impact testing in accordance with para. 323.3 is required for any design minimum temperature below -46°C (-50°F).

FIG. 323.2.2 MINIMUM TEMPERATURES WITHOUT IMPACT TESTING FOR CARBON STEEL MATERIALS

(See Table A-1 for Designated Curve for a Listed Material)

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TABLE 323.3.1
IMPACT TESTING REQUIREMENTS FOR METALS

	Test Characteristics	Column A Materials Tested by the Manufacturer [See Note (1)] or Those in Table 323.2.2 Requiring Impact Tests Only on Welds	Column B Materials Not Tested by the Manufacturer or Those Tested But Heat Treated During or After Fabrication
Tests Materials	Number of tests	A-1 The greater of the number required by: (a) the material specification; or (b) the applicable specification listed in para. 323.3.2. See Note (2).	B-1 The number required by the applicable specification listed in para. 323.3.2. See Note (2).
	Location and orientation of specimens	A-2 As required by the applicable specification listed in para. 323.3.2.	
	Tests by	A-3 The manufacturer	B-3 The fabricator or erector
Tests on Welds in Fabrication or Assembly	Test piece for preparation of impact specimens	A-4 One required for each welding procedure, for each type of filler metal (i.e., AWS E-XXXX classification), and for each flux to be used. Test pieces shall be subjected to essentially the same heat treatment (including time at temperature or temperatures and cooling rate) as the erected piping will have received.	
	Number of test pieces [see Note (3)]	A-5 (a) One piece, thickness T, for each range of material thickness from $T/2$ to T + 6.4 mm (¼ in.). (b) Unless required by the engineering design, pieces need not be made from each lot, nor from material for each job, provided that welds have been tested as required by Section 4 above, for the same type and grade of material (or for the same P-Number and Group Number in BPV Code, Section IX), and of the same thickness range, and that records of the tests are made available.	B-5 (a) One piece from each lot of material in each specification and grade including heat treatment [see Note (4)] unless; (b) materials are qualified by the fabricator or erector as specified in Sections B-1 and B-2 above, in which case the requirements of Section A-5 apply.
	Location and orientation of specimens	6 (a) Weld metal: across the weld, with notch in the weld metal; notch axis shall be normal to material surface, with one face of specimen ≤ 1.5 mm (1/16 in.) from the material surface. (b) Heat affected zone (HAZ): across the weld and long enough to locate notch in the HAZ after etching; notch axis shall be approximately normal to material surface and shall include as much as possible of the HAZ in the fracture.	
	Tests by	7 The fabricator or erector	

NOTES:
(1) A certified report of impact tests performed (after being appropriately heat treated as required by Table 323.2.2, item B-3) by the manufacturer shall be obtained as evidence that the material (including any welds used in its manufacture) meets the requirements of this Code, and that:
  (a) the tests were conducted on specimens representative of the material delivered to and used by the fabricator or erector; or,
  (b) the tests were conducted on specimens removed from test pieces of the material which received heat treatment separately in the same manner as the material (including heat treatment by the manufacturer) so as to be representative of the finished piping:
(2) If welding is used in manufacture, fabrication, or erection, tests of the HAZ will suffice for the tests of the base material.
(3) The test piece shall be large enough to permit preparing three specimens from the weld metal and three from the HAZ (if required) per para. 323.3. If this is not possible, preparation of additional test pieces is required.
(4) For purposes of this requirement, "lot" means the quantity of material described under the "Number of tests" provision of the specification applicable to the product term (i.e., plate, pipe, etc.) listed in para. 323.3.2.

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323.3.3 Test Specimens. Each set of impact test specimens shall consist of three specimen bars. All impact tests shall be made using standard 10 mm (0.394 in.) square cross section Charpy V-notch specimen bars, except when the material shape or thickness does not permit. Charpy impact tests may be performed on specimens of full material thickness, which may be machined to remove surface irregularities. Alternatively, such material may be reduced in thickness to produce the largest possible Charpy subsize specimen. See Table 323.3.4.

323.3.4 Test Temperatures. For all Charpy impact tests, the test temperature criteria in para. 323.3.4(a) or (b) shall be observed. The test specimens, as well as the handling tongs, shall be cooled for a sufficient length of time to reach the test temperature.

(a) For Materials of Thickness Equal to or Greater Than 10 mm (0.394 in.). Where the largest attainable Charpy V-notch specimen has a width along the notch of at least 8 mm (0.315 in.), the Charpy test using such a specimen shall be conducted at a temperature not higher than the design minimum temperature. Where the largest possible test specimen has a width along the notch less than 8 mm, the test shall be conducted at a temperature lower than the design minimum temperature by the amount shown in Table 323.3.4 for that specimen width.

(b) For Materials With Thickness Less Than 10 mm (0.394 in.). Where the largest attainable Charpy V-notch specimen has a width along the notch of at least 80% of the material thickness, the Charpy test of such a specimen shall be conducted at a temperature not higher than the design minimum temperature. Where the largest possible test specimen has a width along the notch of less than 80% of the material thickness, the test shall be conducted at a temperature lower than the design minimum temperature by an amount equal to the difference (referring to Table 323.3.4) between the temperature reduction corresponding to the actual material thickness and the temperature reduction corresponding to the Charpy specimen width actually tested.

323.3.5 Acceptance Criteria

(a) Minimum Energy Requirements. Except for bolting materials, the applicable minimum energy requirement for carbon and low alloy steels with specified minimum tensile strengths less than 656 MPa (95 ksi) shall be those shown in Table 323.3.5.

(b) Lateral Expansion Requirements. Other carbon and low alloy steels having specified minimum tensile strengths equal to or greater than 656 MPa (95 ksi), all bolting materials, and all high alloy steels (P-Nos. 6, 7, and 8) shall have a lateral expansion opposite the notch of not less than 0.38 mm (0.015 in.) for all specimen sizes. The lateral expansion is the increase in width of the broken impact specimen over that of the unbroken specimen measured on the compression side, parallel to the line constituting the bottom of the V-notch (see ASTM A 370).

TABLE 323.3.4
CHARPY IMPACT TEST TEMPERATURE REDUCTION[1]

Actual Material Thickness [See Para. 323.3.4(b)] or Charpy Impact Specimen Width Along the Notch [Note (2)]		Temperature Reduction Below Design Minimum Temperature	
mm	in.	°C	°F
10 (full size standard bar)	0.394	0	0
9	0.354	0	0
8	0.315	0	0
7.5 (¾ size bar)	0.295	2.8	5
7	0.276	4.4	8
6.67 (⅔ size bar)	0.262	5.6	10
6	0.236	8.3	15
5 (½ size bar)	0.197	11.1	20
4	0.157	16.7	30
3.33 (⅓ size bar)	0.131	19.4	35
3	0.118	22.2	40
2.5 (¼ size bar)	0.098	27.8	50

NOTES:
(1) These temperature reduction criteria do not apply when Table 323.3.5 specifies lateral expansion for minimum required values.
(2) Straight line interpolation for intermediate values is permitted.

(c) Weld Impact Test Requirements. Where two base metals having different required impact energy values are joined by welding, the impact test energy requirements shall conform to the requirements of the base material having a specified minimum tensile strength most closely matching the specified minimum tensile strength of the weld metal.

(d) Retests

(1) For Absorbed Energy Criteria. When the average value of the three specimens equals or exceeds the minimum value permitted for a single specimen and the value for more than one specimen is below the required average value, or when the value for one

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TABLE 323.3.5
MINIMUM REQUIRED CHARPY V-NOTCH IMPACT VALUES

Specified Minimum Tensile Strength	No. of Specimens [Note (2)]	Energy [Note (1)]			
		Fully Deoxidized Steels		Other Than Fully Deoxidized Steels	
		Joules	ft-lbf	Joules	ft-lbf
(a) Carbon and Low Alloy Steels					
448 MPa (65 ksi) and less	Average for 3 specimens	18	13	14	10
	Minimum for 1 specimen	16	10	10	7
Over 448 to 517 MPa (75 ksi)	Average for 3 specimens	20	15	18	13
	Minimum for 1 specimen	16	12	14	10
Over 517 but not incl. 656 MPa (95 ksi)	Average for 3 specimens	27	20	...	...
	Minimum for 1 specimen	20	15	...	...
		Lateral Expansion			
656 MPa and over [Note (3)]	Minimum for 3 specimens	0.38 mm (0.015 in.)			
(b) Steels in P-Nos. 6, 7, and 8	Minimum for 3 specimens	0.38 mm (0.015 in.)			

NOTES:
(1) Energy values in this Table are for standard size specimens. For subsize specimens, these values shall be multiplied by the ratio of the actual specimen width to that of a full-size specimen, 10 mm (0.394 in.).
(2) See para. 323.3.5(d) for permissible retests.
(3) For bolting of this strength level in nominal sizes M 52 (2 in.) and under, the impact requirements of ASTM A 320 may be applied. For bolting over M 52, requirements of this Table shall apply.

specimen is below the minimum value permitted for a single specimen, a retest of three additional specimens shall be made. The value for each of these retest specimens shall equal or exceed the required average value.

(2) For Lateral Expansion Criterion. If the value of lateral expansion for one specimen in a group of three is below 0.38 mm (0.015 in.) but not below 0.25 mm (0.01 in.), and if the average value for three specimens equals or exceeds 0.38 mm (0.015 in.), a retest of three additional specimens may be made, each of which must equal or exceed the specified minimum value of 0.38 mm (0.015 in.). In the case of heat treated materials, if the required values are not obtained in the retest or if the values in the initial test are below the minimum allowed for retest, the material may be reheat treated and retested. After reheat treatment, a set of three specimens shall be made. For acceptance, the lateral expansion of each of the specimens must equal or exceed the specified minimum value of 0.38 mm (0.015 in.).

(3) For Erratic Test Results. When an erratic result is caused by a defective specimen or there is uncertainty in the test procedure, a retest will be allowed.

323.4 Fluid Service Requirements for Materials

323.4.1 General. Requirements in para. 323.4 apply to pressure containing parts. They do not apply to materials used for supports, gaskets, packing, or bolting. See also Appendix F, para. F323.4.

323.4.2 Specific Requirements

(a) Ductile Iron. Ductile iron shall not be used for pressure containing parts at temperatures below −29°C (−20°F) (except austenitic ductile iron) or above 343°C (650°F). Austenitic ductile iron conforming to ASTM A 571 may be used at temperatures below −29°C (−20°F) down to the temperature of the impact test conducted in accordance with that specification but not below −196°C (−320°F).

Valves having bodies and bonnets or covers made of materials conforming to ASTM A 395 and meeting the requirements of ASME B16.42 and additional requirements of ASME B16.34 Standard Class, API 594, API 599, or API 609 may be used within the pressure-temperature ratings given in ASME B16.42.

Welding shall not be performed in the fabrication or repair of ductile iron components nor in assembly of such components in a piping system.

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(b) Other Cast Irons. The following shall not be used under severe cyclic conditions. If safeguarding is provided against excessive heat and thermal shock and mechanical shock and abuse, they may be used in other services subject to the following requirements.

(1) Cast iron shall not be used above ground within process unit limits in hydrocarbon or other flammable fluid service at temperatures above 149°C (300°F) nor at gage pressures above 1035 kPa (150 psi). In other locations the pressure limit shall be 2760 kPa (400 psi).

(2) Malleable iron shall not be used in any fluid service at temperatures below −29°C (−20°F) or above 343°C (650°F) and shall not be used in flammable fluid service at temperatures above 149°C (300°F) nor at gage pressures above 2760 kPa (400 psi).

(3) High silicon iron (14.5% Si) shall not be used in flammable fluid service. The manufacturer should be consulted for pressure-temperature ratings and for precautionary measures when using this material.

(c) Other Materials

(1) If welding or thermal cutting is performed on aluminum castings, the stress values in Appendix A and component ratings listed in Table 326.1 are not applicable. It is the designer's responsibility to establish such stresses and ratings consistent with the requirements of this Code.

(2) Lead and tin and their alloys shall not be used in flammable fluid services.

323.4.3 Cladding and Lining Materials. Materials with metallic cladding or metallic lining may be used in accordance with the following provisions.

(a) If piping components are made from integrally clad plate conforming to:

(1) ASTM A 263, Corrosion-Resisting Chromium Steel Clad Plate, Sheet, and Strip, or

(2) ASTM A 264, Stainless Chromium-Nickel Steel Clad Plate, Sheet, and Strip, or

(3) ASTM A 265, Nickel and Nickel-Base Alloy Clad Plate, Sheet, and Strip, pressure design in accordance with rules in para. 304 may be based upon the total thickness of base metal and cladding after any allowance for corrosion has been deducted, provided that both the base metal and the cladding metal are acceptable for Code use under para. 323.1, and provided that the clad plate has been shear tested and meets all shear test requirements of the applicable ASTM specification. The allowable stress for each material (base and cladding) shall be taken from Appendix A, or determined in accordance with the rules in para. 302.3, provided, however, that the allowable stress used for the cladding portion of the design thickness shall never be greater than the allowable stress used for the base portion.

(b) For all other metallic clad or lined piping components, the base metal shall be an acceptable Code material as defined in para. 323.1 and the thickness used in pressure design in accordance with para. 304 shall not include the thickness of the cladding or lining. The allowable stress used shall be that for the base metal at the design temperature. For such components, the cladding or lining may be any material that, in the judgment of the user, is suitable for the intended service and for the method of manufacture and assembly of the piping component.

(c) Except for components designed in accordance with provisions of para. 323 4.3(a), fluid service requirements for materials stated in this Code shall not restrict their use as cladding or lining in pipe or other components. Fluid service requirements for the outer material (including those for components and joints) shall govern, except that temperature limitations of both inner and outer materials, and of any bond between them, shall be considered.

(d) Fabrication by welding of clad or lined piping components and the inspection and testing of such components shall be done in accordance with applicable provisions of the BPV Code, Section VIII, Division 1, UCL-30 through UCL-52, or the provisions of Chapters V and VI of this Code, whichever are more stringent.

323.5 Deterioration of Materials in Service

Selection of material to resist deterioration in service is not within the scope of this Code. It is the designer's responsibility to select materials suitable for the fluid service. Recommendations based on experience are presented for guidance in Appendix F, para. F323.

325 MATERIALS — MISCELLANEOUS

325.1 Joining and Auxiliary Materials

When selecting materials such as adhesives, cements, solvents, solders, brazing materials, packing, and O-rings for making or sealing joints, the designer shall consider their suitability for the fluid service. (Consideration should also be given to the possible effects of the joining or auxiliary materials on the fluid handled.)

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CHAPTER IV
STANDARDS FOR PIPING COMPONENTS

326 DIMENSIONS AND RATINGS OF COMPONENTS

326.1 Dimensional Requirements

326.1.1 Listed Piping Components. Dimensional standards[1] for piping components are listed in Table 326.1. Dimensional requirements contained in specifications listed in Appendix A shall also be considered requirements of this Code.

326.1.2 Unlisted Piping Components. Dimensions of piping components not listed in Table 326.1 or Appendix A shall conform to those of comparable listed components insofar as practicable. In any case, dimensions shall be such as to provide strength and performance equivalent to standard components except as provided in paras. 303 and 304.

326.1.3 Threads. The dimensions of piping connection threads not otherwise covered by a governing component standard or specification shall conform to the requirements of applicable standards listed in Table 326.1 or Appendix A.

326.2 Ratings of Components

326.2.1 Listed Components. The pressure-temperature ratings of components listed in Table 326.1 are accepted for pressure design in accordance with para. 303.

326.2.2 Unlisted Components. The pressure-temperature ratings of unlisted piping components shall conform to the applicable provisions of para. 304.

[1] It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and address of sponsoring organizations, are shown in Appendix E.

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TABLE 326.1
COMPONENT STANDARDS[1]

Standard or Specification	Designation [Note (2)]
Bolting	
Square and Hex Bolts and Screws, Inch Series, Including Hex Cap Screws and Lag Screws	*ASME B18.2.1
Square and Hex Nuts (Inch Series)	*ASME B18.2.2
Metallic Fittings, Valves, and Flanges	
Cast Iron Pipe Flanges and Flanged Fittings	ANSI B16.1
Malleable Iron Threaded Fittings	*ASME B16.3
Gray Iron Threaded Fittings	*ASME B16.4
Pipe Flanges and Flanged Fittings	*ASME B16.5
Factory-Made Wrought Steel Buttwelding Fittings	*ASME B16.9
Face-to-Face and End-To-End Dimensions of Valves	*ASME B16.10
Forged Fittings, Socket-Welding and Threaded	*ASME B16.11
Ferrous Pipe Plugs, Bushings, and Locknuts With Pipe Threads	*ASME B16.14
Cast Bronze Threaded Fittings, Class 125 and 250 [Notes (3), (4)]	*ASME B16.15
Cast Copper Alloy Solder Joint Pressure Fittings	*ASME B16.18
Wrought Copper and Copper Alloy Solder Joint Pressure Fittings	*ASME B16.22
Bronze Pipe Flanges and Flanged Fittings Class 150, 300, 400, 600, 900, 1500, and 2500 and Flanged Fittings, Class 150 and 300	*ASME B16.24
Cast Copper Alloy Fittings for Flared Copper Tubes	*ASME B16.26
Wrought Steel Buttwelding Short Radius Elbows and Returns [Note (5)]	*ASME B16.28
Valves-Flanged, Threaded, and Welding End	*ASME B16.34
Orifice Flanges, Class 300, 600, 900, 1500, and 2500	*ASME B16.36
Malleable Iron Threaded Pipe Unions, Class 150, 250, and 300	*ASME B16.39
Ductile Iron Pipe Flanges and Flanged Fittings, Class 150 and 300	*ASME B16.42
Large Diameter Steel Flanges, NPS 267 Through NPS 60	*ASME B16.47
Flanged Steel Pressure-Relief Valves	API 526
Wafer and Wafer-Lug Check Valves	*API 594
Metal Plug Valves—Flanged and Welding Ends	API 599
Steel Gate Valves — Flanged and Buttwelding Ends, Bolted and Pressure Seal Bonnets	API 600
Compact Steel Gate Valves — Flanged, Threaded, Welding and Extended Body Ends	API 602
Class 150, Cast, Corrosion-Resistant, Flanged-End Gate Valves	*API 603
Metal Ball Valves-Flanged, Threaded, and Welding End	API 608
Lug- and Wafer-Type Butterfly Valves	*API 609
Ductile-Iron and Gray-Iron Fittings, 3 Inch Through 48 Inch (75 mm Through 1200 mm), for Water and Other Liquids	*AWWA C110
Flanged Ductile-Iron with Ductile-Iron or Gray-Iron Threaded Flanges	*AWWA C115
Steel Pipe Flanges for Water works Service, sizes 4 inch Through 144 inch (100 mm Through 3,600 mm)	*AWWA C207
Dimensions for Fabricated Steel Water Pipe Fittings	*AWWA C208
Metal-Seated Gate Valves for Water Supply Service	*AWWA C500
Rubber-Seated Butterfly Valves	*AWWA C504
Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings	MSS SP-6
Spot Facing for Bronze, Iron and Steel Flanges	MSS SP-9
Standard Marking Systems for Valves, Fittings, Flanges, and Unions	MSS SP-25
Class 150 Corrosion-Resistant Gate, Globe, Angle and Check Valves With Flanged and Buttweld Ends	MSS SP-42
Wrought Stainless Steel Buttwelding Fittings	MSS SP-43
Steel Pipe Line Flanges	MSS SP-44

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TABLE 326.1 (CONT'D)
COMPONENT STANDARDS[1]

(99)

Standard or Specification	Designation [Note (2)]
Bypass and Drain Connections	MSS SP-45
Class 150LW Corrosion Resistant Cast Flanges and Flanged Fittings	MSS SP-51
High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets	MSS SP-65
Cast Iron Gate Valves, Flanged and Threaded Ends	MSS SP-70
Cast Iron Swing Check Valves, Flanged and Threaded Ends	MSS SP-71
Ball Valves With Flanged or Buttwelding Ends for General Service	MSS SP-72
Specifications for High Test Wrought Buttwelding Fittings	MSS SP-75
Socket-Welding Reducer Inserts	MSS SP-79
Bronz Gate, Globe, Angle and Check Valves	MSS SP-80
Stainless Steel, Bonnetless, Flanged, Knife Gate Valves	MSS SP-81
Class 3000 Steel Pipe Unions, Socket-Welding and Threaded	MSS SP-83
Cast Iron Globe and Angle Valves, Flanged and Threaded Ends	MSS SP-85
Diaphragm Type Valves	MSS SP-88
Swage (d) Nipples and Bull Plugs	MSS SP-95
Integrally Reinforced Forged Branch Outlet Fittings — Socket Welding, Threaded, and Buttwelding Ends	MSS SP-97
Instrument Valves for Code Applications	MSS SP-105
Refrigeration Tube Fittings — General Specifications	SAE J513
Hydraulic Tube Fittings	SAE J514
Hydraulic Flanged Tube, Pipe, and Hose Connections, Four-Bolt Split Flanged Type	*SAE J518
Metallic Pipe and Tubes [Note (6)]	
Welded and Seamless Wrought Steel Pipe	*ASME B36.10M
Stainless Steel Pipe	*ASME B36.19M
Flanged Ductile-Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges	*AWWA C115
Thickness Design of Ductile-Iron Pipe	*AWWA C150
Ductile-Iron Pipe, Centrifugally Cast, for Water and Other Liquids	*AWWA C151
Steel Water Pipe 6 inches (150 mm) and Larger	AWWA C200
Miscellaneous	
Unified Inch Screw Threads (UN and UNR Thread Form)	*ASME B1.1
Pipe Threads, General Purpose (Inch)	*ASME B1.20.1
Dryseal Pipe Threads (Inch)	*ASME B1.20.3
Hose Coupling Screw Threads (Inch)	*ASME B1.20.7
Metallic Gaskets for Pipe Flanges—Ring: Joint, Spiral Wound, and Jacketed	*ASME B16.20
Nonmetallic Flat Gaskets for Pipe Flanges	*ASME B16.21
Buttwelding Ends	*ASME B16.25
Surface Texture (Surface Roughness, Waviness, and Lay)	*ASME B46.1
Specification for Threading, Gaging and Thread Inspection of Casing, Tubing, and Line Pipe Threads	API 5B
Rubber Gasket Joints for Ductile-Iron Pressure Pipe and Fittings	*AWWA C111
Pipe Hangers and Supports — Materials, Design, and Manufacture	MSS SP-58
Brazing Joints for Wrought and Cast Copper Alloy Solder Joint Fittings	MSS SP-73
Standard for Fire Hose Connections	NFPA 1963

Notes to this Table follow on next page

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TABLE 326.1 (CONT'D)

NOTES:
(1) It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.
(2) An asterisk (*) preceding the designation indicates that the standard has been approved as an American National Standard by the American National Standards Institute.
(3) This standard allows the use of unlisted materials; see para. 323.1.2.
(4) This standard allows straight pipe threads in sizes ≤ DN 15 (NPS ½); see para. 314.2.1(d).
(5) *Cautionary Note:* Pressure ratings of components manufactured in accordance with editions prior to the 1994 edition of this standard were derated to 80% of equivalent seamless pipe. This derating is no longer required for components manufactured in accordance with the 1994 Edition.
(6) See also Appendix A.

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CHAPTER V
FABRICATION, ASSEMBLY, AND ERECTION

327 GENERAL

Metallic piping materials and components are prepared for assembly and erection by one or more of the fabrication processes covered in paras. 328, 330, 331, 332, and 333. When any of these processes is used in assembly or erection, requirements are the same as for fabrication.

328 WELDING

Welding shall conform to paras. 328.1 through 328.6 in accordance with applicable requirements of para. 311.2.

328.1 Welding Responsibility

Each employer is responsible for the welding done by the personnel of his organization and, except as provided in paras. 328.2.2 and 328.2.3, shall conduct the tests required to qualify welding procedures, and to qualify and as necessary requalify welders and welding operators.

328.2 Welding Qualifications

328.2.1 Qualification Requirements

(a) Qualification of the welding procedures to be used and of the performance of welders and welding operators shall conform to the requirements of the BPV Code, Section IX except as modified herein.

(b) Where the base metal will not withstand the 180 deg. guided bend required by Section IX, a qualifying welded specimen is required to undergo the same degree of bending as the base metal, within 5 deg.

(c) The requirements for preheating in para. 330 and for heat treatment in para. 331, as well as such requirements in the engineering design, shall apply in qualifying welding procedures.

(d) When impact testing is required by the Code or the engineering design, those requirements shall be met in qualifying welding procedures.

(e) If consumable inserts [Fig. 328.3.2 sketch (d), (e), (f), or (g)] or their integrally machined equivalents, or backing rings, are used, their suitability shall be demonstrated by procedure qualification, except that a procedure qualified without use of a backing ring is also qualified for use with a backing ring in a single-welded butt joint.

(f) To reduce the number of welding procedure qualifications required, P-Numbers or S-Numbers, and Group Numbers are assigned, in the BPV Code, Section IX, to groupings of metals generally based on composition, weldability, and mechanical properties, insofar as practicable. The P-Numbers or S-Numbers for most metals are listed for the convenience of the Code user in a separate column in Table A-1. See Section IX, QW/QB-422, for Group Numbers for respective P-Numbers and S-Numbers. Use of Section IX, QW-420.2, is required for this Code.

328.2.2 Procedure Qualification by Others. Each employer is responsible for qualifying any welding procedure that personnel of the organization will use. Subject to the specific approval of the Inspector, welding procedures qualified by others may be used, provided that the following conditions are met.

(a) The Inspector shall be satisfied that:

(1) the proposed welding procedure specification (WPS) has been prepared, qualified, and executed by a responsible, recognized organization with expertise in the field of welding; and

(2) the employer has not made any change in the welding procedure.

(b) The base material P-Number is either 1, 3, 4 Gr. No. 1 ($1\frac{1}{4}$ Cr max.), or 8; and impact testing is not required.

(c) The base metals to be joined are of the same P-Number, except that P-Nos. 1, 3, and 4 Gr. No. 1 may be welded to each other as permitted by Section IX.

(d) The material to be welded is not more than 19 mm ($\frac{3}{4}$ in.) in thickness. Postweld heat treatment shall not be required.

(e) The design pressure does not exceed the ASME B16.5 PN 50 (Class 300) rating for the material at design temperature; and the design temperature is in the range −29°C to 399°C (−20°F to 750°F), inclusive.

(f) The welding process is SMAW or GTAW or a combination thereof.

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(g) Welding electrodes for the SMAW process are selected from the following classifications.

AWS A5.1[1]	AWS A5.4[1]	AWS A5.5[1]
E6010	E308-15, -16	E7010-A1
E6011	E308L-15, -16	E7018-A1
E7015	E309-15, -16	E8016-B1
E7016	E310-15, -16	E8018-B1
E7018	E-16-8-2-15, -16	E8015-B2L
	E316-15, -16	E8016-B2
	E316L-15, -16	E8018-B2
	E347-15, -16	E8018-B2L

(h) By signature, the employer accepts responsibility for both the WPS and the procedure qualification record (PQR).

(i) The employer has at least one currently employed welder or welding operator who, while in his employ, has satisfactorily passed a performance qualification test using the procedure and the P-Number material specified in the WPS. The performance bend test required by Section IX, QW-302 shall be used for this purpose. Qualification by radiography is not acceptable.

328.2.3 Performance Qualification by Others. To avoid duplication of effort, an employer may accept a performance qualification made for another employer, provided that the Inspector specifically approves. Acceptance is limited to qualification on piping using the same or equivalent procedure wherein the essential variables are within the limits in Section IX. The employer shall obtain a copy from the previous employer of the performance qualification test record, showing the name of the employer, name of the welder or welding operator, procedure identification, date of successful qualification, and the date that the individual last used the procedure on pressure piping.

328.2.4 Qualification Records. The employer shall maintain a self-certified record, available to the owner (and the owner's agent) and the Inspector, of the procedures used and the welders and welding operators employed, showing the date and results of procedure and performance qualifications, and the identification symbol assigned to each welder and welding operator.

328.3 Welding Materials

328.3.1 Filler Metal. Filler metal shall conform to the requirements of Section IX. A filler metal not yet incorporated in Section IX may be used with the owner's approval if a procedure qualification test is first successfully made.

328.3.2 Weld Backing Material. When backing rings are used, they shall conform to the following.

(a) Ferrous Metal Backing Rings. These shall be of weldable quality. Sulfur content shall not exceed 0.05%.

(b) If two abutting surfaces are to be welded to a third member used as a backing ring and one or two of the three members are ferritic and the other member or members are austenitic, the satisfactory use of such materials shall be demonstrated by welding procedure qualified as required by para. 328.2.

Backing rings may be of the continuous machined or split-band type. Some commonly used types are shown in Fig. 328.3.2.

(c) Nonferrous and Nonmetallic Backing Rings. Backing rings of nonferrous or nonmetallic material may be used, provided the designer approves their use and the welding procedure using them is qualified as required by para. 328.2.

328.3.3 Consumable Inserts. Consumable inserts may be used, provided they are of the same nominal composition as the filler metal, will not cause detrimental alloying of the weld metal, and the welding procedure using them is qualified as required by para. 328.2. Some commonly used types are shown in Fig. 328.3.2.

328.4 Preparation for Welding

328.4.1 Cleaning. Internal and external surfaces to be thermally cut or welded shall be clean and free from paint, oil, rust, scale, and other material that would be detrimental to either the weld or the base metal when heat is applied.

328.4.2 End Preparation

(a) General

(1) End preparation is acceptable only if the surface is reasonably smooth and true, and slag from oxygen or arc cutting is cleaned from thermally cut surfaces. Discoloration remaining on a thermally cut surface is not considered detrimental oxidation.

(2) End preparation for groove welds specified in ASME B16.25, or any other which meets the WPS, is acceptable. [For convenience, the basic bevel angles of ASME B16.25 and some additional J-bevel angles are shown in Fig. 328.4.2 sketches (a) and (b).]

(b) Circumferential Welds

(1) If component ends are trimmed as shown in Fig. 328.3.2 sketch (a) or (b) to fit backing rings or consumable inserts, or as shown in Fig. 328.4.3 sketch

[1] AWS A5.1, Carbon Steel Electrodes for Shielded Metal Arc Welding; AWS A5.4, Stainless Steel Electrodes for Shielded Metal Arc Welding; and AWS A5.5, Low Alloy Steel Covered Arc Welding Electrodes.

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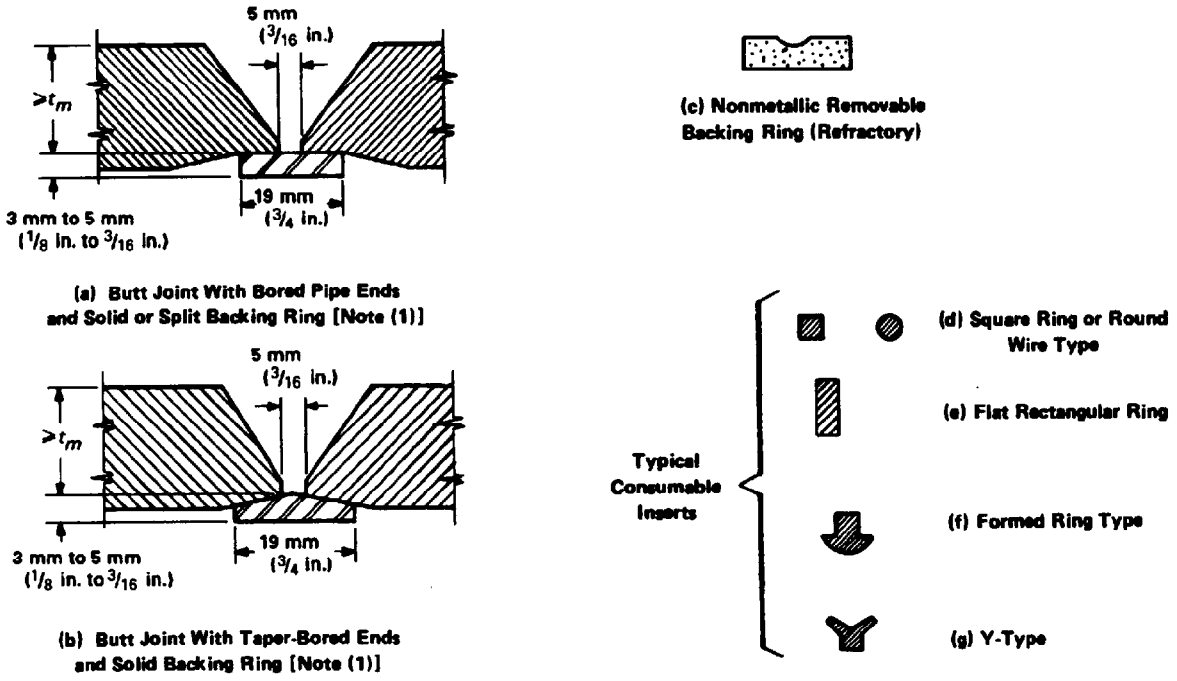

NOTE:
(1) Refer to ASME B16.25 for detailed dimensional information on welding ends.

FIG. 328.3.2 TYPICAL BACKING RINGS AND CONSUMABLE INSERTS

(a) or (b) to correct internal misalignment, such trimming shall not reduce the finished wall thickness below the required minimum wall thickness t_m.

(2) Component ends may be bored to allow for a completely recessed backing ring, provided the remaining net thickness of the finished ends is not less than t_m.

(3) It is permissible to size pipe ends of the same nominal size to improve alignment if wall thickness requirements are maintained.

(4) Where necessary, weld metal may be deposited inside or outside of the component to permit alignment or provide for machining to ensure satisfactory seating of rings or inserts.

(5) When a girth or miter groove weld joins components of unequal wall thickness and one is more than $1\frac{1}{2}$ times the thickness of the other, end preparation and geometry shall be in accordance with acceptable designs for unequal wall thickness in ASME B16.25.

328.4.3 Alignment

(a) Circumferential Welds

(1) Inside surfaces of components at ends to be joined in girth or miter groove welds shall be aligned within the dimensional limits in the WPS and the engineering design.

(2) If the external surfaces of the components are not aligned, the weld shall be tapered between them.

(b) Longitudinal Welds. Alignment of longitudinal groove welds (not made in accordance with a standard listed in Table A-1 or Table 326.1) shall conform to the requirements of para. 328.4.3(a).

(c) Branch Connection Welds

(1) Branch connections which abut the outside surface of the run pipe shall be contoured for groove welds which meet the WPS requirements [see Fig. 328.4.4 sketches (a) and (b)].

(2) Branch connections which are inserted through a run opening shall be inserted at least as far as the inside surface of the run pipe at all points [see Fig. 328.4.4 sketch (c)] and shall otherwise conform to para. 328.4.3(c)(1).

(3) Run openings for branch connections shall not deviate from the required contour more than the dimension m in Fig. 328.4.4. In no case shall deviations

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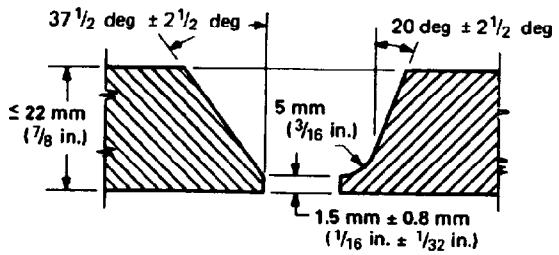
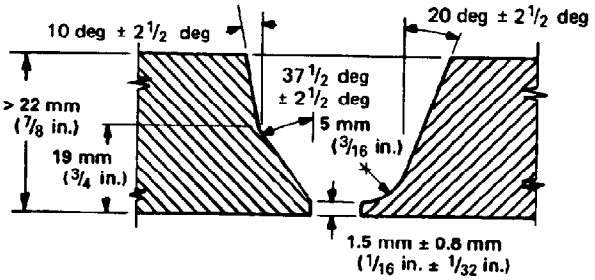
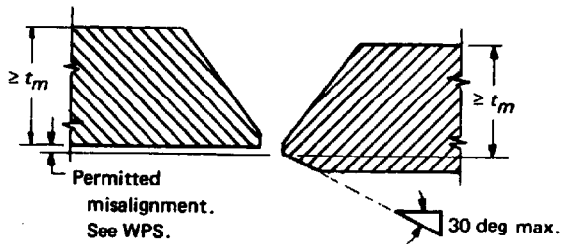


(a) Wall Thickness 6 mm to 22 mm, Inclusive (3/16 in. to 7/8 in.)

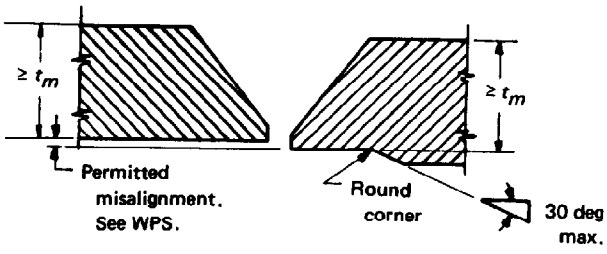


(b) Wall Thickness Over 22 mm (7/8 in.)

FIG. 328.4.2 TYPICAL BUTT WELD END PREPARATION



(a) Thicker Pipe Taper-Bored to Align



(b) Thicker Pipe Bored for Alignment

FIG. 328.4.3 TRIMMING AND PERMITTED MISALIGNMENT

of the shape of the opening cause the root spacing tolerance limits in the WPS to be exceeded. Weld metal may be added and refinished if necessary for compliance.

(d) Spacing. The root opening of the joint shall be within the tolerance limits in the WPS.

328.5 Welding Requirements

328.5.1 General

(a) Welds, including addition of weld metal for alignment [paras. 328.4.2(b)(4) and 328.4.3(c)(3)], shall be made in accordance with a qualified procedure and by qualified welders or welding operators.

(b) Each qualified welder and welding operator shall be assigned an identification symbol. Unless otherwise specified in the engineering design, each pressure containing weld or adjacent area shall be marked with the identification symbol of the welder or welding operator. In lieu of marking the weld, appropriate records shall be filed.

(c) Tack welds at the root of the joint shall be made with filler metal equivalent to that used in the root pass. Tack welds shall be made by a qualified welder or welding operator. Tack welds shall be fused with the root pass weld, except that those which have cracked shall be removed. Bridge tacks (above the weld) shall be removed.

(d) Peening is prohibited on the root pass and final pass of a weld.

(e) No welding shall be done if there is impingement on the weld area of rain, snow, sleet, or excessive wind, or if the weld area is frosted or wet.

(f) Welding End Valves. The welding sequence and procedure and any heat treatment for a welding end valve shall be such as to preserve the seat tightness of the valve.

328.5.2 Fillet and Socket Welds. Fillet welds (including socket welds) may vary from convex to concave. The size of a fillet weld is determined as shown in Fig. 328.5.2A.

(a) Typical weld details for slip-on and socket welding flanges are shown in Fig. 328.5.2B; minimum welding dimensions for other socket welding components are shown in Fig. 328.5.2C.

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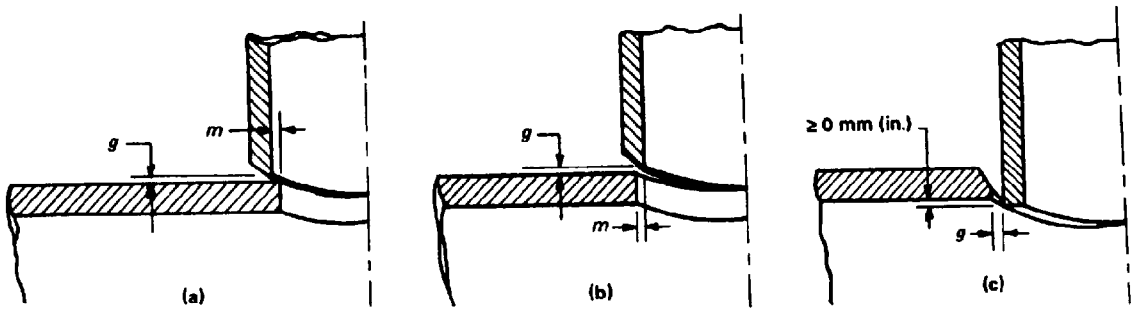
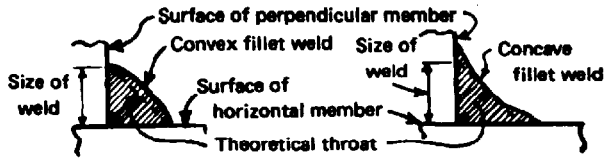


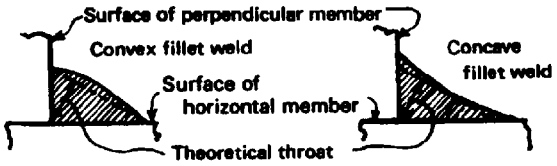
g = root gap per welding specification
m = the lesser of 3.2 mm ($^1/_8$ in.) or 0.5 T_b

FIG. 328.4.4 PREPARATION FOR BRANCH CONNECTIONS



Equal Leg Fillet Weld

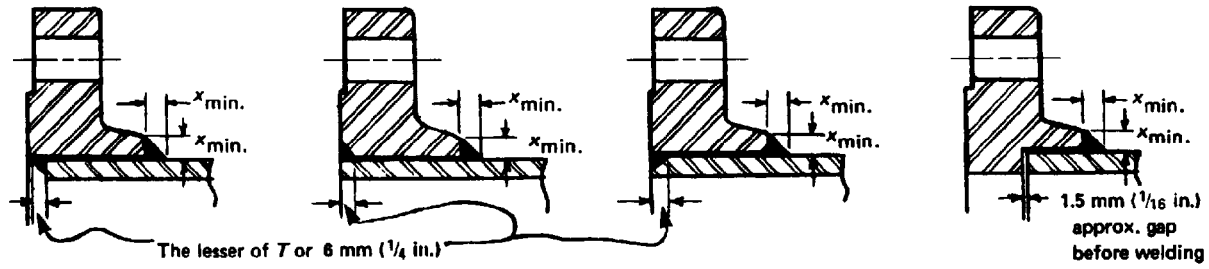
GENERAL NOTE: The size of an equal leg fillet weld is the leg length of the largest inscribed isosceles right triangle (theoretical throat = 0.707 x size).



Unequal Leg Fillet Weld

GENERAL NOTE: The size of unequal leg fillet weld is the leg lengths of the largest right triangle which can be inscribed within the weld cross section, e.g., 13 mm x 19 mm ($^1/_2$ in. x $^3/_4$ in.).

FIG. 328.5.2A FILLET WELD SIZE



(1) Front and Back Welds (2) Face and Back Welds (3) Socket Welding Flange

$X_{min.}$ = the lesser of $1.4\overline{T}$ or the thickness of the hub

FIG. 328.5.2B TYPICAL DETAILS FOR DOUBLE-WELDED SLIP-ON AND SOCKET WELDING FLANGE ATTACHMENT WELDS

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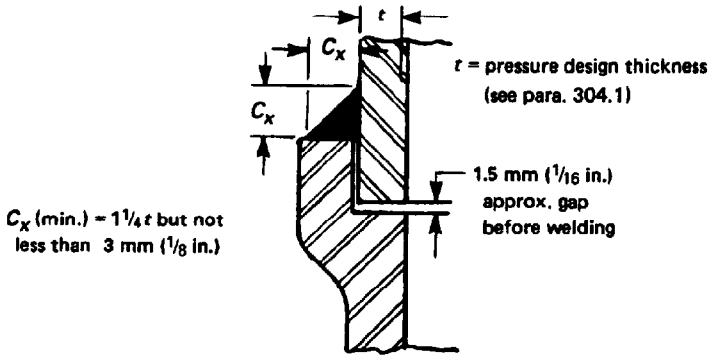
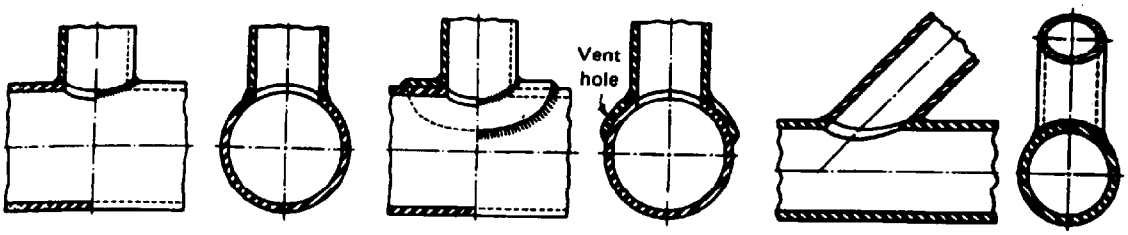


FIG. 328.5.2C MINIMUM WELDING DIMENSIONS FOR SOCKET WELDING COMPONENTS OTHER THAN FLANGES



FIGS. 328.5.4A, B, C TYPICAL WELDED BRANCH CONNECTIONS

(b) If slip-on flanges are single welded, the weld shall be at the hub.

328.5.3 Seal Welds. Seal welding shall be done by a qualified welder. Seal welds shall cover all exposed threads.

328.5.4 Welded Branch Connections

(a) Figures 328.5.4A through 328.5.4E show acceptable details of branch connections with and without added reinforcement, in which the branch pipe is connected directly to the run pipe. The illustrations are typical and are not intended to exclude acceptable types of construction not shown.

(b) Figure 328.5.4D shows basic types of weld attachments used in the fabrication of branch connections. The location and minimum size of attachment welds shall conform to the requirements herein. Welds shall be calculated in accordance with para. 304.3.3 but shall be not less than the sizes shown in Fig. 328.5.4D.

(c) The nomenclature and symbols used herein and in Fig. 328.5.4D are:

t_c = lesser of $0.7\overline{T}_b$ or 6 mm (¼ in.)
$\overline{T}_b$ = nominal thickness of branch
$\overline{T}_h$ = nominal thickness of header
$\overline{T}_r$ = nominal thickness of reinforcing pad or saddle
$t_{min.}$ = lesser of $\overline{T}_b$ or $\overline{T}_r$

(d) Branch connections, including branch connection fittings (see paras. 300.2 and 304.3.2), which abut the outside of the run or which are inserted in an opening in the run shall be attached by fully penetrated groove welds. The welds shall be finished with cover fillet welds having a throat dimension not less than t_c. See Fig. 328.5.4D sketches (1) and (2).

(e) A reinforcing pad or saddle shall be attached to the branch pipe by either:

(1) a fully penetrated groove weld finished with a cover fillet weld having a throat dimension not less than t_c; or

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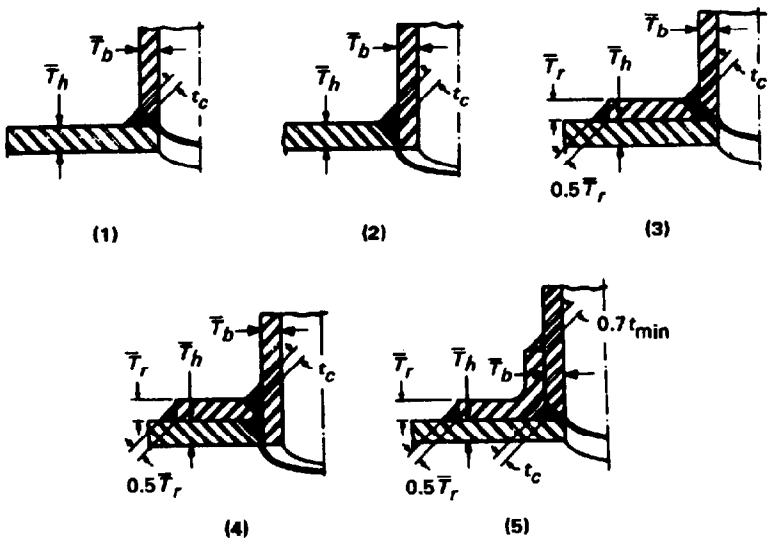

GENERAL NOTE: These sketches show minimum acceptable welds. Welds may be larger than those shown here.

FIG. 328.5.4D ACCEPTABLE DETAILS FOR BRANCH ATTACHMENT WELDS

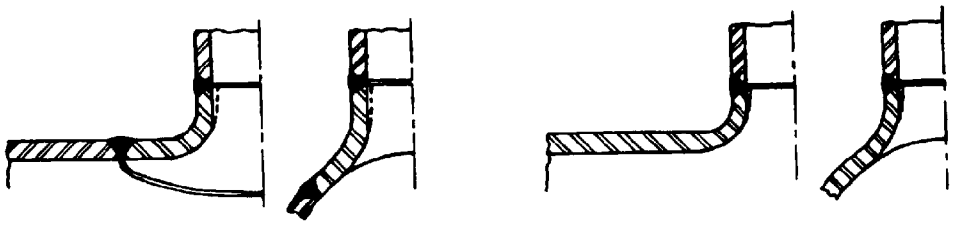

FIG. 328.5.4E ACCEPTABLE DETAILS FOR BRANCH ATTACHMENT SUITABLE FOR 100% RADIOGRAPHY

(2) a fillet weld having a throat dimension not less than $0.7t_{min.}$. See Fig. 328.5.4D sketch (5).

(f) The outer edge of a reinforcing pad or saddle shall be attached to the run pipe by a fillet weld having a throat dimension not less than $0.5\overline{T}_r$. See Fig. 328.5.4D sketches (3), (4), and (5).

(g) Reinforcing pads and saddles shall have a good fit with the parts to which they are attached. A vent hole shall be provided at the side (not at the crotch) of any pad or saddle to reveal leakage in the weld between branch and run and to allow venting during welding and heat treatment. A pad or saddle may be made in more than one piece if joints between pieces have strength equivalent to pad or saddle parent metal, and if each piece has a vent hole.

(h) Examination and any necessary repairs of the completed weld between branch and run shall be made before adding a pad or saddle.

328.5.5 Fabricated Laps. Figure 328.5.5 shows typical fabricated laps. Fabrication shall be in accordance with the applicable requirements of para. 328.5.4.

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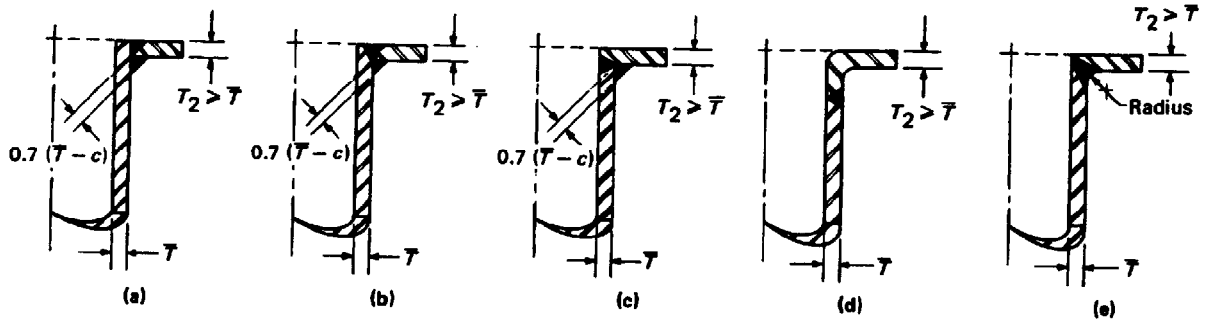

GENERAL NOTE: Laps shall be machined (front and back) or trued after welding. Plate flanges per para. 304.5 or lap joint flanges per ASME B16.5 may be used. Welds may be machined to radius, as in sketch (e), if necessary to match ASME B16.5 lap joint flanges.

FIG. 328.5.5 TYPICAL FABRICATED LAPS

328.5.6 Welding for Severe Cyclic Conditions. A welding procedure shall be employed which provides a smooth, regular, fully penetrated inner surface.

328.6 Weld Repair

A weld defect to be repaired shall be removed to sound metal. Repair welds shall be made using a welding procedure qualified in accordance with para. 328.2.1, recognizing that the cavity to be repaired may differ in contour and dimensions from the original joint. Repair welds shall be made by welders or welding operators qualified in accordance with para. 328.2.1. Preheating and heat treatment shall be as required for the original welding. See also para. 341.3.3.

330 PREHEATING

330.1 General

Preheating is used, along with heat treatment, to minimize the detrimental effects of high temperature and severe thermal gradients inherent in welding. The necessity for preheating and the temperature to be used shall be specified in the engineering design and demonstrated by procedure qualification. The requirements and recommendations herein apply to all types of welding including tack welds, repair welds, and seal welds of threaded joints.

330.1.1 Requirements and Recommendations. Required and recommended minimum preheat temperatures for materials of various P-Numbers are given in Table 330.1.1. If the ambient temperature is below 0°C (32°F), the recommendations in Table 330.1.1 become requirements. The thickness intended in Table 330.1.1 is that of the thicker component measured at the joint.

330.1.2 Unlisted Materials. Preheat requirements for an unlisted material shall be specified in the WPS.

330.1.3 Temperature Verification

(a) Preheat temperature shall be checked by use of temperature indicating crayons, thermocouple pyrometers, or other suitable means to ensure that the temperature specified in the WPS is obtained prior to and maintained during welding.

(b) Thermocouples may be temporarily attached directly to pressure containing parts using the capacitor discharge method of welding without welding procedure and performance qualifications. After thermocouples are removed, the areas shall be visually examined for evidence of defects to be repaired.

330.1.4 Preheat Zone. The preheat zone shall extend at least 25 mm (1 in.) beyond each edge of the weld.

330.2 Specific Requirements

330.2.3 Dissimilar Materials. When materials having different preheat requirements are welded together, it is recommended that the higher temperature shown in Table 330.1.1 be used.

330.2.4 Interrupted Welding. If welding is interrupted, the rate of cooling shall be controlled or other means shall be used to prevent detrimental effects in

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TABLE 330.1.1
PREHEAT TEMPERATURES

Base Metal P-No. or S-No. [Note (1)]	Weld Metal Analysis A-No. [Note (2)]	Base Metal Group	Nominal Wall Thickness		Specified Min. Tensile Strength, Base Metal		Min. Temperature Required		Min. Temperature Recommended	
			mm	in.	MPa	ksi	°C	°F	°C	°F
1	1	Carbon steel	< 25	< 1	≤ 490	≤ 71	...	...	10	50
			≥ 25	≥ 1	All	All	...	...	79	175
			All	All	> 490	> 71	...	...	79	175
3	2, 11	Alloy steels, Cr ≤ ½%	< 13	< ½	≤ 490	≤ 71	...	...	10	50
			≥ 13	≥ ½	All	All	...	...	79	175
			All	All	> 490	> 71	...	...	79	175
4	3	Alloy steels, ½% < Cr ≤ 2%	All	All	All	All	149	300	...	...
5A, 5B, 5C	4, 5	Alloy steels, 2¼% ≤ Cr ≤ 10%	All	All	All	All	177	350	...	...
6	6	High alloy steels martensitic	All	All	All	All	...	...	149[3]	300[3]
7	7	High alloy steels ferritic	All	All	All	All	...	...	10	50
8	8, 9	High alloy steels austenitic	All	All	All	All	...	...	10	50
9A, 9B	10	Nickel alloy steels	All	All	All	All	...	...	93	200
10	...	Cr-Cu steel	All	All	All	All	149–204	300–400	...	...
10I	...	27Cr steel	All	All	All	All	149[4]	300[4]	...	...
11A SG 1	...	8Ni, 9Ni steel	All	All	All	All	...	...	10	50
11A SG 2	...	5Ni steel	All	All	All	All	10	50	...	...
21–52	...	...	All	All	All	All	...	...	10	50

NOTES:
(1) P-Number or S-Number from BPV Code, Section IX, QW/QB-422.
(2) A-Number from Section IX, QW-442.
(3) Maximum interpass temperature 316°C (600°F).
(4) Maintain interpass temperature between 177°–232°C (350°F–450°F).

the piping. The preheat specified in the WPS shall be applied before welding is resumed.

331 HEAT TREATMENT

Heat treatment is used to avert or relieve the detrimental effects of high temperature and severe temperature gradients inherent in welding, and to relieve residual stresses created by bending and forming. Provisions in para. 331 are basic practices which are suitable for most welding, bending, and forming operations, but not necessarily appropriate for all service conditions.

331.1 General

331.1.1 Heat Treatment Requirements

(a) Heat treatment shall be in accordance with the

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material groupings and thickness ranges in Table 331.1.1 except as provided in paras. 331.2.1 and 331.2.2.

(b) Heat treatment to be used after production welding shall be specified in the WPS and shall be used in qualifying the welding procedure.

(c) The engineering design shall specify the examination and/or other production quality control (not less than the requirements of this Code) to ensure that the final welds are of adequate quality.

(d) Heat treatment for bending and forming shall be in accordance with para. 332.4.

331.1.3 Governing Thickness. When components are joined by welding, the thickness to be used in applying the heat treatment provisions of Table 331.1.1 shall be that of the thicker component measured at the joint, except as follows.

(a) In the case of branch connections, metal (other than weld metal) added as reinforcement, whether an integral part of a branch fitting or attached as a reinforcing pad or saddle, shall not be considered in determining heat treatment requirements. Heat treatment is required, however, when the thickness through the weld in any plane through the branch is greater than twice the minimum material thickness requiring heat treatment, even though the thickness of the components at the joint is less than the minimum thickness. Thickness through the weld for the details shown in Fig. 328.5.4D shall be computed using the following formulas:

$$\text{sketch (1)} = \overline{T}_b + t_c$$

$$\text{sketch (2)} = \overline{T}_h + t_c$$

$$\text{sketch (3)} = \text{greater of } \overline{T}_b + t_c \text{ or } \overline{T}_r + t_c$$

$$\text{sketch (4)} = \overline{T}_h + \overline{T}_r + t_c$$

$$\text{sketch (5)} = \overline{T}_b + t_c$$

(b) In the case of fillet welds at slip-on and socket welding flanges and piping connections DN 50 (NPS 2) and smaller, for seal welding of threaded joints in piping DN 50 and smaller, and for attachment of external nonpressure parts such as lugs or other pipe supporting elements in all pipe sizes, heat treatment is required when the thickness through the weld in any plane is more than twice the minimum material thickness requiring heat treatment (even though the thickness of the components at the joint is less than that minimum thickness) except as follows:

(1) not required for P-No. 1 materials when weld throat thickness is 16 mm (5/8 in.) or less, regardless of base metal thickness;

(2) not required for P-No. 3, 4, 5, or 10A materials when weld throat thickness is 13 mm (1/2 in.) or less, regardless of base metal thickness, provided that not less than the recommended preheat is applied, and the specified minimum tensile strength of the base metal is less than 490 MPa (71 ksi);

(3) not required for ferritic materials when welds are made with filler metal which does not air harden. Austenitic welding materials may be used for welds to ferritic materials when the effects of service conditions, such as differential thermal expansion due to elevated temperature, or corrosion, will not adversely affect the weldment.

331.1.4 Heating and Cooling. The heating method shall provide the required metal temperature, metal temperature uniformity, and temperature control, and may include an enclosed furnace, local flame heating, electric resistance, electric induction, or exothermic chemical reaction. The cooling method shall provide the required or desired cooling rate and may include cooling in a furnace, in air, by application of local heat or insulation, or by other suitable means.

331.1.6 Temperature Verification. Heat treatment temperature shall be checked by thermocouple pyrometers or other suitable methods to ensure that the WPS requirements are met. See para. 330.1.3(b) for attachment of thermocouples by the capacitor discharge method of welding.

331.1.7 Hardness Tests. Hardness tests of production welds and of hot bent and hot formed piping are intended to verify satisfactory heat treatment. The hardness limit applies to the weld and to the heat affected zone (HAZ) tested as close as practicable to the edge of the weld.

(a) Where a hardness limit is specified in Table 331.1.1, at least 10% of welds, hot bends, and hot formed components in each furnace heat treated batch and 100% of those locally heat treated shall be tested.

(b) When dissimilar metals are joined by welding, the hardness limits specified for the base and welding materials in Table 331.1.1 shall be met for each material.

331.2 Specific Requirements

Where warranted by experience or knowledge of service conditions, alternative methods of heat treatment or exceptions to the basic heat treatment provisions of

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TABLE 331.1.1
REQUIREMENTS FOR HEAT TREATMENT

Base Metal P-No. or S-No. [Note (1)]	Weld Metal Analysis A-Number [Note (2)]	Base Metal Group	Nominal Wall Thickness		Specified Min. Tensile Strength, Base Metal		Metal Temperature Range		Holding Time: Nominal Wall [Note (3)]		Holding Time: Min. Time, hr	Brinell Hardness, [Note (4)] Max.
			mm	in.	MPa	ksi	°C	°F	min/mm	hr/in.		
1	1	Carbon steel	≤ 19	≤ 3/4	All	All	None	None	...	...	...	...
			> 19	> 3/4	All	All	593–649	1100–1200	2.4	1	1	...
3	2, 11	Alloy steels, Cr ≤ 1/2%	≤ 19	≤ 3/4	≤ 490	≤ 71	None	None	...	...	...	...
			> 19	> 3/4	All	All	593–718	1100–1325	2.4	1	1	225
			All	All	> 490	> 71	593–718	1100–1325	2.4	1	1	225
4[10]	3	Alloy steels, 1/2% < Cr ≤ 2%	≤ 13	≤ 1/2	≤ 490	≤71	None	None	...	...	...	...
			> 13	> 1/2	All	All	704–746	1300–1375	2.4	1	2	225
			All	All	> 490	> 71	704–746	1300–1375	2.4	1	2	225
5A,[10] 5B,[10] 5C[10]	4, 5	Alloy steels, (2 1/4% ≤ Cr ≤ 10%)										
		≤ 3% Cr and ≤ 0.15% C	≤ 13	≤ 1/2	All	All	None	None	...	...	...	...
		≤ 3% Cr and ≤ 0.15% C	> 13	> 1/2	All	All	704–760	1300–1400	2.4	1	2	241
		> 3% Cr or > 0.15% C	All	All	All	All	704–760	1300–1400	2.4	1	2	241
6	6	High alloy steels martensitic	All	All	All	All	732–788	1350–1450	2.4	1	2	241
		A 240 Gr. 429	All	All	All	All	621–663	1150–1225	2.4	1	2	241
7	7	High alloy steels ferritic	All	All	All	All	None	None	...	...	...	...
8	8, 9	High alloy steels austenitic	All	All	All	All	None	None	...	...	...	...
9A, 9B	10	Nickel alloy steels	≤ 19	≤ 3/4	All	All	None	None	...	...	...	...
	...		> 19	> 3/4	All	All	593–635	1100–1175	1.2	1/2	1	...
10	...	Cr-Cu steel	All	All	All	All	760–816 [Note (5)]	1400–1500 [Note (5)]	1.2	1/2	1/2	...

TABLE 331.1.1 (CONT'D)
REQUIREMENTS FOR HEAT TREATMENT

Base Metal P-No. or S-No. [Note (1)]	Weld Metal Analysis A-Number [Note (2)]	Base Metal Group	Nominal Wall Thickness		Specified Min. Tensile Strength, Base Metal		Metal Temperature Range		Holding Time: Nominal Wall [Note (3)]		Holding Time: Min. Time, hr	Brinell Hardness, [Note (4)] Max.
			mm	in.	MPa	ksi	°C	°F	min/mm	hr/in.		
10H	...	Duplex stainless steel	All	All	All	All	Note (7)	Note (7)	1.2	½	½	...
10I	...	27Cr steel	All	All	All	All	663–704 [Note (6)]	1225–1300 [Note (6)]	2.4	1	1	...
11A SG 1	...	8Ni, 9Ni steel	≤ 51	≤ 2	All	All	None	None	...	...	...	...
			> 51	> 2	All	All	552–585 [Note (8)]	1025–1085 [Note (8)]	2.4	1	1	...
11A SG 2	...	5Ni steel	> 51	> 2	All	All	552–585 [Note (8)]	1025–108 [Note (8)]	2.4	1	1	...
62	...	Zr R60705	All	All	All	All	538–593 [Note (9)]	1000–1100 [Note (9)]	Note (9)	Note (9)	1	...

NOTES:
(1) P-Number or S-Number from BPV Code, Section IX, QW/QB-422.
(2) A-Number from Section IX, QW-442.
(3) For holding time in SI metric units use min/mm (minutes per mm thickness). For U.S. units, use hr/in. thickness.
(4) See para. 331.1.7.
(5) Cool as rapidly as possible after the hold period.
(6) Cooling rate to 649°C (1200°F) shall be less than 56°C (100°F)/hr; thereafter, the cooling rate shall be fast enough to prevent embrittlement.
(7) Postweld heat treatment is neither required nor prohibited, but any heat treatment applied shall be as required in the material specification.
(8) Cooling rate shall be > 167°C (300°F)/hr to 316°C (600°F).
(9) Heat treat within 14 days after welding. Hold time shall be increased by ½ hr for each 25 mm (1 in.) over 25 mm thickness. Cool to 427°C (800°F) at a rate ≤ 278°C (500°F)/hr, per 25 mm (1 in.) nominal thickness, 278°C (500°F)/hr max. Cool in still air from 427°C (800°F).
(10) See Appendix F, para. F331.1.

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para. 331.1 may be adopted as provided in paras. 331.2.1 and 331.2.2.

331.2.1 Alternative Heat Treatment. Normalizing, or normalizing and tempering, or annealing may be applied in lieu of the required heat treatment after welding, bending, or forming, provided that the mechanical properties of any affected weld and base metal meet specification requirements after such treatment and that the substitution is approved by the designer.

331.2.2 Exceptions to Basic Requirements. As indicated in para. 331, the basic practices therein may require modification to suit service conditions in some cases. In such cases, the designer may specify more stringent requirements in the engineering design, including heat treatment and hardness limitations for lesser thickness, or may specify less stringent heat treatment and hardness requirements, including none.

(a) When provisions less stringent than those in para. 331 are specified, the designer must demonstrate to the owner's satisfaction the adequacy of those provisions by comparable service experience, considering service temperature and its effects, frequency and intensity of thermal cycling, flexibility stress levels, probability of brittle failure, and other pertinent factors. In addition, appropriate tests shall be conducted, including WPS qualification tests.

331.2.3 Dissimilar Materials

(a) Heat treatment of welded joints between dissimilar ferritic metals or between ferritic metals using dissimilar ferritic filler metal shall be at the higher of the temperature ranges in Table 331.1.1 for the materials in the joint.

(b) Heat treatment of welded joints including both ferritic and austenitic components and filler metals shall be as required for the ferritic material or materials unless otherwise specified in the engineering design.

331.2.4 Delayed Heat Treatment. If a weldment is allowed to cool prior to heat treatment, the rate of cooling shall be controlled or other means shall be used to prevent detrimental effects in the piping.

331.2.5 Partial Heat Treatment. When an entire piping assembly to be heat treated cannot be fitted into the furnace, it is permissible to heat treat in more than one heat, provided there is at least 300 mm (1 ft) overlap between successive heats, and that parts of the assembly outside the furnace are protected from harmful temperature gradients.

331.2.6 Local Heat Treatment. When heat treatment is applied locally, a circumferential band of the run pipe, and of the branch where applicable, shall be heated until the specified temperature range exists over the entire pipe section(s), gradually diminishing beyond a band which includes the weldment or the bent or formed section and at least 25 mm (1 in.) beyond the ends thereof.

332 BENDING AND FORMING

332.1 General

Pipe may be bent and components may be formed by any hot or cold method which is suitable for the material, the fluid service, and the severity of the bending or forming process. The finished surface shall be free of cracks and substantially free from buckling. Thickness after bending or forming shall be not less than that required by the design.

332.2 Bending

332.2.1 Bend Flattening. Flattening of a bend, the difference between maximum and minimum diameters at any cross section, shall not exceed 8% of nominal outside diameter for internal pressure and 3% for external pressure. Removal of metal shall not be used to achieve these requirements.

332.2.2 Bending Temperature

(a) Cold bending of ferritic materials shall be done at a temperature below the transformation range.

(b) Hot bending shall be done at a temperature above the transformation range and in any case within a temperature range consistent with the material and the intended service.

332.2.3 Corrugated and Other Bends. Dimensions and configuration shall conform to the design qualified in accordance with para. 306.2.2.

332.3 Forming

The temperature range for forming shall be consistent with material, intended service, and specified heat treatment.

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332.4 Required Heat Treatment

Heat treatment shall be performed in accordance with para. 331.1.1 when required by the following.

332.4.1 Hot Bending and Forming. After hot bending and forming, heat treatment is required for P-Nos. 3, 4, 5, 6, and 10A materials in all thicknesses. Durations and temperatures shall be in accordance with para. 331.

332.4.2 Cold Bending and Forming. After cold bending and forming, heat treatment is required (for all thicknesses, and with temperature and duration as given in Table 331.1.1) when any of the following conditions exist:

(a) for P-Nos. 1 through 6 materials, where the maximum calculated fiber elongation after bending or forming exceeds 50% of specified basic minimum elongation (in the direction of severest forming) for the applicable specification, grade, and thickness. This requirement may be waived if it can be demonstrated that the selection of pipe and the choice of bending or forming process provide assurance that, in the finished condition, the most severely strained material retains at least 10% elongation.

(b) for any material requiring impact testing, where the maximum calculated fiber elongation after bending or forming will exceed 5%;

(c) when specified in the engineering design.

333 BRAZING AND SOLDERING

333.1 Qualification

333.1.1 Brazing Qualification. The qualification of brazing procedures, brazers, and brazing operators shall be in accordance with the requirements of the BPV Code, Section IX, Part QB. For Category D Fluid Service at design temperature not over 93°C (200°F), such qualification is at the owner's option.

333.2 Brazing and Soldering Materials

333.2.1 Filler Metal. The brazing alloy or solder shall melt and flow freely within the specified or desired temperature range and, in conjunction with a suitable flux or controlled atmosphere, shall wet and adhere to the surfaces to be joined.

333.2.2 Flux. A flux that is fluid and chemically active at brazing or soldering temperature shall be used when necessary to eliminate oxidation of the filler metal and the surfaces to be joined, and to promote free flow of brazing alloy or solder.

333.3 Preparation

333.3.1 Surface Preparation. The surfaces to be brazed or soldered shall be clean and free from grease, oxides, paint, scale, and dirt of any kind. A suitable chemical or mechanical cleaning method shall be used if necessary to provide a clean wettable surface.

333.3.2 Joint Clearance. The clearance between surfaces to be joined by soldering or brazing shall be no larger than necessary to allow complete capillary distribution of the filler metal.

333.4 Requirements

333.4.1 Soldering Procedure. Solderers shall follow the procedure in the Copper Tube Handbook of the Copper Development Association.

333.4.2 Heating. To minimize oxidation, the joint shall be brought to brazing or soldering temperature in as short a time as possible without localized underheating or overheating.

333.4.3 Flux Removal. Residual flux shall be removed if detrimental.

335 ASSEMBLY AND ERECTION

335.1 General

335.1.1 Alignment

(a) Piping Distortions. Any distortion of piping to bring it into alignment for joint assembly which introduces a detrimental strain in equipment or piping components is prohibited.

(b) Cold Spring. Before assembling any joints to be cold sprung, guides, supports, and anchors shall be examined for errors which might interfere with desired movement or lead to undesired movement. The gap or overlap of piping prior to assembly shall be checked against the drawing and corrected if necessary. Heating shall not be used to help in closing the gap because it defeats the purpose of cold springing.

(c) Flanged Joints. Before bolting up, flange faces shall be aligned to the design plane within 1 mm in 200 mm ($\frac{1}{16}$ in./ft) measured across any diameter; flange bolt holes shall be aligned within 3 mm ($\frac{1}{8}$ in.) maximum offset.

335.2 Flanged Joints

335.2.1 Preparation for Assembly. Any damage to the gasket seating surface which would prevent gasket seating shall be repaired, or the flange shall be replaced.

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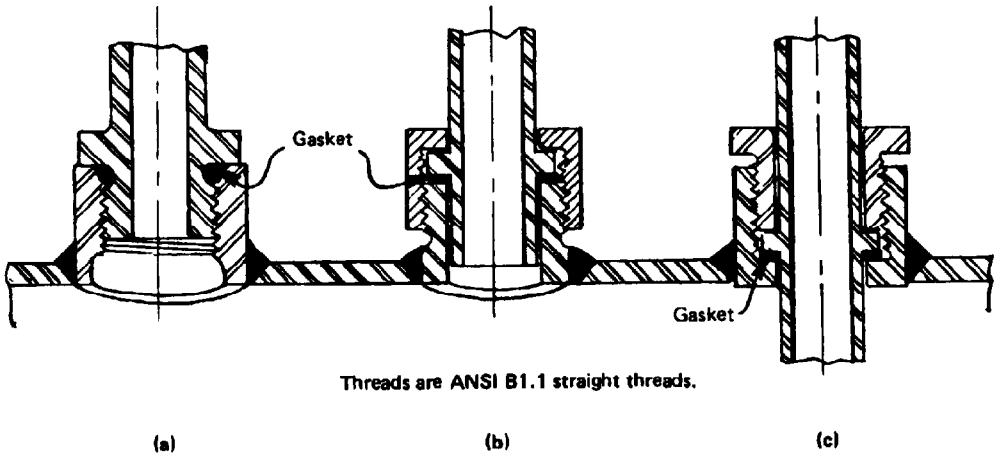

FIG. 335.3.3 TYPICAL THREADED JOINTS USING STRAIGHT THREADS

335.2.2 Bolting Torque

(a) In assembling flanged joints, the gasket shall be uniformly compressed to the proper design loading.

(b) Special care shall be used in assembling flanged joints in which the flanges have widely differing mechanical properties. Tightening to a predetermined torque is recommended.

335.2.3 Bolt Length. Bolts should extend completely through their nuts. Any which fail to do so are considered acceptably engaged if the lack of complete engagement is not more than one thread.

335.2.4 Gaskets. No more than one gasket shall be used between contact faces in assembling a flanged joint.

335.3 Threaded Joints

335.3.1 Thread Compound or Lubricant. Any compound or lubricant used on threads shall be suitable for the service conditions and shall not react unfavorably with either the service fluid or the piping material.

335.3.2 Joints for Seal Welding. A threaded joint to be seal welded shall be made up without thread compound. A joint containing thread compound which leaks during leak testing may be seal welded in accordance with para. 328.5.3, provided all compound is removed from exposed threads.

335.3.3 Straight Threaded Joints. Typical joints using straight threads, with sealing at a surface other than the threads, are shown in Fig. 335.3.3 sketches (a), (b), and (c). Care shall be taken to avoid distorting the seat when incorporating such joints into piping assemblies by welding, brazing, or bonding.

335.4 Tubing Joints

335.4.1 Flared Tubing Joints. The sealing surface of the flare shall be examined for imperfections before assembly and any flare having imperfections shall be rejected.

335.4.2 Flareless and Compression Tubing Joints. Where the manufacturer's instructions call for a specified number of turns of the nut, these shall be counted from the point at which the nut becomes finger tight.

335.5 Caulked Joints

Caulked joints shall be installed and assembled in accordance with the manufacturer's instructions, as modified by the engineering design. Care shall be taken to ensure adequate engagement of joint members.

335.6 Expanded Joints and Special Joints

335.6.1 General. Expanded joints and special joints (as defined in para. 318) shall be installed and assembled in accordance with the manufacturer's instructions, as modified by the engineering design. Care shall be taken to ensure adequate engagement of joint members.

335.6.2 Packed Joints. Where a packed joint is used to absorb thermal expansion, proper clearance shall be provided at the bottom of the socket to permit this movement.

335.9 Cleaning of Piping

See Appendix F, para. F335.9.

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CHAPTER VI
INSPECTION, EXAMINATION, AND TESTING

340 INSPECTION

340.1 General

This Code distinguishes between examination (see para. 341) and inspection. Inspection applies to functions performed for the owner by the owner's Inspector or the Inspector's delegates. References in this Code to the "Inspector" are to the owner's Inspector or the Inspector's delegates.

340.2 Responsibility for Inspection

It is the owner's responsibility, exercised through the owner's Inspector, to verify that all required examinations and testing have been completed and to inspect the piping to the extent necessary to be satisfied that it conforms to all applicable examination requirements of the Code and of the engineering design.

340.3 Rights of the Owner's Inspector

The owner's Inspector and the Inspector's delegates shall have access to any place where work concerned with the piping installation is being performed. This includes manufacture, fabrication, heat treatment, assembly, erection, examination, and testing of the piping. They shall have the right to audit any examination, to inspect the piping using any examination method specified by the engineering design, and to review all certifications and records necessary to satisfy the owner's responsibility stated in para. 340.2.

340.4 Qualifications of the Owner's Inspector

(a) The owner's Inspector shall be designated by the owner and shall be the owner, an employee of the owner, an employee of an engineering or scientific organization, or of a recognized insurance or inspection company acting as the owner's agent. The owner's Inspector shall not represent nor be an employee of the piping manufacturer, fabricator, or erector unless the owner is also the manufacturer, fabricator, or erector.

(b) The owner's Inspector shall have not less than 10 years experience in the design, fabrication, or inspection of industrial pressure piping. Each 20% of satisfactorily completed work toward an engineering degree recognized by the Accreditation Board for Engineering and Technology (Three Park Avenue, New York, NY 10016) shall be considered equivalent to 1 year of experience, up to 5 years total.

(c) In delegating performance of inspection, the owner's Inspector is responsible for determining that a person to whom an inspection function is delegated is qualified to perform that function.

341 EXAMINATION

341.1 General

Examination applies to quality control functions performed by the manufacturer (for components only), fabricator, or erector. Reference in this Code to an examiner is to a person who performs quality control examinations.

341.2 Responsibility for Examination

Inspection does not relieve the manufacturer, the fabricator, or the erector of the responsibility for:

(a) providing materials, components, and workmanship in accordance with the requirements of this Code and of the engineering design [see para. 300(b)(3)];

(b) performing all required examinations; and

(c) preparing suitable records of examinations and tests for the Inspector's use.

341.3 Examination Requirements

341.3.1 General. Prior to initial operation each piping installation, including components and workmanship, shall be examined in accordance with the applicable requirements of para. 341. The type and extent of any additional examination required by the engineering design, and the acceptance criteria to be applied, shall be specified. Joints not included in examinations required by para. 341.4 or by the engineering design are accepted if they pass the leak test required by para. 345.

(a) For P-Nos. 3, 4, and 5 materials, examination

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shall be performed after completion of any heat treatment.

(b) For a welded branch connection the examination of and any necessary repairs to the pressure containing weld shall be completed before any reinforcing pad or saddle is added.

341.3.2 Acceptance Criteria. Acceptance criteria shall be as stated in the engineering design and shall at least meet the applicable requirements stated below, in para. 344.6.2 for ultrasonic examination of welds, and elsewhere in the Code.

(a) Table 341.3.2 states acceptance criteria (limits on imperfections) for welds. See Fig. 341.3.2 for typical weld imperfections.

(b) Acceptance criteria for castings are specified in para. 302.3.3.

341.3.3 Defective Components and Workmanship. An examined item with one or more defects (imperfections of a type or magnitude exceeding the acceptance criteria of this Code) shall be repaired or replaced; and the new work shall be reexamined by the same methods, to the same extent, and by the same acceptance criteria as required for the original work.

341.3.4 Progressive Sampling for Examination. When required spot or random examination reveals a defect:

(a) two additional samples of the same kind (if welded or bonded joints, by the same welder, bonder, or operator) shall be given the same type of examination; and

(b) if the items examined as required by (a) above are acceptable, the defective item shall be repaired or replaced and reexamined as specified in para. 341.3.3, and all items represented by these two additional samples shall be accepted; but

(c) if any of the items examined as required by (a) above reveals a defect, two further samples of the same kind shall be examined for each defective item found by that sampling; and

(d) if all the items examined as required by (c) above are acceptable, the defective item(s) shall be repaired or replaced and reexamined as specified in para. 341.3.3, and all items represented by the additional sampling shall be accepted; but

(e) if any of the items examined as required by (c) above reveals a defect, all items represented by the progressive sampling shall be either:

(1) repaired or replaced and reexamined as required; or

(2) fully examined and repaired or replaced as necessary, and reexamined as necessary to meet the requirements of this Code.

341.4 Extent of Required Examination

341.4.1 Examination Normally Required. Piping in Normal Fluid Service shall be examined to the extent specified herein or to any greater extent specified in the engineering design. Acceptance criteria are as stated in para. 341.3.2 and in Table 341.3.2, for Normal Fluid Service unless otherwise specified.

(a) Visual Examination. At least the following shall be examined in accordance with para. 344.2:

(1) sufficient materials and components, selected at random, to satisfy the examiner that they conform to specifications and are free from defects;

(2) at least 5% of fabrication. For welds, each welder's and welding operator's work shall be represented.

(3) 100% of fabrication for longitudinal welds, except those in components made in accordance with a listed specification. See para 341.5.1(a) for examination of longitudinal welds required to have a joint factor E_j of 0.90.

(4) random examination of the assembly of threaded, bolted, and other joints to satisfy the examiner that they conform to the applicable requirements of para. 335. When pneumatic testing is to be performed, all threaded, bolted, and other mechanical joints shall be examined.

(5) random examination during erection of piping, including checking of alignment, supports, and cold spring;

(6) examination of erected piping for evidence of defects that would require repair or replacement, and for other evident deviations from the intent of the design.

(b) Other Examination

(1) Not less than 5% of circumferential butt and miter groove welds shall be examined fully by random radiography in accordance with para. 344.5 or by random ultrasonic examination in accordance with para. 344.6. The welds to be examined shall be selected to ensure that the work product of each welder or welding operator doing the production welding is included. They shall also be selected to maximize coverage of intersections with longitudinal joints. When a circumferential weld with an intersecting longitudinal weld(s) is examined, at least the adjacent 38 mm (1½ in.) of each intersecting weld shall be examined. In-process examination in accordance with para. 344.7 may be

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TABLE 341.3.2
ACCEPTANCE CRITERIA FOR WELDS

Kind of Imperfection	Criteria (A to M) for Types of Welds, for Service Conditions, and for Required Examination Methods [Note (1)]																							
	Normal Fluid Service									Severe Cyclic Conditions									Category D Fluid Service					
	Methods		Types of Weld							Methods							Types of Weld					Method	Types of Weld			
	Visual	Radiography	Girth and Miter Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]	Visual	Radiography	Magnetic Particle	Liquid Penetrant	Girth and Miter Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]	Visual	Girth and Miter Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]	Visual	Girth and Miter Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]
Crack	X	X	A	A	A	A	X	X	X	X	A	A	A	A	X	A	A	A	A					
Lack of fusion	X	X	A	A	A	A	X	X	X	...	A	A	A	A	X	C	A	NA	A					
Incomplete penetration	X	X	B	A	NA	B	X	X	X	...	A	A	NA	A	X		A	NA	B					
Internal porosity	...	X	E	E	NA	E	...	X	...	...	D	D	NA	D	...	...	...	...	...					
Slag inclusion, tungsten inclusion, or elongated indication	...	X	G	G	NA	G	...	X	...	...	F	F	NA	F	...	...	...	...	...					
Undercutting	X	...	H	A	H	H	X	X	...	...	A	A	A	A	X	I	A	H	H					
Surface porosity or exposed slag inclusion [Note (5)]	X	...	A	A	A	A	X	...	...	...	A	A	A	A	X	A	A	A	A					
Surface finish	...	...	...	...	...	...	X	...	...	...	J	J	J	J	X	K	K	K	K					
Concave root surface (suck-up)	X	X	K	K	NA	K	X	X	...	...	K	K	NA	K	X	K	K	NA	K					
Reinforcement or internal protrusion	X	...	L	L	L	L	X	...	...	...	L	L	L	L	X	M	M	M	M					

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Criterion Value Notes for Table 341.3.2

Symbol	Criterion Measure	Acceptable Value Limits [Note (6)]	
A	Extent of imperfection	Zero (no evident imperfection)	
B	Depth of incomplete penetration Cumulative length of incomplete penetration	≤ 1 mm (1/32 in.) and ≤ $0.2\overline{T}_w$ ≤ 38 mm (1.5 in.) in any 150 mm (6 in.) weld length	
C	Depth of lack of fusion and incomplete penetration Cumulative length of lack of fusion and incomplete penetration [Note (7)]	≤ $0.2\overline{T}_w$ ≤ 38 mm (1.5 in.) in any 150 mm (6 in.) weld length	
D	Size and distribution of internal porosity	See BPV Code, Section VIII, Division 1, Appendix 4	
E	Size and distribution of internal porosity	For $\overline{T}_w$ ≤ 6 mm (1/4 in.), limit is same as D For $\overline{T}_w$ > 6 mm (1/4 in.), limit is 1.5 × D	
F	Slag inclusion, tungsten inclusion, or elongated indication Individual length Individual width Cumulative length	 ≤ $\overline{T}_w/3$ ≤ 2.5 mm (3/32 in.) and ≤ $\overline{T}_w/3$ ≤ $\overline{T}_w$ in any $12\overline{T}_w$ weld length	
G	Slag inclusion, tungsten inclusion, or elongated indication Individual length Individual width Cumulative length	 ≤ $2\overline{T}_w$ ≤ 3 mm (1/8 in.) and ≤ $\overline{T}_w/2$ ≤ $4\overline{T}_w$ in any 150 mm (6 in.) weld length	
H	Depth of undercut	≤ 1 mm (1/32 in.) and ≤ $\overline{T}_w/4$	
I	Depth of undercut	≤ 1.5 mm (1/16 in.) and ≤ [$\overline{T}_w/4$ or 1 mm (1/32 in.)]	
J	Surface roughness	≤ 500 min. Ra per ASME B46.1	
K	Depth of root surface concavity	Total joint thickness, incl. weld reinf., ≥ $\overline{T}_w$	
L	Height of reinforcement or internal protrusion [Note (8)] in any plane through the weld shall be within limits of the applicable height value in the tabulation at right, except as provided in Note (9). Weld metal shall merge smoothly into the component surfaces.	For $\overline{T}_w$, mm (in.) ≤ 6 (1/4) > 6 (1/4), ≤ 13 (1/2) > 13 (1/2), ≤ 25 (1) > 25 (1)	Height, mm (in.) ≤ 1.5 (1/16) ≤ 3 (1/8) ≤ 4 (5/32) ≤ 5 (3/16)
M	Height of reinforcement or internal protrusion [Note (8)] as described in L. Note (9) does not apply.	Limit is twice the value applicable for L above	

X = required examination NA = not applicable ... = not required

Notes follow on next page

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TABLE 341.3.2 (CONT'D)

NOTES:
(1) Criteria given are for required examination. More stringent criteria may be specified in the engineering design. See also paras. 341.5 and 341.5.3.
(2) Longitudinal groove weld includes straight and spiral seam. Criteria are not intended to apply to welds made in accordance with a standard listed in Table A-1 or Table 326.1.
(3) Fillet weld includes socket and seal welds, and attachment welds for slip-on flanges, branch reinforcement, and supports.
(4) Branch connection weld includes pressure containing welds in branches and fabricated laps.
(5) These imperfections are evaluated only for welds ≤ 5 mm ($^{3}/_{16}$ in.) in nominal thickness.
(6) Where two limiting values are separated by "and," the lesser of the values determines acceptance. Where two sets of values are separated by "or," the larger value is acceptable. $\overline{T}_w$ is the nominal wall thickness of the thinner of two components joined by a butt weld.
(7) Tightly butted unfused root faces are unacceptable.
(8) For groove welds, height is the lesser of the measurements made from the surfaces of the adjacent components; both reinforcement and internal protrusion are permitted in a weld. For fillet welds, height is measured from the theoretical throat, Fig. 328.5.2A; internal protrusion does not apply.
(9) For welds in aluminum alloy only, internal protrusion shall not exceed the following values:
    (a) for thickness ≤ 2 mm ($^{5}/_{64}$ in.): 1.5 mm ($^{1}/_{16}$ in.);
    (b) for thickness > 2 mm and ≤ 6 mm ($^{1}/_{4}$ in.): 2.5 mm ($^{3}/_{32}$ in.).
    For external reinforcement and for greater thicknesses, see the tabulation for Symbol L.

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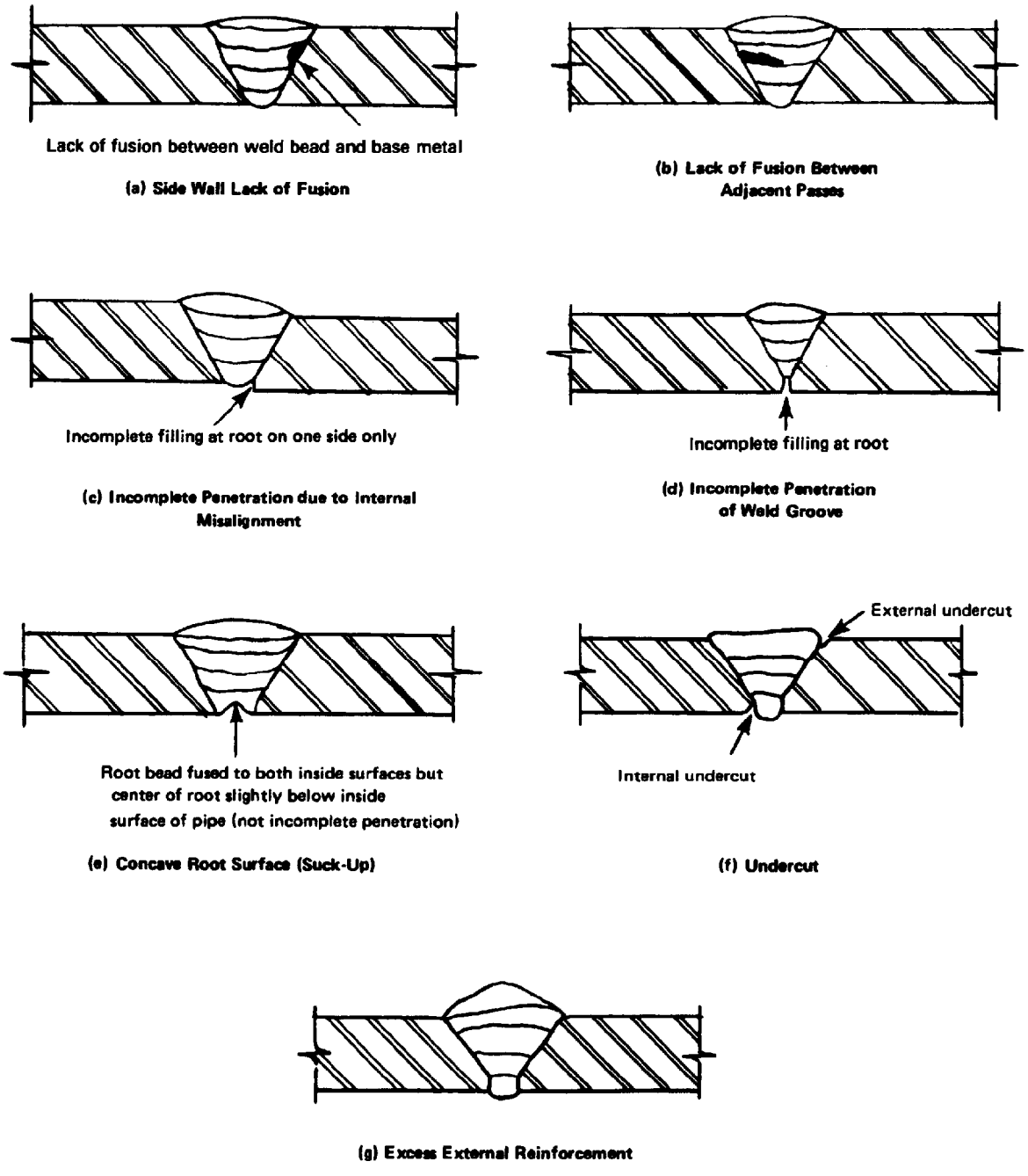

FIG. 341.3.2 TYPICAL WELD IMPERFECTIONS

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substituted for all or part of the radiographic or ultrasonic examination on a weld-for-weld basis if specified in the engineering design or specifically authorized by the Inspector.

(2) Not less than 5% of all brazed joints shall be examined by in-process examination in accordance with para. 344.7, the joints to be examined being selected to ensure that the work of each brazer making the production joints is included.

(c) Certifications and Records. The examiner shall be assured, by examination of certifications, records, and other evidence, that the materials and components are of the specified grades and that they have received required heat treatment, examination, and testing. The examiner shall provide the Inspector with a certification that all the quality control requirements of the Code and of the engineering design have been carried out.

341.4.2 Examination — Category D Fluid Service. Piping and piping elements for Category D Fluid Service as designated in the engineering design shall be visually examined in accordance with para. 344.2 to the extent necessary to satisfy the examiner that components, materials, and workmanship conform to the requirements of this Code and the engineering design. Acceptance criteria are as stated in para. 341.3.2 and in Table 341.3.2, for Category D fluid service, unless otherwise specified.

341.4.3 Examination — Severe Cyclic Conditions. Piping to be used under severe cyclic conditions shall be examined to the extent specified herein or to any greater extent specified in the engineering design. Acceptance criteria are as stated in para. 341.3.2 and in Table 341.3.2, for severe cyclic conditions, unless otherwise specified.

(a) Visual Examination. The requirements of para. 341.4.1(a) apply with the following exceptions.

(1) All fabrication shall be examined.

(2) All threaded, bolted, and other joints shall be examined.

(99) *(3)* All piping erection shall be examined to verify dimensions and alignment. Supports, guides, and points of cold spring shall be checked to ensure that movement of the piping under all conditions of startup, operation, and shutdown will be accommodated without undue binding or unanticipated constraint.

(b) Other Examination. All circumferential butt and miter groove welds and all fabricated branch connection welds comparable to those shown in Fig. 328.5.4E shall be examined by 100% radiography in accordance with para. 344.5, or (if specified in the engineering design) by 100% ultrasonic examination in accordance with para. 344.6. Socket welds and branch connection welds which are not radiographed shall be examined by magnetic particle or liquid penetrant methods in accordance with para. 344.3 or 344.4.

(c) In-process examination in accordance with para. 344.7, supplemented by appropriate nondestructive examination, may be substituted for the examination required in (b) above on a weld-for-weld basis if specified in the engineering design or specifically authorized by the Inspector.

(d) Certification and Records. The requirements of para. 341.4.1(c) apply.

341.5 Supplementary Examination

Any of the methods of examination described in para. 344 may be specified by the engineering design to supplement the examination required by para. 341.4. The extent of supplementary examination to be performed and any acceptance criteria that differ from those in para. 341.3.2 shall be specified in the engineering design.

341.5.1 Spot Radiography

(a) Longitudinal Welds. Spot radiography for longitudinal groove welds required to have a weld joint factor E_j of 0.90 requires examination by radiography in accordance with para. 344.5 of at least 300 mm (1 ft) in each 30 m (100 ft) of weld for each welder or welding operator. Acceptance criteria are those stated in Table 341.3.2 for radiography under Normal Fluid Service.

(b) Circumferential Butt Welds and Other Welds. It is recommended that the extent of examination be not less than one shot on one in each 20 welds for each welder or welding operator. Unless otherwise specified, acceptance criteria are as stated in Table 341.3.2 for radiography under Normal Fluid Service for the type of joint examined.

(c) Progressive Sampling for Examination. The provisions of para. 341.3.4 are applicable.

(d) Welds to Be Examined. The locations of welds and the points at which they are to be examined by spot radiography shall be selected or approved by the Inspector.

341.5.2 Hardness Tests. The extent of hardness testing required shall be in accordance with para. 331.1.7 except as otherwise specified in the engineering design.

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341.5.3 Examinations to Resolve Uncertainty. Any method may be used to resolve doubtful indications. Acceptance criteria shall be those for the required examination.

342 EXAMINATION PERSONNEL

342.1 Personnel Qualification and Certification

Examiners shall have training and experience commensurate with the needs of the specified examinations.[1] The employer shall certify records of the examiners employed, showing dates and results of personnel qualifications, and shall maintain them and make them available to the Inspector.

342.2 Specific Requirement

For in-process examination, the examinations shall be performed by personnel other than those performing the production work.

343 EXAMINATION PROCEDURES

Any examination shall be performed in accordance with a written procedure that conforms to one of the methods specified in para. 344, including special methods (see para. 344.1.2). Procedures shall be written as required in the BPV Code, Section V, Article 1, T-150. The employer shall certify records of the examination procedures employed, showing dates and results of procedure qualifications, and shall maintain them and make them available to the Inspector.

344 TYPES OF EXAMINATION

344.1 General

344.1.1 Methods. Except as provided in para. 344.1.2, any examination required by this Code, by the engineering design, or by the Inspector shall be performed in accordance with one of the methods specified herein.

344.1.2 Special Methods. If a method not specified herein is to be used, it and its acceptance criteria shall be specified in the engineering design in enough detail to permit qualification of the necessary procedures and examiners.

344.1.3 Definitions. The following terms apply to any type of examination.

100% examination: complete examination of all of a specified kind of item in a designated lot of piping[2]

random examination:[3] complete examination of a percentage of a specified kind of item in a designated lot of piping[2]

spot examination:[3] a specified partial examination of each of a specified kind of item in a designated lot of piping,[2] e.g., of part of the length of all shop-fabricated welds in a lot of jacketed piping.

random spot examination:[3] a specified partial examination of a percentage of a specified kind of item in a designated lot of piping[2]

344.2 Visual Examination

344.2.1 Definition. Visual examination is observation of the portion of components, joints, and other piping elements that are or can be exposed to view before, during, or after manufacture, fabrication, assembly, erection, examination, or testing. This examination includes verification of Code and engineering design requirements for materials, components, dimensions, joint preparation, alignment, welding, bonding, brazing, bolting, threading, or other joining method, supports, assembly, and erection.

344.2.2 Method. Visual examination shall be performed in accordance with the BPV Code, Section V, Article 9. Records of individual visual examinations are not required, except for those of in-process examination as specified in para. 344.7.

344.3 Magnetic Particle Examination

Examination of castings is covered in para. 302.3.3. Magnetic particle examination of welds and of components other than castings shall be performed in accordance with BPV Code, Section V, Article 7.

[1] For this purpose, SNT-TC-1A, Recommended Practice for Nondestructive Testing Personnel Qualification and Certification, may be used as a guide.

[2] A designated lot is that quantity of piping to be considered in applying the requirements for examination in this Code. The quantity or extent of a designated lot should be established by agreement between the contracting parties before the start of work. More than one kind of designated lot may be established for different kinds of piping work.

[3] Random or spot examination will not ensure a fabrication product of a prescribed quality level throughout. Items not examined in a lot of piping represented by such examination may contain defects which further examination could disclose. Specifically, if all radiographically disclosable weld defects must be eliminated from a lot of piping, 100% radiographic examination must be specified.

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344.4 Liquid Penetrant Examination

Examination of castings is covered in para. 302.3.3. Liquid penetrant examination of welds and of components other than castings shall be performed in accordance with BPV Code, Section V, Article 6.

344.5 Radiographic Examination

344.5.1 Method. Radiography of castings is covered in para. 302.3.3. Radiography of welds and of components other than castings shall be performed in accordance with BPV Code, Section V, Article 2.

344.5.2 Extent of Radiography

(a) 100% Radiography. This applies only to girth and miter groove welds and to fabricated branch connection welds comparable to Fig. 328.5.4E, unless otherwise specified in the engineering design.

(b) Random Radiography. This applies only to girth and miter groove welds.

(c) Spot Radiography. This requires a single exposure radiograph in accordance with para. 344.5.1 at a point within a specified extent of welding. For girth, miter, and branch groove welds the minimum requirement is:

(1) for sizes ≤ DN 65 (NPS 2½), a single elliptical exposure encompassing the entire weld circumference;

(2) for sizes > DN 65, the lesser of 25% of the inside circumference or 152 mm (6 in.).

For longitudinal welds the minimum requirement is 152 mm (6 in.) of weld length.

344.6 Ultrasonic Examination

344.6.1 Method. Examination of castings is covered in para. 302.3.3; other product forms are not covered. Ultrasonic examination of welds shall be performed in accordance with BPV Code, Section V, Article 5, except that the alternative specified in (a) and (b) below is permitted for basic calibration blocks specified in T-542.2.1 and T-542.8.1.1.

(a) When the basic calibration blocks have not received heat treatment in accordance with T-542.1.1(c) and T-542.8.1.1, transfer methods shall be used to correlate the responses from the basic calibration block and the component. Transfer is accomplished by noting the difference between responses received from the same reference reflector in the basic calibration block and in the component and correcting for the difference.

(b) The reference reflector may be a V-notch (which must subsequently be removed), an angle beam search unit acting as a reflector, or any other reflector which will aid in accomplishing the transfer.

(c) When the transfer method is chosen as an alternative, it shall be used, at the minimum:

(1) for sizes ≤ DN 50 (NPS 2), once in each 10 welded joints examined;

(2) for sizes > DN 50 and ≤ DN 450 (NPS 18), once in each 1.5 m (5 ft) of welding examined;

(3) for sizes > DN 450, once for each welded joint examined.

(d) Each type of material and each size and wall thickness shall be considered separately in applying the transfer method. In addition, the transfer method shall be used at least twice on each type of weld joint.

(e) The reference level for monitoring discontinuities shall be modified to reflect the transfer correction when the transfer method is used.

344.6.2 Acceptance Criteria. A linear-type discontinuity is unacceptable if the amplitude of the indication exceeds the reference level and its length exceeds:

(a) 6 mm (¼ in.) for $\overline{T}_w \leq 19$ mm (¾ in.);

(b) $\overline{T}_w/3$ for 19 mm < $\overline{T}_w \leq 57$ mm (2¼ in.);

(c) 19 mm for $\overline{T}_w > 57$ mm.

344.7 In-Process Examination

344.7.1 Definition. In-process examination comprises examination of the following, as applicable:

(a) joint preparation and cleanliness;

(b) preheating;

(c) fit-up, joint clearance, and internal alignment prior to joining;

(d) variables specified by the joining procedure, including filler material; and:

(1) (for welding) position and electrode;

(2) (for brazing) position, flux, brazing temperature, proper wetting, and capillary action;

(e) (for welding) condition of the root pass after cleaning — external and, where accessible, internal — aided by liquid penetrant or magnetic particle examination when specified in the engineering design;

(f) (for welding) slag removal and weld condition between passes; and

(g) appearance of the finished joint.

344.7.2 Method. The examination is visual, in accordance with para. 344.2, unless additional methods are specified in the engineering design.

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345 TESTING

345.1 Required Leak Test

Prior to initial operation, and after completion of the applicable examinations required by para. 341, each piping system shall be tested to ensure tightness. The test shall be a hydrostatic leak test in accordance with para. 345.4 except as provided herein.

(a) At the owner's option, a piping system in Category D fluid service may be subjected to an initial service leak test in accordance with para. 345.7, in lieu of the hydrostatic leak test.

(b) Where the owner considers a hydrostatic leak test impracticable, either a pneumatic test in accordance with para. 345.5 or a combined hydrostatic-pneumatic test in accordance with para. 345.6 may be substituted, recognizing the hazard of energy stored in compressed gas.

(c) Where the owner considers both hydrostatic and pneumatic leak testing impracticable, the alternative specified in para. 345.9 may be used if both of the following conditions apply:

(1) a hydrostatic test would damage linings or internal insulation, or contaminate a process which would be hazardous, corrosive, or inoperative in the presence of moisture, or would present the danger of brittle fracture due to low metal temperature during the test; and

(2) a pneumatic test would present an undue hazard of possible release of energy stored in the system, or would present the danger of brittle fracture due to low metal temperature during the test.

345.2 General Requirements for Leak Tests

Requirements in para. 345.2 apply to more than one type of leak test.

345.2.1 Limitations on Pressure

(a) Stress Exceeding Yield Strength. If the test pressure would produce a nominal pressure stress or longitudinal stress in excess of yield strength at test temperature, the test pressure may be reduced to the maximum pressure that will not exceed the yield strength at test temperature. [See paras. 302.3.2(e) and (f).]

(b) Test Fluid Expansion. If a pressure test is to be maintained for a period of time and the test fluid in the system is subject to thermal expansion, precautions shall be taken to avoid excessive pressure.

(c) Preliminary Pneumatic Test. A preliminary test using air at no more than 170 kPa (25 psi) gage pressure may be made prior to hydrostatic testing to locate major leaks.

345.2.2 Other Test Requirements

(a) Examination for Leaks. A leak test shall be maintained for at least 10 min, and all joints and connections shall be examined for leaks.

(b) Heat Treatment. Leak tests shall be conducted after any heat treatment has been completed.

(c) Low Test Temperature. The possibility of brittle fracture shall be considered when conducting leak tests at metal temperatures near the ductile-brittle transition temperature.

345.2.3 Special Provisions for Testing

(a) Piping Subassemblies. Piping subassemblies may be tested either separately or as assembled piping.

(b) Flanged Joints. A flanged joint at which a blank is inserted to isolate other equipment during a test need not be tested.

(c) Closure Welds. The final weld connecting piping systems or components which have been successfully tested in accordance with para. 345 need not be leak tested provided the weld is examined in-process in accordance with para. 344.7 and passes with 100% radiographic examination in accordance with para. 344.5 or 100% ultrasonic examination in accordance with para. 344.6.

345.2.4 Externally Pressured Piping. Piping subject to external pressure shall be tested at an internal gage pressure 1.5 times the external differential pressure, but not less than 105 kPa (15 psi).

345.2.5 Jacketed Piping

(a) The internal line shall be leak tested on the basis of the internal or external design pressure, whichever is critical. This test must be performed before the jacket is completed if it is necessary to provide visual access to joints of the internal line as required by para. 345.3.1.

(b) The jacket shall be leak tested in accordance with para. 345.1 on the basis of the jacket design pressure unless otherwise specified in the engineering design.

345.2.6 Repairs or Additions After Leak Testing. If repairs or additions are made following the leak test, the affected piping shall be retested, except that for minor repairs or additions the owner may waive retest requirements when precautionary measures are taken to assure sound construction.

345.2.7 Test Records. Records shall be made of each piping system during the testing, including:

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(*a*) date of test
(*b*) identification of piping system tested
(*c*) test fluid
(*d*) test pressure
(*e*) certification of results by examiner

These records need not be retained after completion of the test if a certification by the Inspector that the piping has satisfactorily passed pressure testing as required by this Code is retained.

345.3 Preparation for Leak Test

345.3.1 Joints Exposed. All joints, including welds and bonds, are to be left uninsulated and exposed for examination during leak testing, except that joints previously tested in accordance with this Code may be insulated or covered. All joints may be primed and painted prior to leak testing unless a sensitive leak test (para. 345.8) is required.

345.3.2 Temporary Supports. Piping designed for vapor or gas shall be provided with additional temporary supports, if necessary, to support the weight of test liquid.

345.3.3 Expansion Joints. Expansion joints shall be tested without temporary restraint at the lesser of the required test pressure or 150% of design pressure. For this test, expansion joints which depend on external main anchors to restrain pressure end load shall be system tested in place. Self-restrained expansion joints may be tested in place or remotely. For test continuation above 150% of design pressure, the expansion joints may be provided with temporary restraint and tested in place or remotely. A metallic bellows expansion joint shall not be subjected to any pressure in excess of its shop test pressure. See para. 345.4.2 and Appendix X, para. X302.2.3(a).

345.3.4 Limits of Tested Piping. Equipment which is not to be tested shall be either disconnected from the piping or isolated by blinds or other means during the test. A valve may be used provided the valve (including its closure mechanism) is suitable for the test pressure.

345.4 Hydrostatic Leak Test

345.4.1 Test Fluid. The fluid shall be water unless there is the possibility of damage due to freezing or to adverse effects of water on the piping or the process. In that case another suitable nontoxic liquid may be used. If the liquid is flammable, its flash point shall be at least 49°C (120°F), and consideration shall be given to the test environment.

345.4.2 Test Pressure. Except as provided in para. 345.4.3, the hydrostatic test pressure at any point in a metallic piping system shall be as follows:

(*a*) not less than $1\frac{1}{2}$ times the design pressure;

(*b*) for design temperature above the test temperature, the minimum test pressure shall be calculated by Eq. (24), except that the value of S_T/S shall not exceed 6.5:

$$P_T = \frac{1.5\,PS_T}{S} \qquad (24)$$

where

P_T = minimum test gage pressure
P = internal design gage pressure
S_T = stress value at test temperature
S = stress value at design temperature (see Table A-1)

(*c*) if the test pressure as defined above would produce a nominal pressure stress or longitudinal stress in excess of the yield strength at test temperature, the test pressure may be reduced to the maximum pressure that will not exceed the yield strength at test temperature. [See paras. 302.3.2(e) and (f).] For metallic bellows expansion joints, see Appendix X, para. X302.2.3(a).

345.4.3 Hydrostatic Test of Piping With Vessels[4] as a System

(*a*) Where the test pressure of piping attached to a vessel is the same as or less than the test pressure for the vessel, the piping may be tested with the vessel at the piping test pressure.

(*b*) Where the test pressure of the piping exceeds the vessel test pressure, and it is not considered practicable to isolate the piping from the vessel, the piping and the vessel may be tested together at the vessel test pressure, provided the owner approves and the vessel test pressure is not less than 77% of the piping test pressure calculated in accordance with para. 345.4.2(b).

345.5 Pneumatic Leak Test

345.5.1 Precautions. Pneumatic testing involves the hazard of released energy stored in compressed gas. Particular care must therefore be taken to minimize the chance of brittle failure during a pneumatic leak

[4] The provisions of para. 345.4.3 do not affect the pressure test requirements of any applicable vessel code.

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test. Test temperature is important in this regard and must be considered when the designer chooses the material of construction. See para. 345.2.2(c) and Appendix F, para. F323.4.

345.5.2 Pressure Relief Device. A pressure relief device shall be provided, having a set pressure not higher than the test pressure plus the lesser of 345 kPa (50 psi) or 10% of the test pressure.

345.5.3 Test Fluid. The gas used as test fluid, if not air, shall be nonflammable and nontoxic.

345.5.4 Test Pressure. The test pressure shall be 110% of design pressure.

345.5.5 Procedure. The pressure shall be gradually increased until a gage pressure which is the lesser of one-half the test pressure or 170 kPa (25 psi) is attained, at which time a preliminary check shall be made, including examination of joints in accordance with para. 341.4.1(a). Thereafter, the pressure shall be gradually increased in steps until the test pressure is reached, holding the pressure at each step long enough to equalize piping strains. The pressure shall then be reduced to the design pressure before examining for leakage in accordance with para. 345.2.2(a).

345.6 Hydrostatic-Pneumatic Leak Test

If a combination hydrostatic-pneumatic leak test is used, the requirements of para. 345.5 shall be met, and the pressure in the liquid filled part of the piping shall not exceed the limits stated in para. 345.4.2.

345.7 Initial Service Leak Test

This test is applicable only to piping in Category D Fluid Service, at the owner's option. See para. 345.1(a).

345.7.1 Test Fluid. The test fluid is the service fluid.

345.7.2 Procedure. During or prior to initial operation, the pressure shall be gradually increased in steps until the operating pressure is reached, holding the pressure at each step long enough to equalize piping strains. A preliminary check shall be made as described in para. 345.5.5 if the service fluid is a gas or vapor.

345.7.3 Examination for Leaks. In lieu of para. 345.2.2(a), it is permissible to omit examination for leakage of any joints and connections previously tested in accordance with this Code.

345.8 Sensitive Leak Test

The test shall be in accordance with the Gas and Bubble Test method specified in the BPV Code, Section V, Article 10, or by another method demonstrated to have equal sensitivity. Sensitivity of the test shall be not less than 10^{-3} atm·ml/sec under test conditions.

(a) The test pressure shall be at least the lesser of 105 kPa (15 psi) gage, or 25% or the design pressure.

(b) The pressure shall be gradually increased until a gage pressure the lesser of one-half the test pressure or 170 kPa (25 psi) is attained, at which time a preliminary check shall be made. Then the pressure shall be gradually increased in steps until the test pressure is reached, the pressure being held long enough at each step to equalize piping strains.

345.9 Alternative Leak Test

The following procedures and leak test method may be used only under the conditions stated in para. 345.1(c).

345.9.1 Examination of Welds. Welds, including those used in the manufacture of welded pipe and fittings, which have not been subjected to hydrostatic or pneumatic leak tests in accordance with this Code, shall be examined as follows.

(a) Circumferential, longitudinal, and spiral groove welds shall be 100% radiographed in accordance with para. 344.5.

(b) All welds, including structural attachment welds, not covered in (a) above, shall be examined using the liquid penetrant method (para. 344.4) or, for magnetic materials, the magnetic particle method (para. 344.3).

345.9.2 Flexibility Analysis. A flexibility analysis of the piping system shall have been made in accordance with the requirements of para. 319.4.2 (b), if applicable, or (c) and (d).

345.9.3 Test Method. The system shall be subjected to a sensitive leak test in accordance with para. 345.8.

346 RECORDS

346.2 Responsibility

It is the responsibility of the piping designer, the manufacturer, the fabricator, and the erector, as applicable, to prepare the records required by this Code and by the engineering design.

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346.3 Retention of Records

Unless otherwise specified by the engineering design, the following records shall be retained for at least 5 years after the record is generated for the project:

(a) examination procedures; and

(b) examination personnel qualifications.

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CHAPTER VII
NONMETALLIC PIPING AND PIPING LINED WITH NONMETALS

A300 GENERAL STATEMENTS

(a) Chapter VII pertains to nonmetallic piping and to piping lined with nonmetals.

(b) The organization, content, and paragraph designations of this Chapter correspond to those of the first six Chapters (the base Code). The prefix A is used.

(c) Provisions and requirements of the base Code apply only as stated in this Chapter.

(d) Metallic piping which provides the pressure containment for a nonmetallic lining shall conform to the requirements of Chapters I through VI, and to those in Chapter VII not limited to nonmetals.

(e) This Chapter makes no provision for piping to be used under severe cyclic conditions.

(f) With the exceptions stated above, Chapter I applies in its entirety.

PART 1
CONDITIONS AND CRITERIA

A301 DESIGN CONDITIONS

Paragraph 301 applies in its entirety, with the exception of paras. 301.2 and 301.3. See below.

A301.2 Design Pressure

Paragraph 301.2 applies in its entirety, except that references to paras. A302.2.4 and A304 replace references to paras. 302.2.4 and 304, respectively.

A301.3 Design Temperature

Paragraph 301.3 applies with the following exceptions.

A301.3.1 Design Minimum Temperature. Paragraph 301.3.1 applies; but see para. A323.2.2, rather than para. 323.2.2.

A301.3.2 Uninsulated Components. The component design temperature shall be the fluid temperature, unless a higher temperature will result from solar radiation or other external heat sources.

A302 DESIGN CRITERIA

Paragraph A302 states pressure-temperature ratings, stress criteria, design allowances, and minimum design values, together with permissible variations of these factors as applied to the design of piping.

A302.1 General

The designer shall be satisfied as to the adequacy nonmetallic material and its manufacture, considering at least the following:

(a) tensile, compressive, flexural, and shear strength, and modulus of elasticity, at design temperature (long term and short term);
(b) creep rate at design conditions;
(c) design stress and its basis;
(d) ductility and plasticity;
(e) impact and thermal shock properties;
(f) temperature limits;
(g) transition temperature: melting and vaporization;
(h) porosity and permeability;
(i) testing methods;
(j) methods of making joints and their efficiency;
(k) possibility of deterioration in service.

A302.2 Pressure-Temperature Design Criteria

A302.2.1 Listed Components Having Established Ratings. Paragraph 302.2.1 applies, except that reference to Table A326.1 replaces reference to Table 326.1.

A302.2.2 Listed Components Not Having Specific Ratings. Nonmetallic piping components for which design stresses have been developed in accordance with para. A302.3, but which do not have specific pressure-temperature ratings, shall be rated by rules for pressure design in para. A304, within the range of temperatures

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for which stresses are shown in Appendix B, modified as applicable by other rules of this Code.

Piping components which do not have allowable stresses or pressure-temperature ratings shall be qualified for pressure design as required by para. A304.7.2.

A302.2.3 Unlisted Components. Paragraph 302.2.3 applies, except that references to Table A326.1 and paras. A304 and A304.7.2 replace references to Table 326.1 and paras. 304 and 304.7.2, respectively.

A302.2.4 Allowances for Pressure and Temperature Variations

(a) Nonmetallic Piping. Allowances for variations of pressure or temperature, or both, above design conditions are not permitted. The most severe conditions of coincident pressure and temperature shall be used to determine the design conditions for a piping system. See paras. 301.2 and 301.3.

(b) Metallic Piping With Nonmetallic Lining. Allowances for pressure and temperature variations provided in para. 302.2.4 are permitted only if the suitability of the lining material for the increased conditions is established through prior successful service experience or tests under comparable conditions.

A302.2.5 Rating at Junction of Different Services. When two services that operate at different pressure-temperature conditions are connected, the valve segregating the two services shall be rated for the more severe service condition.

A302.3 Allowable Stresses and Other Design Limits for Nonmetals

A302.3.1 General

(a) Table B-1 contains hydrostatic design stresses (HDS). Tables B-2 and B-3 are listings of specifications which meet the criteria of paras. A302.3.2(b) and (c), respectively. Tables B-4 and B-5 contain allowable pressures. These HDS values, allowable stress criteria, and pressures shall be used in accordance with the Notes to Appendix B, and may be used in design calculations (where the allowable stress S means the appropriate design stress) except as modified by other provisions of this Code. Use of hydrostatic design stresses for calculations other than pressure design has not been verified. The bases for determining allowable stresses and pressures are outlined in para. A302.3.2.

(b) The stresses and allowable pressures are grouped by materials and listed for stated temperatures. Straight-line interpolation between temperatures is permissible.

A302.3.2 Bases for Allowable Stresses and Pressures[1]

(a) Thermoplastics. The method of determining HDS is described in ASTM D 2837. HDS values are given in Table B-1 for those materials and temperatures for which sufficient data have been compiled to substantiate the determination of stress.

(b) Reinforced Thermosetting Resin (Laminated). The design stress (DS) values for materials listed in Table B-2 shall be one-tenth of the minimum tensile strengths specified in Table 1 of ASTM C 582 and are valid only in the temperature range from −29°C (−20°F) through 82°C (180°F).

(c) Reinforced Thermosetting Resin and Reinforced Plastic Mortar (Filament Wound and Centrifugally Cast). The hydrostatic design basis stress (HDBS) values for materials listed in Table B-3 shall be obtained by the procedures in ASTM D 2992 and are valid only at 23°C (73°F). HDS shall be obtained by multiplying the HDBS by a service (design) factor[2] selected for the application, in accordance with procedures described in ASTM D 2992, within the following limits.

(1) When using the cyclic HDBS, the service (design) factor F shall not exceed 1.0.

(2) When using the static HDBS, the service (design) factor F shall not exceed 0.5.

(d) Other Materials. Allowable pressures in Tables B-4 and B-5 have been determined conservatively from physical properties of materials conforming to the listed specifications, and have been confirmed by extensive experience. Use of other materials shall be qualified as required by para. A304.7.2.

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[1] Titles of ASTM Specifications and AWWA Standards referenced herein are:
ASTM C 14, Concrete Sewer, Storm Drain, and Culvert Pipe
ASTM C 301, Method of Testing Vitrified Clay Pipe
ASTM C 582, Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion Resistant Equipment.
ASTM D 2321, Practice for Underground Installation of Flexible Thermoplastic Pipe
ASTM D 2837, Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials
ASTM D 2992, Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber-RTR) Pipe and Fittings
ASTM D 3839, Underground Installation of Fiberglass Pipe
AWWA C900, PVC Pressure Pipe, 4-inch through 12-inch, for Water
AWWA C950, Glass-Fiber-Reinforced Thermosetting Resin Pressure Pipe

[2] The service (design) factor F should be selected by the designer after evaluating fully the service conditions and the engineering properties of the specific material under consideration. Aside from the limits in paras. A302.3.2(c)(1) and (2), it is not the intent of this Code to specify service (design) factors.

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A302.3.3 Limits of Calculated Stresses due to Sustained Loads[1]

(a) Internal Pressure Stresses. Limits of stress due to internal pressure are covered in para. A304.

(b) External Pressure Stresses. Stresses due to uniform external pressure shall be considered safe when the wall thickness of the component and its means of stiffening have been qualified as required by para. A304.7.2.

(c) External Loading Stresses. Design of piping under external loading shall be based on the following:

(1) Thermoplastic Piping. ASTM D 2321 or AWWA C900;

(2) Reinforced Thermosetting Resin (RTR) and Reinforced Plastic Mortar (RPM) Piping. ASTM D 3839 or Appendix A of AWWA C950;

(3) strain and possible buckling shall be considered when determining the maximum allowable deflection in (1) or (2) above, but in no case shall the allowable diametral deflection exceed 5% of the pipe inside diameter;

(4) nonmetallic piping not covered in (1) or (2) above shall be subjected to a crushing or three-edge bearing test in accordance with ASTM C 14 or C 301; the allowable load shall be 25% of the minimum value obtained.

A302.3.4 Limits of Calculated Stresses due to Occasional Loads

(a) Operation. The sum of the stresses in any component in a piping system due to pressure, weight, and other sustained loadings and of the stresses produced by occasional loads, such as wind and earthquake, shall not exceed the limits in the applicable part of para. A302.3.3. Wind and earthquake forces need not be considered as acting concurrently.

(b) Test. Stresses due to test conditions are not subject to the limitations in para. A302.3.3. It is not necessary to consider other occasional loads, such as wind and earthquake, as occurring concurrently with test loads.

A302.4 Allowances

Paragraph 302.4 applies in its entirety.

PART 2
PRESSURE DESIGN OF NONMETALLIC PIPING COMPONENTS

A303 GENERAL

Paragraph 303 applies, except that references to Table A326.1 and para. A302.2.1 replace references to Table 326.1 and para. 302.2.1. For nonmetallic components, reference to para. A304 replaces reference to para. 304.

A304 PRESSURE DESIGN OF NONMETALLIC COMPONENTS

A304.1 Straight Pipe

A304.1.1 General

(a) The required thickness of straight sections of pipe shall be determined by Eq. (25).

$$t_m = t + c \tag{25}$$

The minimum thickness T for the pipe selected, considering manufacturer's minus tolerance, shall be not less than t_m.

(b) The following nomenclature is used in the equations for pressure design of straight pipe.

t_m = minimum required thickness, including mechanical, corrosion, and erosion allowances

t = pressure design thickness, as calculated in accordance with para. A304.1.2 for internal pressure or as determined in accordance with para. A304.1.3 for external pressure

c = the sum of mechanical allowances (thread or groove depth) plus corrosion and erosion allowance. For threaded components, the nominal thread depth (dimension h of ASME B1.20.1 or equivalent) shall apply. For machined surfaces or grooves where the tolerance is not specified, the tolerance shall be assumed to be 0.5 mm (0.02 in.) in addition to the specified depth of the cut.

T = pipe wall thickness (measured or minimum per purchase specification)

F = service (design) factor. See para. A302.3.2(c).

P = internal design gage pressure

D = outside diameter of pipe

S = design stress from applicable Table in Appendix B

A304.1.2 Straight Pipe Under Internal Pressure. The internal pressure design thickness t shall be not less than that calculated by one of the following equations, using stress values listed in or derived from the appropriate table in Appendix B.

(a) Thermoplastic Pipe [See Para. A302.3.2(a)]

$$t = \frac{PD}{2S + P} \text{ (Table B-1)} \tag{26a}$$

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(b) RTR (Laminated) Pipe [See Para. A302.3.2(b)]

$$t = \frac{PD}{2S + P} \text{ (Table B-2)} \qquad (26b)^3$$

(c) RTR (Filament Wound) and RPM (Centrifugally Cast) Pipe [See Para. A302.3.2(c)]

$$t = \frac{PD}{2SF + P} \text{ (Table B-3)} \qquad (26c)^3$$

A304.1.3 Straight Pipe Under External Pressure

(a) Nonmetallic Pipe. The external pressure design thickness t shall be qualified as required by para. A304.7.2.

(b) Metallic Pipe Lined With Nonmetals

(1) The external pressure design thickness t for the base (outer) material shall be determined in accordance with para. 304.1.3.

(2) The external pressure design thickness t for the lining material shall be qualified as required by para. A304.7.2.

A304.2 Curved and Mitered Segments of Pipe

A304.2.1 Pipe Bends. The minimum required thickness t_m of a bend, after bending, shall be determined as for straight pipe in accordance with para. A304.1.

A304.2.2 Elbows. Manufactured elbows not in accordance with para. A303 shall be qualified as required by para. A304.7.2.

A304.2.3 Miter Bends. Miter bends shall be qualified as required by para. A304.7.2.

A304.3 Branch Connections

A304.3.1 General. A pipe having a branch connection is weakened by the opening that must be made in it and, unless the wall thickness of the pipe is sufficiently in excess of that required to sustain the pressure, it is necessary to provide added reinforcement. The amount of reinforcement shall be qualified as required by para. A304.7.2 except as provided in para. A304.3.2.

A304.3.2 Branch Connections Using Fittings. It may be assumed without calculation that a branch connection has adequate strength to sustain the internal and external pressure which will be applied to it if it utilizes a fitting (a tee, lateral, or cross) in accordance with para. A303.

A304.3.3 Additional Design Considerations. The requirements of paras. A304.3.1 and A304.3.2 are intended to assure satisfactory performance of a branch connection subjected only to internal or external pressure. The designer shall also consider paras. 304.3.5(a), (c), and (d).

A304.4 Closures

Closures not in accordance with para. A303 shall be qualified as required by para. A304.7.2.

A304.5 Pressure Design of Flanges

A304.5.1 General

(a) Flanges not in accordance with para. A303 or A304.5.1(b) or (c) shall be qualified as required by para. A304.7.2.

(b) Flanges for use with flat ring gaskets may be designed in accordance with BPV Code, Section VIII, Division 1, Appendix 2, except that the allowable stresses and temperature limits of this Code shall govern. Nomenclature shall be as defined in the BPV Code, except for the following:

P = design gage pressure
S_a = bolt design stress at atmospheric temperature[4]
S_b = bolt design stress at design temperature[4]
S_f = allowable stress for flange material from Table B-1, B-2, or B-3

(c) The flange design rules in para. A304.5.1(b) are not applicable to designs employing full face gaskets which extend beyond the bolts, usually to the outside diameter of the flange, or whose flanges are in solid contact beyond the bolts. The forces and reactions in such a joint differ from those joints employing flat ring gaskets, and the flange should be designed in accordance with BPV Code, Section VIII, Division 1, Appendix Y.

A304.5.2 Blind Flanges. Blind flanges not in accordance with para. A303 may be designed in accordance with para. 304.5.2, except that allowable stress S shall be taken from Tables in Appendix B. Otherwise, they shall be qualified as required by para. A304.7.2.

[3] The internal design pressure thickness t shall not include any thickness of the pipe wall reinforced with less than 20% by weight of reinforcing fibers.

[4] Bolt design stresses shall not exceed those in Table A-2.

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A304.6 Reducers

Reducers not in accordance with para. A303 shall be qualified as required by para. A304.7.2.

A304.7 Pressure Design of Other Components

A304.7.1 Listed Components. Other pressure containing components, manufactured in accordance with standards in Table A326.1 but not covered elsewhere in para. A304, may be utilized in accordance with para. A303.

A304.7.2 Unlisted Components and Elements. Pressure design of unlisted components and joints, to which the rules elsewhere in para. A304 do not apply, shall be based on calculations consistent with the design criteria of this Code. Calculations shall be substantiated by one or both of the means stated in (a) and (b) below, considering applicable ambient and dynamic effects in paras. 301.4 through 301.11:

(a) extensive, successful service experience under comparable design conditions with similarly proportioned components made of the same or like material;

(b) performance test under design conditions including applicable dynamic and creep effects, continued for a time period sufficient to determine the acceptability of the component or joint for its design life;

(c) for (a) or (b) above, the designer may interpolate between sizes, wall thicknesses, and pressure classes, and may determine analogies among related materials.

A304.7.3 Nonmetallic Components With Metallic Pressure Parts. Components not covered by standards in Table A326.1, in which both nonmetallic and metallic parts contain the pressure, shall be evaluated by applicable requirements of para. 304.7.2 as well as those of para. A304.7.2.

PART 3
FLUID SERVICE REQUIREMENTS FOR NONMETALLIC PIPING COMPONENTS

A305 PIPE

Listed nonmetallic pipe may be used in Normal Fluid Service, subject to the limitations of the pressure-containing material and para. A323.4. Unlisted pipe may be used only in accordance with para. A302.2.3.

A306 NONMETALLIC FITTINGS, BENDS, MITERS, LAPS, AND BRANCH CONNECTIONS

General. Fittings, bends, miters, laps, and branch connections may be used in accordance with paras. A306.1 through A306.5. Pipe and other materials used in such components shall be suitable for the manufacturing process and the fluid service.

A306.1 Pipe Fittings

A306.1.1 Listed Fittings. Listed fittings may be used in Normal Fluid Service subject to limitations on materials.

A306.1.2 Unlisted Fittings. Unlisted fittings may be used only in accordance with para. A302.2.3.

A306.2 Pipe Bends

A306.2.1 General. A bend made in accordance with para. A332 and verified for pressure design in accordance with para. A304.2.1 shall be suitable for the same service as the pipe from which it is made.

A306.2.2 Corrugated and Other Bends. Bends of other designs (such as creased or corrugated) shall be qualified for pressure design as required by para. A304.7.2.

A306.3 Miter Bends

Except as specified in para. 306.3.2, a miter bend which conforms to para. A304.2.3 may be used in Normal Fluid Service.

A306.4 Fabricated or Flared Laps

The following requirements do not apply to fittings conforming to para. A306.1.

A306.4.1 Fabricated Laps

(a) The requirements in paras. 306.4.1(a) and (b) shall be met.

(b) Lap material shall be suitable for the service conditions. Pressure design shall be qualified as required by para. A304.7.2.

A306.4.2 Flared Laps. Flared laps shall not be used in nonmetallic piping.

A306.5 Fabricated Branch Connections

The following requirements do not apply to fittings conforming to para. A306.1.

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A306.5.1 General. A fabricated branch connection made by bonding the branch pipe directly to the header pipe, with or without added reinforcement as stated in para. 328.5.4, and shown in Fig. 328.5.4, may be used in Normal Fluid Service, provided that pressure design is qualified as required by para. A304.7.2.

A306.5.2 Specific Requirements. Fabricated branch connections shall be made as specified in para. A328.5.

A307 NONMETALLIC VALVES AND SPECIALTY COMPONENTS

Paragraph 307 applies in its entirety, except that in para. 307.1.2 reference to paras. A302.2.3 and A304.7.2 replaces reference to paras. 302.2.3 and 304.7.2, respectively.

A308 FLANGES, BLANKS, FLANGE FACINGS, AND GASKETS

A308.1 General

Paragraph 308.1 applies, except that in para. 308.1.2 reference to para. A302.2.3 replaces reference to para. 302.2.3.

A308.2 Nonmetallic Flanges

A308.2.1 General

(a) Nonmetallic flanges shall be adequate, with suitable facing, gasketing, and bolting, to develop the full rating of the joint and to withstand expected external loadings.

(b) The designer should consult the manufacturer for ratings of nonmetallic flanges.

A308.2.2 Threaded Flanges. Threaded flanges are subject to the requirements for threaded joints in para. A314.

A308.3 Flange Facings

Paragraph 308.3 applies in its entirety.

A308.4 Limitations on Gaskets

See also Appendix F, para. F308.4.

A308.4.1 Lining Used as Facing or Gasket. Lining material extended over the flange face and used as a gasket shall conform to para. 308.4.

A309 BOLTING

Bolting includes bolts, bolt studs, studs, cap screws, nuts, and washers. See Appendix F, para. F309.

A309.1 General

Paragraph 309.1 applies in its entirety.

A309.2 Specific Bolting

Any bolting which meets the requirements of para. 309.1 may be used with any combination of flange materials and flange facings. Joint assembly shall conform to the requirements of para. A335.2.

A309.3 Tapped Holes in Nonmetallic Components

Tapped holes for pressure retaining bolting in nonmetallic piping components may be used provided pressure design is qualified as required by para. A304.7.2.

PART 4
FLUID SERVICE REQUIREMENTS FOR NONMETALLIC PIPING JOINTS

A310 GENERAL

Paragraph 310 applies in its entirety.

A311 BONDED JOINTS IN PLASTICS

A311.1 General

Bonding shall be in accordance with para. A328 and examination shall be in accordance with para. A341.4.1 for use in Normal Fluid Service, subject to the limitations of the material.

A311.2 Specific Requirements

A311.2.1 Fillet Bonds. A fillet bond may be used only in conjunction with a qualified hot gas welding procedure for bonding (see para. A328.5.2).

A311.2.2 Seal Bonds. A seal bond may be used only to prevent leakage of a threaded joint and only if it has been demonstrated that there will be no deleterious effect on the materials bonded.

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A311.2.3 Joints Limited to Category D Fluid Service. Joints which have been examined in accordance with para. 341.4.2 may be used only for Category D Fluid Service.

A312 FLANGED JOINTS

The designer should consult the manufacturer for ratings of flanged joints in nonmetallic piping and in piping lined with nonmetals.

A313 EXPANDED JOINTS

Paragraph 313 applies in its entirety.

A314 THREADED JOINTS

A314.1 General

A threaded joint is suitable for use in Normal Fluid Service, subject to the limitations of the material and requirements elsewhere in para. A314. A joint conforming to para. 314.1(d) shall not be used.

A314.2 Specific Requirements

A314.2.1 Thermoplastic Piping. Threaded joints shall conform to all of the following.

(a) The pipe wall shall be at least as thick as Schedule 80 as defined in ASTM D 1785.

(b) Male threads shall be NPT, ASME B1.20.1.

(c) Threads shall conform to applicable standards in Table A326.1.

(d) A suitable thread lubricant and sealant shall be used.

A314.2.2 Reinforced Thermosetting Resin Piping. Threaded joints in reinforced thermosetting resin (RTR) piping shall conform to the following.

(a) Male threads shall be factory cut or molded on special thick-walled pipe ends.

(b) Matching female threads shall be factory cut or molded in the fittings.

(c) Threading of plain ends of RTR pipe is not permitted, except where such threads are limited to the function of a mechanical lock to matching female threads factory cut or molded in the bottom portions of fittings with deep sockets.

(d) Factory cut or molded threaded nipples, couplings, or adapters, bonded to plain-end RTR pipe and fittings, may be used where it is necessary to provide connections to threaded metallic piping.

A314.2.3 Reinforced Plastic Mortar Piping. Threaded joints are not permitted in reinforced plastic mortar (RPM) piping.

A315 TUBING JOINTS

Paragraph 315 applies in its entirety, subject to material limitations, exclusion of 315.2(b) regarding severe cyclic conditions, and replacement of reference to Table 326.1 and para. 304.7.2 with reference to Table A326.1 and para. A304.7.2, respectively.

A316 CAULKED JOINTS

Paragraph 316 applies in its entirety.

A318 SPECIAL JOINTS

Special joints are those not covered elsewhere in Chapter VII, Part 4, such as bell type and packed gland type joints.

A318.1 General

Paragraph 318.1 applies in its entirety, except that, in para. 318.1.2, reference to para. A304.7.2 replaces reference to para. 304.7.2.

A318.2 Specific Requirements

Paragraph 318.2 applies with the exception of para. 318.2.3.

A318.3 Piping Lined With Nonmetals

A318.3.1 Welding of Metallic Piping

(a) General. Joints made in accordance with the rules in para. A329.1 may be used in Normal Fluid Service, subject to material limitations.

(b) Specific Requirements. Welds shall be limited to those which do not affect the serviceability of the lining.

A318.3.2 Flared Linings

(a) General. Flared ends of linings made in accordance with the rules in para. A329.2 may be used in Normal Fluid Service, subject to material limitations.

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(b) Specific Requirements. Flaring shall be limited to applications which do not affect the serviceability of the lining.

A318.4 Flexible Elastomeric Sealed Joints

Flexible elastomeric seals conforming to the following may be used in Normal Fluid Service, subject to material limitations.

(a) Seals for joints in thermoplastic piping shall conform to ASTM D 3139.

(b) Seals for joints in RTR and RPM piping shall conform to ASTM D 4161.

PART 5
FLEXIBILITY AND SUPPORT

A319 FLEXIBILITY OF NONMETALLIC PIPING

A319.1 Requirements

A319.1.1 Basic Requirements. Piping systems shall be designed to prevent thermal expansion or contraction, pressure expansion, or movement of piping supports and terminals from causing:

(a) failure of piping or supports from overstrain or fatigue;

(b) leakage at joints; or

(c) detrimental stresses or distortion in piping or in connected equipment (pumps, for example), resulting from excessive thrusts and moments in the piping.

A319.1.2 Specific Requirements

(a) In para. A319, guidance, concepts, and data are given to assist the designer in assuring adequate flexibility in piping systems. No specific stress-limiting criteria or methods of stress analysis are presented since stress–strain behavior of most nonmetals differs considerably from that of metals covered by para. 319 and is less well defined for mathematical analysis.

(b) Piping systems should be designed and laid out so that flexural stresses resulting from displacement due to expansion, contraction, and other movement are minimized. This concept requires special attention to supports, terminals, and other restraints, as well as to the techniques outlined in para. A319.7. See also para. A319.2.2(b).

(c) Further information on design of thermoplastic piping can be found in PPI Technical Report TR-21.

A319.2 Concepts

A319.2.1 Displacement Strains. The concepts of strain imposed by restraint of thermal expansion or contraction, and by external movement, described in para. 319.2.1, apply in principle to nonmetals. Nevertheless, the assumption that stresses throughout the piping system can be predicted from these strains because of fully elastic behavior of the piping materials is not generally valid.

(a) In thermoplastics and some RTR and RPM piping, displacement strains are not likely to produce immediate failure but may result in detrimental distortion. Especially in thermoplastic piping, progressive deformation may occur upon repeated thermal cycling or on prolonged exposure to elevated temperature.

(b) In brittle piping (such as porcelain, glass, etc.) and some RTR and RPM piping, the materials show rigid behavior and develop high displacement stresses up to the point of sudden breakage due to overstrain.

A319.2.2 Displacement Stresses

(a) Elastic Behavior. The assumption that displacement strains will produce proportional stress over a sufficiently wide range to justify an elastic stress analysis often is not valid for nonmetals. In brittle piping, strains initially will produce relatively large elastic stresses. The total displacement strain must be kept small, however, since overstrain results in failure rather than plastic deformation. In thermoplastic and thermosetting resin piping, strains generally will produce stresses of the overstrained (plastic) type, even at relatively low values of total displacement strain. If a method of flexibility analysis which assumes elastic behavior is selected, the designer must be able to demonstrate its validity for the piping system under consideration, and shall establish safe limits for computed stresses.

(b) Overstrained Behavior. Stresses cannot be considered proportional to displacement strains throughout a piping system in which an excessive amount of strain may occur in localized portions of the piping [an unbalanced system; see para. 319.2.2(b)] or in which elastic behavior of the piping material cannot be assumed. Overstrain shall be minimized by system layout and excessive displacements shall be minimized by special joints or expansion devices (see para. A319.7).

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A319.2.3 Cold Spring. Cold spring is the intentional deformation of piping during assembly to produce a desired initial displacement or stress. Cold spring may be beneficial in serving to balance the magnitude of stress under initial and extreme displacement conditions. When cold spring is properly applied, there is less likelihood of overstrain during initial operation. There is also less deviation from as-installed dimensions during initial operation, so that hangers will not be displaced as far from their original settings. No credit for cold spring is permitted in stress range calculations, or in calculating thrusts and moments.

A319.3 Properties for Flexibility Analysis

A319.3.1 Thermal Expansion Data. Appendix C lists coefficients of thermal expansion for several nonmetals. More precise values in some instances may be obtainable from manufacturers of components. If these values are to be used in stress analysis, the thermal displacements shall be determined as stated in para. 319.3.1.

A319.3.2 Modulus of Elasticity. Appendix C lists representative data on the tensile modulus of elasticity E for several nonmetals as obtained under typical laboratory rate of strain (loading) conditions. Because of their viscoelasticity, the effective moduli of plastics under actual conditions of use will depend on both the specific course of the strain (or load) with time and the specific characteristics of the plastic. More precise values of the short term and working estimates of effective moduli of elasticity for given conditions of loading and temperature may be obtainable from the manufacturer. The modulus may also vary with the orientation of the specimen, especially for resins with filament-wound reinforcement. For materials and temperatures not listed, refer to ASTM or PPI documents, or to manufacturer's data.

A319.3.3 Poisson's Ratio. Poisson's ratio varies widely depending upon material and temperature. For that reason simplified formulas used in stress analysis for metals may not be valid for nonmetals.

A319.3.4 Dimensions. Nominal thicknesses and outside diameters of pipe and fittings shall be used in flexibility calculations.

A319.4 Analysis

A319.4.1 Formal Analysis Not Required. No formal analysis is required for a piping system which:

(a) duplicates, or replaces without significant change, a system operating with a successful service record;

(b) can readily be judged adequate by comparison with previously analyzed systems; or

(c) is laid out with a conservative margin of inherent flexibility, or employs joining methods or expansion joint devices, or a combination of these methods, in accordance with manufacturers' instructions.

A319.4.2 Formal Analysis Requirements. For a piping system which does not meet the above criteria, the designer shall demonstrate adequate flexibility by simplified, approximate, or comprehensive stress analysis, using a method which can be shown to be valid for the specific case. If substantially elastic behavior can be demonstrated for the piping system [see para A319.2.2(a)], methods outlined in para. 319.4 may be applicable.

A319.5 Reactions

Paragraph 319.5 may be applicable if a formal stress analysis can be shown to be valid for the specific case.

A319.6 Movements

Special attention shall be given to movement (displacement or rotation) of piping with respect to supports and points of close clearance. Movements of the run pipe at the junction of a small branch connection shall be considered in determining the need for flexibility in the branch pipe.

A319.7 Means of Increasing Flexibility

Piping layout often provides adequate inherent flexibility through changes in direction, wherein displacements produce chiefly bending and torsional strains of low magnitude. The amount of tension or compression strain (which can produce larger reactions) usually is small.

Where piping lacks inherent flexibility or is unbalanced, additional flexibility shall be provided by one or more of the following means: bends, loops, or offsets; swivel or flexible joints; corrugated, bellows, or slip-joint expansion joints; or other devices permitting angular, rotational, or axial movement. Suitable anchors, ties, or other devices shall be provided as necessary to resist end forces produced by fluid pressure, frictional resistance to movement, and other causes.

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A321 PIPING SUPPORT

Paragraph 321 applies in its entirety.

A321.5 Supports for Nonmetallic Piping

A321.5.1 General. In addition to other applicable requirements of para. 321, supports, guides, and anchors shall be selected and applied to comply with the principles and requirements of para. A319 and the following.

(a) Piping shall be supported, guided, and anchored in such a manner as to prevent damage to the piping. Point loads and narrow areas of contact between piping and supports shall be avoided. Suitable padding shall be placed between piping and supports where damage to piping may occur.

(b) Valves and equipment which would transmit excessive loads to the piping shall be independently supported to prevent such loads.

(c) Consideration shall be given to mechanical guarding in traffic areas.

(d) Manufacturers' recommendations for support shall be considered.

A321.5.2 Supports for Thermoplastic, RTR, and RPM Piping. Supports shall be spaced to avoid excessive sag or deformation at the design temperature and within the design life of the piping system. Decreases in the modulus of elasticity with increasing temperature and creep of material with time shall be considered when applicable. The coefficient of thermal expansion shall be considered in the design and location of supports.

A321.5.3 Supports for Brittle Piping. Brittle piping, such as glass, shall be well supported but free of hindrance to expansion or other movement. Not more than one anchor shall be provided in any straight run without an expansion joint.

PART 6
SYSTEMS

A322 SPECIFIC PIPING SYSTEMS

A322.3 Instrument Piping

Paragraph 322.3 applies in its entirety, except that references to paras. A301 and A302.2.4 replace references to paras. 301 and 302.2.4, respectively.

A322.6 Pressure Relieving Systems

Paragraph 322.6 applies in its entirety, except for para. 322.6.3. See para. A322.6.3 below.

A322.6.3 Overpressure Protection. Paragraph 322.6.3 applies, except that maximum relieving pressure shall be in accordance with para. A302.2.4.

PART 7
MATERIALS

A323 GENERAL REQUIREMENTS

A323.1 Materials and Specifications

Paragraph 323.1 applies except for para. 323.1.4. See para. A323.1.4 below.

A323.1.4 Reclaimed Materials. Reclaimed piping components may be used, provided they are properly identified as conforming to a listed or published specification (see para. 323.1.1) and otherwise meet the requirements of this Code. The user shall verify that components are suitable for the intended service. Sufficient cleaning, examination, and testing shall be performed to determine the minimum available wall thickness and freedom from any of the following to an extent that would be unacceptable in the intended service:

(a) imperfections;

(b) reduction of mechanical properties; or

(c) absorption of deleterious substances.

A323.2 Temperature Limitations, Nonmetals

The designer shall verify that materials which meet other requirements of the Code are suitable for service throughout the operating temperature range. Also see the Notes for Tables B-1 through B-5 in Appendix B.

A323.2.1 Upper Temperature Limits, Listed Materials

(a) Except as provided in (b) below, a listed material shall not be used at a design temperature higher than the maximum for which a stress value or rating is shown, or higher than the maximum recommended temperature in Table A323.4.2C for RTR materials and in Table A323.4.3 for thermoplastics used as linings.

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TABLE A323.2.2
REQUIREMENTS FOR LOW TEMPERATURE TOUGHNESS TESTS FOR NONMETALS
In addition to the requirements of the material specification

Type of Material	Column A At or Above Listed Minimum Temperature	Column B Below Listed Minimum Temperature
Listed nonmetallic materials	No added requirement	The designer shall have test results at or below the lowest expected service temperature, which assure that the materials and bonds will have adequate toughness and are suitable at the design minimum temperature.
Unlisted materials	An unlisted material shall conform to a published specification. Where composition, properties, and product form are comparable to those of a listed material, requirements for the corresponding listed material shall be met. Other unlisted materials shall be qualified as required in Column B.	

(b) A listed material may be used at a temperature higher than the maximum stated in (a) above if there is no prohibition in Appendix B or elsewhere in the Code, and if the designer verifies the serviceability of the material in accordance with para. 323.2.4.

A323.2.2 Lower Temperature Limits, Listed Materials

(a) Materials for use at design minimum temperatures below certain limits must usually be tested to determine that they have suitable toughness for use in Code piping. Table A323.2.2 sets forth those requirements.

(b) When materials are qualified for use at temperatures below the minimum temperature listed in Appendix B, the allowable stresses or pressures shall not exceed the values for the lowest temperatures shown.

(c) See also the recommended limits in Table A323.4.2C for reinforced thermosetting resin pipe and in Table A323.4.3 for thermoplastics used as linings.

A323.2.3 Temperature Limits, Unlisted Materials. Paragraph 323.2.3 applies.

A323.2.4 Verification of Serviceability. When an unlisted material is to be used, or when a listed material is to be used above or below the limits in Appendix B or Table A323.4.2C or Table A323.4.3, the designer shall comply with the requirements of para. 323.2.4.

A323.4 Fluid Service Requirements for Nonmetallic Materials

A323.4.1 General

(a) Nonmetallic materials shall be safeguarded against excessive temperature, shock, vibration, pulsation, and mechanical abuse in all fluid services.

(b) Requirements in para. A323.4 apply to pressure containing parts. They do not apply to materials used for supports, gaskets, or packing. See also Appendix F, para. FA323.4.

A323.4.2 Specific Requirements

(a) Thermoplastics

(1) They shall not be used in flammable fluid service above ground.

(2) They shall be safeguarded when used in other than Category D Fluid Service.

(3) PVC and CPVC shall not be used in compressed air or other compressed gas service.

(b) Reinforced Plastic Mortars (RPM) Piping. This piping shall be safeguarded when used in other than Category D Fluid Service.

(c) Reinforced Thermosetting Resins (RTR) Piping. This piping shall be safeguarded when used in toxic or flammable fluid services. Table A323.4.2C gives the recommended temperature limits for reinforced thermosetting resins.

(d) Borosilicate Glass and Porcelain

(1) They shall be safeguarded when used in toxic or flammable fluid services.

(2) They shall be safeguarded against large, rapid temperature changes in fluid services.

A323.4.3 Piping Lined With Nonmetals

(a) Metallic Piping Lined With Nonmetals. Fluid service requirements for the base (outer) material in para. 323.4 govern except as stated in (d) below.

(b) Nonmetallic Piping Lined With Nonmetals. Fluid service requirements for the base (outer) material in para. A323.4.2 govern, except as stated in (d) below.

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TABLE A323.4.2C
RECOMMENDED TEMPERATURE LIMITS[1]
FOR REINFORCED THERMOSETTING RESIN PIPE

Materials		Recommended Temperature Limits			
		Minimum		Maximum	
Resin	Reinforcing	°C	°F	°C	°F
Epoxy	Glass Fiber	−29	−20	149	300
Phenolic	Glass Fiber				
Furan	Carbon	−29	−20	93	200
Furan	Glass Fiber				
Polyester	Glass Fiber				
Vinyl Ester	Glass Fiber				

NOTE:
(1) These temperature limits apply only to materials listed and do not reflect evidence of successful use in specific fluid services at these temperatures. The designer should consult the manufacturer for specific applications, particularly as the temperature limits are approached.

TABLE A323.4.3
RECOMMENDED TEMPERATURE LIMITS[1]—THERMOPLASTICS
USED AS LININGS

Materials [Note (2)]	Minimum		Maximum	
	°C	°F	°C	°F
PFA	−198	−325	260	500
PTFE				
FEP	−198	−325	204	400
ECTFE			171	340
ETFE			149	300
PVDF	−18	0	135	275
PP			107	225
PVDC			79	175

NOTES:
(1) These temperature limits are based on material tests and do not necessarily reflect evidence of successful use as piping component linings in specific fluid services at these temperatures. The designer should consult the manufacturer for specific applications, particularly as temperature limits are approached.
(2) See para. A326.3 for definitions of materials.

(c) Nonmetallic Lining Materials. The lining may be any material that, in the judgment of the user, is suitable for the intended service and for the method of manufacture and assembly of the piping. Fluid service requirements in para. A323.4.2 do not apply to materials used as linings.

(d) Properties of both the base and lining materials, and of any bond between them, shall be considered in establishing temperature limitations. Table A323.4.3 gives recommended temperature limits for thermoplastic materials used as linings.

A323.5 Deterioration of Materials in Service

Paragraph 323.5 applies in its entirety.

A325 MATERIALS — MISCELLANEOUS

Paragraph 325 applies in its entirety.

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PART 8
PIPING COMPONENTS, STANDARDS

A326 DIMENSIONS AND RATINGS OF COMPONENTS

A326.1 Requirements

Paragraph 326 applies in its entirety except that references to Table A326.1 and Appendix B replace references to Table 326.1 and Appendix A, respectively.

A326.3 Abbreviations in Table A326.1 and Appendix B

The abbreviations tabulated below are used in this Chapter to replace lengthy phrases in the text and in the titles of standards in Table A326.1 and the Specifications Index for Appendix B. Those marked with an asterisk (*) are in accordance with ASTM D 1600, Terminology Relating to Abbreviations, Acronyms, and Codes for Terms Relating to Plastics.

Abbreviation	Term
*ABS	Acrylonitrile-Butadiene-Styrene
*CAB	Cellulose Acetate-Butyrate
CP	Chlorinated Polyether
*CPVC	Chlorinated Poly (Vinyl Chloride)
ECTFE	Ethylene-Chlorotrifluoroethylene
ETFE	Ethylene-Tetrafluoroethylene
*FEP	Perfluoro (Ethylene-Propylene) copolymer
PB	Polybutylene
*PE	Polyethylene
PFA	Perfluoro (Alkoxyalkane) copolymer
*POM	Polyacetal, Poly (Oxymethylene)
POP	Poly (Phenylene Oxide)
*PP	Polypropylene
*PPS	Poly (Phenylene Sulfide)
PR	Pressure Rated
*PTFE	Polytetrafluoroethylene
*PVC	Poly (Vinyl Chloride)
*PVDC	Poly (Vinylidene Chloride)
*PVDF	Poly (Vinylidene Fluoride)
RPM	Reinforced Plastic Mortar
RTR	Reinforced Thermosetting Resin
SDR	Standard Dimensional Ratio

PART 9
FABRICATION, ASSEMBLY, AND ERECTION

A327 GENERAL

Piping materials and components are prepared for assembly and erection by one or more of the fabrication processes in paras. A328, A329, A332, and A334. When any of these processes is used in assembly and erection, requirements are the same as for fabrication.

A328 BONDING OF PLASTICS

Paragraph A328 applies only to joints in thermoplastic, RTR, and RPM piping. Bonding shall conform to paras. A328.1 through A328.7 and the applicable requirements of para. A311.

A328.1 Bonding Responsibility

Each employer is responsible for the bonding done by personnel of his organization and, except as provided in paras. A328.2.2 and A328.2.3, shall conduct the required performance qualification tests to qualify bonding procedure specifications (BPS) and bonders or bonding operators.

A328.2 Bonding Qualifications

A328.2.1 Qualification Requirements

(a) Qualification of the BPS to be used, and of the performance of bonders and bonding operators, is required. To qualify a BPS, all tests and examinations specified therein and in para. A328.2.5 shall be completed successfully.

(b) In addition to the procedure for making the bonds, the BPS shall specify at least the following:

(1) all materials and supplies (including storage requirements);

(2) tools and fixtures (including proper care and handling);

(3) environmental requirements (e.g., temperature, humidity, and methods of measurement);

(4) joint preparation;

(5) dimensional requirements and tolerances;

(6) cure time;

(7) protection of work;

(8) tests and examinations other than those required by para. A328.2.5; and

(9) acceptance criteria for the completed test assembly.

A328.2.2 Procedure Qualification by Others. Subject to the specific approval of the Inspector, a BPS qualified by others may be used provided that:

(a) the Inspector satisfies himself that the proposed qualified BPS has been prepared and executed by a responsible recognized organization with expertise in the field of bonding;

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(99)

TABLE A326.1
COMPONENT STANDARDS[1]

Standard or Specification	Designation [Note (2)]
Nonmetallic Fittings	
Process Glass Pipe and Fittings	ASTM C 599
Threaded PVC Plastic Pipe Fittings, Sch 80	ASTM D 2464
PVC Plastic Pipe Fittings, Sch 40	ASTM D 2466
Socket-Type PVC Plastic Pipe Fittings, Sch 80	ASTM D 2467
Socket-Type ABS Plastic Pipe Fittings, Sch 40	ASTM D 2468
Thermoplastic Gas Pressure Pipe, Tubing, and Fittings	ASTM D 2513
Reinforced Epoxy Resin Gas Pressure Pipe and Fittings	ASTM D 2517
Plastic Insert Fittings for PE Plastic Pipe	ASTM D 2609
Socket-Type PE Fittings for Outside Diameter-Controlled PE Pipe and Tubing	ASTM D 2683
CPVC Plastic Hot and Cold Water Distribution Systems	ASTM D 2846
Butt Heat Fusion PE Plastic Fittings for PE Plastic Pipe and Tubing	ASTM D 3261
PB Plastic Hot-Water Distribution Systems	ASTM D 3309
Fiberglass RTR Pipe Fittings for Nonpressure Applications [Note (3)]	ASTM D 3840
RTR Flanges	ASTM D 4024
Contact Molded Fiberglass RTR Flanges [Note (3)]	ASTM D 5421
PTFE Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 423
Threaded CPVC Plastic Pipe Fittings, Sch 80	ASTM F 437
Socket-Type CPVC Plastic Pipe Fittings, Sch 40	ASTM F 438
Socket-Type CPVC Plastic Pipe Fittings, Sch 80	ASTM F 439
PVDF Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 491
Propylene and PP Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 492
FEP Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 546
PVDC Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 599
PFA Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 781
Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing	ASTM F 1055
Plastic-Lined Ferrous Metal Pipe, Fittings, and Flanges [Note (4), (5)]	ASTM F 1545
Nonmetallic Pipes and Tubes	
PE Line Pine	API 15LE
Thermoplastic Line Pipe (PVC and CPVC)	API 15LP
Low Pressure Fiberglass Line Pipe	API 15LR
Reinforced Concrete Low-Head Pressure Pipe	ASTM C 361
Process Glass Pipe and Fittings	ASTM C 599
ABS Plastic Pipe, Sch 40 and 80	ASTM D 1527
PVC Plastic Pipe, Sch 40, 80 and 120	ASTM D 1785
PE Plastic Pipe, Sch 40	ASTM D 2104
PE Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter	ASTM D 2239
PVC Plastic Pressure-Rated Pipe (SDR Series)	ASTM D 2241
ABS Plastic Pipe (SDR-PR)	ASTM D 2282
Classification for Machine-Made RTR Pipe	ASTM D 2310
PE Plastic Pipe, Sch 40 & 80, Based on Outside Diameter	ASTM D 2447
Thermoplastic Gas Pressure Pipe, Tubing, and Fittings	ASTM D 2513
Reinforced Epoxy Resin Gas Pressure Pipe and Fittings	ASTM D 2517
PB Plastic Pipe (SDR-PR)	ASTM D 2662
PB Plastic Tubing	ASTM D 2666

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TABLE A326.1 (CONT'D)
COMPONENT STANDARDS[1]

Standard or Specification	Designation [Note (2)]
Bell End PVC Plastic Pipe	ASTM D 2672
PE Plastic Tubing	ASTM D 2737
CPVC Plastic Hot and Cold Water Distribution System	ASTM D 2846
Filament-Wound Fiberglass RTR Pipe [Note (3)]	ASTM D 2996
Centrifugally Cast RTR Pipe	ASTM D 2997
PB Plastic Pipe (SDR-PR) Based on Outside Diameter	ASTM D 3000
PE Plastic Pipe (SDR-PR) Based on Controlled Outside Diameter	ASTM D 3035
PB Plastic Hot-Water Distribution Systems	ASTM D 3309
Fiberglass RTR Pressure Pipe [Note (3)]	ASTM D 3517
Fiberglass RTR Sewer and Industrial Pressure Pipe [Note (3)]	ASTM D 3754
PTFE Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 423
CPVC Plastic Pipe	ASTM F 441
CPVC Plastic Pipe (SDR-PR)	ASTM F 442
PVDF Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 491
Propylene and PP Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 492
FEP Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 546
PVDC Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 599
PFA Plastic-Lined Ferrous Metal Pipe and Fittings [Notes (4), (5)]	ASTM F 781
Plastic-Lined Ferrous Metal Pipe, Fittings, and Flanges [Notes (4), (5)]	ASTM F 1545
Reinforced Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids	AWWA C300
Prestressed Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids	AWWA C301
Reinforced Concrete Pressure Pipe, Noncylinder Type, for Water and Other Liquids	AWWA C302
PVC Pressure Pipe, 4-inch through 12-inch, for Water	AWWA C900
Glass-Fiber-Reinforced Thermosetting Resin Pressure Pipe	*AWWA C950
Miscellaneous	
Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion Resistant Equipment	ASTM C 582
Threads for Fiberglass RTR Pipe (60 deg stub) [Note (3)]	ASTM D 1694
Solvent Cements for ABS Plastic Pipe and Fittings	ASTM D 2235
Solvent Cements for PVC Plastic Pipe and Fittings	ASTM D 2564
Bell End PVC Plastic Pipe	ASTM D 2672
Joints for Plastic Pressure Pipes using Flexible Elastomeric Seals	ASTM D 3139
Fiberglass RTR Pipe Joints Using Flexible Elastomeric Seals [Note (3)]	ASTM D 4161
Design and Construction of Nonmetallic Enveloped Gaskets for Corrosive Service	ASTM F 336
Solvent Cements for CPVC Plastic Pipe and Fittings	ASTM F 493

NOTES:
(1) It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.
(2) An asterisk (*) preceding the designation indicates that the standard has been approved as an American National Standard by the American National Standards Institute.
(3) The term *fiberglass RTR* takes the place of the ASTM designation: "*fiberglass*" (*glass-fiber-reinforced thermosetting resin*).
(4) This Standard allows the use of unlisted materials; see para. 323.1.2.
(5) This Standard contains no pressure-temperature ratings.

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(b) by signature, the employer accepts both the BPS and procedure qualification record (PQR) as his own; and

(c) the employer has at least one currently employed bonder who, while in his employ, has satisfactorily passed a performance qualification test using the proposed qualified BPS.

A328.2.3 Performance Qualification by Others. Without the Inspector's specific approval, an employer shall not accept a performance qualification test made by a bonder or bonding operator for another employer. If approval is given, it is limited to work on piping using the same or equivalent BPS. An employer accepting such performance qualification tests shall obtain a copy of the performance qualification test record from the previous employer showing the name of the employer by whom the bonder or bonding operator was qualified, the date of such qualification, and the date the bonder or bonding operator last bonded pressure piping under such performance qualification.

A328.2.4 Qualification Records. The employer shall maintain a self-certified record, available to the owner or owner's agent and to the Inspector, of the BPS used and the bonders or bonding operators employed by him, and showing the dates and results of BPS qualifications and bonding performance qualifications.

A328.2.5 Qualification Tests. Tests, as specified in para. A328.2.1(a), shall be performed to qualify each BPS and the performance of each bonder and bonding operator. Test assemblies shall conform to (a) below and the test method shall be in accordance with either (b) or (c).

(a) Test Assembly. The assembly shall be fabricated in one pipe size in accordance with the BPS and shall contain at least one of each different type of joint identified in the BPS. More than one test assembly may be prepared if necessary to accommodate all of the joint types or to assure that at least one of each joint type is loaded in both circumferential and longitudinal directions. The size of pipe and fittings in the assembly shall be as follows.

(1) When the largest size to be joined is 110 mm (NPS 4) or smaller, the test assembly shall be the largest size to be joined.

(2) When the largest size to be joined is greater than 110 mm, the size of the test assembly shall be either 110 mm or 25% of the largest piping size to be joined, whichever is greater.

(b) Burst Test Method. The test assembly shall be subjected to a burst test in accordance with the applicable sections of ASTM D 1599.[5] The time to burst in this standard may be extended. The test is successful if failure initiates outside of any bonded joint.

(c) Hydrostatic Test Method. The test assembly shall be subjected to hydrostatic pressure of at least P_T for not less than 1 hr with no leakage or separation of joints.

(1) For thermoplastics, P_T shall be determined in accordance with Eq. (27):

$$P_T = 0.80\overline{T}\left(\frac{(S_S + S_H)}{D - \overline{T}}\right) \quad (27)$$

where

D = outside diameter of pipe
$\overline{T}$ = nominal thickness of pipe
S_S = mean short term burst stress in accordance with ASTM D 1599,[5] from Table B-1 if listed, otherwise from manufacturer's data.
S_H = mean long term hydrostatic strength (LTHS) in accordance with ASTM D 2837. Use twice the 23°C (73°F) HDB design stress from Table B-1 if listed; or use manufacturer's data.

(2) For RTR (laminated and filament-wound) and RPM, P_T shall be three times the manufacturer's allowable pressure for the components being joined.

(3) The test shall be conducted so that the joint is loaded in both the circumferential and longitudinal directions.

A328.2.6 Performance Requalification. Renewal of a bonding performance qualification is required when:

(a) a bonder or bonding operator has not used the specific bonding process for a period of 3 months or more; or (99)

(b) there is specific reason to question the individual's ability to make bonds that meet the BPS.

A328.3 Bonding Materials and Equipment

A328.3.1 Materials. Bonding materials that have deteriorated by exposure to air or prolonged storage, or will not spread smoothly, shall not be used in making joints.

A328.3.2 Equipment. Fixtures and tools used in making joints shall be in such condition as to perform their functions satisfactorily.

[5] Titles of referenced standards and specifications are listed in Table A326.1, except ASTM D 1599 and ASTM D 2855, Practice for Making Solvent-Cemented Joints with PVC Pipe and Fittings.

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A328.4 Preparation for Bonding

Preparation shall be defined in the BPS and shall specify such requirements as:

(a) cutting;
(b) cleaning;
(c) preheat;
(d) end preparation; and
(e) fit-up.

(99) ### A328.5 Bonding Requirements

A328.5.1 General

(a) Production joints shall be made only in accordance with a written bonding procedure specification (BPS) that has been qualified in accordance with para. A328.2. Manufacturers of piping materials, bonding materials, and bonding equipment should be consulted in the preparation of the BPS.

(b) Production joints shall be made only by qualified bonders or bonding operators who have appropriate training or experience in the use of the applicable BPS and have satisfactorily passed a performance qualification test that was performed in accordance with a qualified BPS.

(c) Each qualified bonder and bonding operator shall be assigned an identification symbol. Unless otherwise specified in the engineering design, each pressure containing bond or adjacent area shall be stenciled or otherwise suitably marked with the identification symbol of the bonder or bonding operator. Identification stamping shall not be used and any marking paint or ink shall not be detrimental to the piping material. In lieu of marking the bond, appropriate records may be filed.

(d) Qualification in one BPS does not qualify a bonder or bonding operator for any other bonding procedure.

(e) Longitudinal joints are not covered in para. A328.

A328.5.2 Hot Gas Welded Joints in Thermoplastic Piping[5]

(a) Preparation. Surfaces to be hot gas welded together shall be cleaned of any foreign material. For butt welds, the joining edges should be beveled at 20 deg to 40 deg with 1 mm ($\frac{1}{32}$ in.) root face and root gap.

(b) Procedure. Joints shall be made in accordance with the qualified BPS.

(c) Branch Connections. A fabricated branch connection shall be made by inserting the branch pipe in the hole in the run pipe. Dimensions of the joint shall conform to Fig. 328.4.4 sketch (c). The hole in the run pipe shall be beveled at 45 deg. Alternatively, a fabricated branch connection shall be made using a manufactured full reinforcement saddle with integral socket.

A328.5.3 Solvent Cemented Joints in Thermoplastic Piping[5]

(a) Preparation. PVC and CPVC surfaces to be solvent cemented shall be cleaned by wiping with a clean cloth moistened with acetone or methylethyl ketone. Cleaning for ABS shall conform to ASTM D 2235. A slight interference fit between pipe and fitting socket is preferred and diametral clearance between pipe and entrance of fitting socket shall not exceed 1.0 mm (0.04 in.). This fit shall be checked before solvent cementing.

(b) Procedure. Joints shall be made in accordance with the qualified BPS. ASTM D 2855 provides a suitable basis for development of such a procedure. Solvent cements for PVC, CPVC, and ABS shall conform to ASTM D 2564, D 2846, and D 2235, respectively. Application of cement to both surfaces to be joined and assembly of these surfaces shall produce a continuous bond between them with visual evidence of cement at least flush with the outer end of the fitting bore around the entire joint perimeter. See Fig. A328.5.3.

(c) Branch Connections. A fabricated branch connection shall be made using a manufactured full reinforcement saddle with integral branch socket. The reinforcement saddle shall be solvent cemented to the run pipe over its entire contact surface.

A328.5.4 Heat Fusion Joints in Thermoplastic Piping[5]

(a) Preparation. Surfaces to be heat fused together shall be cleaned of all foreign material.

(b) Procedure. Joints shall be made in accordance with the qualified BPS. The general procedures in ASTM D 2657, Techniques I — Socket Fusion, II — Butt Fusion, and III — Saddle Fusion, provide a suitable basis for development of such a procedure. Uniform heating of both surfaces to be joined and assembly of these surfaces shall produce a continuous homogeneous bond between them and shall produce a small fillet of fused material at the outer limits of the joint. See Fig. A328.5.4 for a typical heat fusion socket joint and butt joint. Fixtures shall be used to align components when joints are made.

(c) Branch Connections. A fabricated branch connection is permitted only where molded fittings are unavailable.

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A328.5.5 Electrofusion Joints in Thermoplastic Piping

(a) Preparation. Surfaces to be heat fused together shall be cleaned of all foreign material.

(b) Procedure. Joints shall be made in accordance with the qualified BPS. The general procedures in ASTM F 1290, Technique I — Coupling Procedure and Technique II — Saddle Procedure provide a suitable basis for the development of such a procedure. See Fig. A328.5.5.

A328.5.6 Adhesive Joints in RTR and RPM Piping

(a) Procedure. Joints shall be made in accordance with the qualified BPS. Application of adhesive to the surfaces to be joined and assembly of these surfaces shall produce a continuous bond between them and shall seal over all cuts to protect the reinforcement from the service fluid. See Fig. A328.5.6.

(b) Branch Connections. A fabricated branch connection shall be made using a manufactured full reinforcement saddle having a socket or integral length of branch pipe suitable for a nozzle or coupling. The hole in the run pipe shall be made with a hole saw; the cut edges of the hole shall be sealed with adhesive at the time the saddle is bonded to the run pipe.

A328.5.7 Butt-and-Wrapped Joints in RTR and RPM Piping[5]

(a) Procedure. Joints shall be made in accordance with the qualified BPS. Application of plies of reinforcement saturated with catalyzed resin to the surfaces to be joined shall produce a continuous structure with them. Cuts shall be sealed to protect the reinforcement from the service fluid. See Fig. A328.5.7.

(b) Branch Connections. For a fabricated branch connection made by inserting the branch pipe into a hole in the run pipe, the hole shall be made with a hole saw.

A328.6 Bonding Repair

Defective material, joints, and other workmanship that fails to meet the requirements of this Code and of the engineering design shall be repaired or replaced. See also para. 341.3.3.

A328.7 Seal Bonds

If threaded joints are to be seal bonded in accordance with para. A311.2.2, the work shall be done by qualified bonders and all exposed threads shall be covered by the seal bond.

A329 FABRICATION OF PIPING LINED WITH NONMETALS

A329.1 Welding of Metallic Piping

A329.1.1 General

(a) Paragraph A329.1 applies only to welding subassemblies of metallic piping that have previously been lined with nonmetals.

(b) Welding which conforms to para. A329.1 may be used in accordance with para. A318.3.1.

A329.1.2 Specific Welding Requirements. Welding shall conform to the requirements of para. 328 and the following additional requirements.

(a) Modifications made in preparation for welding to suit manufacturer's recommendations shall be specified in the engineering design.

(b) Welding shall be performed so as to maintain the continuity of the lining and its serviceability.

(c) If a lining has been damaged, it shall be repaired or replaced.

(d) Qualification to one WPS for a specific lining material does not qualify a welder or welding operator for any other welding procedure involving different lining materials.

A329.2 Flaring of Nonmetallic Linings

A329.2.1 General

(a) Paragraph A329.2 applies only to the flaring of linings in pipe that has previously been lined with nonmetals.

(b) Flaring which conforms to para. A329.2 may be used in accordance with para. A318.3.2.

(c) Flaring shall be performed only in accordance with a written flaring procedure specification, and only by qualified operators who have appropriate training or experience in the use of the applicable flaring procedure specification.

A332 BENDING AND FORMING

A332.1 General

Paragraph 332.1 applies in its entirety.

A332.2 Bending

Paragraph 332.2 applies, except para. 332.2.2.

A332.3 Forming

Paragraph 332.3 applies, except for heat treatment.

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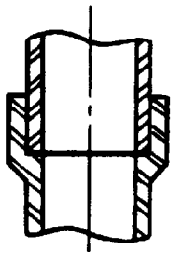
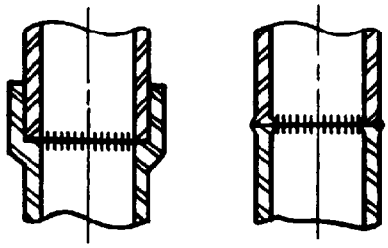


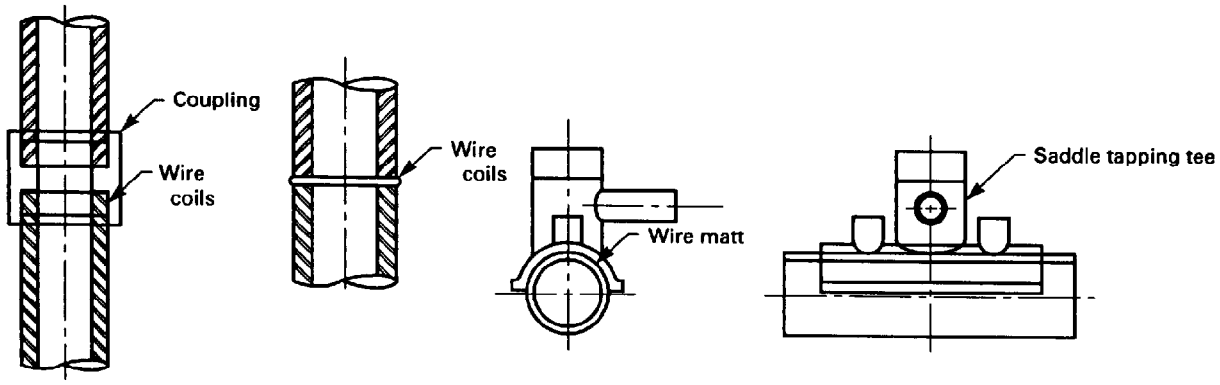
Socket Joint

FIG. A328.5.3 THERMOPLASTIC SOLVENT CEMENTED JOINT



Socket Joint Butt Joint

FIG. A328.5.4 THERMOPLASTIC HEAT FUSION JOINTS



Coupling Butt Saddle

FIG. A328.5.5 TERMOPLASTIC ELECTROFUSION JOINTS

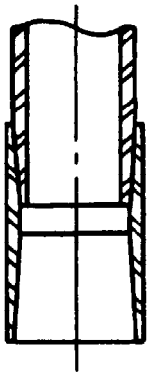
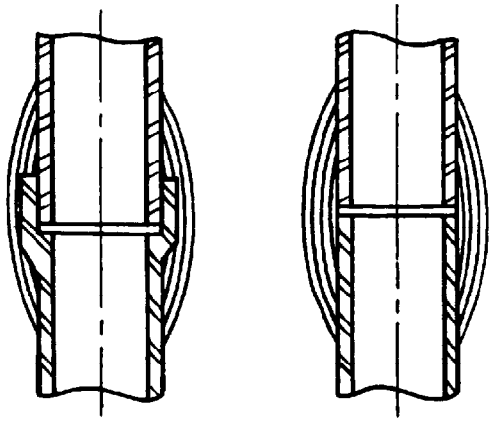


FIG. A328.5.6 FULLY TAPERED TERMOSETTING ADHESIVE JOINT



Overwrapped Bell and Spigot Joint

Butt and Wrapped Joint

FIG. A328.5.7 THERMOSETTING WRAPPED JOINTS

FIG. A328.5 TYPICAL PLASTIC PIPING JOINTS (99)

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A334 JOINING NONPLASTIC PIPING

A334.1 Borosilicate Glass Piping

Short unflanged pieces used to correct for differences between fabrication drawings and field dimensions may be cut to length and finished in the field.

A334.2 Repair of Defects

Defective material, joints, and other workmanship in nonplastic piping that fail to meet the requirements of para. A334 or of the engineering design shall be repaired or replaced.

Completed repairs and replacements shall be examined, subject to the same limitations on imperfections as the original work.

A335 ASSEMBLY AND ERECTION

A335.1 General

Paragraph 335.1.1 applies in its entirety.

A335.2 Flanged and Mechanical Joints

Paragraph 335.2 applies in its entirety.

A335.2.5 Nonmetallic Bolted Joints

(a) Bolted joints in nonmetallic piping may be assembled with any combination of flange material and flange facings, except that when other than flat face flanges and full face gaskets are used:

(1) consideration shall be given to the strength of the flanges, and to sustained loads, displacement strains, and occasional loads described in paras. A302.3.4 and A302.3.5; and

(2) an appropriate bolt-up sequence shall be specified.

(b) Appropriate limits shall be specified for bolt-up torque, and those limits shall not be exceeded.

(c) Flat washers shall be used under bolt heads and nuts.

A335.2.6 Metallic Piping Lined With Nonmetals. In assembling mechanical joints in metallic piping lined with nonmetals, consideration shall be given to means for maintaining electrical continuity between pipe sections, where static sparking could cause ignition of flammable vapors. See Appendix F, para. FA323.4(a).

A335.3 Threaded Joints

Paragraph 335.3 applies except for para. 335.3.2. See para. A335.3.2.

A335.3.2 Joints for Seal Bonding. A threaded joint to be seal bonded shall be made up without thread compound. A joint containing thread compound which leaks during leak testing may be seal bonded in accordance with para. A328.6, provided all compound is removed from exposed threads.

A335.3.4 General, Nonmetallic Piping. Either strap wrenches or other full circumference wrenches shall be used to tighten threaded pipe joints. Tools and other devices used to hold or apply forces to the pipe shall be such that the pipe surface is not scored or deeply scratched.

A335.3.5 RTR and RPM Piping. In assembling threaded joints in RTR and RPM piping, where threads may be exposed to fluids which can attack the reinforcing material, threads shall be coated with sufficient resin to cover the threads and completely fill the clearance between the pipe and the fitting.

A335.4 Tubing Joints

A335.4.1 Flared Joints in Thermoplastic Tubing. In addition to preparation in accordance with para. 335.4.1, flared joints shall be made in accordance with ASTM D 3140, Flared Joints for Polyolefins.

A335.4.2 Flareless and Compression Tubing Joints. Paragraph 335.4.2 applies.

A335.5 Caulked Joints

Paragraph 335.5 applies.

A335.6 Special Joints

Paragraph 335.6 applies, except that expanded joints are not permitted.

A335.6.3 Flexible Elastomeric Sealed Joints. Assembly of flexible elastomeric sealed joints shall be in accordance with the manufacturer's recommendations and the following.

(a) Seal and bearing surfaces shall be free from injurious imperfections.

(b) Any lubricant used to facilitate joint assembly shall be compatible with the joint components and the intended service.

(c) Proper joint clearances and piping restraints (if not integral in the joint design) shall be provided to

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prevent joint separation when expansion can occur due to thermal and/or pressure effects.

A335.8 Assembly of Brittle Piping

Care shall be used to avoid scratching of brittle nonmetallic piping in handling and supporting. Any scratched or chipped components shall be replaced. Care shall be used in handling glass-lined and cement-lined steel pipe because the lining can be injured or broken by blows which do not dent or break the pipe.

A335.8.1 Borosilicate Glass Piping. In addition to the precaution in para. A335.8, borosilicate glass piping components shall be protected from weld spatter. Any component so damaged shall be replaced. Flanges and cushion inserts shall be carefully fitted and aligned to pipe, fitting, and valve ends. Gaskets shall be of the construction recommended for the joint. Installation and torquing of bolts shall be in accordance with the manufacturer's recommendations.

A335.9 Cleaning of Piping

See Appendix F, para. F335.9.

PART 10
INSPECTION, EXAMINATION, AND TESTING

A340 INSPECTION

Paragraph 340 applies in its entirety.

A341 EXAMINATION

A341.1 General

Paragraph 341.1 applies.

A341.2 Responsibility for Examination

Paragraph 341.2 applies in its entirety.

A341.3 Examination Requirements

A341.3.1 Responsibility for Examination. Paragraph 341.3.1 applies, except for (a) and (b), which apply only for metals.

A341.3.2 Acceptance Criteria. Acceptance criteria shall be as stated in the engineering design and shall at least meet the applicable requirements for bonds in Table A341.3.2 and requirements elsewhere in the Code.

A341.3.3 Defective Components and Workmanship. Paragraph 341.3.3 applies in its entirety.

A341.3.4 Progressive Sampling for Examination. Paragraph 341.3.4 applies in its entirety.

A341.4 Extent of Required Examination

A341.4.1 Examination Normally Required. Piping in Normal Fluid Service shall be examined to the extent specified herein or to any greater extent specified in the engineering design. Acceptance criteria are as stated in para. A341.3.2 unless otherwise specified.

(a) Visual Examination. At least the following shall be examined in accordance with para. 344.2:

(1) materials and components in accordance with para. 341.4.1(a)(1);

(2) at least 5% of fabrication. For bonds, each type of bond made by each bonder and bonding operator shall be represented.

(3) 100% of fabrication for bonds other than circumferential, except those in components made in accordance with a listed specification;

(4) assembly and erection of piping in accordance with paras. 341.4.1(a)(4), (5), and (6).

(b) Other Examination. Not less than 5% of all bonded joints shall be examined by in-process examination in accordance with para. 344.7, the joints to be examined being selected to ensure that the work of each bonder and bonding operator making the production joints is examined.

(c) Certifications and Records. Paragraph 341.4.1(c) applies.

A341.4.2 Examination — Category D Fluid Service. Piping and piping elements for Category D Fluid Service as designated in the engineering design shall be visually examined to the extent necessary to satisfy the examiner that components, materials, and workmanship conform to the requirements of this Code and the engineering design.

A341.5 Supplementary Examination

A341.5.1 General. Any applicable method of examination described in para. 344 may be specified by the engineering design to supplement the examination required by para. A341.4. The extent of supplementary examination to be performed and any acceptance criteria that differ from those in para. A341.3.2 shall be specified in the engineering design.

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TABLE A341.3.2
ACCEPTANCE CRITERIA FOR BONDS

Kind of Imperfection	Thermoplastic			RTR and RPM [Note (1)]
	Hot Gas Welded	Solvent Cemented	Heat Fusion	Adhesive Cemented
Cracks	None permitted	Not applicable	Not applicable	Not applicable
Unfilled areas in joint	None permitted	None permitted	None permitted	None permitted
Unbonded areas in joint	Not applicable	None permitted	None permitted	None permitted
Inclusions of charred material	None permitted	Not applicable	Not applicable	Not applicable
Unfused filler material inclusions	None permitted	Not applicable	Not applicable	Not applicable
Protrusion of material into pipe bore, % of pipe wall thickness	Not applicable	Cement, 50%	Fused material, 25%	Adhesive, 25%

NOTE:
(1) RTR = reinforced thermosetting resin; RPM = reinforced plastic mortar.

A341.5.2 Examinations to Resolve Uncertainty. Paragraph 341.5.3 applies.

A342 EXAMINATION PERSONNEL

Paragraph 342 applies in its entirety.

A343 EXAMINATION PROCEDURES

Paragraph 343 applies in its entirety.

A344 TYPES OF EXAMINATION

A344.1 General

Paragraph 344.1 applies in its entirety.

A344.2 Visual Examination

Paragraph 344.2 applies in its entirety.

A344.5 Radiographic Examination

Radiographic examination may be used in accordance with para. 344.1.2.

A344.6 Ultrasonic Examination

Ultrasonic examination may be used in accordance with para. 344.1.2.

A344.7 In-Process Examination

Paragraph 344.7 applies in its entirety.

A345 TESTING

A345.1 Required Leak Test

(a) Prior to initial operation, each piping system shall be tested to ensure tightness. The test shall be a hydrostatic leak test in accordance with para. A345.4, except as provided herein.

(b) Paragraphs 345.1(a) and (b) apply.

A345.2 General Requirements for Leak Test

Requirements in para. A345.2 apply to more than one type of leak test.

A345.2.1 Limitations on Pressure. Paragraphs 345.2.1(b) and (c) apply.

A345.2.2 Other Test Requirements

(a) Paragraph 345.2.2(a) applies.

(b) The possibility of brittle fracture shall be considered when conducting leak tests on brittle materials or at low temperature.

(c) Paragraphs 345.2.3 through 345.2.7 apply.

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A345.3 Preparation for Leak Test

Paragraph 345.3 applies in its entirety, considering bonds in place of welds, and excluding expansion joints.

A345.4 Hydrostatic Leak Test

A345.4.1 Test Fluid. Paragraph 345.4.1 applies.

A345.4.2 Test Pressure

(a) Nonmetallic Piping. Except as provided in para. 345.4.3(b), the hydrostatic test pressure at any point in a nonmetallic piping system shall be not less than 1.5 times the design pressure, but shall not exceed 1.5 times the maximum rated pressure of the lowest-rated component in the system.

(b) Thermoplastic Piping. For piping systems in which the design temperature is above the test temperature, para. 345.4.2(b) applies, except that S and S_T shall be from Table B-1 instead of A-1.

(c) Metallic Piping with Nonmetallic Lining. Paragraph 345.4.2 applies.

A345.4.3 Hydrostatic Test of Piping With Vessels as a System. Paragraph 345.4.3 applies.

A345.5 Pneumatic Leak Test

A345.5.1 Precautions. In addition to the requirements of para. 345.5.1, a pneumatic test of nonmetallic piping is permitted only with the owner's approval, and precautions in Appendix F, para. FA323.4 should be considered.

A345.5.2 Other Requirements

(a) Paragraphs 345.5.2 through 345.5.5 apply.

(b) PVC and CPVC piping shall not be pneumatically tested.

A345.6 Hydrostatic-Pneumatic Leak Test

If a combined hydrostatic-pneumatic leak test is used, the requirements of para. A345.5 shall be met, and the pressure in the liquid-filled part of the piping shall not exceed the values calculated in accordance with para. A345.4.2 or 345.4.2, as applicable.

A345.7 Initial Service Leak Test

Paragraph 345.7 applies in its entirety for Category D Fluid Service only.

A345.8 Sensitive Leak Test

Paragraph 345.8 applies.

A346 RECORDS

Paragraph 346 applies in its entirety.

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CHAPTER VIII
PIPING FOR CATEGORY M FLUID SERVICE

M300 GENERAL STATEMENTS

(a) Chapter VIII pertains to piping designated by the owner as being in Category M Fluid Service. See also Appendix M.

(b) The organization, content, and paragraph designations of this Chapter correspond to those of the base Code (Chapters I through VI) and Chapter VII. The prefix M is used.

(c) Provisions and requirements of the base Code and Chapter VII apply only as stated in this Chapter.

(d) Consideration shall be given to the possible need for engineered safeguards (see Appendix G, para. G300.3) in addition to the safeguards already provided (paras. G300.1 and G300.2).

(e) This Chapter makes no provision for piping to be used under severe cyclic conditions. The occurrence of such conditions can ordinarily be circumvented by piping layout, component selection, and other means. If this is not feasible, the engineering design shall specify any necessary provisions in accordance with para. 300(c)(5).

(f) Chapter I applies in its entirety.

PART 1
CONDITIONS AND CRITERIA

M301 DESIGN CONDITIONS

Paragraph 301 applies in its entirety, with the exceptions of paras. 301.3 and 301.5. See paras. M301.3 and M301.5.

M301.3 Design Temperature, Metallic Piping

Use of any temperature other than the fluid temperature as the design temperature shall be substantiated by heat transfer calculations confirmed by tests or by experimental measurements.

M301.5 Dynamic Effects

Paragraph 301.5 applies with the exception of paras. 301.5.1 and 301.5.4. See paras. M301.5.1 and M301.5.4.

M301.5.1 Impact. Design, layout, and operation of piping shall be conducted so as to minimize impact and shock loads. In the event that such loadings are unavoidable, para. 301.5.1 applies.

M301.5.4 Vibration. Suitable dynamic analysis, such as computer simulation, shall be made where necessary to avoid or minimize conditions which lead to detrimental vibration, pulsation, or resonance effects in the piping.

M302 DESIGN CRITERIA

M302.1 General

Paragraph M302 pertains to pressure-temperature ratings, stress criteria, design allowances, and minimum design values, together with permissible variations of these factors as applied to piping design.

Paragraph 302 applies in its entirety, with the exception of paras. 302.2 and 302.3. See paras. M302.2 and M302.3.

M302.2 Pressure-Temperature Design Criteria

Paragraph 302.2 applies in its entirety, with the exception of paras. 302.2.4 and 302.2.5. See paras. M302.2.4 and M302.2.5.

M302.2.4 Allowance for Pressure and Temperature Variations, Metallic Piping. Use of allowances in para. 302.2.4 is not permitted. Design temperature and pressure shall be based on coincident pressure-temperature conditions requiring the greatest wall thickness or the highest component rating.

M302.2.5 Ratings at Junction of Different Services, Metallic Piping. When two services that operate at different pressure-temperature conditions are connected, the valve segregating the services shall be rated for the more severe service condition.

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M302.3 Allowable Stresses and Other Stress Limits for Metallic Piping

Paragraph 302.3 applies in its entirety, with the exception of para. 302.3.2. See para. M302.3.2.

M302.3.2 Bases for Allowable Stresses. The designer shall fully document the basis for using any stress limit not in accordance with the stress Tables in Appendix A.

M302.4 Allowances

Paragraph 302.4 applies in its entirety.

PART 2
PRESSURE DESIGN OF METALLIC PIPING COMPONENTS

M303 GENERAL

Paragraph 303 applies in its entirety.

M304 PRESSURE DESIGN OF METALLIC COMPONENTS

Paragraph 304 applies in its entirety.

PART 3
FLUID SERVICE REQUIREMENTS FOR METALLIC PIPING COMPONENTS

M305 PIPE

M305.1 General

Listed pipe may be used in accordance with para. M305.2. Unlisted pipe may be used only as provided in para. 302.2.3.

M305.2 Specific Requirements for Metallic Pipe

Pipe listed in para. 305.2.2 shall not be used. The provision for severe cyclic conditions in para. 305.2.3 does not apply [see para. M300(e)].

M306 METALLIC FITTINGS, BENDS, MITERS, LAPS, AND BRANCH CONNECTIONS

General. Fittings, bends, miters, laps, and branch connections may be used in accordance with paras. M306.1 through M306.6. Pipe and other materials used in such components shall be suitable for the manufacturing process and the fluid service.

M306.1 Pipe Fittings

Paragraph 306.1 applies in its entirety, with the exception of para. 306.1.3. See para. M306.1.3 below. The provision for severe cyclic conditions in para. 306.1.4 does not apply [see para. M300(e)].

M306.1.3 Specific Fittings. The following shall not be used:

(a) fittings conforming to MSS SP-43;

(b) proprietary "Type C" lap-joint stub-end butt welding fittings.

M306.2 Pipe Bends

Paragraph 306.2 applies, except that bends in accordance with para. 306.2.2 shall not be used and para. 306.2.3 does not apply [see para. M300(e)].

M306.3 Miter Bends

A miter bend shall conform to para. 306.3.1 and shall not make a change in direction at a single joint (angle α in Fig. 304.2.3) greater than 22.5 deg. Paragraph 306.3.3 does not apply [see para. M300(e)].

M306.4 Fabricated or Flared Laps

M306.4.1 General. The following requirements do not apply to fittings conforming to para. M306.1, nor to laps integrally forged on pipe ends. Paragraph 306.4.1 applies.

M306.4.2 Flared Laps. A flared lap shall meet the requirements of para. 306.4.2. In addition:

(a) pipe size shall be $\leq$ DN 100 (NPS 4), with wall thickness before flaring $\geq$ the value of T for Schedule 10S;

(b) pressure-temperature rating shall be $\leq$ that of an ASME B16.5 PN 20 (Class 150) Group 1.1 flange; and

(c) service temperature shall be $\leq$ 204°C (400°F).

M306.5 Fabricated Branch Connections

The following requirements do not apply to fittings conforming to para. M306.1. Paragraph 306.5.1 applies, with the following exceptions.

(a) Of the methods listed in para. 304.3.1(a), the one in subpara. (3) may be used only if those in (1) and (2) are unavailable.

(b) Of the branch connections described in paras.

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304.3.2(b) and (c), those having threaded outlets are permitted only in accordance with para. M314 and those having socket welding outlets are permitted only in accordance with para. M311.2.

M306.6 Closures

The following requirements do not apply to blind flanges or to fittings conforming to para. M306.1. Of the closures described in para. 304.4, flat closures in accordance with the BPV Code, Section VIII, Division 1, UG-34 and UW-13, and conical closures without transition knuckles [UG-32(g) and UG-33(f)], may be used only if others are not available. The requirements in M306.5 apply to openings in closures [see also para. 304.4.2(b)].

M307 METALLIC VALVES AND SPECIALTY COMPONENTS

The following requirements for valves shall also be met as applicable by other pressure containing piping components, such as strainers and separators. See also Appendix F, para. F307.

M307.1 General

Paragraph 307.1 applies, subject to the requirements in para. M307.2.

M307.2 Specific Requirements

(a) Valves having threaded bonnet joints (other than union joints) shall not be used.

(b) Only metallic valves conforming to the following requirements may be used.

(1) Special consideration shall be given to valve design to prevent stem leakage to the environment.

(2) Bonnet or cover plate closures shall be: flanged, secured by at least four bolts with gasketing conforming to para. 308.4; or proprietary, attached by bolts, lugs, or other substantial means, and having a gasket design that increases gasket compression as fluid pressure increases; or secured with a full penetration weld made in accordance with para. M311; or secured by a straight thread sufficient for mechanical strength, a metal-to-metal seat, and a seal weld made in accordance with para. M311, all acting in series.

(3) Body joints, other than bonnet or cover plate joints, shall conform to para. M307.2(b)(2).

M308 FLANGES, BLANKS, FLANGE FACINGS, AND GASKETS

Paragraph 308.1 applies in its entirety.

M308.2 Specific Requirements for Metallic Flanges

Paragraph 308.2.4 does not apply [see para. M300(e)]. The following shall not be used:

(a) single-welded slip-on flanges;

(b) expended-joint flanges;

(c) slip-on flanges used as lapped flanges unless the requirements in para. 308.2.1(c) are met;

(d) threaded metallic flanges, except those employing lens rings or similar gaskets and those used in lined pipe where the liner extends over the gasket face.

M308.3 Flange Facings

Paragraph 308.3 applies.

M308.4 Gaskets

Paragraph 308.4 applies.

M308.5 Blanks

All blanks shall be marked with material, rating, and size.

M309 BOLTING

Paragraph 309 applies, except for para. 309.2.4 [see para. M300(e)].

PART 4
FLUID SERVICE REQUIREMENTS FOR METALLIC PIPING JOINTS

M310 METALLIC PIPING, GENERAL

Paragraph 310 applies in its entirety.

M311 WELDED JOINTS IN METALLIC PIPING

Welded joints may be made in any metal for which it is possible to qualify welding procedures, welders, and welding operators in accordance with para. M328.

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M311.1 General

Paragraph 311.1 applies with the following exceptions.

(a) Split backing rings shall not be used.

(b) Socket welded joints greater than DN 50 (NPS 2) are not permitted.

(c) Examination shall be in accordance with para. M341.4.

M311.2 Specific Requirements

Paragraphs 311.2.3(a), 311.2.4(a), (b), and (d), 311.2.5, and 311.2.6 apply.

M312 FLANGED JOINTS IN METALLIC PIPING

Paragraph 312 applies in its entirety.

M313 EXPANDED JOINTS IN METALLIC PIPING

Expanded joints shall not be used.

M314 THREADED JOINTS IN METALLIC PIPING

M314.1 General

Paragraphs 314.1(a), (b), and (c) apply.

M314.2 Specific Requirements

M314.2.1 Taper-Threaded Joints. Paragraph 314.2.1 applies except that only components suitable for Normal Fluid Service in sizes 8 ≤ DN ≤ 25 (1/4 ≤ NPS ≤ 1) are permitted (see Table 314.2.1). Sizes smaller than DN 20 (NPS 3/4) shall be safeguarded (see Appendix G).

N314.2.2 Straight-Threaded Joints. Paragraph 314.2.2 applies. In addition, components shall have adequate mechanical strength and the joint shall have a confined seating surface not subject to relative rotation as or after the joint is tightened. [See Fig. 335.3.3 sketches (b) and (c) for acceptable construction.]

M315 TUBING JOINTS IN METALLIC PIPING

Paragraph 315 applies, except for para. 315.2(b).

M316 CAULKED JOINTS

Caulked joints shall not be used.

M317 SOLDERED AND BRAZED JOINTS

Soldered, brazed, and braze welded joints shall not be used.

M318 SPECIAL JOINTS IN METALLIC PIPING

Paragraph 318 applies, with the exception that adhesive joints and bell type joints shall not be used.

PART 5
FLEXIBILITY AND SUPPORT OF METALLIC PIPING

M319 FLEXIBILITY OF METALLIC PIPING

Paragraph 319 applies, with the exception that the simplified rules in para. 319.4.1(c) do not apply.

M321 PIPING SUPPORT

Paragraph 321 applies, except that supporting elements shall be of listed material.

PART 6
SYSTEMS

M322 SPECIFIC PIPING SYSTEMS

M322.3 Instrument Piping

Paragraph 322.3 applies, with the exception that, for signal lines in contact with process fluids and process temperature–pressure conditions:

(a) tubing shall be not larger than 5/8 in. (16 mm) O.D. and shall be suitable for the service;

(b) an accessible block valve shall be provided to isolate the tubing from the pipeline;

(c) joining methods shall conform to the requirements of paras. 315.1 and 315.2.

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M322.6 Pressure Relieving Systems

Paragraph 322.6 applies, except for para. 322.6.3. See para. M322.6.3.

M322.6.3 Overpressure Protection. For metallic piping, the design pressure may be exceeded by no more than 10% during operation of a pressure relieving system.

PART 7
METALLIC MATERIALS

M323 GENERAL REQUIREMENTS

M323.1 Materials and Specifications

Paragraphs 323.1.1 and 323.1.2 apply. See paras. M323.1.3 and M323.1.4.

M323.1.3 Unknown Materials. Materials of unknown specification shall not be used.

M323.1.4 Reclaimed Metallic Materials. Reclaimed materials may be used when the material certification records are available for the specific materials employed, and the designer is assured that the material is sound and free from harmful defects.

M323.2 Temperature Limitations

Paragraph 323.2 applies with the exception that, in regard to lower temperature limits, the relaxation of minimum temperature limits stated in Note (3) of Table 323.2.2 is not permitted.

M323.3 Impact Testing Methods and Acceptance Criteria

Paragraph 323.3 applies in its entirety.

M323.4 Fluid Service Requirements for Metallic Materials

Paragraph 323.4.1 applies.

M323.4.2 Specific Requirements. Paragraph 323.4.2 applies, except that cast irons other than ductile iron shall not be used for pressure-containing parts, and lead and tin shall be used only as linings.

M323.4.3 Metallic Cladding and Lining Materials. In addition to the requirements of para. 323.4.3, where materials covered in paras. 323.4.2(c)(2) and 323.4.3 are used as cladding or lining in which the cladding or lining also serves as a gasket or as part of the flange facing, consideration shall be given to the design of the flanged joint to prevent leakage to the environment.

M323.5 Deterioration of Materials in Service

Paragraph 323.5 applies in its entirety.

M325 MATERIALS — MISCELLANEOUS

M325.1 Joining and Auxiliary Materials

In applying para. 325, materials such as solvents, brazes, and solders shall not be used. Nonmetallic materials used as gaskets and packing materials shall be suitable for the fluid service.

PART 8
STANDARDS FOR PIPING COMPONENTS

M326 DIMENSIONS AND RATINGS OF COMPONENTS

Paragraph 326.1.3 applies.

M326.1 Dimensional Requirements

M326.1.1 Listed Piping Components. Except for prohibitions and restrictions stated elsewhere in Chapter VIII, components made in accordance with standards and specifications listed in Table 326.1 may be used in Category M service.

M326.1.2 Unlisted Piping Components. Dimensions of unlisted components shall be governed by requirements in paras. 303 and 304.

M326.2 Ratings of Components

Paragraph 326.2 applies in its entirety.

PART 9
FABRICATION, ASSEMBLY, AND ERECTION OF METALLIC PIPING

M327 GENERAL

Metallic piping materials and components are prepared for assembly and erection by one or more of the fabrication processes in paras. M328, M330, M331,

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and M332. When any of these processes is used in assembly and erection, requirements are the same as for fabrication.

M328 WELDING OF METALS

Welding shall be in accordance with paras. M311.1 and 328, except see para. M328.3.

M328.3 Welding Materials

Paragraph 328.3 applies in its entirety, except that split backing rings shall not be used, and removable backing rings and consumable inserts may be used only where their suitability has been demonstrated by procedure qualification.

M330 PREHEATING OF METALS

Paragraph 330 applies in its entirety.

M331 HEAT TREATMENT OF METALS

Paragraph 331 applies in its entirety, with the exception that no requirements less stringent than those of Table 331.1.1 shall be specified.

M332 BENDING AND FORMING OF METALS

Paragraph 332 applies in its entirety, except that bending which conforms to para. 332.2.3 is not permitted.

M335 ASSEMBLY AND ERECTION OF METALLIC PIPING

M335.1 General

M335.1.1 Alignment. In addition to the requirements of para. 335.1.1, any bending or forming required for alignment and fit-up shall be heat treated if required by para. 332.4.

M335.2 Flanged Joints

Paragraph 335.2 applies in its entirety.

M335.3 Threaded Joints

Paragraphs 335.3.1 and 335.3.2 apply. See paras. M335.3.3 and M335.3.4.

M335.3.3 Straight-Threaded Joints. The requirements of para. 335.3.3 are subject to the limitations in para. M322.

M335.3.4 Condition of Threads. Taper-threaded components and threaded ends permitted under para. M314.2.1 shall be examined before assembly for cleanliness and continuity of threads and shall be rejected if not in conformance with ASME B1.20.1 or other applicable standards.

M335.4 Tubing Joints

M335.4.1 Flared Tubing Joints. The requirements of para. 335.4.1 apply; however, see para. M322 for limitations associated with specific piping systems. (99)

M335.4.2 Flareless and Compression Tubing Joints. The requirements of para. 335.4.2 apply; however, see para. M322 for limitations associated with specific piping systems. (99)

M335.6 Special Joints

Special joints shall be in accordance with paras. M318 and 335.6.1.

M335.9 Cleaning of Piping

See Appendix F, para. F335.9.

PART 10
INSPECTION, EXAMINATION, TESTING, AND RECORDS OF METALLIC PIPING

M340 INSPECTION

Paragraph 340 applies in its entirety.

M341 EXAMINATION

Paragraphs 341.1, 341.2, 341.3, and 341.5 apply in their entirety. See para. M341.4.

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M341.4 Extent of Required Examination

Paragraph 341.4.1 applies with the following exceptions.

(a) Visual Examination

(1) All fabrication shall be examined.

(2) All threaded, bolted, and other mechanical joints shall be examined.

(b) Other Examination

(1) The random radiography/ultrasonic examination requirements of para. 341.4.1(b)(1) apply except that at least 20% of circumferential butt and miter welds and of fabricated lap and branch connection welds comparable to those shown in Figs. 328.5.4E and 328.5.5 sketches (d) and (e) shall be examined.

(2) The in-process examination alternative permitted in para. 341.4.1(b)(1) may be specified on a weld-for-weld basis in the engineering design or by the Inspector. It shall be supplemented by appropriate nondestructive examination.

M342 EXAMINATION PERSONNEL

Paragraph 342 applies.

M343 EXAMINATION PROCEDURES

Paragraph 343 applies.

M344 TYPES OF EXAMINATION

Paragraph 344 applies in its entirety.

M345 TESTING

Paragraph 345 applies in its entirety, except that:

(a) a sensitive leak test in accordance with para. 345.8 shall be included in the required leak test (para. 345.1); and

(b) the initial service leak test (para. 345.7) does not apply.

M346 RECORDS

Paragraph 346 applies in its entirety.

PARTS 11 THROUGH 20, CORRESPONDING TO CHAPTER VII

See para. M300(b).

MA300 GENERAL STATEMENTS

Paragraphs MA300 through MA346 apply to nonmetallic piping and piping lined with nonmetals, based on Chapter VII. Paragraph A300(d) applies.

PART 11
CONDITIONS AND CRITERIA

MA301 DESIGN CONDITIONS

Paragraph A301 applies in its entirety.

MA302 DESIGN CRITERIA

Paragraphs A302.1 and A302.4 apply. See paras. MA302.2 and MA302.3.

MA302.2 Pressure-Temperature Design Criteria

Paragraph A302.2 applies, with the exception of para. A302.2.4. See para. MA302.2.4.

MA302.2.4 Allowances for Pressure and Temperature Variation. Paragraph A302.2.4(a) applies to both nonmetallic piping and to metallic piping with nonmetallic lining.

MA302.3 Allowable Stresses and Other Design Limits

Paragraph A302.3 applies, with the exception of para. A302.3.2. See para. MA302.3.2.

MA302.3.2 Bases for Allowable Stress. The designer shall fully document the bases for using any stress or allowable pressure limit not in accordance with both para. A302.3.2 and the Tables in Appendix B.

MA302.4 Allowances

Paragraph 302.4 applies in its entirety.

PART 12
PRESSURE DESIGN OF NONMETALLIC PIPING COMPONENTS

MA303 GENERAL

Paragraph A303 applies.

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MA304 PRESSURE DESIGN OF NONMETALLIC COMPONENTS

Paragraph A304 applies in its entirety.

PART 13
FLUID SERVICE REQUIREMENTS FOR NONMETALLIC PIPING COMPONENTS

MA305 PIPE

Paragraph A305 applies without further restrictions.

MA306 NONMETALLIC FITTINGS, BENDS, MITERS, LAPS, AND BRANCH CONNECTIONS

Paragraphs A306.1 and A306.2 apply without further restrictions. See para. MA306.3.

MA306.3 Miter Bends

Miter bends not designated as fittings conforming to para. A306.1 shall not be used.

MA306.4 Fabricated Laps

Fabricated laps shall not be used.

MA306.5 Fabricated Branch Connections

Nonmetallic fabricated branch connections shall not be used.

MA307 NONMETALLIC VALVES AND SPECIALTY COMPONENTS

Nonmetallic valves and specialty components shall not be used.

MA308 FLANGES, BLANKS, FLANGE FACINGS, AND GASKETS

Paragraphs A308.1, 308.3, and A308.4 apply without further restrictions. See para. MA308.2.

MA308.2 Nonmetallic Flanges

Threaded nonmetallic flanges shall not be used.

MA309 BOLTING

Paragraph A309 applies without further restrictions.

PART 14
FLUID SERVICE REQUIREMENTS FOR NONMETALLIC PIPING JOINTS

MA310 GENERAL

Paragraph 310 applies in its entirety.

MA311 BONDED JOINTS

MA311.1 General

Paragraph A311.1 applies in its entirety.

MA311.2 Specific Requirements

Hot gas welded, heat fusion, solvent cemented, and adhesive bonded joints are not permitted except in linings.

MA312 FLANGED JOINTS

Paragraph 312 applies in its entirety.

MA313 EXPANDED JOINTS

Expanded joints shall not be used.

MA314 THREADED JOINTS

MA314.1 General

Threaded joints shall not be used in nonmetallic piping.

MA315 TUBING JOINTS IN NONMETALLIC PIPING

Paragraph A315 applies in its entirety.

MA316 CAULKED JOINTS

Caulked joints shall not be used.

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MA318 SPECIAL JOINTS

Paragraph A318 applies in its entirety.

PART 15
FLEXIBILITY AND SUPPORT OF NONMETALLIC PIPING

MA319 PIPING FLEXIBILITY

Paragraph A319 applies in its entirety.

MA321 PIPING SUPPORT

Paragraph A321 applies in its entirety.

PART 16
NONMETALLIC AND NONMETALLIC LINED SYSTEMS

MA322 SPECIFIC PIPING SYSTEMS

Paragraph A322 applies in its entirety.

PART 17
NONMETALLIC MATERIALS

MA323 GENERAL REQUIREMENTS

Paragraphs A323.1 and A323.2 apply in their entirety. See para. MA323.4.

MA323.4 Fluid Service Requirements for Nonmetallic Materials

Paragraph A323.4.1 applies. See paras. MA323.4.2 and MA323.4.3.

MA323.4.2 Specific Requirements. Materials listed under paras. A323.4.2(a) and (b) may be used only as linings, except that thermoplastics may be used as gaskets in accordance with paras. M325.1 and MA323.4.3.

MA323.4.3 Nonmetallic Lining Materials. Where a material in para. A323.4.2 is used as a lining which also serves as a gasket or as part of the flange facing, consideration shall be given to design of the flanged joint to prevent leakage to the environment.

PART 18
STANDARDS FOR NONMETALLIC AND NONMETALLIC LINED PIPING COMPONENTS

MA326 DIMENSIONS AND RATINGS OF COMPONENTS

Paragraph A326 applies in its entirety. Table A326.1 applies, except for components and systems prohibited or restricted elsewhere in this Chapter.

PART 19
FABRICATION, ASSEMBLY, AND ERECTION OF NONMETALLIC AND NONMETALLIC LINED PIPING

MA327 GENERAL

Paragraph A327 applies.

MA328 BONDING OF PLASTICS

Paragraph A328 applies in its entirety.

MA329 FABRICATION OF PIPING LINED WITH NONMETALS

Paragraph A329 applies in its entirety.

MA332 BENDING AND FORMING

Paragraph A332 applies.

MA334 JOINING NONPLASTIC PIPING

Paragraph A334 applies in its entirety.

MA335 ASSEMBLY AND ERECTION

Paragraph A335 applies in its entirety.

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PART 20
INSPECTION, EXAMINATION, TESTING, AND RECORDS OF NONMETALLIC AND NONMETALLIC LINED PIPING

MA340 INSPECTION

Paragraph 340 applies in its entirety.

MA341 EXAMINATION

Paragraph A341 applies in its entirety.

MA342 EXAMINATION PERSONNEL

Paragraph 342 applies.

MA343 EXAMINATION PROCEDURES

Paragraph 343 applies.

MA344 TYPES OF EXAMINATION

Paragraph A344 applies in its entirety.

MA345 TESTING

Paragraph A345 applies in its entirety.

MA346 RECORDS

Paragraph 346 applies in its entirety.

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CHAPTER IX
HIGH PRESSURE PIPING

K300 GENERAL STATEMENTS

(a) Applicability. This Chapter pertains to piping designated by the owner as being in High Pressure Fluid Service. Its requirements are to be applied in full to piping so designated. High pressure is considered herein to be pressure in excess of that allowed by the ASME B16.5 PN 420 (Class 2500) rating for the specified design temperature and material group. However, there are no specified pressure limitations for the application of these rules.

(b) Responsibilities. In addition to the responsibilities stated in para. 300(b):

(1) for each piping system designated as being in High Pressure Fluid Service, the owner shall provide all information necessary to perform the analyses and testing required by this Chapter;

(2) the designer shall make a written report to the owner summarizing the design calculations and certifying that the design has been performed in accordance with this Chapter.

(c) The identification, intent, and Code requirements in paras. 300(a), (c), (d), (e), and (f) apply.

(d) The organization, content, and, wherever possible, paragraph designations of this Chapter correspond to those of the first six Chapters (the base Code). The prefix K is used.

(e) Provisions and requirements of the base Code apply only as stated in this Chapter.

K300.1 Scope

K300.1.1 Content and Coverage. Paragraph 300.1.1 applies with the exceptions stated in paras. K300.1.3 and K300.1.4.

K300.1.2 Packaged Equipment Piping. Interconnecting piping as described in para. 300.1.2 shall conform to the requirements of this Chapter.

K300.1.3 Exclusions. In addition to the exclusions stated in para. 300.1.3, this Chapter excludes nonmetallic and nonmetallic-lined piping.

K300.1.4 Category M Fluid Service. This Chapter makes no provision for piping in Category M Fluid Service. If such piping is required by the owner, the engineering design shall be developed as provided in para. 300(c)(5).

K300.2 Definitions

Paragraph 300.2 applies except for terms relating only to nonmetals and severe cyclic conditions.

The term allowable stress is used in lieu of basic allowable stress.

The term safeguarding and other terms characterizing hazardous fluid services are not used in this Chapter but should be taken into account in design.

K300.3 Nomenclature

Paragraph 300.3 applies.

K300.4 Status of Appendices

Paragraph 300.4 and Table 300.4 apply, except for Appendices A, B, H, and X.

PART 1
CONDITIONS AND CRITERIA

K301 DESIGN CONDITIONS

Paragraph 301 applies with the exceptions of paras. 301.1, 301.2, 301.3, and 301.5.

K301.1 General

Paragraph 301.1 applies but refer to para. K301 instead of para. 301.

K301.2 Design Pressure

K301.2.1 General. Paragraph 301.2.1(a) applies except that reference to para. 302.2.4 is not applicable. Paragraphs 301.2.1(b) and (c) apply, but refer to para. K304 instead of para. 304.

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K301.2.2 Required Pressure Containment or Relief. Paragraphs 301.2.2(a) and (b) apply, but refer to para. K322.6.3 instead of para. 322.6.3. Paragraph 301.2.2(c) is not applicable.

K301.3 Design Temperature

Paragraph 301.3 applies with the exceptions of paras. 301.3.1 and 301.3.2 and the following exceptions in the text.

(a) Refer to para. K301.2 instead of para. 301.2.

(b) Refer to para. K301.3.2 instead of para. 301.3.2.

K301.3.1 Design Minimum Temperature. Paragraph 301.3.1 applies, but refer to para. K323.2.2 instead of para. 323.2.2.

K301.3.2 Uninsulated Components. The fluid temperature shall be used as the component temperature.

K301.5 Dynamic Effects

Paragraph 301.5 applies with the exception of para. 301.5.4.

K301.5.4 Vibration. Suitable dynamic analysis shall be made where necessary, to avoid or minimize conditions which lead to detrimental vibration, pulsation, or resonance effects in the piping.

K302 DESIGN CRITERIA

K302.1 General

In para. K302, pressure-temperature ratings, stress criteria, design allowances, and minimum design values are stated, and permissible variations of these factors as applied to design of high pressure piping systems are formulated.

The designer shall be satisfied as to the adequacy of the design, and of materials and their manufacture, considering at least the following:

(a) tensile, compressive, flexural, and shear strength at design temperature;

(b) fatigue strength;

(c) design stress and its basis;

(d) ductility and toughness;

(e) possible deterioration of mechanical properties in service;

(f) thermal properties;

(g) temperature limits;

(h) resistance to corrosion and erosion;

(i) fabrication methods;

(j) examination and testing methods;

(k) hydrostatic test conditions; and

(l) bore imperfections.

K302.2 Pressure-Temperature Design Criteria

K302.2.1 Listed Components Having Established Ratings. Pressure-temperature ratings for certain piping components have been established and are contained in some of the standards in Table K326.1. Unless limited elsewhere in this Chapter, those ratings are acceptable for design pressures and temperatures under this Chapter. With the owner's approval, the rules and limits of this Chapter may be used to extend the pressure-temperature ratings of a component beyond the ratings of the listed standard, but not beyond the limits stated in para. K323.2.

K302.2.2 Listed Components Not Having Specific Ratings

(a) Piping components for which design stresses have been developed in accordance with para. K302.3, but which do not have specific pressure-temperature ratings, shall be rated by rules for pressure design in para. K304, within the range of temperatures for which stresses are shown in Table K-1, modified as applicable by other rules of this Chapter.

(b) Piping components which do not have allowable stresses or pressure-temperature ratings shall be qualified for pressure design as required by para. K304.7.2.

K302.2.3 Unlisted Components

(a) Piping components not listed in Table K326.1 or Table K-1, but which conform to a published specification or standard, may be used subject to the following requirements:

(1) the designer shall determine that composition, mechanical properties, method of manufacture, and quality control are comparable to the corresponding characteristics of listed components; and

(2) pressure design shall be verified in accordance with para. K304, including the fatigue analysis required by para. K304.8.

(b) Other unlisted components shall be qualified for pressure design as required by para. K304.7.2.

K302.2.4 Allowance for Pressure and Temperature Variations. Variations in pressure above the design pressure at the coincident temperature, except for accumulation during pressure relieving (see para. K322.6.3), are not permitted for any piping system.

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K302.2.5 Ratings at Junction of Different Services. Paragraph 302.2.5 applies.

K302.3 Allowable Stresses and Other Design Limits

K302.3.1 General. The allowable stresses defined below shall be used in design calculations unless modified by other provisions of this Chapter.

(a) Tension. Allowable stresses in tension for use in design in accordance with this Chapter are listed in Table K-1, except that maximum allowable stress values and design stress intensity values for bolting, respectively, are listed in the BPV Code, Section II, Part D, Tables 3 and 4.

The tabulated stress values in Table K-1 are grouped by materials and product form and are for stated temperatures up to the limit provided for the materials in para. K323.2.1. Straight line interpolation between temperatures to determine the allowable stress for a specific design temperature is permissible. Extrapolation is not permitted.

(b) Shear and Bearing. Allowable stress in shear shall be 0.80 times the allowable stress in tension tabulated in Table K-1. Allowable stress in bearing shall be 1.60 times the allowable stress in tension.

(c) Compression. Allowable stress in compression shall be no greater than the allowable stress in tension tabulated in Table K-1. Consideration shall be given to structural stability.

(d) Fatigue. Allowable values of stress amplitude, which are plotted as a function of design life in the BVP Code, Section VIII, Division 2, Appendix 5, may be used in fatigue analysis in accordance with para. K304.8.

K302.3.2 Bases for Allowable Stresses. The bases for establishing allowable stress values for materials in this Chapter are as follows.

(99) *(a) Bolting Materials.* The criteria of Section II, Part D, Appendix 2, para. 2-120 or 2-130, or Section VIII, Division 3, Article KD-6, para. KD-620, as applicable, apply.

(b) Other Materials. For materials other than bolting materials, the following rules apply.

(1) Except as provided in (b)(2) below, allowable stress values at design temperature for materials listed in Section II, Part D shall not exceed the lower of: two-thirds of the specified minimum yield strength at room temperature (SMYS), and two-thirds of the yield strength at temperature.

(2) For solution heat treated austenitic stainless steels and certain nickel alloys with similar stress-strain behavior, allowable stress values shall not exceed the lower of: two-thirds of the SMYS, and 90% of the yield strength at temperature.

(3) Allowable stresses for materials which are not listed in Section II, Part D shall not exceed the following:

(a) Temperatures not exceeding 100°F. Two-thirds of the SMYS.

(b) Temperatures exceeding 100°F. The corresponding values listed in Table A-1 (see para. 302.3.2).

(c) Application Limits. Application of stress values determined in accordance with (b)(2) above is not recommended for flanged joints and other components in which slight deformation can cause leakage or malfunction. [These values are shown in *italics* or **boldface** in Table K-1, as explained in Note (5) to Appendix K Tables.] Instead, either 75% of the stress value in Table K-1 or two-thirds of the yield strength at temperature listed in Section II, Part D, Table Y-1 should be used.

(d) Unlisted Materials. For a material which conforms to para. K323.1.2, the yield strength at temperature shall be derived by multiplying the average expected yield strength at temperature by the SMYS divided by the average expected yield strength at room temperature.

(e) Cyclic Stresses. Allowable values of alternating stress shall be in accordance with Section VIII, Division 2, Appendices 4 and 5.

K302.3.3 Casting Quality Factor.[1] The casting quality factor E_c shall be 1.00 by conformance to all of the following supplementary requirements.

(a) All surfaces shall have a surface finish not rougher than 6.3 μm R_a (250 μin. R_a per ASME B46.1).

(b) All surfaces shall be examined by either the liquid penetrant method in accordance with ASTM E 165, or the magnetic particle method in accordance with ASTM E 709. Acceptability of imperfections and weld repairs shall be judged in accordance with MSS SP-53, using ASTM E 125 as reference.

(c) Each casting shall be fully examined either ultrasonically in accordance with ASTM E 114, or radiographically in accordance with ASTM E 142. Cracks and hot tears (Category D and E discontinuities per the standards listed in Table K302.3.3D) and imperfections whose depth exceeds 3% of nominal wall thickness

[1] See Notes to Tables 302.3.3C and 302.3.3D for titles of standards referenced herein.

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TABLE K302.3.3D
ACCEPTABLE SEVERITY LEVELS FOR STEEL CASTINGS

Thickness Examined, mm (in.)	Applicable Standards	Acceptable Severity Level	Acceptable Discontinuity Categories
$\overline{T} \le 51$ (2)	ASTM E 446	1	A, B, C
$51 < \overline{T} \le 114$ (4.5)	ASTM E 186	1	A, B, C
$114 < \overline{T} \le 305$ (12)	ASTM E 280	1	A, B, C

are not permitted. Acceptable severity levels for radiographic examination of castings shall be in accordance with Table K302.3.3D.

K302.3.4 Weld Joint Quality Factor. Piping components containing welds shall have a weld joint quality factor $E_j = 1.00$ (see Table 302.3.4 for requirements) except that the acceptance criteria for these welds shall be in accordance with para. K341.3.2. Spiral welds are not permitted.

K302.3.5 Limits of Calculated Stresses Due to Sustained Loads and Displacement Strains

(a) Internal Pressure Stresses. Stresses due to internal pressure shall be considered safe when the wall thickness of the piping component, and its means of stiffening, meet the requirements of para. K304.

(b) External Pressure Stresses. Stresses due to external pressure shall be considered safe when the wall thickness of the piping component, and its means of stiffening, meet the requirements of para. K304.

(c) Longitudinal Stresses S_L. The sum of longitudinal stresses in any component in a piping system, due to pressure, weight, and other sustained loadings S_L shall not exceed S_h in (d) below. The thickness of pipe used in calculating S_L shall be the nominal thickness minus mechanical, corrosion, and erosion allowance c.

(d) Allowable Displacement Stress Range S_A. The computed displacement stress range S_E in a piping system (see para. 319.4.4) shall not exceed the allowable displacement stress range S_A (see para. 319.2.3) calculated by

$$S_A = 1.25S_c + 0.25S_h \quad (32)$$

In the above equation,

S_c = allowable stress from Table K-1 at minimum metal temperature expected during the displacement cycle under analysis

S_h = allowable stress from Table K-1 at maximum metal temperature expected during the displacement cycle under analysis

K302.3.6 Limits of Calculated Stresses Due to Occasional Loads

(a) Operation. The sum of the longitudinal stresses due to pressure, weight, and other sustained loadings S_L, and of the stresses produced by occasional loads such as wind or earthquake, may be as much as 1.2 times the allowable stress given in Table K-1. Wind and earthquake forces need not be considered as acting concurrently.

(b) Test. Stresses due to test conditions are not subject to the limitations in para. K302.3. It is not necessary to consider other occasional loads, such as wind and earthquake, as occurring concurrently with test loads.

K302.4 Allowances

In determining the minimum required thickness of a piping component, allowances shall be included for corrosion, erosion, and thread or groove depth. See the definition of c in para. K304.1.1(b).

K302.4.1 Mechanical Strength. Paragraph 302.4.1 applies. In addition, a fatigue analysis in accordance with para. K304.8 shall be performed for any means used to increase the strength of a piping component.

PART 2
PRESSURE DESIGN OF PIPING COMPONENTS

K303 GENERAL

Components manufactured in accordance with standards listed in Table K326.1 shall be considered suitable for use at pressure-temperature ratings in accordance with para. K302.2.

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K304 PRESSURE DESIGN OF HIGH PRESSURE COMPONENTS

K304.1 Straight Pipe

K304.1.1 General

(a) The required wall thickness of straight sections of pipe shall be determined in accordance with Eq. (33).

$$t_m = t + c \tag{33}$$

The minimum wall thickness T for the pipe selected, considering manufacturer's minus tolerance, shall be not less than t_m.

(b) The following nomenclature is used in the equation for pressure design of straight pipe.

t_m = minimum required wall thickness, including mechanical, corrosion, and erosion allowances

t = pressure design wall thickness, as calculated in para. K304.1.2 for internal pressure, or in accordance with the procedure listed in para. K304.1.3 for external pressure

c = $c_i + c_o$

= the sum of mechanical allowances[2] (thread or groove depth) plus corrosion and erosion allowances (where c_i = the sum of *internal* allowances and c_o = the sum of *external* allowances). For threaded components, the nominal thread depth (dimension h of ASME B1.20.1 or equivalent) shall apply, except that for straight threaded connections, the external thread groove depth need not be considered provided:

(a) it does not exceed 20% of the wall thickness;

(b) the ratio of outside to inside diameter, D/d, is greater than 1.1;

(c) the internally threaded attachment provides adequate reinforcement; and

(d) the thread plus the undercut area, if any, does not extend beyond the reinforcement for a distance more than the nominal wall thickness of the pipe.

Adequate reinforcement by the attachment is defined as that necessary to ensure that the static burst pressure of the connection will equal or exceed that of the unthreaded portion of the pipe. The adequacy of the reinforcement shall be substantiated as required by para. K304.7.2.

T = pipe wall thickness (measured or minimum per purchase specification)

P = internal design gage pressure

D = outside diameter of pipe. For design calculations in accordance with this Chapter, the outside diameter of the pipe is the maximum value allowable under the specifications.

d = inside diameter of pipe. For design calculations in accordance with this Chapter, the inside diameter of the pipe is the maximum value allowable under the specifications.

S = basic allowable stress from Table K-1

K304.1.2 Straight Pipe Under Internal Pressure. The internal pressure design wall thickness t shall be not less than that calculated in accordance with Eq. (34a) for pipe with a specified outside diameter and minimum wall thickness, or Eq. (34b) for pipe with a specified inside diameter and minimum wall thickness.

$$t = \frac{D - 2c_o}{2}\left[1 - \exp\left(\frac{-1.155P}{S}\right)\right] \tag{34a}^{3,4,5}$$

or

$$t = \frac{d + 2c_i}{2}\left[\exp\left(\frac{1.155P}{S}\right) - 1\right] \tag{34b}^{3,4,5}$$

Alternatively, the internal design gage pressure P may be calculated by Eq. (35a) or (35b).

$$P = \frac{S}{1.155}\ln\left[\frac{D - 2c_o}{D - 2(T - c_i)}\right] \tag{35a}^{4,5}$$

or

$$P = \frac{S}{1.155}\ln\left[\frac{d + 2(T - c_o)}{d + 2c_i}\right] \tag{35b}^{4,5}$$

[2] For machined surfaces or grooves where the tolerance is not specified, the tolerance shall be assumed to be 0.5 mm (0.02 in.) in addition to the specified depth of the cut.

[3] An exponential [e.g., the term exp $(-1.155P/S)$] represents the base of natural logarithms e raised to the stated power (i.e., $-1.155P/S$).

[4] The intent of this equation is to provide a factor of not less than 2.0 on the pressure required, according to the von Mises theory, to initiate yielding on the outside surface of a cylinder made from a perfect elastic-plastic material.

[5] Any mechanical, corrosion, or erosion allowance c not specified as internal c_i or external c_o shall be assumed to be internal, i.e., $c = c_i$ and $c_o = 0$.

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K304.1.3 Straight Pipe Under External Pressure. The pressure design thickness for straight pipe under external pressure shall be determined in accordance with para. K304.1.2 for pipe where $D/t < 3.33$, if at least one end of the pipe is exposed to full external pressure, producing a compressive axial stress. For $D/t \geq 3.33$, and for $D/t < 3.33$ where external pressure is not applied to at least one end of the pipe, the pressure design wall thickness shall be determined in accordance with para. 304.1.3 except that the stress values shall be taken from Table K-1.

K304.2 Curved and Mitered Segments of Pipe

K304.2.1 Pipe Bends. The minimum required wall thickness t_m of a bend, after bending, may be determined as for straight pipe in accordance with para. K304.1, provided that the bend radius of the pipe center line is equal to or greater than ten times the nominal pipe outside diameter and the tolerances and strain limits of para. K332 are met. Otherwise the design shall be qualified as required by para. K304.7.2.

K304.2.2 Elbows. Manufactured elbows not in accordance with para. K303 and pipe bends not in accordance with para. K304.2.1 shall be qualified as required by para. K304.7.2.

K304.2.3 Miter Bends. Miter bends are not permitted.

K304.2.4 Curved Segments of Pipe Under External Pressure. The wall thickness of curved segments of pipe subjected to external pressure may be determined as specified for straight pipe in para. K304.1.3 provided the design length L is the running center line length between any two sections which are stiffened in accordance with para. 304.1.3.

K304.3 Branch Connections

K304.3.1 General. Acceptable branch connections include: a fitting in accordance with para. K303; an extruded outlet in accordance with para. 304.3.4; or a branch connection fitting (see para. 300.2) similar to that shown in Fig. K328.5.4.

K304.3.2 Strength of Branch Connections

(a) The opening made for a branch connection reduces both static and fatigue strength of the run pipe. There shall be sufficient material in the branch connection to contain pressure and meet reinforcement requirements.

(b) Static pressure design of a branch connection not in accordance with para. K303 shall conform to para. 304.3.4 for an extruded outlet or shall be qualified as required by para. K304.7.2.

K304.3.3 Reinforcement of Welded Branch Connections. Branch connections made as provided in para. 304.3.3 are not permitted.

K304.4 Closures

(a) Closures not in accordance with para. K303 or (b) below shall be qualified as required by para. K304.7.2.

(b) Closures may be designed in accordance with (99) the rules, allowable stresses, and temperature limits of the BPV Code, Section VIII, Division 2 or Division 3, and Section II, Part D.

K304.5 Pressure Design of Flanges and Blanks

K304.5.1 Flanges — General

(a) Flanges not in accordance with para. K303 or (b) below shall be qualified as required by para. K304.7.2.

(b) A flange may be designed in accordance with (99) the rules, allowable stresses, and temperature limits of Section VIII, Division 2, Appendix 3 (or Appendices 4, 5, and 6) or Division 3, Article KD-6, and Section II, Part D.

K304.5.2 Blind Flanges (99)

(a) Blind flanges not in accordance with para. K303 or (b) or (c) below shall be qualified as required by para. K304.7.2.

(b) A blind flange may be designed in accordance with Eq. (36). The thickness of the flange selected shall be not less than t_m (see para. K304.1.1 for nomenclature), considering manufacturing tolerance.

$$t_m = t + c \tag{36}$$

The rules, allowable stresses, and temperature limits of Section VIII, Division 2, AD-700 may be used, with the following changes in nomenclature, to calculate t_m.

t = pressure design thickness (in place of T) as calculated for the given style of blind flange using the appropriate equation of AD-700.

c = sum of mechanical allowances, defined in para. K304.1.1.

(c) A blind flange may be designed in accordance with the rules, allowable stresses, and temperature limits of Section VIII, Division 3, Article KD-6 and Section II, Part D.

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K304.5.3 Blanks. Design of blanks shall be in accordance with para. 304.5.3, except that E shall be 1.00 and the definitions of S and c shall be in accordance with para. K304.1.1.

K304.6 Reducers

Reducers not in accordance with para. K303 shall be qualified as required by para. K304.7.2.

K304.7 Pressure Design of Other Components

K304.7.1 Listed Components. Other pressure containing components manufactured in accordance with standards in Table K326.1 may be utilized in accordance with para. K303.

K304.7.2 Unlisted Components and Elements. Static pressure design of unlisted components and other piping elements, to which the rules in paras. K304.1 through K304.6 do not apply, shall be based on calculations consistent with the design philosophy of this Chapter. Calculations shall be substantiated by one or both of the means stated in (a) and (b) below, considering applicable ambient and dynamic effects in paras. 301.4 through 301.11:

(a) extensive, successful service experience under comparable design conditions with similarly proportioned components made of the same or like material;

(b) performance testing sufficient to substantiate both the static pressure design and fatigue life at the intended operating conditions. Static pressure design may be substantiated by demonstrating that failure or excessive plastic deformation does not occur at a pressure equivalent to two times the internal design pressure P. The test pressure shall be two times the design pressure multiplied by the ratio of allowable stress at test temperature to the allowable stress at design temperature, and by the ratio of actual yield strength to the specified minimum yield strength at room temperature from Table K-1.

(c) for (a) and (b) above, reasonable interpolations, supported by analysis, are permitted between sizes, wall thicknesses, and pressure classes, as well as reasonable analogies among related materials with supporting material property data. Extrapolation is not permitted.

K304.7.3 Components With Nonmetallic Parts. Except for gaskets and packing, nonmetallic parts are not permitted.

K304.7.4 Bellows Type Expansion Joints. Bellows type expansion joints are not permitted.

K304.8 Fatigue Analysis

K304.8.1 General. A fatigue analysis shall be performed on each piping system, including all components[6] and joints therein, and considering the stresses resulting from attachments, to determine its suitability for the cyclic operating conditions[7] specified in the engineering design. Except as permitted in (a) and (b) below, or in paras. K304.8.5 and K304.8.6, this analysis shall be in accordance with the BPV Code, Section VIII, Division 2.[8] The cyclic conditions shall include pressure variations as well as thermal variations or displacement stresses. The requirements of para. K304.8 are in addition to the requirements for a flexibility analysis stated in para. K319. No formal fatigue analysis is required in systems that:

(a) are duplicates of successfully operating installations or replacements without significant change of systems with a satisfactory service record; or

(b) can readily be judged adequate by comparison with previously analyzed systems.

K304.8.2 Amplitude of Alternating Stress. The value of the alternating stress amplitude for comparison with design fatigue curves shall be determined in accordance with Section VIII, Division 2, Appendices 4 and 5.

K304.8.3 Allowable Amplitude of Alternating Stress. The allowable amplitude of alternating stress shall be determined from the applicable design fatigue curve in Section VIII, Division 2, Appendix 5. The designer is cautioned that the considerations listed in para. K302.1 may reduce the fatigue life of the component below the value predicted by that curve.

K304.8.4 Pressure Stress Evaluation for Fatigue Analysis

(a) For fatigue analysis of straight pipe, Eq. (37) may be used to calculate the stress intensity[9] at the

[6] Bore imperfections may reduce fatigue life.

[7] If the range of temperature change varies, equivalent full temperature cycles N may be computed as provided in footnote 6 to para. 302.3.5.

[8] Fatigue analysis in accordance with Section VIII, Division 2, requires that stress concentration factors be used in computing the cyclic stresses.

[9] The term "stress intensity" is defined in Section VIII, Division 2.

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inside surface due only to internal pressure.

$$S = \frac{PD^2}{2(T-c)[D-(T-c)]} \quad (37)$$

(b) For fatigue analysis of curved pipe, Eq. (37) may be used, with the dimensions of the straight pipe from which it was formed, to calculate the maximum stress intensity at the inside surface due only to internal pressure, provided that the center line bend radius is not less than ten times the nominal outside diameter of the pipe, and that the tolerance and strain limits of para. K332 are met. Bends of smaller radius shall be qualified as required by para. K304.7.2.

(c) If the value of S calculated by Eq. (37) exceeds three times the allowable stress from Table K-1 at the average temperature during the loading cycle, an inelastic analysis is required.

K304.8.5 Fatigue Evaluation by Test. With the owner's approval, the design fatigue life of a component may be established by destructive testing in accordance with para. K304.7.2 in lieu of the above analysis requirements.

K304.8.6 Extended Fatigue Life. The design fatigue life of piping components may be extended beyond that determined by the Section VIII, Division 2, Appendix 5 fatigue curves by the use of one of the methods listed below, provided that the component is qualified in accordance with para. K304.7.2:

(a) surface treatments, such as improved surface finish; and

(b) prestressing methods, such as autofrettage, shot peening, or shrink fit.

The designer is cautioned that the benefits of prestress may be reduced due to thermal, strain softening, or other effects.

PART 3
FLUID SERVICE REQUIREMENTS FOR PIPING COMPONENTS

K305 PIPE

Pipe includes components designated as "tube" or "tubing" in the material specification, when intended for pressure service.

TABLE K305.1.2
REQUIRED ULTRASONIC OR EDDY CURRENT EXAMINATION OF PIPE AND TUBING FOR LONGITUDINAL DEFECTS

Diameter, mm (in.)	Examination Required	Paragraph Reference
$d < 3.2$ ($\frac{1}{8}$) or $D < 6.4$ ($\frac{1}{4}$)	None	...
$3.2 \le d \le 17.5$ ($\frac{11}{16}$) and $6.4 \le D \le 25.4$ (1)	Eddy Current (ET) (1) or Ultrasonic (UT)	K344.8 K344.6
$d > 17.5$ or $D > 25.4$	Ultrasonic (UT)	K344.6

NOTE:
(1) This examination is limited to cold drawn austenitic stainless steel pipe and tubing.

K305.1 Requirements

K305.1.1 General. Pipe and tubing shall be either seamless or longitudinally welded with straight seam and a joint quality factor $E_j = 1.00$, examined in accordance with Note (2) of Table K341.3.2.

K305.1.2 Additional Examination. Pipe and tubing shall have passed a 100% examination for longitudinal defects in accordance with Table K305.1.2. This examination is in addition to acceptance tests required by the material specification.

K305.1.3 Heat Treatment. Heat treatment, if required, shall be in accordance with para. K331.

K305.1.4 Unlisted Pipe and Tubing. Unlisted pipe and tubing may be used only in accordance with para. K302.2.3.

K306 FITTINGS, BENDS, AND BRANCH CONNECTIONS

Pipe and other materials used in fittings, bends, and branch connections shall be suitable for the manufacturing or fabrication process and otherwise suitable for the service.

K306.1 Pipe Fittings

K306.1.1 General. All castings shall have a casting

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quality factor E_c = 1.00, with examination and acceptance criteria in accordance with para. K302.3.3. All welds shall have a weld quality factor E_j = 1.00, with examination and acceptance criteria in accordance with paras. K341 through K344. Listed fittings may be used in accordance with para. K303. Unlisted fittings may be used only in accordance with para. K302.2.3.

K306.1.2 Specific Fittings

(a) Socket welding fittings are not permitted.

(b) Threaded fittings are permitted only in accordance with para. K314.

(c) Branch connection fittings (see para. 300.2) whose design has been performance tested successfully as required by para. K304.7.2(b) may be used within their established ratings.

K306.2 Pipe Bends

K306.2.1 General. A bend made in accordance with para. K332.2 and verified for pressure design in accordance with para. K304.2.1 shall be suitable for the same service as the pipe from which it is made.

K306.2.2 Corrugated and Other Bends. Bends of other design (such as creased or corrugated) are not permitted.

K306.3 Miter Bends

Miter bends are not permitted.

K306.4 Fabricated or Flared Laps

Only forged laps are permitted.

K306.5 Fabricated Branch Connections

Fabricated branch connections constructed by welding shall be fabricated in accordance with para. K328.5.4 and examined in accordance with para. K341.4.

K307 VALVES AND SPECIALTY COMPONENTS

The following requirements for valves shall also be met, as applicable, by other pressure containing piping components, such as traps, strainers, and separators.

K307.1 General

Pressure design of unlisted valves shall be qualified as required by para. K304.7.2.

K308 FLANGES, BLANKS, FLANGE FACINGS, AND GASKETS

K308.1 General

Pressure design of unlisted flanges shall be verified in accordance with para. K304.5.1 or qualified as required by para. K304.7.2.

K308.2 Specific Flanges

K308.2.1 Threaded Flanges. Threaded flanges may be used only within the limitations on threaded joints in para. K314.

K308.2.2 Other Flange Types. Slip-on, socket welding, and expanded joint flanges, and flanges for flared laps, are not permitted.

K308.3 Flange Facings

The flange facing shall be suitable for the service and for the gasket and bolting employed.

K308.4 Gaskets

Gaskets shall be selected so that the required seating load is compatible with the flange rating and facing, the strength of the flange, and its bolting. Materials shall be suitable for the service conditions. Mode of gasket failure shall be considered in gasket selection and joint design.

K308.5 Blanks

Blanks shall have a marking identifying material, pressure-temperature rating, and size, which is visible after installation.

K309 BOLTING

Bolting, including bolts, bolt studs, studs, cap screws, nuts, and washers, shall meet the requirements of the BPV Code, Section VIII, Division 2, Article M-5. See also Appendix F, para. F309, of this Code.

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PART 4
FLUID SERVICE REQUIREMENTS FOR PIPING JOINTS

K310 GENERAL

Joints shall be suitable for the fluid handled, and for the pressure-temperature and other mechanical loadings expected in service.

K311 WELDED JOINTS

K311.1 General

Welds shall conform to the following.

(a) Welding shall be in accordance with para. K328.

(b) Preheating and heat treatment shall be in accordance with paras. K330 and K331, respectively.

(c) Examination shall be in accordance with para. K341.4, with acceptance criteria as shown in Table K341.3.2.

K311.2 Specific Requirements

K311.2.1 Backing Rings and Consumable Inserts. Backing rings shall not be used. Consumable inserts shall not be used in butt welded joints except when specified by the engineering design.

K311.2.2 Fillet Welds. Fillet welds may be used only for structural attachments in accordance with the requirements of paras. K321 and K328.5.2.

K311.2.3 Other Weld Types. Socket welds and seal welds are not permitted.

K312 FLANGED JOINTS

Flanged joints shall be selected for leak tightness, considering the requirements of para. K308, flange facing finish, and method of attachment. See also para. F312.

K312.1 Joints Using Flanges of Different Ratings

Paragraph 312.1 applies.

K313 EXPANDED JOINTS

Expanded joints are not permitted.

K314 THREADED JOINTS

K314.1 General

Except as provided in paras. K314.2 and K314.3, threaded joints are not permitted as pipeline assembly joints.

(a) Layout of piping should be such as to minimize strain on threaded joints which could adversely affect sealing.

(b) Supports shall be designed to control or minimize strain and vibration on threaded joints and seals.

K314.2 Special Threaded Joints

Special threaded joints may be used to attach flanges or fittings for joints in which the pipe end projects through the flange or fitting and is machined to form the sealing surface with a lens ring, cone ring, the mating pipe end, or other similar sealing device.

K314.3 Other Threaded Joints

Threaded joints not in accordance with para. K314.2 shall be used only for instrumentation, vents, drains, and similar purposes, and shall be not larger than DN 15 (NPS $\frac{1}{2}$). Such joints shall not be subject to bending or vibration loads.

K314.3.1 Taper-Threaded Joints. For mechanical strength, male-threaded components shall be at least Schedule 160 in nominal wall thickness.

K314.3.2 Straight-Threaded Joints. Threaded joints in which the tightness of the joint is provided by a seating surface other than the threads (e.g., construction shown in Fig. 335.3.3) shall be qualified as required by para. K304.7.2.

K315 TUBING JOINTS

Tubing joints of the flared, flareless, and compression type are not permitted.

K316 CAULKED JOINTS

Caulked joints are not permitted.

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K317 SOLDERED AND BRAZED JOINTS

K317.1 Soldered Joints

Soldered joints are not permitted.

K317.2 Brazed Joints

(a) Braze welded joints and fillet joints made with brazing filler metal are not permitted.

(b) Brazed joints shall be made in accordance with para. K333 and shall be qualified as required by para. K304.7.2. Such application is the owner's responsibility. The melting point of brazing alloys shall be considered when exposure to fire is possible.

K318 SPECIAL JOINTS

Special joints include coupling, mechanical, and gland nut and collar types of joints.

K318.1 General

Joints may be used in accordance with para. 318.2 and the requirements for materials and components in this Chapter.

K318.2 Specific Requirements

K318.2.1 Prototype Tests. A prototype joint shall have been subjected to performance tests in accordance with para. K304.7.2(b) to determine the safety of the joint under test conditions simulating all expected service conditions. Testing shall include cyclic simulation.

K318.2.2 Prohibited Joints. Bell type and adhesive joints are not permitted.

PART 5
FLEXIBILITY AND SUPPORT

K319 FLEXIBILITY

Flexibility analysis shall be performed for each piping system. Paragraphs 319.1 through 319.7 apply, except for paras. 319.4.1(c) and 319.4.5. The computed displacement stress range shall be within the allowable displacement stress range in para. K302.3.5 and shall also be included in the fatigue analysis in accordance with para. K304.8.

K321 PIPING SUPPORT

Piping supports and methods of attachment shall be in accordance with para. 321 except as modified below, and shall be detailed in the engineering design.

K321.1.1 Objectives. Paragraph 321.1.1 applies, but substitute "Chapter" for "Code" in (1).

K321.1.4 Materials. Paragraph 321.1.4 applies, but replace (e) with the following:

(e) Attachments welded to the piping shall be of a material compatible with the piping and the service. Other requirements are specified in paras. K321.3.2 and K323.4.2(b).

K321.3.2 Integral Attachments. Paragraph 321.3.2 applies, but substitute "K321.1.4(e)" for "321.1.4(e)" and "Chapter IX" for "Chapter V."

PART 6
SYSTEMS

K322 SPECIFIC PIPING SYSTEMS

K322.3 Instrument Piping

K322.3.1 Definition. Instrument piping within the scope of this Chapter includes all piping and piping components used to connect instruments to high pressure piping or equipment. Instruments, permanently sealed fluid-filled tubing systems furnished with instruments as temperature- or pressure-responsive devices, and control piping for air or hydraulically operated control apparatus (not connected directly to the high pressure piping or equipment) are not within the scope of this Chapter.

K322.3.2 Requirements. Instrument piping within the scope of this Chapter shall be in accordance with para. 322.3.2 except that the design pressure and temperature shall be determined in accordance with para. K301, and the requirements of para. K310 shall apply. Instruments, and control piping not within the scope of this Chapter, shall be designed in accordance with para. 322.3.

K322.6 Pressure Relieving Systems

Paragraph 322.6 applies, except for para. 322.6.3.

K322.6.3 Overpressure Protection. Overpressure protection for high pressure piping systems shall conform to the following.

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(a) The cumulative capacity of the pressure relieving devices shall be sufficient to prevent the pressure from rising more than 10% above the piping design pressure at the operating temperature during the relieving condition for a single relieving device or more than 16% above the design pressure when more than one device is provided, except as provided in (c) below.

(b) System protection must include one relief device set at or below the design pressure at the operating temperature for the relieving condition, with no device set to operate at a pressure greater than 105% of the design pressure, except as provided in (c) below.

(c) Supplementary pressure relieving devices provided for protection against overpressure due to fire or other unexpected sources of external heat shall be set to operate at a pressure not greater than 110% of the design pressure of the piping system and shall be capable of limiting the maximum pressure during relief to no more than 121% of the design pressure.

PART 7
MATERIALS

K323 GENERAL REQUIREMENTS

(a) Paragraph K323 states limitations and required qualifications for materials based on their inherent properties. Their use is also subject to requirements elsewhere in Chapter IX and in Table K-1.

(b) Specific attention should be given to the manufacturing process to ensure uniformity of properties throughout each piping component.

(c) See para. K321.1.4 for support materials.

K323.1 Materials and Specifications

K323.1.1 Listed Materials. Any material used in a pressure-containing piping component shall conform to a listed specification, except as provided in para. K323.1.2.

K323.1.2 Unlisted Materials. An unlisted material may be used, provided it conforms to a published specification covering chemistry, physical and mechanical properties, method and process of manufacture, heat treatment, and quality control, and otherwise meets the requirements of this Chapter. Allowable stresses shall be determined in accordance with the applicable allowable stress basis of this Chapter or a more conservative basis.

K323.1.3 Unknown Materials. Materials of unknown specification, type, or grade are not permitted.

K323.1.4 Reclaimed Materials. Reclaimed pipe and other piping components may be used provided they are properly identified as conforming to a listed specification, have documented service history for the material and fatigue life evaluation, and otherwise meet the requirements of this Chapter. Sufficient cleaning and inspection shall be made to determine minimum wall thickness and freedom from defects which would be unacceptable in the intended service.

K323.1.5 Product Analysis. Conformance of materials to the product analysis chemical requirements of the applicable specification shall be verified, and certification shall be supplied. Requirements for product analysis are defined in the applicable materials specification.

K323.1.6 Repair of Materials by Welding. A material defect may be repaired by welding, provided that all of the following criteria are met.

(a) The material specification provides for weld repair.

(b) The welding procedure and welders or welding operators are qualified as required by para. K328.2.

(c) The repair and its examination are performed in accordance with the material specification and with the owner's approval.

K323.2 Temperature Limitations

K323.2.1 Upper Temperature Limits

(a) A listed material shall not be used at a design temperature higher than the maximum temperature for which a stress value or rating is shown in Table K-1.

(b) In addition, the upper temperature limit shall be less than the temperature for which an allowable stress determined in accordance with para. 302.3.2 is governed by the creep or stress rupture provisions of that paragraph.

K323.2.2 Lower Temperature Limits

(a) The lowest permitted service temperature for a component or weld shall be the impact test temperature determined in accordance with para. K323.3.4(a), except as provided in (b) or (c) below.

(b) For a component or weld subjected to a longitudinal or circumferential stress ≤ 41 MPa (6 ksi), the lowest service temperature shall be the lower of −46°C (−50°F) or the impact test temperature determined in para. K323.3.4(a).

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(c) For materials exempted from Charpy testing by Note (6) of Table K323.3.1, the service temperature shall not be lower than −46°C (−50°F).

K323.2.3 Temperature Limits, Unlisted Materials. An unlisted material acceptable under para. K323.1.2 shall be qualified for service at all temperatures within a stated range from design minimum temperature to design (maximum) temperature, in accordance with para. K323.2.4.

K323.2.4 Verification of Serviceability

(a) When an unlisted material is used, the designer is responsible for demonstrating the validity of the allowable stresses and other design limits, and of the approach taken in using the material, including the derivation of stress data and the establishment of temperature limits.

(b) Paragraph 323.2.4(b) applies except that allowable stress values shall be determined in accordance with para. K302.3.

K323.3 Impact Testing Methods and Acceptance Criteria

K323.3.1 General. Impact testing shall be performed in accordance with Table K323.3.1 on representative samples using the testing methods described in paras. K323.3.2, K323.3.3, and K323.3.4. Acceptance criteria are described in para. K323.3.5.

K323.3.2 Procedure. Paragraph 323.3.2 applies.

K323.3.3 Test Specimens

(a) Each set of impact test specimens shall consist of three specimen bars. Impact tests shall be made using standard 10 mm (0.394 in.) square cross section Charpy V-notch specimen bars oriented in the transverse direction.

(b) Where component size and/or shape does not permit specimens as specified in (a) above, standard 10 mm square cross-section longitudinal Charpy specimens may be prepared.

(c) Where component size and/or shape does not permit specimens as specified in (a) or (b) above, subsize longitudinal Charpy specimens may be prepared. Test temperature shall be reduced in accordance with Table 323.3.4. See also Table K323.3.1, Note (6).

(d) If necessary in (a), (b), or (c) above, corners of specimens parallel to and on the side opposite the notch may be as shown in Fig. K323.3.3.

K323.3.4 Test Temperatures. For all Charpy impact tests, the test temperature criteria in (a) or (b) below shall be observed.

(a) Charpy impact tests shall be conducted at a temperature no higher than the lowest metal temperature at which a piping component or weld will be subjected to a stress greater than 41 MPa (6 ksi). In specifying the required test temperature, the following shall be considered:

(1) range of operating conditions;

(2) upset conditions;

(3) ambient temperature extremes; and

(4) required leak test temperature.

(b) Where the largest possible test specimen has a width along the notch less than the lesser of 80% of the material thickness or 8 mm (0.315 in.), the test shall be conducted at a reduced temperature in accordance with Table 323.3.4, considering the temperature as reduced below the test temperature required by (a) above.

K323.3.5 Acceptance Criteria

(a) Minimum Energy Requirements for Materials Other Than Bolting. The applicable minimum impact energy requirements for materials shall be those shown in Table K323.3.5. Lateral expansion shall be measured in accordance with ASTM A 370 (for title see para. 323.3.2). The results shall be included in the impact test report.

(b) Minimum Energy Requirements for Bolting Materials. The applicable minimum energy requirements shall be those shown in Table K323.3.5 except as provided in Table K323.3.1.

(c) Weld Impact Test Requirements. Where two base metals having different required impact energy values are joined by welding, the impact test energy requirements shall equal or exceed the requirements of the base material having the lower required impact energy.

(d) Retests

(1) Retest for Absorbed Energy Criteria. When the average value of the three specimens equals or exceeds the minimum value permitted for a single specimen, and the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, a retest of three additional specimens shall be made. The value for each of these retest specimens shall equal or exceed the required average value.

(2) Retest for Erratic Test Results. When an erratic result is caused by a defective specimen or uncertainty in the test, a retest will be allowed. The report giving

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TABLE K323.3.1
IMPACT TESTING REQUIREMENTS

	Test Characteristics	Column A Pipe, Tubes, and Components Made From Pipe or Tubes	Column B Other Components, Fittings, Etc.	Column C Bolts
Tests on Materials	Number of tests	As required by the material specification, or one test set per lot [see Note (1)], whichever is greater, except as permitted by Note (6).		
	Location and orientation of specimens [see Note (2)]	(a) Transverse to the longitudinal axis, with notch parallel to axis. [See Note (3).] (b) Where component size and/or shape does not permit specimens as specified in (a) above, paras. K323.3.3(b), (c), and (d) apply as needed.	(a) Transverse to the direction of maximum elongation during rolling or to direction of major working during forging. Notch shall be oriented parallel to direction of maximum elongation or major working. (b) If there is no single identifiable axis, e.g., for castings or triaxial forgings, specimens shall either meet the longitudinal values of Table K323.3.5, or three sets of orthogonal specimens shall be prepared, and the lowest impact values obtained from any set shall meet the transverse values of Table K323.3.5. (c) Where component size and/or shape does not permit specimens as specified in (a) or (b) above, paras. K323.3.3(c) and (d) apply as needed.	(a) Bolts ≤ 52 mm (2 in.) nominal size made in accordance with ASTM A 320 shall meet the impact requirements of that specification. (b) For all other bolts, longitudinal specimens shall be taken. The impact values obtained shall meet the transverse values of Table K323.3.5.
Tests on Welds in Fabrication or Assembly	Test pieces [see Note (5)]	Test pieces for preparation of impact specimens shall be made for each welder, welding procedure, type of electrode, or filler metal (i.e., AWS E-XXXX classification) and each flux to be used. All test pieces shall be subject to heat treatment, including cooling rates and aggregate time at temperature or temperatures, essentially the same as the heat treatment which the finished component will have received.		
	Number of test pieces [see Note (4)]	(1) One test piece with a thickness T for each range of material thicknesses which can vary from $\frac{1}{2}T$ to $T + 6$ mm ($\frac{1}{4}$ in.). (2) Unless otherwise specified in this Chapter [see Note (3)] or the engineering design, test pieces need not be made from individual material lots, or from material for each job, provided welds in other certified material of the same thickness ranges and to the same specification (type and grade, not heat or lot) have been tested as required and the records of those tests are made available.		
	Location and orientation of specimens	(1) Weld metal impact specimens shall be taken across the weld with the notch in the weld metal. Each specimen shall be oriented so that the notch axis is normal to the surface of the material and one face of the specimen shall be within 1.5 mm ($\frac{1}{16}$ in.) of the surface of the material. (2) Heat affected zone impact specimens shall be taken across the weld and have sufficient length to locate the notch in the heat affected zone, after etching. The notch shall be cut approximately normal to the material surface in such a manner as to include as much heat affected zone material as possible in the resulting fracture. (3) The impact values obtained from both the weld metal and heat affected zone specimens shall be compared to the transverse values in Table K323.3.5 for the determination of acceptance criteria.		

Notes to this Table follow on next page

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TABLE K323.3.1 (CONT'D)

NOTES:

(1) A lot shall consist of pipe or components of the same nominal size, made from the same heat of material, and heat treated together. If a continuous type furnace is used, pipe or components may be considered to have been heat treated together if they are processed during a single continuous time period at the same furnace conditions.

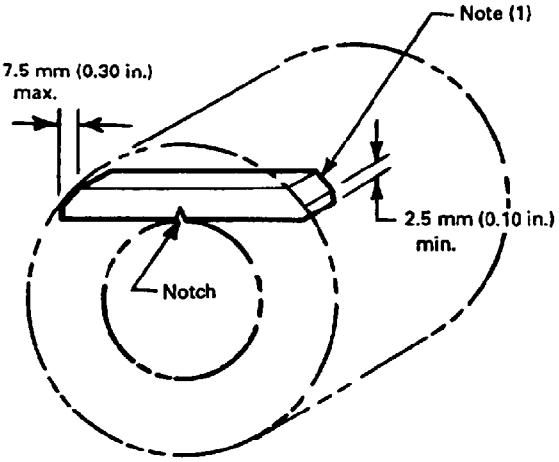
(2) Impact tests shall be performed on a representative sample of material after completion of all heat treatment and forming operations involving plastic deformation, except that cold bends made in accordance with para. K304.2.1 need not be tested after bending.

(3) For longitudinally welded pipe, specimens shall be taken from the base metal, weld metal, and the heat affected zone.

(4) The test piece shall be large enough to permit preparing the number of specimens required by para. K323.3. If this is not possible, additional test pieces shall be prepared.

(5) For welds in the fabrication or assembly of piping or components, including repair welds.

(6) Impact tests are not required when the maximum obtainable longitudinal Charpy specimen has a width along the notch less than 2.5 mm (0.098 in.). See para. K323.2.2(c).



GENERAL NOTE: This Figure illustrates how an acceptable transverse Charpy specimen can be obtained from a tubing or component shape too small for a full length standard specimen in accordance with ASTM A 370. The corners of a longitudinal specimen parallel to and on the side opposite the notch may be as shown.

NOTE:

(1) Corners of the Charpy specimen [see para. K323.3.3(d)] may follow the contour of the component within the dimension limits shown.

FIG. K323.3.3 EXAMPLE OF AN ACCEPTABLE IMPACT TEST SPECIMEN

test results shall specifically state why the original specimen was considered defective or which step of the test procedure was carried out incorrectly.

K323.4 Requirements for Materials

K323.4.1 General. Requirements in para. K323.4 apply to pressure-containing parts, not to materials used as supports, gaskets, packing, or bolting. See also Appendix F, para. F323.4.

K323.4.2 Specific Requirements

(a) Ductile iron and other cast irons are not permitted.

(b) Zinc-coated materials are not permitted for pressure containing components and may not be attached to pressure-containing components by welding.

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TABLE K323.3.5
MINIMUM REQUIRED CHARPY V-NOTCH IMPACT VALUES

Specimen Orientation	Pipe Wall or Component Thickness, mm (in.)	No. of Specimens [Note (1)]	Energy, J (ft-lbf) [Note (2)] Specified Minimum Yield Strength, MPa (ksi) ≤ 932 (≤ 135)	Specified Minimum Yield Strength, MPa (ksi) > 932 (> 135)
Transverse	≤ 25 (≤ 1)	Average for 3	27 (20)	34 (25)
		Minimum for 1	20 (15)	27 (20)
	> 25 and ≤ 51 (> 1 and ≤ 2)	Average for 3	34 (25)	41 (30)
		Minimum for 1	27 (20)	33 (24)
	> 51 (> 2)	Average for 3	41 (30)	47 (35)
		Minimum for 1	33 (24)	38 (28)
Longitudinal	≤ 25 (≤ 1)	Average for 3	54 (40)	68 (50)
		Minimum for 1	41 (30)	54 (40)
	> 25 and ≤ 51 (> 1 and ≤ 2)	Average for 3	68 (50)	81 (60)
		Minimum for 1	54 (40)	65 (48)
	> 51 (> 2)	Average for 3	81 (60)	95 (70)
		Minimum for 1	65 (48)	76 (56)

NOTES:
(1) See para. K323.3.5(c) for permissible retests.
(2) Energy values in this Table are for standard size specimens. For subsize specimens, these values shall be multiplied by the ratio of the actual specimen width to that of a full-size specimen, 10 mm (0.394 in.).

K323.4.3 Metallic Clad and Lined Materials. Materials with metallic cladding or lining may be used in accordance with the following provisions.

(a) For metallic clad or lined piping components, the base metal shall be an acceptable material as defined in para. K323, and the thickness used in pressure design in accordance with para. K304 shall not include the thickness of the cladding or lining. The allowable stress used shall be that for the base metal at the design temperature. For such components, the cladding or lining may be any material that, in the judgment of the user, is suitable for the intended service and for the method of manufacture and assembly of the piping component.

(b) Fabrication by welding of clad or lined piping components and the inspection and testing of such components shall be done in accordance with applicable provisions of the BPV Code, Section VIII, Division 1, UCL-30 through UCL-52, and the provisions of this Chapter.

(c) If a metallic liner also serves as a gasket or as part of the flange facing, the requirements and limitations in para. K308.4 apply.

K323.5 Deterioration of Materials in Service

Paragraph 323.5 applies.

K325 MISCELLANEOUS MATERIALS

Paragraph 325 applies.

PART 8
STANDARDS FOR PIPING COMPONENTS

K326 DIMENSIONS AND RATINGS OF COMPONENTS (99)

Paragraphs 326.1 and 326.2 apply except as follows:

(a) Refer to Table K326.1 instead of Table 326.1.

(b) Refer to Appendix K instead of Appendix A.

(c) Refer to para. K303 instead of para. 303.

(d) Refer to para. K304 instead of para. 304.

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TABLE K326.1
COMPONENT STANDARDS[1]

Standard or Specification	Designation [Note (3)]
Bolting	
Square and Hex Bolts and Screws, Inch Series; Including Hex Cap Screws and Lag Screws	*ASME B18.2.1
Square and Hex Nuts (Inch Series)	ANSI B18.2.2
Metallic Fittings, Valves, and Flanges	
Pipe Flanges and Flanged Fittings [Note (2)]	*ASME B16.5
Factory Made Wrought Steel Buttwelding Fittings [Note (2)]	*ASME B16.9
Forged Fittings, Socket Welding and Threaded [Note (2)]	*ASME B16.11
Valves—Flanged, Threaded, and Welding End [Note (2)]	*ASME B16.34
Standard Marking System for Valves, Fittings, Flanges, and Unions	MSS SP-25
High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets	MSS SP-65
Metallic Pipe and Tubes	
Welded and Seamless Wrought Steel Pipe [Note (2)]	*ASME B36.10M
Stainless Steel Pipe [Note (2)]	*ASME B36.19M
Miscellaneous	
Unified Inch Screw Threads (UN and UNR Thread Form)	*ASME B1.1
Specification for Threading, Gaging and Thread Inspection of Casing, Tubing, and Line Pipe Threads	API 5B
Metallic Gaskets for Pipe Flanges	ANSI B16.20
Buttwelding Ends	*ASME B16.25
Surface Texture (Surface Roughness, Waviness, and Lay)	*ASME B46.1

NOTES:
(1) It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.
(2) The use of components made in accordance with these standards is permissible provided they meet all of the requirements of this Chapter.
(3) An asterisk (*) preceding the designation indicates that the standard has been approved as an American National Standard by the American National Standards Institute.

PART 9
FABRICATION, ASSEMBLY, AND ERECTION

K327 GENERAL

Piping materials and components are prepared for assembly and erection by one or more of the fabrication processes covered in paras. K328, K330, K331, K332, and K333. When any of these processes is used in assembly or erection, requirements are the same as for fabrication.

K328 WELDING

Welding which conforms to the requirements of para. K328 may be used in accordance with para. K311.

K328.1 Welding Responsibility

Each employer is responsible for the welding done by the personnel of his organization and shall conduct the tests required to qualify welding procedures, and to qualify and as necessary requalify welders and welding operators.

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K328.2 Welding Qualifications

K328.2.1 Qualification Requirements. Qualification of the welding procedures to be used and of the performance of welders and welding operators shall comply with the requirements of the BPV Code, Section IX, except as modified herein.

(a) Impact tests shall be performed for all procedure and performance qualifications in accordance with para. K323.3.

(b) Test weldments shall be made using the same specification and type or grade of base metal(s), and the same specification and classification of filler metal(s) as will be used in production welding.

(c) Test weldments shall be subjected to essentially the same heat treatment, including cooling rate and cumulative time at temperature, as the production welds.

(d) When tensile specimens are required by Section IX, the yield strength shall also be determined, using the method required for the base metal. The yield strength of each test specimen shall be not less than the specified minimum yield strength (SMYS) for the base metals joined. Where two base metals having different SMYS values are joined by welding, the yield strength of each test specimen shall be not less than the lower of the two SMYS values.

(e) Mechanical testing is required for all performance qualification tests.

(f) Qualification on pipe or tubing shall also qualify for plate, but qualification on plate does not qualify for pipe or tubing.

(g) For thickness greater than 51 mm (2 in.), the procedure test coupon shall be at least 75% as thick as the thickest joint to be welded in production.

(h) Paragraph 328.2.1(f) applies.

K328.2.2 Procedure Qualification by Others. Qualification of welding procedures by others is not permitted.

K328.2.3 Performance Qualification by Others. Welding performance qualification by others is not permitted.

K328.2.4 Qualification Records. Paragraph 328.2.4 applies.

K328.2.5 Performance Requalification. Requalification of welders and welding operators is required in accordance with para. K328.2.1 when:

(a) welder or welding operator has not used the specific process for a period of 3 months or more; or

(b) there is specific reason to question the individual's ability to produce welds that meet the requirements of this Chapter.

K328.3 Materials

K328.3.1 Filler Metal. Filler metal shall be specified in the engineering design and shall conform to the requirements of the BPV Code, Section IX. A filler metal not yet incorporated in Section IX may be used with the owner's approval if a procedure qualification test, including an all-weld-metal test, is first successfully made.

K328.3.2 Weld Backing Material. Backing rings shall not be used.

K328.3.3 Consumable Inserts. Paragraph 328.3.3 applies, except that procedures shall be qualified as required by para. K328.2.

K328.4 Preparation for Welding

K328.4.1 Cleaning. Paragraph 328.4.1 applies.

K328.4.2 End Preparation

(a) General

(1) Butt weld end preparation is acceptable only if the surface is machined or ground to bright metal.

(2) Butt welding end preparation contained in ASME B16.25 or any other end preparation which meets the procedure qualification is acceptable. [For convenience, the basic bevel angles taken from B16.25, with some additional J-bevel angles, are shown in Fig. 328.4.2 sketches (a) and (b).]

(b) Circumferential Welds

(1) If components ends are trimmed as shown in Fig. 328.4.2 sketch (a) or (b) to accommodate consumable inserts, or as shown in Fig. K328.4.3 to correct internal misalignment, such trimming shall not result in a finished wall thickness before welding less than the required minimum wall thickness t_m.

(2) It is permissible to size pipe ends of the same nominal size to improve alignment, if wall thickness requirements are maintained.

(3) Where necessary, weld metal may be deposited on the inside or outside of the component to permit alignment or provide for machining to ensure satisfactory seating of inserts.

(4) When a butt weld joins sections of unequal wall thickness and the thicker wall is more than $1\frac{1}{2}$ times the thickness of the other, end preparation and geometry shall be in accordance with acceptable designs for unequal wall thickness in ASME B16.5.

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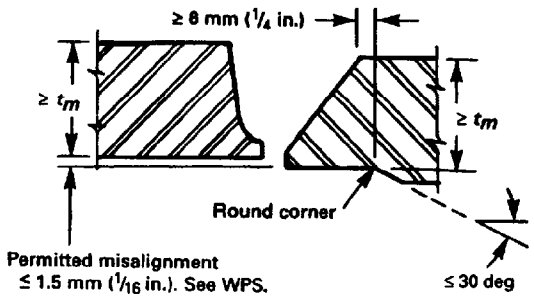

FIG. K328.4.3 PIPE BORED FOR ALIGNMENT: TRIMMING AND PERMITTED MISALIGNMENT

K328.4.3 Alignment

(a) Girth Butt Welds

(1) Inside diameters of components at the ends to be joined shall be aligned within the dimensional limits in the welding procedure and the engineering design, except that no more than 1.6 mm (1/16 in.) misalignment is permitted as shown in Fig. K328.4.3.

(2) If the external surfaces of the two components are not aligned, the weld shall be tapered between the two surfaces with a slope not steeper than 1:4.

(b) Longitudinal Butt Joints. Preparation for longitudinal butt welds (not made in accordance with a standard listed in Table K-1 or Table K326.1) shall conform to the requirements of para. K328.4.3(a).

(c) Branch Connection Welds

(1) The dimension m in Fig. K328.5.4 shall not exceed ±1.5 mm (1/16 in.).

(2) The dimension g in Fig. K328.5.4 shall be specified in the engineering design and the welding procedure.

K328.5 Welding Requirements

K328.5.1 General. The requirements of paras. 328.5.1 (b), (d), (e), and (f) apply in addition to the requirements specified below.

(a) All welds, including tack welds, repair welds, and the addition of weld metal for alignment [paras. K328.4.2(b)(3) and K328.4.3(c)(1)], shall be made by qualified welders or welding operators, in accordance with a qualified procedure.

(b) Tack welds at the root of the joint shall be made with filler metal equivalent to that used for the root pass. Tack welds shall be fused with the root pass weld, except that those which have cracked shall be removed. Bridge tacks (above the root) shall be removed.

K328.5.2 Fillet Welds. Fillet welds, where permitted (see para. K311.2.2), shall be fused with and shall merge smoothly into the component surfaces.

K328.5.3 Seal Welds. Seal welds are not permitted.

K328.5.4 Welded Branch Connections. Branch connection fittings (see para. 300.2), attached by smoothly contoured full penetration groove welds of a design that permits 100% interpretable radiographic examination are the only types acceptable.

Figure K328.5.4 shows acceptable details of welded branch connections. The illustrations are typical and are not intended to exclude acceptable types of construction not shown.

K328.5.5 Fabricated Laps. Fabricated laps are not permitted.

K328.6 Weld Repair

Paragraph 328.6 applies, except that procedures and performance shall be qualified as required by para. K328.2.1. See also para. K341.3.3.

K330 PREHEATING

The text introducing para. 330 applies.

K330.1 General

K330.1.1 Requirements and Recommendations. The necessity for preheating prior to welding, and the temperature to be used, shall be established by the engineering design and demonstrated by the procedure qualification. However, the minimum preheat temperatures for the various P-Number materials specified in Table 330.1.1 are required.

K330.1.2 Unlisted Materials. Preheat requirements for an unlisted material shall be specified in the WPS.

K330.1.3 Temperature Verification. Preheat temperature shall be checked by use of temperature-indicating crayons, thermocouple pyrometers, or other suitable means to ensure that the temperature specified in the WPS is obtained prior to and maintained during welding. Temperature-indicating materials and techniques shall not be detrimental to the base metals.

K330.1.4 Preheat Zone. The preheat zone shall extend at least 25 mm (1 in.) beyond each edge of the weld.

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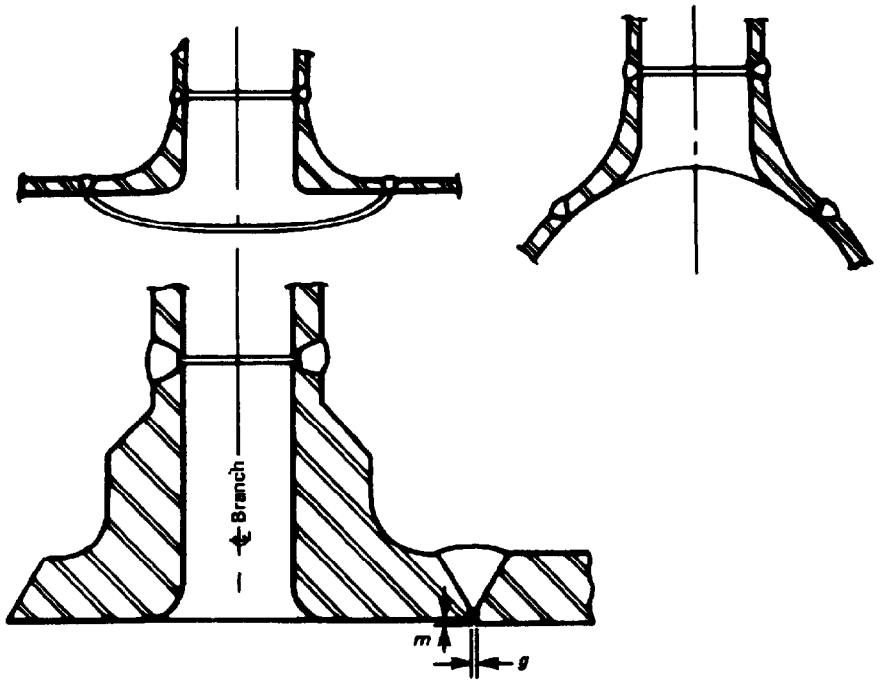

FIG. K328.5.4 SOME ACCEPTABLE WELDED BRANCH CONNECTIONS SUITABLE FOR 100% RADIOGRAPHY

K330.2 Specific Requirements

Paragraph 330.2 applies in its entirety.

K331 HEAT TREATMENT

The text introducing para. 331 applies.

K331.1 General

K331.1.1 Heat Treatment Requirements. The provisions of para. 331 and Table 331.1.1 apply, except as specified below.

(a) Heat treatment is required for all thicknesses of P-Nos. 4 and 5 materials.

(b) For welds other than longitudinal in quenched and tempered materials, when heat treatment is required by the engineering design, the temperature shall not be higher than 28°C (50°F) below the tempering temperature of the material.

(c) Longitudinal welds in quenched and tempered material shall be heat treated in accordance with the applicable material specification.

K331.1.3 Governing Thickness. When components are joined by welding, the thickness to be used in applying the heat treatment provisions of Table 331.1.1 shall be that of the thicker component measured at the joint, except as follows.

In the case of fillet welds used for attachment of external nonpressure parts, such as lugs or other pipe-supporting elements, heat treatment is required when the thickness through the weld and base metal in any plane is more than twice the minimum material thickness requiring heat treatment (even though the thickness of the components at the joint is less than that minimum thickness) except as follows:

(a) not required for P-No. 1 materials when weld throat thickness is 16 mm (5/8 in.) or less, regardless of base metal thickness;

(b) not required for P-Nos. 3, 4, 5, 10A, and 10B materials when weld throat thickness is 6 mm (1/4 in.) or less, regardless of base metal thickness, provided that not less than the recommended minimum preheat is applied and the specified minimum tensile strength of the base metal is less than 490 MPa (71 ksi); and

(c) not required for ferritic materials when welds

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are made with filler metal which does not air harden. Austenitic welding materials may be used for welds to ferritic materials when the effects of service conditions, such as differential thermal expansion due to elevated temperature, or corrosion, will not adversely affect the weldment.

K331.1.4 Heating and Cooling. Paragraph 331.1.4 applies.

K331.1.6 Temperature Verification. Heat treatment temperature shall be checked by thermocouple pyrometers or other suitable methods to ensure that the WPS requirements are met. Temperature-indicating materials and techniques shall not be detrimental to the base metals.

K331.1.7 Hardness Tests. Paragraph 331.1.7 applies.

K331.2 Specific Requirements

Paragraph 331.2 applies in its entirety.

K332 BENDING AND FORMING

K332.1 General

Pipe shall be hot or cold bent in accordance with a written procedure to any radius which will result in surfaces free of cracks and free of buckles. The procedure shall address at least the following, as applicable:

(a) material specification and range of size and thickness;

(b) range of bend radii and fiber elongation;

(c) minimum and maximum metal temperature during bending;

(d) method of heating and maximum hold time;

(e) description of bending apparatus and procedure to be used;

(f) mandrels or material and procedure used to fill the bore;

(g) method for protection of thread and machined surfaces;

(h) examination to be performed;

(i) required heat treatment; and

(j) postheat treatment dimensional adjustment technique.

K332.2 Bending

K332.2.1 Bend Flattening. The difference between the maximum and the minimum diameters at any cross section of a bend shall not exceed 8% of nominal outside diameter for internal pressure and 3% for external pressure.

K332.2.2 Bending Temperature. Paragraph 332.2.2 applies, except that in cold bending of quenched and tempered ferritic materials, the temperature shall be at least 28°C (50°F) below the tempering temperature.

K332.3 Forming

Piping components shall be formed in accordance with a written procedure. The temperature range shall be consistent with material characteristics, end use, and specified heat treatment. The thickness after forming shall be not less than required by design. The procedure shall address at least the following, as applicable:

(a) material specification and range of size and thickness;

(b) maximum fiber elongation expected during forming;

(c) minimum and maximum metal temperature during bending;

(d) method of heating and maximum hold time;

(e) description of forming apparatus and procedure to be used;

(f) materials and procedures used to provide internal support during forming;

(g) examination to be performed; and

(h) required heat treatment.

K332.4 Required Heat Treatment

K332.4.1 Hot Bending and Forming. After hot bending and forming, heat treatment is required for all thicknesses of P-Nos. 3, 4, 5, 6, 10A, and 10B materials that are not quenched and tempered. Times and temperatures shall be in accordance with para. 331. Quenched and tempered materials shall be reheat treated to the original material specification.

K332.4.2 Cold Bending and Forming

(a) After cold bending and forming, heat treatment in accordance with (b) below is required, regardless of thickness, when specified in the engineering design or when the maximum calculated fiber elongation exceeds 5% strain or 50% of the basic minimum specified longitudinal elongation for the applicable specification, grade, and thickness for P-Nos. 1 through 6 materials (unless it has been demonstrated that the selection of the pipe and the procedure for making the components provide assurance that the most severely formed portion of the material has retained an elongation of not less than 10%).

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(b) Heat treatment is required regardless of thickness and shall conform to the temperatures and durations given in Table 331.1.1, except that for quenched and tempered materials, the stress relieving temperature shall not exceed a temperature 28°C (50°F) below the tempering temperature of the material.

K333 BRAZING AND SOLDERING

Brazing shall be in accordance with para. 333. The owner shall specify examination requirements for brazed joints.

K335 ASSEMBLY AND ERECTION

K335.1 General

Paragraph 335.1 applies.

K335.2 Flanged Joints

Paragraph 335.2 applies, except that bolts shall extend completely through their nuts.

K335.3 Threaded Joints

Paragraph 335.3 applies, except that threaded joints shall not be seal welded.

K335.4 Special Joints

Special joints (as defined in para. K318) shall be installed and assembled in accordance with the manufacturer's instructions, as modified by the engineering design. Care shall be taken to ensure full engagement of joint members.

K335.5 Cleaning of Piping

See Appendix F, para. F335.9.

PART 10
INSPECTION, EXAMINATION, AND TESTING

K340 INSPECTION

Paragraphs 340.1 through 340.4 apply.

K341 EXAMINATION

Paragraphs 341.1 and 341.2 apply.

K341.3 Examination Requirements

K341.3.1 General. Prior to initial operation, each piping installation, including components and workmanship, shall be examined in accordance with para. K341.4 and the engineering design. If heat treatment is performed, examination shall be conducted after its completion.

K341.3.2 Acceptance Criteria. Acceptance criteria shall be as stated in the engineering design and shall at least meet the applicable requirements stated in (a) and (b) below, and elsewhere in this Chapter.

(a) Table K341.3.2 states acceptance criteria (limits on imperfections) for welds. See Fig. 341.3.2 for typical weld imperfections.

(b) Acceptance criteria for castings are specified in para. K302.3.3.

K341.3.3 Defective Components and Workmanship

(a) Defects (imperfections of a type or magnitude not acceptable by the criteria specified in para. K341.3.2) shall be repaired, or the defective item shall be replaced.

(b) Repaired or replaced items shall be examined as required for the original work.

K341.4 Extent of Required Examination

Piping shall be examined to the extent specified herein or to any greater extent specified in the engineering design.

K341.4.1 Visual Examination

(a) The requirements of para. 341.4.1(a) apply with the following exceptions in regard to extent of examination:

(1) Materials and Components. 100%.

(2) Fabrication. 100%.

(3) Threaded, Bolted, and Other Joints. 100%. (99)

(4) Piping Erection. All piping erection shall be (99) examined to verify dimensions and alignment. Supports, guides, and points of cold spring shall be checked to ensure that movement of the piping under all conditions of startup, operation, and shutdown will be accommodated without undue binding or unanticipated constraint.

(b) Pressure-Containing Threads. 100% examination for finish and fit is required. Items with visible imperfections in thread finish and/or the following defects shall be rejected:

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TABLE K341.3.2
ACCEPTANCE CRITERIA FOR WELDS

Type of Imperfection	Criteria (A–E) for Types of Welds, and for Required Examination Methods [Note (1)]					
	Methods		Type of Weld			
	Visual	100% Radiography	Girth Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]
Crack	X	X	A	A	A	A
Lack of fusion	X	X	A	A	A	A
Incomplete penetration	X	X	A	A	A	A
Internal porosity	...	X	B	B	NA	B
Slag inclusion or elongated indication	...	X	C	C	NA	C
Undercutting	X	X	A	A	A	A
Surface porosity or exposed slag inclusion	X	...	A	A	A	A
Concave root surface (suck-up)	X	X	D	D	NA	D
Surface Finish	X	...	E	E	E	E
Reinforcement or internal protrusion	X	...	F	F	F	F

GENERAL NOTE: X = required examination; NA = not applicable; ... = not required.

Criterion Value Notes for Table K341.3.2

Criterion Symbol	Criterion Measure	Acceptable Value Limits [Note (5)]
A	Extent of imperfection	Zero (no evident imperfection)
B	Size and distribution of internal porosity	See BPV Code, Section VIII, Division 1, Appendix 4
C	Slag inclusion or elongated indication	
	Individual length	$\leq \overline{T}_w/4$ and ≤ 4 mm ($^5/_{32}$ in.)
	Individual width	$\leq \overline{T}_w/4$ and ≤ 2.5 mm ($^3/_{32}$ in.)
	Cumulative length	$\leq \overline{T}_w$ in any 12 $\overline{T}_w$ weld length
D	Depth of surface concavity	Total joint thickness including weld reinforcement, $\geq \overline{T}_w$
E	Surface roughness	≤ 12.5 μm R_a (500 μin. R_a per ASME B46.1)
F	Height of reinforcement or internal protrusion [Note (6)] in any plane through the weld shall be within the limits of the applicable height value in the tabulation at the right. Weld metal shall be fused with and merge smoothly into the component surfaces.	Wall Thickness $\overline{T}_w$, mm (in.) / External Weld Reinforcement or Internal Weld Protrusion: ≤ 13 ($^1/_2$) / 1.5 ($^1/_{16}$); > 13; ≤ 51 (2) / 3 ($^1/_8$); > 51 / 4 ($^5/_{32}$)

NOTES:
(1) Criteria given are for required examination. More stringent criteria may be specified in the engineering design.
(2) Longitudinal welds include only those permitted in paras. K302.3.4 and K305. The radiographic criteria shall be met by all welds, including those made in accordance with a standard listed in Table K326.1 or in Appendix K.
(3) Fillet welds include only those permitted in para. 311.2.5(b).
(4) Branch connection welds include only those permitted in para. K328.5.4.
(5) Where two limiting values are given, the lesser measured value governs acceptance. $\overline{T}_w$ is the nominal wall thickness of the thinner of two components joined by a butt weld.
(6) For groove welds, height is the lesser of the measurements made from the surfaces of the adjacent components. For fillet welds, height is measured from the theoretical throat; internal protrusion does not apply. Required thickness t_m shall not include reinforcement or internal protrusion.

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(1) Tapered Threads. Failure to meet gaging requirements in API Std 5B;

(2) Straight Threads. Excessively loose or tight fit when gaged for light interference fit.

K341.4.2 Radiographic Examination

(a) All girth, longitudinal, and branch connection welds shall be 100% examined as specified in para. K344.5.

(b) Ultrasonic examination shall not be substituted for radiography, but may supplement it.

(c) In-process examination (see para. 344.7) shall not be substituted for radiography.

K341.4.3 Certifications and Records. Paragraph 341.4.1(c) applies.

K341.5 Supplementary Examination

Any of the examination methods described in para. K344 may be specified by the engineering design to supplement the examination required by para. K341.4. The extent of supplementary examination to be performed and any acceptance criteria that differ from those specified in para. K341.3.2 shall be specified in the engineering design.

K341.5.1 Hardness Tests. Paragraph 341.5.2 applies.

K341.5.2 Examinations to Resolve Uncertainty. Paragraph 341.5.3 applies.

K342 EXAMINATION PERSONNEL

Paragraph 342 applies in its entirety.

K343 EXAMINATION PROCEDURES

Paragraph 343 applies. See also para. 344.6.1.

K344 TYPES OF EXAMINATION

K344.1 General

Paragraphs 344.1.1 and 344.1.2 apply. In para. 344.1.3, terms other than "100% examination" apply only to supplementary examinations.

K344.2 Visual Examination

Paragraph 344.2 applies in its entirety.

K344.3 Magnetic Particle Examination

The method for magnetic particle examination shall be as specified in:

(a) paragraph K302.3.3(b) for castings;

(b) BPV Code, Section V, Article 7 for welds and other components.

K344.4 Liquid Penetrant Examination

The method for liquid penetrant examination shall be as specified in:

(a) paragraph K302.3.3(b) for castings;

(b) BPV Code, Section V, Article 6 for welds and other components.

K344.5 Radiographic Examination

The method for radiographic examination shall be as specified in:

(a) paragraph K302.3.3(c) for castings;

(b) BPV Code, Section V, Article 2 for welds and other components.

K344.6 Ultrasonic Examination

K344.6.1 Method. The method for ultrasonic examination shall be as specified in:

(a) paragraph K302.3.3(c) for castings;

(b) paragraph 344.6.1 for welds and other components;

(c) paragraph K344.6.2 for pipe.

K344.6.2 Examination of Pipe and Tubing. Pipe and tubing, required or selected in accordance with Table K305.1.2 to undergo ultrasonic examination, shall pass a 100% examination for longitudinal defects in accordance with ASTM E 213, Ultrasonic Inspection of Metal Pipe and Tubing. The following specific requirements shall be met.

(a) A calibration (reference) standard shall be prepared from a representative sample. Longitudinal (axial) reference notches shall be introduced on the outer and inner surfaces of the standard in accordance with Fig. 2(c) of E 213 to a depth not greater than the larger of 0.1 mm (0.004 in.) or 4% of specimen thickness and a length not more than 10 times the notch depth.

(b) The pipe or tubing shall be scanned in both circumferential directions in accordance with Supplemental Requirement S1 of E 213. (Removal of external

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weld reinforcement of welded pipe may be necessary prior to this examination.)

K344.6.3 Acceptance Criteria. Any indication greater than that produced by the calibration notch represents a defect; defective pipe and tubing shall be rejected.

K344.6.4 Records. For pipe and tubing which passes this examination, records specified in Supplemental Requirement S5 of E 213 shall be prepared. [See para. K346.2(g).]

K344.7 In-Process Examination

Paragraph 344.7 applies in its entirety.

K344.8 Eddy Current Examination

K344.8.1 Method. The method for eddy current examination of pipe and tubing shall follow the general guidelines of the ASME BPV Code, Section V, Article 8, subject to the following specific requirements.

(a) Cold drawn austenitic stainless steel pipe and tubing, selected in accordance with Table K305.1.2 for eddy current examination, shall pass a 100% examination for longitudinal defects.

(b) A calibration (reference) standard shall be prepared from a representative sample. A longitudinal (axial) reference notch shall be introduced on the inner surface of the standard to a depth not greater than the larger of 0.1 mm (0.004 in.) or 5% of specimen thickness and a length not more than 6.4 mm (0.25 in.).

K344.8.2 Acceptance Criteria. Any indication greater than that produced by the calibration notch represents a defect; defective pipe or tubing shall be rejected.

K344.8.3 Records. For pipe and tubing which passes this examination, a report shall be prepared which includes at least the following information:

(a) material identification by type, size, lot, heat, etc;

(b) listing of examination equipment and accessories;

(c) details of examination technique (including examination speed and frequency) and end effects, if any;

(d) description of the calibration standard, including dimensions of the notch, as measured;

(e) examination results.

K345 TESTING

K345.1 Required Leak Test

Prior to initial operation, each piping system shall be leak tested.

(a) Each weld and each piping component, except bolting and individual gaskets to be used during final system assembly, shall be hydrostatically or pneumatically leak tested in accordance with para. K345.4 or K345.5, respectively. The organization conducting the test shall ensure that during the required leak testing of components and welds, adequate protection is provided to prevent injury to people and damage to property from missile fragments, shock waves, or other consequences of any failure which might occur in the pressurized system.

(b) In addition to the requirements of (a) above, a leak test of the installed piping system shall be conducted at a pressure not less than 110% of the design pressure to ensure tightness, except as provided in (c) below.

(c) If the leak test required in (a) above is conducted on the installed piping system, the additional test in (b) above is not required.

(d) For systems that are all welded, the closing weld may be leak tested in accordance with para. 345.4.3(b).

(e) None of the following leak tests may be used in lieu of the leak tests required in para. K345.1:

(1) initial service leak test (para. 345.7);

(2) sensitive leak test (para. 345.8); or

(3) alternative leak test (para. 345.9).

K345.2 General Requirements for Leak Tests

Paragraphs 345.2.3 through 345.2.7 apply. See below for paras. K345.2.1 and K345.2.2.

K345.2.1 Limitations on Pressure

(a) Through-Thickness Yielding. If the test pressure would produce stress in excess of the specified minimum yield strength throughout the thickness of a component[10] at test temperature, as determined by calculation or by testing in accordance with para. K304.7.2(b), the test pressure may be reduced to the maximum pressure that will result in a stress which will not exceed the specified minimum yield strength.

(b) The provisions of paras. 345.2.1(b) and (c) apply.

[10] See para. K304.1.2, footnote 3.

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K345.2.2 Other Test Requirements. Paragraph 345.2.2 applies. In addition, the minimum metal temperature during testing shall be not less than the impact test temperature (see para. K323.3.4).

K345.3 Preparation for Leak Test

Paragraph 345.3 applies in its entirety.

K345.4 Hydrostatic Leak Test

Paragraph 345.4.1 applies. See paras. K345.4.2 and K345.4.3 below.

K345.4.2 Test Pressure for Components and Welds. The hydrostatic test pressure shall be as calculated in paras. 345.4.2(a) and (b), excluding the limitation of 6.5 for the maximum value of S_T/S, and using allowable stresses from Table K-1 in Eq. (24), rather than stress values from Table A-1.

K345.4.3 Hydrostatic Test of Piping With Vessels as a System. Paragraph 345.4.3(a) applies.

K345.5 Pneumatic Leak Test

Paragraph 345.5 applies, except para. 345.5.4. See para. K345.5.4 below.

K345.5.4 Test Pressure. The pneumatic test pressure for components and welds shall be identical to that required for the hydrostatic test in accordance with para. K345.4.2.

K345.6 Hydrostatic-Pneumatic Leak Test for Components and Welds

If a combination hydrostatic-pneumatic leak test is used, the requirements of para. K345.5 shall be met, and the pressure in the liquid-filled part of the piping shall not exceed the limits stated in para. K345.4.2.

K346 RECORDS

K346.1 Responsibility

It is the responsibility of the piping designer, the manufacturer, the fabricator, and the erector, as applicable, to prepare the records required by this Chapter and by the engineering design.

K346.2 Required Records

At least the following records, as applicable, shall be provided to the owner or the Inspector by the person responsible for their preparation:

(a) the engineering design;

(b) material certifications;

(c) procedures used for fabrication, welding, heat treatment, examination, and testing;

(d) repair of materials including the procedure used for each, and location of repairs;

(e) performance qualifications for welders and welding operators;

(f) qualifications of examination personnel;

(g) records of examination of pipe and tubing for longitudinal defects as specified in paras. K344.6.4 and K344.8.3.

K346.3 Retention of Records

The owner shall retain one set of the required records for at least 5 years after they are received.

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APPENDIX A
ALLOWABLE STRESSES AND QUALITY FACTORS FOR METALLIC PIPING AND BOLTING MATERIALS

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NOTE:
(1) It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.

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NOTES FOR APPENDIX A TABLES

GENERAL NOTES:

(a) The allowable stress values, P-Number or S-Number assignments, weld joint and casting quality factors, and minimum temperatures in Tables A-1, A-1A, A-1B and A-2, together with the referenced Notes and single or double bars in the stress Tables, are requirements of this Code.

(b) Notes (1) through (7) are referenced in Table headings and in headings for material type and product form; Notes (8) and following are referenced in the Notes column for specific materials. Notes marked with an asterisk (*) restate requirements found in the text of the Code.

(c) At this time, metric equivalents have not been provided in Appendix A Tables. To convert stress values in Table A-1 to MPa at a given temperature in °C, determine the equivalent temperature in °F and interpolate to calculate the stress value in ksi at the given temperature. Multiply that value by 6.895 to determine basic allowable stress S in MPa at the given temperature.

NOTES:

(1) *The stress values in Table A-1 and the design stress values in Table A-2 are basic allowable stresses in tension in accordance with para. 302.3.1(a). For pressure design, the stress values from Table A-1 are multiplied by the appropriate quality factor E (E_c from Table A-1A or E_j from Table A-1B). Stress values in shear and bearing are stated in para. 302.3.1(b); those in compression in para. 302.3.1(c).

(2) *The quality factors for castings E_c in Table A-1A are basic factors in accordance with para. 302.3.3(b). The quality factors for longitudinal weld joints E_j in Table A-1B are basic factors in accordance with para. 302.3.4(a). See paras. 302.3.3(c) and 302.3.4(b) for enhancement of quality factors. See also para. 302.3.1(a), footnote 1.

(3) The stress values for austenitic stainless steels in these Tables may not be applicable if the material has been given a final heat treatment other than that required by the material specification or by reference to Note (30) or (31).

(4) *Stress values printed in *italics* exceed two-thirds of the expected yield strength at temperature. Stress values in **boldface** are equal to 90% of expected yield strength at temperature. See paras. 302.3.2(d)(3) and (e).

(5) *See para. 328.2.1(f) for description of P-Number and S-Number groupings. P-Numbers are indicated by number or by a number followed by a letter (e.g., 8, or 5B, or 11A). S-Numbers are preceded by an S (e.g., S-1).

(6) *The minimum temperature shown is that design minimum temperature for which the material is normally suitable without impact testing other than that required by the material specification. However, the use of a material at a design minimum temperature below −29°C (−20°F) is established by rules elsewhere in this Code, including para. 323.2.2(a) and other impact test requirements. For carbon steels with a letter designation in the Min. Temp. column, see para. 323.2.2(b) and the applicable curve and Notes in Fig. 323.2.2.

(7) *A single bar (|) adjacent to a stress value indicates that use of the material above (if the bar is to the right) or (if the bar is to the left) below the corresponding temperature is affected as described in a referenced Note. A single bar adjacent to the "Min. Temp." value has the same significance. A double bar (‖) adjacent to a stress value indicates that use of a material is prohibited above the corresponding temperature or above some lower temperature, depending on location (as described above) and on the referenced Note. A double bar to the left of "Min. Temp." indicates prohibition below that temperature. Where no stress values are listed, a material may be used in accordance with para. 323.2 unless prohibited by a double bar.

(8) *There are restrictions on the use of this material in the text of the Code as follows.
- (a) See para. 305.2.1; temperature limits are −29°C to 186°C (−20°F to 366°F).
- (b) See para. 305.2.2; pipe shall be safeguarded when used outside the temperature limits in Note (8a).
- (c) See Table 323.2.2, Section B-2.
- (d) See para. 323.4.2(a).
- (e) See para. 323.4.2(b).
- (f) See para. 309.2.1.
- (g) See para. 309.2.2.

(9) *For pressure-temperature ratings of components made in accordance with standards listed in Table 326.1, see para. 326.2.1. Stress values in Table A-1 may be used to calculate ratings for unlisted components, and special ratings for listed components, as permitted by para. 303.

(9a) Component standards listed in Table 326.1 impose the following restrictions on this material when used as a forging: composition, properties, heat treatment, and grain size shall conform to this specification: manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B 564.

(10) *This casting quality factor is applicable only when proper supplementary examination has been performed (see para. 302.3.3).

(11) *For use under this Code, radiography shall be performed after heat treatment.

(12) *Certain forms of this material, as stated in Table 323.2.2, must be impact tested to qualify for service below −29°C (−20°F). Alternatively, if provisions for impact testing are included in the material specification as supplementary requirements and are invoked, the material may be used down to the temperature at which the test was conducted in accordance with the specification.

(13) Properties of this material vary with thickness or size. Stress values are based on minimum properties for the thickness listed.

(14) For use in Code piping at the stated stress values, the required minimum tensile and yield properties must be verified by tensile test. If such tests are not required by the material specification, they shall be specified in the purchase order.

(15) These stress values are established from a consideration of strength only and will be satisfactory for average service. For bolted joints where freedom from leakage over a long period of time without retightening is required, lower stress values may be necessary as determined from the flexibility of the flange and bolts and corresponding relaxation properties.

(16) An E_j factor of 1.00 may be applied only if all welds, including welds in the base material, have passed 100% radiographic examination. Substitution of ultrasonic examination for radiography is not permitted for the purpose of obtaining an E_j of 1.00.

(17) Filler metal shall not be used in the manufacture of this pipe or tube.

(18) *This specification does not include requirements for 100% radiographic inspection. If this higher joint factor is to be used, the material shall be purchased to the special requirements of Table 341.3.2 for longitudinal butt welds with 100% radiography in accordance with Table 302.3.4.

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(19) *This specification includes requirements for random radiographic inspection for mill quality control. If the 0.90 joint factor is to be used, the welds shall meet the requirements of Table 341.3.2 for longitudinal butt welds with spot radiography in accordance with Table 302.3.4. This shall be a matter of special agreement between purchaser and manufacturer.

(20) For pipe sizes ≥ DN 200 (NPS 8) with wall thicknesses ≥ Sch 140, the specified minimum tensile strength is 483 MPa (70 ksi).

(21) For material thickness > 127 mm (5 in.), the specified minimum tensile strength is 483 MPa (70 ksi).

(21a) For material thickness > 127 mm (5 in.), the specified minimum tensile strength is 448 MPa (65 ksi).

(22) The minimum tensile strength for weld (qualification) and stress values shown shall be multiplied by 0.90 for pipe having an outside diameter less than 51 mm (2 in.) and a D/t value less than 15. This requirement may be waived if it can be shown that the welding procedure to be used will consistently produce welds that meet the listed minimum tensile strength of 165 MPa (24 ksi).

(23) Light-weight aluminum alloy welded fittings conforming to dimensions in MSS SP-43 shall have full penetration welds.

(24) Yield strength is not stated in the material specification. The value shown is based on yield strengths of materials with similar characteristics.

(25) This steel may develop embrittlement after service at approximately 316°C (600°F) and higher temperature.

(26) This unstabilized grade of stainless steel increasingly tends to precipitate intergranular carbides as the carbon content increases above 0.03%. See also para. F323.4(c)(2).

(27) For temperatures above 427°C (800 °F), these stress values apply only when the carbon content is 0.04% or higher.

(28) For temperatures above 538°C (1000°F), these stress values apply only when the carbon content is 0.04% or higher.

(29) The stress values above 538°C (1000°F) listed here shall be used only when the steel's austenitic micrograin size, as defined in ASTM E 112, is No. 6 or less (coarser grain). Otherwise, the lower stress values listed for the same material, specification, and grade shall be used.

(30) For temperatures above 538°C (1000°F), these stress values may be used only if the material has been heat treated at a temperature of 1093°C (2000°F) minimum.

(31) For temperatures above 538°C (1000°F), these stress values may be used only if the material has been heat treated by heating to a minimum temperature of 1038°C (1900°F) and quenching in water or rapidly cooling by other means.

(32) Stress values shown are for the lowest strength base material permitted by the specification to be used in the manufacture of this grade of fitting. If a higher strength base material is used, the higher stress values for that material may be used in design.

(33) For welded construction with work hardened grades, use the stress values for annealed material; for welded construction with precipitation hardened grades, use the special stress values for welded construction given in the Tables.

(34) If material is welded, brazed, or soldered, the allowable stress values for the annealed condition shall be used.

(35) This steel is intended for use at high temperatures; it may have low ductility and/or low impact properties at room temperature, however, after being used above the temperature indicated by the single bar (|). See also para. F323.4(c)(4).

(36) The specification permits this material to be furnished without solution heat treatment or with other than a solution heat treatment. When the material has not been solution heat treated, the minimum temperature shall be −29°C (−20°F) unless the material is impact tested per para. 323.3.

(37) Impact requirements for seamless fittings shall be governed by those listed in this Table for the particular base material specification in the grades permitted (A 312, A 240, and A 182). When A 276 materials are used in the manufacture of these fittings, the Notes, minimum temperatures, and allowable stresses for comparable grades of A 240 materials shall apply.

(38) When furnished in a quenched and tempered condition, this material may be used at a temperature not lower than −45°C (−50°F) without impact testing.

(39) This material when used below −29°C (−20°F) shall be impact tested if the carbon content is above 0.10%.

(40) *This casting quality factor can be enhanced by supplementary examination in accordance with para. 302.3.3(c) and Table 302.3.3C. The higher factor from Table 302.3.3C may be substituted for this factor in pressure design equations.

(41) Design stresses for the cold drawn temper are based on hot rolled properties until required data on cold drawn are submitted.

(42) This is a product specification. No design stresses are necessary. Limitations on metal temperature for materials covered by this specification are:

	°C
Grades 1 and 2	−29 to 482
Grades 2H and 2HM	−46 to 593
Grade 3	−29 to 593
Grade 4 [see Note (42a)]	−101 to 593
Grade 6	−29 to 427
Grades 7 and 7M [see Note (42a)]	−101 to 593
Grade 8FA [see Note (39)]	−29 to 427
Grades 8MA and 8TA	−198 to 816
Grades 8, 8A, and 8CA	−254 to 816

	°F
Grades 1 and 2	−20 to 900
Grades 2H and 2HM	−50 to 1100
Grade 3	−20 to 1100
Grade 4 [see Note (42a)]	−150 to 1100
Grade 6	−20 to 800
Grades 7 and 7M [see Note (42a)]	−150 to 1100
Grade 8FA [see Note (39)]	−20 to 800
Grades 8MA and 8TA	−325 to 1500
Grades 8, 8A, and 8CA	−425 to 1500

(42a) When used below −46°C (−50°F), this material shall be impact tested as required by A 320 for Grade L7.

(42b) This is a product specification. No design stresses are necessary. For limitations on usage, see paras. 309.2.1 and 309.2.2.

(43) *The stress values given for this material are not applicable when either welding or thermal cutting is employed [see para. 323.4.2(c)].

(44) This material shall not be welded.

(45) Stress values shown are applicable for "die" forgings only.

(46) The letter "a" indicates alloys which are not recommended for welding and which, if welded, must be individually qualified. The letter "b" indicates copper base alloys which must be individually qualified.

(47) If no welding is employed in fabrication of piping from these materials, the stress values may be increased to 230 MPa (33.3 ksi).

(48) The stress value to be used for this gray cast iron material at its upper temperature limit of 232°C (450°F) is the same as that shown in the 204°C (400°F) column.

(49) If the chemical composition of this Grade is such as to render it hardenable, qualification under P-No. 6 is required.

(50) This material is grouped in P-No. 7 because its hardenability is low.

(51) This material may require special consideration for welding qualification. See the BPV Code, Section IX, QW/QB-422. For

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use in this Code, a qualified WPS is required for each strength level of material.

(52) Copper-silicon alloys are not always suitable when exposed to certain media and high temperature, particularly above 100°C (212°F). The user should satisfy himself that the alloy selected is satisfactory for the service for which it is to be used.

(53) Stress relief heat treatment is required for service above 232°C (450°F).

(54) The maximum operating temperature is arbitrarily set at 260°C (500°F) because hard temper adversely affects design stress in the creep rupture temperature ranges.

(55) Pipe produced to this specification is not intended for high temperature service. The stress values apply to either nonexpanded or cold expanded material in the as-rolled, normalized, or normalized and tempered condition.

(56) Because of thermal instability, this material is not recommended for service above 427°C (800°F).

(57) Conversion of carbides to graphite may occur after prolonged exposure to temperatures over 427°C (800°F). See para. F323.4(b)(2).

(58) Conversion of carbides to graphite may occur after prolonged exposure to temperatures over 468°C (875°F). See para. F323.4(b)(3).

(59) For temperatures above 482°C (900°F), consider the advantages of killed steel. See para. F323.4(b)(4).

(60) For all design temperatures, the maximum hardness shall be Rockwell C35 immediately under the thread roots. The hardness shall be taken on a flat area at least 3 mm (⅛ in.) across, prepared by removing threads. No more material than necessary shall be removed to prepare the area. Hardness determination shall be made at the same frequency as tensile tests.

(61) Annealed at approximately 982°C (1800°F).

(62) Annealed at approximately 1121°C (2050°F).

(63) For stress relieved tempers (T351, T3510, T3511, T451, T4510, T4511, T651, T6510, T6511), stress values for material in the listed temper shall be used.

(64) The minimum tensile strength of the reduced section tensile specimen in accordance with the BPV Code, Section IX, QW-462.1, shall not be less than 758 MPa (110.0 ksi).

(65) The minimum temperature shown is for the heaviest wall permissible by the specification. The minimum temperature for lighter walls shall be as shown in the following tabulation:

Impact Test Temp. (°C) for Plate Thicknesses Shown

Spec. No. & Grade	25 mm Max.	51 mm Max.	Over 51 to 76 mm
A 203 A	−68	−68	−59
A 203 B	−68	−68	−59
A 203 D	−101	−101	−87
A 203 E	−101	−101	−87

Impact Test Temp. (°F) for Plate Thicknesses Shown

Spec. No. & Grade	1 in. Max.	2 in. Max.	Over 2 in. to 3 in.
A 203 A	−90	−90	−75
A 203 B	−90	−90	−75
A 203 D	−150	−150	−125
A 203 E	−150	−150	−125

(66) Stress values shown are 90% of those for the corresponding core material.

(67) For use under this Code, the heat treatment requirements for pipe manufactured to A 671, A 672, and A 691 shall be as required by para. 331 for the particular material being used. In some cases, para. 331 does not require heat treatment. In these cases, if the user requires no radiography, the designation shall be Class 13. If 100% radiography is required, it shall be Class 12. If heat treatment is required by the plate thickness or by the engineering design, the designation shall be Class 23 (no radiography) or 22 (100% radiography).

(68) The tension test specimen from plate 12.7 mm (½ in.) and thicker is machined from the core and does not include the cladding alloy; therefore, the stress values listed are those for materials less than 12.7 mm.

(69) This material may be used only in nonpressure applications.

(70) Alloy 625 (UNS N06625) in the annealed condition is subject to severe loss of impact strength at room temperature after exposure in the range of 538°C to 760°C (1000°F to 1400°F).

(71) These materials are normally microalloyed with Cb, V, and/or Ti. Supplemental specifications agreed to by manufacturer and purchaser commonly establish chemistry more restrictive than the base specification, as well as plate rolling specifications and requirements for weldability (i.e., C-equivalent) and toughness.

(72) For service temperature > 454°C (850°F), weld metal shall have a carbon content > 0.05%.

(73) Heat treatment is required after welding for all products of zirconium Grade R60705. See Table 331.1.1.

(74) Mechanical properties of fittings made from forging stock shall meet the requirements of one of the bar, forging, or rod specifications listed in Table 1 of B 366.

(75) Stress values shown are for materials in the normalized and tempered condition, or when the heat treatment is unknown. If material is annealed, use the following values above 510°C (950°F):

Temp., °F	1000	1050	1100	1150	1200
S, ksi	8.0	5.7	3.8	2.4	1.4

(76) Hydrostatic testing is an option (not required) in this specification. For use under this Code, hydrostatic testing is required.

(77) The pipe grades listed below, produced in accordance with CSA (Canadian Standards Association) Z245.1, shall be considered as equivalents to API 5L and treated as listed materials. (99)

Grade Equivalents

API 5L	CSA Z245.1
A25	172
A	207
B	241
X42	290
X46	317
X52	359
X56	386
X60	414

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TABLE A-1
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Basic Allowable Stress S, ksi (1), at Metal Temperature, °F (7)						
						Tensile	Yield	Min. Temp. to 100	200	300	400	500	600	650
Iron Castings (2)														
Gray	A 48	...	20	(8e)(48)	−20	20	...	2.0	2.0	2.0	2.0	...	...	...
Gray	A 278													
Gray	A 126	...	A	(8e)(9)(48)	−20	21	...							
Gray	A 48	...	25	(8e)(48)	−20	25	...	2.5	2.5	2.5	2.5	...	...	...
Gray	A 278													
Gray	A 48	...	30	(8e)(48)	−20	30	...	3.0	3.0	3.0	3.0	...	...	...
Gray	A 278													
Gray	A 126	...	B	(8e)(9)(48)	−20	31	...							
Gray	A 48	...	35	(8e)(48)	−20	35	...	3.5	3.5	3.5	3.5	...	...	...
Gray	A 278													
Gray	A 48	...	40	(8e)(9)(48)	−20	40	...	4.0	4.0	4.0	4.0	...	...	...
Gray	A 126	...	C	(8e)(9)(48)	−20	41	...							
Gray	A 278	...	40	(8e)(9)(53)	−20	40	...	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Gray	A 48	...	45	(8e)(48)	−20	45	...	4.5	4.5	4.5	4.5	...	...	...
Gray	A 48	...	50	(8e)(48)	−20	50	...	5.0	5.0	5.0	5.0	...	...	...
Gray	A 278	...	50	(8e)(53)	−20	50	...	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Gray	A 48	...	55	(8e)(48)	−20	55	...	5.5	5.5	5.5	5.5	...	...	...
Gray	A 48	...	60	(8e)(48)	−20	60	...	6.0	6.0	6.0	6.0	...	...	...
Gray	A 278	...	60	(8e)(53)	−20	60	...	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Cupola malleable	A 197	...	...	(8e)(9)	−20	40	30	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Malleable	A 47	...	32510	(8e)(9)	−20	50	32.5	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Ferritic ductile	A 395	...	...	(8d)(9)	−20	60	40	20.0	19.0	17.9	16.9	15.9	14.9	14.1
Austenitic ductile	A 571	...	Type D-2M, Cl.1	(8d)	−20	65	30	20.0	...	...	...	...	...	...

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.		
						Tensile	Yield	to 100	200	300
Carbon Steel Pipes and Tubes (2)										
A 285 Gr. A	A 134	1	...	(8b)(57)	B	45	24	15.0	14.6	14.2
A 285 Gr. A	A 672	1	A45	(57)(59)(67)	B	45	24	15.0	14.6	14.2
Butt weld	API 5L	S-1	A25	(8a)	−20	45	25	15.0	15.0	14.5
Smls & ERW	API 5L	S-1	A25	(57)(59)	B	45	25	15.0	15.0	14.5
...	A 179	1	...	(57)(59)	−20	47	26	15.7	15.0	14.2
Type F	A 53	1	Gr. A	(8a)(77)	20	48	30	16.0	16.0	16.0
...	A 139	S-1	A	(8b)(77)	A	48	30	16.0	16.0	16.0
...	A 587	1	...	(57)(59)	−20	48	30	16.0	16.0	16.0
...	A 53	1	A	(57)(59)	B	48	30	16.0	16.0	16.0
...	A 106	1	A	(57)						
...	A 135	1	A	(57)(59)						
...	A 369	1	FPA	(57)						
...	API 5L	S-1	A	(57)(59)(77)						
A 285 Gr. B	A 134	1	...	(8b)(57)	B	50	27	16.7	16.4	16.0
A 285 Gr. B	A 672	1	A50	(57)(59)(67)	B	50	27	16.7	16.4	16.0
A 285 Gr. C	A 134	1	...	(8b)(57)	A	55	30	18.3	18.3	17.7
...	A 524	1	Gr. II	(57)	−20	55	30	18.3	18.3	17.7
...	A 333	1	1	(57)(59)	−50	55	30	18.3	18.3	17.7
...	A 334	1	1	(57)(59)	−50	55	30	18.3	18.3	17.7
A 285 Gr. C	A 671	1	CA55	(59)(67)	A	55	30	18.3	18.3	17.7
A 285 Gr. C	A 672	1	A55	(57)(59)(67)	A	55	30	18.3	18.3	17.7
A 516 Gr. 55	A 672	1	C55	(57)(67)	C	55	30	18.3	18.3	17.7
A 516 Gr. 60	A 671	1	CC60	(57)(67)	C	60	32	20.0	19.5	18.9
A 515 Gr. 60	A 671	1	CB60	(57)(67)	B	60	32	20.0	19.5	18.9
A 515 Gr. 60	A 672	1	B60	(57)(67)	B	60	32	20.0	19.5	18.9
A 516 Gr. 60	A 672	1	C60	(57)(67)	C	60	32	20.0	19.5	18.9
...	A 139	S-1	B	(8b)	A	60	35	20.0	20.0	20.0
...	A 135	1	B	(57)(59)	B	60	35	20.0	20.0	20.0
...	A 524	1	Gr. 1	(57)	−20	60	35	20.0	20.0	20.0

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TABLE A-1 (CONT'D) (99)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)														
400	500	600	650	700	750	800	850	900	950	1000	1050	1100	Grade	Spec. No.
														Carbon Steel Pipe and Tubes (2)
13.7	13.0	11.8	11.6	11.5	10.3	9.0	7.8	6.5	...	...	...	...	...	A 134
13.7	13.0	11.8	11.6	11.5	10.3	9.0	7.8	6.5	4.5	2.5	1.6	1.0	A45	A 672
13.8	...	...	...	...	...	...	...	...	...	...	...	...	A25	API 5L
13.8	...	...	...	...	...	...	...	...	...	...	...	...	A25	API 5L
13.5	12.8	12.1	11.8	11.5	10.6	9.2	7.9	6.5	4.5	2.5	1.6	1.0	...	A 179
16.0	...	...	...	...	...	...	...	...	...	...	...	...	Gr. A	A 53
...	...	...	...	...	...	...	...	...	...	...	...	...	A	A 139
16.0	16.0	14.8	14.5	14.4	10.7	9.3	7.9	...	...	...	...	...	...	A 587
16.0	16.0	14.8	14.5	14.4	10.7	9.3	7.9	6.5	4.5	2.5	1.6	1.0	A	A 53
													A	A 106
													A	A 135
													FPA	A 369
													A	API 5L
15.4	14.6	13.3	13.1	13.0	11.2	9.6	8.1	6.5	...	...	...	...	...	A 134
15.4	14.6	13.3	13.1	13.0	11.2	9.6	8.1	6.5	4.5	2.5	1.6	1.0	A 50	A 672
17.2	16.2	14.8	14.5	14.4	12.0	10.2	8.3	6.5	...	...	...	...	...	A 134
17.2	16.2	14.8	14.5	14.4	12.0	10.2	8.3	6.5	4.5	2.5	...	...	Gr. II	A 524
17.2	16.2	14.8	14.5	14.4	12.0	10.2	8.3	6.5	4.5	2.5	1.6	1.0	1	A 333
													1	A 334
													CA55	A 671
													A55	A 672
17.2	16.2	14.8	14.5	14.4	12.1	10.2	8.4	6.5	4.5	2.5	1.6	1.0	C55	A 672
18.3	17.3	15.8	15.5	15.4	13.0	10.8	8.7	6.5	4.5	2.5	...	...	CC60	A 671
18.3	17.3	15.8	15.5	15.4	13.0	10.8	8.7	6.5	4.5	2.5	1.6	1.0	CB60	A 671
													B60	A 672
													C60	A 672
...	...	...	...	...	...	...	...	...	...	...	...	...	B	A 139
20.0	18.9	17.3	17.0	16.5	13.0	10.8	8.7	6.5	4.5	2.5	...	...	B	A 135
													Gr. 1	A 524

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200	300
						Tensile	Yield			
Carbon Steel (Cont'd) Pipes and Tubes (2) (Cont'd)										
...	A 53	1	B	(57)(59)	B					
...	A 106	1	B	(57)	B					
...	A 333									
...	A 334	1	6	(57)	−50	60	35	20.0	20.0	20.0
...	A 369	1	FPB	(57)	−20					
...	A 381	S-1	Y35	...	A					
...	API 5L	S-1	B	(57)(59)(77)	B					
...	A 139	S-1	C	(8b)	A	60	42			
...	A 139	S-1	D	(8b)	A	60	46	20.0	20.0	20.0
...	API 5L	S-1	X42	(55)(77)	A	60	42	20.0	20.0	20.0
...	A 381	S-1	Y42	...	A	60	42	20.0	20.0	20.0
...	A 381	S-1	Y48	...	A	62	48	20.6	19.7	18.7
...	API 5L	S-1	X46	(55)(77)	A	63	46	21.0	21.0	21.0
...	A 381	S-1	Y46	...	A	63	46	21.0	21.0	21.0
...	A 381	S-1	Y50	...	A	64	50	21.3	20.3	19.3
A 516 Gr. 65	A 671	1	CC65	(57)(67)	B	65	35	21.7	21.3	20.7
A 515 Gr. 65	A 671	1	CB65							
A 515 Gr. 65	A 672	1	B65	(57)(67)	A	65	35	21.7	21.3	20.7
A 516 Gr. 65	A 672	1	C65	(57)(67)	B					
...	A 139	S-1	E	(8b)	A	66	52	22.0	22.0	22.0
...	API 5L	S-1	X52	(55)(77)	A	66	52	22.0	22.0	22.0
...	A 381	S-1	Y52	...	A	66	52	22.0	22.0	22.0
A 516 Gr. 70	A 671	1	CC70	(57)(67)	B	70	38	23.3	23.1	22.5
A 515 Gr. 70	A 671	1	CB70							
A 515 Gr. 70	A 672	1	B70	(57)(67)	A	70	38	23.3	23.1	22.5
A 516 Gr. 70	A 672	1	C70	(57)(67)	B					
...	A 106	1	C	(57)	B	70	40	23.3	23.3	23.3
A 537 Cl. 1 (≤ 2½ in. thick)	A 671	1	CD70							
A 537 Cl. 1 (≤ 2½ in. thick)	A 672	1	D70	(67)	D	70	50	23.3	23.3	22.9
A 537 Cl. 1 (≤ 2½ in. thick)	A 691	1	CMSH70							
...	API 5L	S-1	X56	(51)(55)(71)(77)	A	71	56	23.7	23.7	23.7
...	A 381	S-1	Y56	(51)(55)(71)	A	71	56	23.7	23.7	23.7

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)														
400	500	600	650	700	750	800	850	900	950	1000	1050	1100	Grade	Spec. No.
													Carbon Steel (Cont'd) Pipes and Tubes (2) (Cont'd)	
20.0	18.9	17.3	17.0	16.5	13.0	10.8	8.7	6.5	4.5	2.5	1.6	1.0	B	A 53
													B	A 106
													6	A 333
													6	A 334
													FPB	A 369
													Y35	A 381
													B	API 5L
...	...	...	...	...	...	...	...	...	...	...	...	...	C	A 139
...	...	...	...	...	...	...	...	...	...	...	...	...	D	A 139
20.0	...	...	...	...	...	...	...	...	...	...	...	...	X42	API 5L
20.0	...	...	...	...	...	...	...	...	...	...	...	...	Y42	A 381
17.8	16.9	16.0	15.5	...	...	...	...	...	...	...	...	...	Y48	A 381
21.0	...	...	...	...	...	...	...	...	...	...	...	...	X46	API 5L
21.0	...	...	...	...	...	...	...	...	...	...	...	...	Y46	A 381
18.4	17.4	16.5	16.0	...	...	...	...	...	...	...	...	...	Y50	A 381
20.0	18.9	17.3	17.0	16.8	13.9	11.4	9.0	6.5	4.5	2.5	...	...	CC65	A 671
													CB65	A 671
20.0	18.9	17.3	17.0	16.8	13.9	11.4	9.0	6.5	4.5	2.5	1.6	1.0	B65	A 672
													C65	A 672
...	...	...	...	...	...	...	...	...	...	...	...	...	E	A 139
22.0	...	...	...	...	...	...	...	...	...	...	...	...	X52	API 5L
22.0	...	...	...	...	...	...	...	...	...	...	...	...	Y52	A 381
21.7	20.5	18.7	18.4	18.3	14.8	12.0	9.3	6.5	4.5	2.5	...	...	CC70	A 671
													CB70	A 671
21.7	20.5	18.7	18.4	18.3	14.8	12.0	9.3	6.5	4.5	2.5	1.6	1.0	B70	A 672
													C70	A 672
22.9	21.6	19.7	19.4	19.2	14.8	12.0	...	...	...	...	...	...	C	A 106
													CD70	A 671
22.9	22.9	22.6	22.0	21.4	...	...	...	...	...	...	...	...	D70	A 672
													CMSH70	A 691
23.7	...	...	...	...	...	...	...	...	...	...	...	...	X56	API 5L
23.7	...	...	...	...	...	...	...	...	...	...	...	...	Y56	A 381

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200	300
						Tensile	Yield			
Carbon Steel (Cont'd)										
Pipes and Tubes (2) (Cont'd)										
A 299 (> 1 in. thick)	A 671	1	CK75	(57)(67)	A	75	40	25.0	24.4	23.7
A 299 (> 1 in. thick)	A 672	1	N75							
A 299 (> 1 in. thick)	A 691	1	CMS75							
A 299 (≤ 1 in. thick)	A 671	1	CK75	(57)(67)	A	75	42	25.0	25.0	24.8
A 299 (≤ 1 in. thick)	A 672	1	N75							
A 299 (≤ 1 in. thick)	A 691	1	CMS75							
...	API 5L	S-1	X60	(51)(55)(71)(77)	A	75	60	25.0	25.0	25.0
...	A 381	S-1	Y60	(51)(71)	A	75	60	25.0	25.0	25.0
Pipes (Structural Grade) (2)										
A 283 Gr. A	A 134	1	...	(8a)(8c)	−20	45	24	13.7	13.0	12.4
A 570 Gr. 30	A 134	S-1	...	(8a)(8c)	−20	49	30	15.0	15.0	15.0
A 283 Gr. B	A 134	1	...	(8a)(8c)	−20	50	27	15.3	14.4	13.9
A 570 Gr. 33	A 134	S-1	...	(8a)(8c)	−20	52	33	15.9	15.9	15.9
A 570 Gr. 36	A 134	S-1	...	(8a)(8c)	−20	53	36	16.3	16.3	16.3
A 570 Gr. 40	A 134	1	...	(8a)(8c)	−20	55	40	16.9	16.9	16.9
A 36	A 134	1	...	(8a)(8c)	−20	58	36	17.6	16.8	16.8
A 283 Gr. D	A 134	1	...	(8a)(8c)	−20	60	33	18.4	17.4	16.6
A 570 Gr. 45	A 134	S-1	...	(8a)(8c)	−20	60	45	18.4	18.4	18.4
A 570 Gr. 50	A 134	1	...	(8a)(8c)	−20	65	50	19.9	19.9	19.9

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)														
400	500	600	650	700	750	800	850	900	950	1000	1050	1100	Grade	Spec. No.
													Carbon Steel (Cont'd) Pipes and Tubes (2) (Cont'd)	
22.9	21.6	19.7	19.4	19.2	15.7	12.6	9.5	6.5	4.5	2.5	1.6	1.0	CK75	A 671
													N75	A 672
													CMS75	A 691
24.0	22.7	20.7	20.4	20.2	...	...	...	...	...	...	...	...	CK75	A 671
													N75	A 672
													CMS75	A 691
25.0	...	...	...	...	...	...	...	...	...	...	...	...	X60	API 5L
25.0	...	...	...	...	...	...	...	...	...	...	...	...	Y60	A 381
													Pipes (Structural Grade) (2)	
11.8	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
15.0	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
...	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
15.9	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
16.3	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
16.9	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
16.8	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
...	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
18.4	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134
19.9	...	...	...	...	...	...	...	...	...	...	...	...	...	A 134

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200	300
						Tensile	Yield			
Carbon Steel (Cont'd)										
Plates and Sheets										
...	A 285	1	A	(57)(59)	B	45	24	15.0	14.6	14.2
...	A 285	1	B	(57)(59)	B	50	27	16.7	16.4	16.0
...	A 516	1	55	(57)	C	55	30	18.3	18.3	17.7
...	A 285	1	C	(57)(59)	A	55	30	18.3	18.3	17.7
...	A 516	1	60	(57)	C	60	32	20.0	19.5	18.9
...	A 515	1	60	(57)	B	60	32	20.0	19.5	18.9
...	A 516	1	65	(57)	B	65	35	21.7	21.3	20.7
...	A 515	1	65	(57)	A	65	35	21.7	21.3	20.7
...	A 516	1	70	(57)	B	70	38	23.3	23.1	22.5
...	A 515	1	70	(57)	A	70	38	23.3	23.1	22.5
(≤ 2½ in. thick)	A 537	1	Cl. 1	...	D	70	50	23.3	23.3	22.9
(> 1 in. thick)	A 299	1	...	(57)	A	75	40	25.0	24.4	23.7
(≤ 1 in. thick)	A 299	1	...	(57)	A	75	42	25.0	25.0	24.8
Plates and Sheets (Structural)										
...	A 283	1	A	(8c)(57)	A	45	24	13.8	13.2	12.5
...	A 570	S-1	30	(8c)(57)	A	49	30	15.0	15.0	15.0
...	A 283	1	B	(8c)(57)	A	50	27	15.3	14.6	14.0
...	A 570	S-1	33	(8c)(57)	A	52	33	15.9	15.9	15.9
...	A 570	S-1	36	(8c)(57)	A	53	36	16.3	16.3	16.3
...	A 283	1	C	(8c)(57)	A	55	30	16.9	16.1	15.3
...	A 570	S-1	40	(8c)(57)	A	55	40	16.9	16.9	16.9
...	A 36	1	...	(8c)	A	58	36	17.8	16.9	16.9
...	A 283	1	D	(8c)(57)	A	60	33	18.4	17.5	16.7
...	A 570	S-1	45	(8c)(57)	A	60	45	18.4	18.4	18.4
...	A 570	S-1	50	(8c)(57)	A	65	50	19.9	19.9	19.9

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)														
400	500	600	650	700	750	800	850	900	950	1000	1050	1100	Grade	Spec. No.
														Carbon Steel (Cont'd) Plates and Sheets
13.7	13.0	11.8	11.6	11.5	10.2	9.0	7.7	6.5	4.5	2.5	1.6	1.0	A	A 285
15.4	14.6	13.3	13.1	13.0	11.1	9.6	8.0	6.5	4.5	2.5	1.6	1.0	B	A 285
17.2	16.2	14.8	14.5	14.4	12.0	10.2	8.3	...	...	...	...	...	55	A 516
17.2	16.2	14.8	14.5	14.4	12.0	10.2	8.3	6.5	4.5	2.5	1.6	1.0	C	A 285
18.3	17.3	15.8	15.5	15.4	12.9	10.8	8.6	...	...	...	...	...	60	A 516
18.3	17.3	15.8	15.5	15.4	12.9	10.8	8.6	6.5	4.5	2.5	...	...	60	A 515
20.0	18.9	17.3	17.0	16.8	13.8	11.4	8.9	...	...	...	...	...	65	A 516
20.0	18.9	17.3	17.0	16.8	13.8	11.4	8.9	6.5	4.5	2.5	...	...	65	A 515
21.7	20.5	18.7	18.4	18.3	14.7	12.0	9.2	...	...	...	...	...	70	A 516
21.7	20.5	18.7	18.4	18.3	14.7	12.0	9.2	6.5	4.5	2.5	...	...	70	A 515
22.9	22.9	22.6	22.0	21.4	...	...	...	...	...	...	...	...	Cl. 1	A 537
22.9	21.6	19.7	19.4	19.2	15.6	12.6	9.5	6.5	4.5	2.5	1.6	1.0	...	A 299
24.0	22.7	20.7	20.4	20.2	15.6	12.6	9.5	6.5	4.5	2.5	1.6	1.0	...	A 299
														Plates and Sheets (Structural)
11.9	11.3	10.7	10.3	10.1	9.4	...	...	...	...	...	...	...	A	A 283
15.0	15.0	13.8	13.5	13.4	10.5	...	...	...	...	...	...	...	30	A 570
13.3	12.5	11.8	11.5	11.1	10.2	...	...	...	...	...	...	...	B	A 283
15.9	15.9	14.7	14.4	14.3	11.2	...	...	...	...	...	...	...	33	A 570
16.3	16.3	15.0	14.7	14.6	11.4	...	...	...	...	...	...	...	36	A 570
14.6	13.8	13.0	12.6	12.2	11.1	...	...	...	...	...	...	...	C	A 283
16.9	16.9	15.6	15.3	15.2	11.6	...	...	...	...	...	...	...	40	A 570
16.9	16.9	16.9	16.9	16.9	...	...	...	...	...	...	...	...	...	A 36
15.9	15.0	14.2	13.8	13.2	11.9	...	...	...	...	...	...	...	D	A 283
18.4	17.2	15.7	15.4	15.2	12.2	...	...	...	...	...	...	...	45	A 570
19.9	18.6	17.2	16.9	16.7	12.9	...	...	...	...	...	...	...	50	A 570

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200	300
						Tensile	Yield			
Carbon Steel (Cont'd)										
Forgings and Fittings (2)										
...	A 350	1	LF-1	(9)(57)(59)	−20	60	30	20.0	18.3	17.7
...	A 181	1	Cl. 60	(9)(57)(59)	A	60	30	20.0	18.3	17.7
...	A 420	1	WPL-6	(57)	−50	60	35	20.0	20.0	20.0
...	A 234	1	WPB	(57)(59)	B	60	35	20.0	20.0	20.0
...	A 350	1	LF-2	(9)(57)	−50	70	36	23.3	21.9	21.3
...	A 105	1	...	(9)(57)(59)	−20	70	36	23.3	21.9	21.3
...	A 181	1	Cl. 70	(9)(57)(59)	A					
...	A 234	1	WPC	(57)(59)	B	70	40	23.3	23.3	23.3
Castings (2)										
...	A 216	1	WCA	(57)	−20	60	30	20.0	18.3	17.7
...	A 352	1	LCB	(9)(57)	−50	65	35	21.7	21.3	20.7
...	A 216	1	WCB	(9)(57)	−20	70	36	23.3	21.9	21.3
...	A 216	1	WCC	(9)(57)	−20	70	40	23.3	23.3	23.3

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)														
400	500	600	650	700	750	800	850	900	950	1000	1050	1100	Grade	Spec. No.
													Carbon Steel (Cont'd) Forgings and Fittings (2)	
17.2	16.2	14.8	14.5	14.4	13.0	10.8	7.8	5.0	3.0	1.5	...	...	LF-1	A 350
17.2	16.2	14.8	14.5	14.4	13.0	10.8	8.7	6.5	4.5	2.5	1.6	1.0	Cl. 60	A 181
20.0	18.9	17.3	17.0	16.8	13.0	10.8	7.8	5.0	3.0	1.5	...	...	WPL-6	A 420
20.0	18.9	17.3	17.0	16.8	13.0	10.8	8.7	6.5	4.5	2.5	1.6	1.0	WPB	A 234
20.6	19.4	17.8	17.4	17.3	14.8	12.0	7.8	5.0	3.0	1.5	...	...	LF-2	A 350
20.6	19.4	17.8	17.4	17.3	14.8	12.0	9.3	6.5	4.5	2.5	1.6	1.0	... Cl. 70	A 105 A 181
22.9	21.6	19.7	19.4	19.2	14.8	12.0	...	...	...	...	...	...	WPC	A 234
														Castings (2)
17.2	16.2	14.8	14.5	14.4	13.0	10.8	8.6	6.5	4.5	2.5	1.6	1.0	WCA	A 216
20.0	18.9	17.3	17.0	16.8	13.8	11.4	8.9	6.5	4.5	2.5	1.6	1.0	LCB	A 352
20.6	19.4	17.8	17.4	17.3	14.8	12.0	9.3	6.5	4.5	2.5	1.6	1.0	WCB	A 216
22.9	21.6	19.7	19.4	19.2	14.8	12.0	9.3	6.5	4.5	2.5	...	...	WCC	A 216

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.	
						Tensile	Yield	to 100	200
Low and Intermediate Alloy Steel Pipes (2)									
½Cr-½Mo	A 335	3	P2	...	−20	55	30	18.3	18.3
½Cr-½Mo A 387 Gr. 2 Cl. 1	A 691	3	½Cr	(11)(67)	−20	55	33	18.3	18.3
C-½Mo	A 335	3	P1						
C-½Mo	A 369	3	FP1	(58)	−20	55	30	18.3	18.3
½Cr-½Mo	A 369	3	FP2	...	−20	55	30	18.3	18.3
1Cr-½Mo A 387 Gr. 12 Cl. 1	A 691	4	1Cr	(11)(67)	−20	55	33	18.3	18.3
½Cr-½Mo	A 426	3	CP2	(10)	−20	60	30	18.4	17.7
1½Si-½Mo	A 335	3	P15	...					
1½Si-½Mo	A 426	3	CP15	(10)	−20	60	30	18.8	18.2
1Cr-½Mo	A 426	4	CP12	(10)	−20	60	30	18.8	18.3
5Cr-½Mo-1½Si	A 426	5B	CP5b	(10)	−20	60	30	18.8	17.9
3Cr-Mo	A 426	5A	CP21	(10)	−20	60	30	18.8	18.1
¾Cr-¾Ni-Cu-Al	A 333	4	4	...	−150	60	35	20.0	19.1
2Cr-½Mo	A 369	4	FP3b	...	−20	60	30	20.0	18.5
1Cr-½Mo	A 335	4	P12						
1Cr-½Mo	A 369	4	FP12	...	−20	60	32	20.0	18.7
1¼Cr-½Mo	A 335	4	P11						
1¼Cr-½Mo	A 369	4	FP11	...	−20	60	30	20.0	18.7
1¼Cr-½Mo A 387 Gr. 11 Cl. 1	A 691	4	1¼Cr	(11)(67)	−20	60	35	20.0	20.0
5Cr-½Mo A 387 Gr. 5 Cl. 1	A 691	5B	5Cr	(11)(67)	−20	60	30	20.0	18.1
5Cr-½Mo	A 335	5B	P5						
5Cr-½Mo-Si	A 335	5B	P5b	...	−20	60	30	20.0	18.1
5Cr-½Mo-Ti	A 335	5B	P5c						
5Cr-½Mo	A 369	5B	FP5						
9Cr-1Mo	A 335	5B	P9						
9Cr-1Mo	A 369	5B	FP9	...	−20	60	30	20.0	18.1
9Cr-1Mo A 387 Gr. 9 Cl. 1	A 691	5B	9Cr						

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																	
300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
																Low and Intermediate Alloy Steel Pipes (2)	
17.5	16.9	16.3	15.7	15.4	15.1	13.8	13.5	13.2	12.8	9.2	5.9	...	...	...	...	P2	A 335
18.3	18.3	17.9	17.3	16.9	16.6	13.8	13.8	13.4	12.8	9.2	5.9	...	...	...	...	½Cr	A 691
17.5	16.9	16.3	15.7	15.4	15.1	13.8	13.5	13.2	12.7	8.2	4.8	4.0	2.4	...	...	P1	A 335
																FP1	A 369
17.5	16.9	16.3	15.7	15.4	15.1	13.8	13.5	13.2	12.8	9.2	5.9	4.0	2.4	...	...	FP2	A 369
18.3	18.3	17.9	17.3	16.9	16.6	16.3	15.9	15.4	14.0	11.3	7.2	4.5	2.8	1.8	1.1	1Cr	A 691
17.0	16.3	15.6	14.9	14.6	14.2	13.9	13.5	13.2	12.5	10.0	6.3	4.0	2.4	...	...	CP2	A 426
17.6	17.0	16.5	15.9	15.6	15.3	15.0	14.4	13.8	12.5	10.0	6.3	4.0	2.4	...	...	P15	A 335
																CP15	A 426
17.6	17.1	16.5	15.9	15.7	15.4	15.1	14.8	14.2	13.1	11.3	7.2	4.5	2.8	1.8	1.1	CP12	A 426
17.1	16.2	15.4	14.5	14.1	13.7	13.3	12.8	12.4	10.9	9.0	5.5	3.5	2.5	1.8	1.2	CP5b	A 426
17.4	16.8	16.1	15.5	15.2	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	2.7	1.5	CP21	A 426
18.2	17.3	16.4	15.5	15.0	...	...	...	...	...	...	...	...	...	...	...	4	A 333
17.5	16.4	16.3	15.7	15.4	15.1	13.9	13.5	13.1	12.5	10.0	6.2	4.2	2.6	1.4	1.0	FP3b	A 369
18.0	17.5	17.2	16.7	16.2	15.6	15.2	15.0	14.5	12.8	11.3	7.2	4.5	2.8	1.8	1.1	P12	A 335
																FP12	A 369
18.0	17.5	17.2	16.7	16.2	15.6	15.2	15.0	14.5	12.8	9.3	6.3	4.2	2.8	1.9	1.2	P11	A 335
																FP11	A 369
20.0	19.7	18.9	18.3	18.0	17.6	17.3	16.8	16.3	15.0	9.9	6.3	4.2	2.8	1.9	1.2	1¼Cr	A 691
17.4	17.2	17.1	16.8	16.6	16.3	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.8	2.0	1.3	5Cr	A 691
17.4	17.2	17.1	16.8	16.6	16.3	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	P5	A 335
																P5b	A 335
																P5c	A 335
																FP5	A 369
17.4	17.2	17.1	16.8	16.6	16.3	13.2	12.8	12.1	11.4	10.6	7.4	5.0	3.3	2.2	1.5	F9	A 335
																FP9	A 369
																9Cr	A 691

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.	
						Tensile	Yield	to 100	200
Low and Intermediate Alloy Steel (Cont'd)									
Pipes (2) (Cont'd)									
3Cr-1Mo	A 335	5A	P21	...	−20	60	30	20.0	18.7
3Cr-1Mo	A 369	5A	FP21						
3Cr-1Mo A 387 Gr. 21 Cl. 1	A 691	5A	3Cr	(11)(67)	−20	60	30	20.0	18.5
2¼Cr-1Mo A 387 Gr. 22 Cl. 1	A 691	5A	2¼Cr	(11)(67)(72)(75)					
2¼Cr-1Mo	A 369	5A	FP22	(72)(75)	−20	60	30	20.0	18.5
2¼Cr-1Mo	A 335	5A	P22	(72)(75)					
2Ni-1Cu	A 333	9A	9	...	−100	63	46	21.0	...
2Ni-1Cu	A 334								
2¼Ni	A 333	9A	7	...	−100	65	35	21.7	19.6
2¼Ni	A 334								
3½Ni	A 333	9B	3	...	−150	65	35	21.7	19.6
3½Ni	A 334								
C-½Mo	A 426	3	CP1	(10)(58)	−20	65	35	21.7	21.7
C-Mo A 204 Gr. A	A 672	3	L65	(11)(58)(67)	−20	65	37	21.7	21.7
C-Mo A 204 Gr. A	A 691	3	CM65						
2¼Ni A 203 Gr. B	A 671	9A	CF70	(11)(65)(67)	−20	70	40	23.3	...
3½Ni A 203 Gr. E	A 671	9B	CF71						
C-Mo A 204 Gr. B	A 672	3	L70	(11)(58)(67)	−20	70	40	23.3	23.3
C-Mo A 204 Gr. B	A 691	3	CM70						
1¼Cr-½Mo	A 426	4	CP11	(10)	−20	70	40	23.3	23.3
2¼Cr-1Mo	A 426	5A	CP22	(10)(72)	−20	70	40	23.3	23.3
C-Mo A 204 Gr. C	A 672	3	L75	(11)(58)(67)	−20	75	43	25.0	25.0
C-Mo A 204 Gr. C	A 691	3	CM75						
9Cr-1Mo-V ≤ 3 in. thick	A 335	5B	P91	...	−20	85	60	28.3	28.3
5Cr-½Mo	A 426	5B	CP5	(10)	−20	90	60	30.0	28.0
9Cr-1Mo	A 426	5B	CP9	(10)	−20	90	60	30.0	22.5
9Ni	A 333	11A	8	(47)	−320	100	75	31.7	31.7
9Ni	A 334	11A	8	...					

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																	
300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
																Low and Intermediate Alloy Steel (Cont'd) Pipes (2) (Cont'd)	
18.0	17.5	17.2	16.7	16.2	15.6	15.2	15.0	14.0	12.0	9.0	7.0	5.5	4.0	2.7	1.5	P21	A 335
																FP21	A 369
18.1	17.9	17.9	17.9	17.9	17.9	17.9	17.8	14.0	12.0	9.0	7.0	5.5	4.0	2.7	1.5	3Cr	A 691
18.0	17.9	17.9	17.9	17.9	17.9	17.9	17.8	14.5	12.8	10.8	7.8	5.1	3.2	2.0	1.6	2¼Cr	A 691
																FP22	A 369
																P22	A 335
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9	A 333, A 334
19.6	18.7	17.6	16.8	16.3	15.5	13.9	11.4	9.0	6.5	4.5	2.5	1.6	1.0	...	...	7	A 333, A 334
19.6	18.7	17.8	16.8	16.3	15.5	13.9	11.4	9.0	6.5	4.5	2.5	1.6	1.0	...	...	3	A 333, A 334
21.7	21.7	21.3	20.7	20.4	20.0	16.3	15.7	14.4	12.5	10.0	6.3	4.0	2.4	...	...	CP1	A 426
21.7	20.7	20.0	19.3	19.0	18.6	16.3	15.8	15.3	13.7	8.2	4.8	4.0	2.4	...	...	L65	A 672
																CM65	A 691
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CF70	A 671
																CF71	A 671
23.3	22.5	21.7	20.9	20.5	20.1	17.5	17.5	17.1	13.7	8.2	4.8	4.0	2.4	...	...	L70	A 672
																CM70	A 691
23.3	23.3	22.9	22.3	21.6	20.9	15.5	15.0	14.4	13.7	9.3	6.3	4.2	2.8	1.9	1.2	CP11	A 426
23.3	23.3	22.9	22.3	21.6	20.9	17.5	17.5	16.0	14.0	11.0	7.8	5.1	3.2	2.0	1.2	CP22	A 426
25.0	24.1	23.3	22.5	22.1	21.7	18.8	18.8	18.3	13.7	8.2	4.8	4.0	2.4	...	...	L75	A 672
																CM75	A 691
28.3	28.2	28.1	27.7	27.3	26.7	25.9	24.9	23.7	22.3	20.7	18.0	14.0	10.3	7.0	4.3	P91	A 335
26.1	24.1	22.1	20.1	19.0	17.5	16.0	14.5	12.8	10.4	7.6	5.6	4.2	3.1	1.8	1.0	CP5	A 426
22.5	22.5	22.5	22.5	22.5	22.0	21.0	19.4	17.3	15.0	10.7	8.5	5.5	3.3	2.2	1.5	CP9	A 426
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8	A 333
																8	A 334

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.	
						Tensile	Yield	to 100	200
Low and Intermediate Alloy Steel (Cont'd)									
Plates									
½Cr-½Mo	A 387	3	Gr. 2 Cl. 1	...	−20	55	33	18.3	18.3
1Cr-½Mo	A 387	4	Gr. 12 Cl. 1	...	−20	55	33	18.3	18.3
9Cr-1Mo	A 387	5	Gr. 9 Cl. 1	...	−20	60	30	20.0	18.1
1¼Cr-½Mo	A 387	4	Gr. 11 Cl. 1	...	−20	60	35	20.0	20.0
5Cr-½Mo	A 387	5B	Gr. 5 Cl. 1	...	−20	60	30	20.0	18.1
3Cr-1Mo	A 387	5A	Gr. 21 Cl. 1	...	−20	60	30	20.0	18.5
2¼Cr-1Mo	A 387	5A	Gr. 22 Cl. 1	(72)	−20	60	30	20.0	18.5
2¼Ni	A 203	9A	A	(12)(65)	−20	65	37	21.7	19.6
3½Ni	A 203	9B	D						
C-½Mo	A 204	3	A	(58)	−20	65	37	21.7	21.7
1Cr-½Mo	A 387	4	Gr. 12 Cl. 2	...	−20	65	40	21.7	21.7
2¼Ni	A 203	9A	B	(12)(65)	−20	70	40	23.3	21.1
3½Ni	A 203	9B	E						
½Cr-½Mo	A 387	3	Gr. 2 Cl. 2	...	−20	70	45	23.3	17.5
C-½Mo	A 204	3	B	(58)	−20	70	40	23.3	23.3
Cr-n-Si	A 202	4	A	...	−20	75	45	25.0	23.9
Mn-Mo	A 302	3	A	...	−20	75	45	25.0	25.0
C-½Mo	A 204	3	C	(58)	−20	75	43	25.0	25.0
1¼Cr-½Mo	A 387	4	Gr. 11 Cl. 2	...	−20	75	45	25.0	25.0
5Cr-½Mo	A 387	5B	Gr. 5 Cl. 2	...	−20	75	45	25.0	24.9
3Cr-½Mo	A 387	5A	Gr. 21 Cl. 2	...	−20	75	45	25.0	25.0
2¼Cr-1Mo	A 387	5A	Gr. 22 Cl. 2	(72)	−20	75	45	25.0	25.0
Mn-Mo	A 302	3	B	...	−20	80	50	26.7	26.7
Mn-Mo-Ni	A 302	3	C						
Mn-Mo-Ni	A 302	3	D						
Cr-n-Si	A 202	4	B	...	−20	85	47	28.4	27.1
9Cr-1Mo-V ≤ 3 in. thick	A 387	5B	91 Cl. 2	...	−20	85	60	28.3	28.3
8Ni	A 553	11A	Type II	(47)	−275	100	85	31.7	...
5Ni	A 645	11A	...	...	−275	95	65	31.7	31.6
9Ni	A 553	11A	Type I	(47)	−320	100	85	31.7	31.7
9Ni	A 353	11A	...	(47)	−320	100	75		

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																	
300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
																Low and Intermediate Alloy Steel (Cont'd) Plates	
18.3	18.3	17.9	17.3	16.9	16.6	13.8	13.8	13.4	12.8	9.2	5.9	...	...	...	...	Gr. 2 Cl. 1	A 387
18.3	18.3	17.9	17.3	16.9	16.6	16.3	15.9	15.4	14.0	11.3	7.2	4.5	2.8	1.8	1.1	Gr. 12 Cl. 1	A 387
17.4	17.2	17.1	16.8	16.6	16.3	13.2	12.8	12.1	11.4	10.6	7.4	5.0	3.3	2.2	1.5	Gr. 9 Cl. 1	A 387
20.0	19.7	18.9	18.3	18.0	17.6	17.3	16.8	16.3	13.7	9.3	6.3	4.2	2.8	1.9	1.2	Gr. 11 Cl. 1	A 387
17.4	17.2	17.1	16.8	16.6	16.3	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	Gr. 5 Cl. 1	A 387
18.1	17.9	17.9	17.9	17.9	17.9	17.9	17.8	14.0	12.0	9.0	7.0	5.5	4.0	2.7	1.5	Gr. 21 Cl. 1	A 387
18.0	17.9	17.9	17.9	17.9	17.9	17.9	17.8	14.5	12.8	10.8	8.0	5.7	3.8	2.4	1.4	Gr. 22 Cl. 1	A 387
19.6	16.3	16.3	16.3	16.3	15.5	13.9	11.4	9.0	6.5	4.5	2.5	...	...	...	...	A	A 203
																D	A 203
21.7	20.7	20.0	19.3	19.0	18.6	16.3	15.8	15.3	13.7	8.2	4.8	4.0	2.4	...	...	A	A 204
21.7	21.7	21.7	20.9	20.5	20.1	19.7	19.2	18.7	18.0	11.3	7.2	4.5	2.8	1.8	1.1	Gr. 12 Cl. 2	A 387
21.1	17.5	17.5	17.5	17.5	16.6	14.8	12.0	9.3	6.5	4.5	2.5	...	...	...	...	B	A 203
																E	A 203
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	16.8	14.5	10.0	6.3	...	...	...	...	Gr. 2 Cl. 2	A 387
23.3	22.5	21.7	20.9	20.5	20.1	17.5	17.5	17.1	13.7	8.2	4.8	4.0	2.4	...	...	B	A 204
22.8	21.6	20.5	19.3	18.8	17.7	15.7	12.0	7.8	5.0	3.0	1.5	...	...	...	...	A	A 202
25.0	25.0	25.0	25.0	25.0	25.0	18.3	17.7	16.8	13.7	8.2	4.8	...	...	...	...	A	A 302
25.0	24.1	23.3	22.5	22.1	21.7	18.8	18.8	18.3	13.7	8.2	4.8	4.0	2.4	...	...	C	A 204
25.0	25.0	24.3	23.5	23.1	22.7	22.2	21.6	21.1	13.7	9.3	6.3	4.2	2.8	1.9	1.2	Gr. 11 Cl. 2	A 387
24.2	24.1	23.9	23.6	23.2	22.8	16.5	16.0	15.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	Gr. 5 Cl. 2	A 387
24.5	24.1	23.9	23.8	23.6	23.4	23.0	22.5	19.0	13.1	9.5	6.8	4.9	3.2	2.4	1.3	Gr. 21 Cl. 2	A 387
24.5	24.1	23.9	23.8	23.6	23.4	23.0	22.5	21.8	17.0	11.4	7.8	5.1	3.2	2.0	1.2	Gr. 22 Cl. 2	A 387
26.7	26.7	26.7	26.7	26.7	26.7	19.6	18.8	17.9	13.7	8.2	4.8	...	...	...	...	B	A 302
																C	A 302
																D	A 302
25.8	24.5	23.2	21.9	21.3	19.8	17.7	12.0	7.8	5.0	3.0	1.5	...	...	...	...	B	A 202
28.3	28.2	28.1	27.7	27.3	26.7	25.9	24.9	23.7	22.3	20.7	18.0	14.0	10.3	7.0	4.3	91 Cl. 2	A 387
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Type II	A 553
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	A 645
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Type I	A 553
																...	A 353

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.	
						Tensile	Yield	to 100	200
Low and Intermediate Alloy Steel (Cont'd)									
Forgings and Fittings (2)									
C-½Mo	A 234	3	WP1	(58)	−20	55	30	18.3	18.3
1Cr-½Mo	A 182	4	F12 Cl. 1	(9)	−20	60	30		
1Cr-½Mo	A 234	4	WP12 Cl. 1	...	−20	60	32	20.0	18.7
1¼Cr-½Mo	A 182	4	F11 Cl. 1	(9)					
1¼Cr-½Mo	A 234	4	WP11b Cl. 1	...	−20	60	30	20.0	18.7
2¼Cr-1Mo	A 182	...	F22 Cl. 1	(9)(72)(75)					
2¼Cr-1Mo	A 234	5A	WP22 Cl. 1	(72)	−20	60	30	20.0	18.5
5Cr-½Mo	A 234	5B	WP5	...	−20	60	30	20.0	18.1
9Cr-1Mo	A 234	5B	WP9	...	−20	60	30	20.0	18.1
3½Ni	A 420	9B	WPL3	...	−150	65	35	21.7	...
3½Ni	A 350	9B	LF3	(9)	−150	70	37.5	23.3	...
½Cr-½Mo	A 182	3	F2	(9)	−20	70	40	23.3	23.3
C-½Mo	A 182	3	F1	(9)(58)	−20	70	40	23.3	23.3
1Cr-½Mo	A 182	4	F12 Cl. 2	(9)					
1Cr-½Mo	A 234	4	WP12 Cl. 2	...	−20	70	40	23.3	23.3
1¼Cr-½Mo	A 182	4	F11 Cl. 2	(9)					
1¼Cr-½Mo	A 234	4	WP11 Cl. 2	...	−20	70	40	23.3	23.3
5Cr-½Mo	A 182	5B	F5	(9)	−20	70	40	23.3	23.3
3Cr-1Mo	A 182	5A	F21	(9)	−20	75	45	25.0	25.0
2¼Cr-1Mo	A 182	5A	F22 Cl. 3	(9)(72)					
2¼Cr-1Mo	A 234	5A	WP22 Cl. 3	(72)	−20	75	45	25.0	25.0
9Cr-1Mo	A 182	5B	F9	(9)	−20	85	55	28.3	28.3
9Cr-1Mo-V ≤ 3 in. thick	A 182	5B	F91						
9Cr-1Mo-V ≤ 3 in. thick	A 234	5B	WP91	...	−20	85	60	28.3	28.3
5Cr-½Mo	A 182	5B	F5a	(9)	−20	90	65	30.0	29.9

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress S, ksi (1), at Metal Temperature, °F (7)																	
300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
																Low and Intermediate Alloy Steel (Cont'd) Forgings and Fittings (2)	
17.5	16.9	16.3	15.7	15.4	15.1	13.8	13.5	13.2	12.7	8.2	4.8	4.0	2.4	...	...	WP1	A 234
18.0	17.5	17.2	16.7	16.2	15.6	15.2	15.0	14.5	12.8	11.3	7.2	4.5	2.8	1.8	1.1	F12 Cl. 1	A 182
																WP12 Cl. 1	A 234
18.0	17.5	17.2	16.7	16.2	15.6	15.2	15.0	14.5	12.8	9.3	6.3	4.2	2.8	1.9	1.2	F11 Cl. 1	A 182
																WP11b Cl. 1	A 234
18.0	17.9	17.9	17.9	17.9	17.9	17.9	17.8	14.5	12.8	10.8	7.8	5.1	3.2	2.0	1.2	F22 Cl. 1	A 182
																WP22 Cl. 1	A 234
17.4	17.2	17.1	16.8	16.6	16.3	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	WP5	A 234
17.4	17.2	17.1	16.8	16.6	16.3	13.2	12.8	12.1	11.4	10.6	7.4	5.0	3.3	2.2	1.5	WP9	A 234
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	WPL3	A 420
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	LF3	A 350
23.3	22.5	21.7	20.9	20.5	20.1	17.5	17.5	17.1	15.0	9.2	5.9	...	...	...	...	F2	A 182
23.3	22.5	21.7	20.9	20.5	20.1	17.5	17.5	17.1	13.7	8.2	4.8	4.0	2.4	...	...	F1	A 182
23.3	22.5	21.7	20.9	20.5	20.1	19.7	19.2	18.7	18.0	11.3	7.2	4.5	2.8	1.8	1.1	F12 Cl. 2	A 182
																WP12 Cl. 2	A 234
23.3	22.5	21.7	20.9	20.5	20.1	19.7	19.2	18.7	13.7	9.3	6.3	4.2	2.8	1.9	1.2	F11 Cl. 2	A 182
																WP11 Cl. 2	A 234
22.6	22.4	22.4	22.0	21.7	21.3	15.4	14.8	14.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	F5	A 182
24.5	24.1	23.9	23.8	23.6	23.4	23.0	22.5	19.0	13.1	9.5	6.8	4.9	3.2	2.4	1.3	F21	A 182
24.5	24.1	23.9	23.8	23.6	23.4	23.0	22.5	21.8	17.0	11.4	7.8	5.1	3.2	2.0	1.2	F22 Cl. 3	A 182
																WP22 Cl. 3	A 234
27.5	27.2	27.1	26.8	26.3	25.8	18.7	18.1	17.1	16.2	11.0	7.4	5.0	3.3	2.2	1.5	F9	A 182
28.3	28.2	28.1	27.7	27.3	26.7	25.9	24.9	23.7	22.3	20.7	18.0	14.0	10.3	7.0	4.3	F91	A 182
																WP91	A 234
29.1	28.9	28.7	28.3	27.9	27.3	19.8	19.1	14.3	10.9	8.0	5.8	4.2	2.9	1.8	1.0	F5a	A 182

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.	
						Tensile	Yield	to 100	200
Low and Intermediate Alloy Steel (Cont'd)									
Forgings and Fittings (2) (Cont'd)									
9Ni	A 420	11A	WPL8	(47)	−320	110	75	31.7	31.7
Castings (2)									
C-½Mo	A 352	3	LC1	(9)(58)	−75	65	35	21.7	21.5
C-½Mo	A 217	3	WC1	(9)(58)	−20	65	35	21.7	21.5
2½Ni	A 352	9A	LC2	(9)	−100	70	40	23.3	17.5
3½Ni	A 352	9B	LC3	(9)	−150				
Ni-Cr-½Mo	A 217	4	WC4	(9)	−20	70	40	23.3	23.3
Ni-Cr-1Mo	A 217	4	WC5	(9)	−20	70	40	23.3	23.3
1¼Cr-½Mo	A 217	4	WC6	(9)	−20	70	40	23.3	23.3
2¼Cr-1Mo	A 217	5A	WC9	(9)	−20	70	40	23.3	23.3
5Cr-½Mo	A 217	5B	C5	(9)	−20	90	60	30.0	29.9
9Cr-1Mo	A 217	5B	C12	(9)	−20	90	60	30.0	29.9

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																	
300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
																Low and Intermediate Alloy Steel (Cont'd) Forgings and Fittings (2) (Cont'd)	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	WPL8	A 420
																	Castings (2)
20.5	19.7	18.9	18.3	18.0	17.6	...	...	...	...	...	...	...	...	...	...	LC1	A 352
20.5	19.7	18.9	18.3	18.0	17.6	16.2	15.8	15.3	13.7	8.2	4.8	4.0	2.4	...	...	WC1	A 352
17.5	17.5	17.5	17.5	17.5	...	...	...	...	...	...	...	...	...	...	...	LC2	A 352
																LC3	A 352
23.3	22.5	21.7	20.9	20.5	20.1	17.5	17.5	17.1	15.0	9.2	5.9	...	...	...	...	WC4	A 217
23.3	22.5	21.7	20.9	20.5	20.1	17.5	17.5	17.1	16.3	11.0	6.9	4.6	2.8	...	...	WC5	A 217
23.3	22.5	21.7	20.9	20.5	20.1	19.7	19.2	18.7	14.5	11.0	6.9	4.6	2.8	2.5	1.3	WC6	A 217
23.1	22.5	22.4	22.4	22.2	21.9	21.5	21.0	19.8	17.0	11.4	7.8	5.1	3.2	2.0	1.2	WC9	A 217
29.1	28.9	28.7	28.3	27.9	27.3	19.8	19.1	14.3	10.9	8.0	5.8	4.2	2.9	1.8	1.0	C5	A 217
29.1	28.9	28.7	28.3	27.9	27.3	19.8	19.1	18.2	16.5	11.0	7.4	5.0	3.3	2.2	1.5	C12	A 217

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi Tensile	Yield	Min. Temp. to 100	200	300	400	500	600
Stainless Steel (3) (4) Pipes and Tubes (2)													
18Cr-10Ni-Ti pipe smls > 3/8 in. thick	A 312	8	TP321	(30)(36)	−325	70	25	16.7	*16.7*	*16.7*	16.7	16.1	15.2
18Cr-10Ni-Ti pipe > 3/8 in. thick	A 376	8	TP321	(30)(36)	−325	70	25	16.7	*16.7*	*16.7*	16.7	16.1	15.2
18Cr-8Ni tube	A 269	8	TP304L	(14)(36)	−425	70	25	16.7	*16.7*	*16.7*	15.8	14.8	14.0
18Cr-8Ni pipe	A 312	8	TP304L	...	−425	70	25	16.7	*16.7*	*16.7*	15.8	14.8	14.0
Type 304L A 240	A 358	8	304L	(36)	−425	70	25	16.7	*16.7*	*16.7*	15.8	14.8	14.0
16Cr-12Ni-2Mo tube	A 269	8	TP316L	(14)(36)	−325	70	25	16.7	*16.7*	*16.7*	15.5	14.4	13.5
16Cr-12Ni-2Mo pipe	A 312	8	TP316L	...	−325	70	25	16.7	*16.7*	*16.7*	15.5	14.4	13.5
Type 316L A 240	A 358	8	316L	(36)	−325	70	25	16.7	*16.7*	*16.7*	15.5	14.4	13.5
18Cr-10Ni-Ti pipe smls > 3/8 in. thick	A 312	8	TP321	(28)(30)(36)	−325	70	25	16.7	*16.7*	*16.7*	16.7	16.1	15.2
18Cr-10Ni-Ti pipe > 3/8 in. thick	A 376	8	TP321	(28)(30)(36)	−325	70	25	16.7	*16.7*	*16.7*	16.7	16.1	15.2
18Cr-10Ni-i pipe smls > 3/8 in. thick	A 312	8	TP321H	(30)(36)	−325	70	25	16.7	*16.7*	*16.7*	16.7	16.1	15.2
18Cr-10Ni-Ti pipe > 3/8 in. thick	A 376	8	TP321H	...	−325	70	25	16.7	*16.7*	*16.7*	16.7	16.1	15.2
23Cr-13Ni	A 451	8	CPH8	(26)(28)(35)	−325	65	28	18.7	*18.7*	*18.7*	*18.7*	*18.7*	18.0
25Cr-20Ni	A 451	8	CPK20	(12)(28)(35)(39)	−325	65	28	18.7	*18.7*	*18.7*	*18.7*	*18.7*	18.0
11Cr-Ti tube	A 268	7	TP409	(35)	−20	60	30	20.0	...	...	...	...	...
18Cr-i tube	A 268	7	TP430Ti	(35)(49)	−20	60	40	20.0	...	...	...	...	...
15Cr-13Ni-2Mo-Cb	A 451	S-8	CPF10MC	(28)	−325	70	30	20.0	...	...	...	...	...
16Cr-8Ni-2Mo pipe	A 376	8	16-8-2H	(26)(31)(35)	−325	75	30	20.0	...	...	...	...	...
12Cr-Al tube	A 268	7	TP405	(35)	−20	60	30	20.0	18.4	17.7	17.4	17.2	16.8
13Cr tube	A 268	6	TP410	(35)	−20	60	30	20.0	18.4	17.7	17.4	17.2	16.8
16Cr tube	A 268	7	TP430	(35)(49)	−20	60	35	20.0	20.0	19.6	19.2	19.0	18.5
18Cr-13Ni-3Mo pipe	A 312	8	TP317L	...	−325	75	30	20.0	*20.0*	*20.0*	18.9	17.7	16.8
25Cr-20Ni pipe	A 312	8	TP310	(28)(35)(39)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	20.0	19.2
Type 310S A 240	A 358	8	310S	(28)(31)(35)(36)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	20.0	19.2
25Cr-20Ni pipe	A 409	8	TP310	(28)(31)(35)(36)(39)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	20.0	19.2
18Cr-10Ni-Ti pipe smls ≤ 3/8 in. thk & wld	A 312	8	TP321	(30)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	19.3	18.3
18Cr-10Ni-Ti pipe	A 358	8	321	(30)(36)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	19.3	18.3
18Cr-10Ni-Ti pipe ≤ 3/8 in. thick	A 376	8	321	(30)(36)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	19.3	18.3
18Cr-10Ni-Ti pipe	A 409	8	TP321	(30)(36)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	19.3	18.3
23Cr-12Ni pipe	A 312	8	TP309	(28)(35)(39)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
Type 309S A 240	A 358	8	309S	(28)(31)(35)(36)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
23Cr-12Ni pipe	A 409	8	TP309	(28)(31)(35)(36)(39)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
18Cr-8Ni	A 451	8	CPF8	(26)(28)	−425	70	30	20.0	*20.0*	*19.8*	17.5	16.4	15.7

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																			
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Grade	Spec. No.
																		Stainless Steel (3) (4) Pipes and Tubes (2)	
14.9	14.6	14.3	14.1	14.0	13.8	13.6	13.5	9.6	6.9	5.0	3.6	2.6	1.7	1.1	0.8	0.5	0.3	TP321	A 312 A 376
13.7	13.5	13.3	13.0	12.8	*11.9*	*9.9*	7.8	6.3	5.1	4.0	3.2	2.6	2.1	1.7	1.1	1.0	0.9	TP304L TP304L 304L	A 269 A 312 A 358
13.2	12.9	12.6	12.4	12.1	11.8	11.5	11.2	10.8	*10.2*	*8.8*	6.4	4.7	3.5	2.5	1.8	1.3	1.0	TP316L TP316L 316L	A 269 A 312 A 358
14.9	14.6	14.3	14.1	14.0	13.8	13.6	13.5	11.7	9.1	6.9	5.4	4.1	3.2	2.5	1.9	1.5	1.1	TP321 TP321 TP321H TP321H	A 312 A 376 A 312 A 376
17.4	17.1	16.8	16.3	*12.8*	*12.4*	*11.8*	10.4	8.4	6.4	5.0	3.7	2.9	2.3	1.7	1.3	0.9	0.8	CPH8	A 451
17.4	17.1	16.8	16.3	*12.8*	*12.4*	*11.9*	11.0	9.8	8.4	7.2	6.0	4.8	3.4	2.3	1.5	1.1	0.8	CPK20	A 451
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	TP409	A 268
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	TP430Ti	A 268
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CPF10MC	A 451
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	16-8-2H	A 376
16.5	16.2	15.7	15.1	10.4	9.7	8.4	4.0	...	...	...	...	...	...	...	...	...	...	TP405	A 268
16.5	16.2	15.7	15.1	10.4	9.7	8.4	6.4	4.4	2.9	1.8	1.0	...	...	...	...	...	...	TP410	A 268
18.2	17.6	17.1	16.4	10.4	9.7	8.5	6.5	4.5	3.2	2.4	1.8	...	...	...	...	...	...	TP430	A 268
16.6	16.2	15.8	15.5	15.2	...	...	...	...	...	...	...	...	...	...	...	...	...	TP317L	A312
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	11.0	7.1	5.0	3.6	2.5	1.5	0.8	0.5	0.4	0.3	0.2	TP310 310S TP310	A 312 A 358 A 409
17.9	17.5	17.2	16.9	16.7	16.6	16.4	16.2	9.6	6.9	5.0	3.6	2.6	1.7	1.1	0.8	0.5	0.3	TP321 321 TP321 TP321	A 312 A 358 A 376 A 409
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	10.5	8.5	6.5	5.0	3.8	2.9	2.3	1.8	1.3	0.9	0.7	TP309 309S TP309	A 312 A 358 A 409
15.3	15.1	14.9	14.8	*12.9*	*12.7*	*12.3*	*10.8*	9.5	7.4	5.8	4.4	3.2	2.4	1.8	1.3	1.0	0.8	CPF8	A 451

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.					
						Tensile	Yield	to 100	200	300	400	500	600
Stainless Steel (3) (4) (Cont'd)													
Pipes and Tubes (2) (Cont'd)													
18Cr-10Ni-Cb pipe	A 312	8	TP347	...	−425	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
Type 347 A 240	A 358	8	347	(30)(36)	−425								
18Cr-10Ni-Cb pipe	A 376	8	TP347	(30)(36)	−425								
18Cr-10Ni-Cb pipe	A 409	8	TP347	(30)(36)	−425								
18Cr-10Ni-Cb pipe	A 312	8	TP348	...	−325								
Type 348 A 240	A 358	8	348	(30)(36)	−325								
18Cr-10Ni-b pipe	A 376	8	TP348	(30)(36)	−325								
18Cr-10Ni-Cb pipe	A 409	8	TP348	(30)(36)	−325								
23Cr-13Ni	A 451	8	CPH10 or CPH20	(12)(14)(28)(35)(39)	−325	70	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
25Cr-20Ni pipe	A 312	8	TP310	(28)(29)(35)(39)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
Type 310S A 240	A 358	8	310S	(28)(29)(31)(35)(36)									
18Cr-10Ni-Cb	A 451	8	CPF8C	(28)	−325	70	30	20.0	*20.0*	*20.0*	*20.0*	19.3	18.3
18Cr-10Ni-i pipe	A 430	8	FP321	(30)(36)	−325	70	30						
18Cr-10Ni-Ti pipe smls ≤ 3/8 in. thk; wld	A 312	8	TP321	(28)(30)									
Type 321 A 240	A 358	8	321										
18Cr-10Ni-Ti pipe ≤ 3/8 in. thick	A 376	8	TP321	(28)(30)(36)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	19.3	18.3
18Cr-10Ni-Ti pipe	A 409												
18Cr-0Ni-Ti pipe	A 430	8	FP321H	(30)(36)	−325								
18Cr-10Ni-Ti pipe ≤ 3/8 in. thick	A 376	8	TP321H										
18Cr-10Ni-Ti pipe smls ≤ 3/8 in. thk; wld	A 312	8	TP321H	...	−325								
16Cr-12Ni-2Mo pipe	A 430	8	FP316	(26)(31)(36)	−425	70	30						
16Cr-12Ni-Mo pipe	A 430	8	FP316H	(26)(31)(36)	−325								
16Cr-12Ni-Mo tube	A 269	8	TP316	(14)(26)(28)(31)(36)	−425	75	30	20.0	*20.0*	*20.0*	19.3	17.9	17.0
16Cr-12Ni-2Mo pipe	A 312	8	TP316	(26)(28)									
Type 316 A 240	A 358	8	316	(26)(28)(31)(36)	−425								
16Cr-12Ni-2Mo pipe	A 376	8	TP316	(26)(28)(31)(36)	−425								
16Cr-12Ni-2Mo pipe	A 409	8	TP316	(26)(28)(31)(36)	−425								
18Cr-3Ni-3Mo pipe	A 312	8	TP317	(26)(28)	−425								
18Cr-3Ni-3Mo pipe	A 409	8	TP317	(26)(28)(31)(36)	−325								
16Cr-12Ni-2Mo pipe	A 376	8	TP316H	(26)(31)(36)	−325								
					−325								
16Cr-12Ni-2Mo pipe	A 312	8	TP316H	(26)	−325	75	30	20.0	*20.0*	*20.0*	19.3	17.9	17.0
16Cr-12Ni-2Mo	A 452												
18Cr-10Ni-Cb pipe	A 430	8	FP347	(30)(36)	−425	70	30	20.0	*20.0*	*20.0*	*19.3*	*18.6*	*18.5*
18Cr-10Ni-Cb pipe	A 430	8	FP347H	(30)(36)	−325	70	30	20.0	*20.0*	*20.0*	*19.3*	*18.6*	*18.5*
18Cr-10Ni-Cb pipe	A 376	8	TP347H	(30)(36)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-0Ni-Cb pipe	A 312	8	TP347	(28)	−425								
Type 347 A 240	A 358	8	347	(28)(30)(36)	−425								
18Cr-10Ni-Cb pipe	A 376	8	TP347	(28)(30)(36)	−425								
18Cr-10Nib pipe	A 409	8	TP347	(28)(30)(36)	−425								
18Cr-10Ni-b pipe	A 312	8	TP348	(28)	−325								
Type 348 A 240	A 358	8	348	(28)(30)(36)	−325								
18Cr-10Ni-Cb pipe	A 376	8	TP348	(28)(30)(36)	−325								
18Cr-10Ni-Cb pipe	A 409	8	TP348	(28)(30)(36)	−325								
18Cr-10Ni-Cb pipe	A 312	8	TP347H	...	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-10Ni-Cb pipe	A 312	8	TP348H										

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																			
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Grade	Spec. No.
																		Stainless Steel (3) (4) (Cont'd) Pipes and Tubes (2) (Cont'd)	
19.0	18.6	18.5	18.4	*18.2*	*18.1*	*18.1*	*18.0*	*12.1*	9.1	6.1	4.4	3.3	2.2	1.5	1.2	0.9	0.8	TP347	A 312
																		347	A 358
																		TP347	A 376
																		TP347	A 409
																		TP348	A 312
																		348	A 358
																		TP348	A 376
																		TP348	A 409
18.8	18.3	18.0	17.4	*13.5*	*13.3*	*12.4*	10.5	8.4	6.4	5.0	3.7	2.9	2.3	1.7	1.3	0.9	0.8	CPH10 or CPH20	A 451
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	11.0	9.8	8.5	7.3	6.0	4.8	3.5	2.3	1.6	1.1	0.8	TP310	A 312
																		310S	A 358
18.0	17.5	17.2	17.1	*14.0*	*13.9*	*13.7*	*13.4*	*13.0*	*10.8*	8.0	5.0	3.5	2.7	2.0	1.4	1.1	1.0	CPF8C	A 451
																		FP321H	A 430
																		TP321	A 312
																		321	A 358
17.9	17.5	17.2	16.9	*16.7*	*16.6*	*16.4*	*16.2*	*11.7*	9.1	6.9	5.4	4.1	3.2	2.5	1.9	1.5	1.1	TP321	A 376
																		TP321	A 409
																		FP321H	A 430
																		TP321H	A 376
																		TP321H	A 312
																		FP316	A 430
																		FP316H	A 430
																		TP316	A 269
																		TP316	A 312
																		316	A 358
16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	*14.5*	*12.4*	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	TP316	A 376
																		TP316	A 409
																		TP317	A 312
																		TP317	A 409
																		TP316H	A 376
16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	*14.5*	*12.4*	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	TP316H	A 312, A 452
18.4	*18.2*	*18.2*	*18.2*	*18.2*	*18.1*	*18.1*	*18.0*	*17.1*	14.2	10.5	7.9	5.9	4.4	3.2	2.5	1.8	1.3	FP347	A 430
18.4	*18.2*	*18.2*	*18.2*	*18.2*	18.1	18.1	18.0	*17.1*	14.2	10.5	7.9	5.9	4.4	3.2	2.5	1.8	1.3	FP347H	A 430
																		TP347H	A 376
																		TP347	A 312
																		347	A 358
																		TP347	A 376
19.0	18.6	18.5	18.4	18.2	18.1	18.1	18.0	*17.1*	*14.2*	10.5	7.9	5.9	4.4	3.2	2.5	1.8	1.3	TP347	A 409
																		TP348	A 312
																		348	A 358
																		TP348	A 376
																		TP348	A 409
																		TP347H	A 312
19.0	18.6	18.5	18.4	18.2	18.1	18.1	18.0	*17.1*	*14.2*	10.5	7.9	5.9	4.4	3.2	2.5	1.8	1.3	TP348H	A 312

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.	Stress, ksi				
						Tensile	Yield	to 100	200	300	400	500	600
Stainless Steel (3) (4) (Cont'd)													
Pipes and Tubes (2) (Cont'd)													
18Cr-8Ni pipe	A 430	8	FP304	(26)(31)(36)	−425	70							
18Cr-8Ni pipe	A 430	8	FP304H	(26)(31)(36)	−325								
18Cr-8Ni tube	A 269	8	TP304	(14)(26)(28)(31)(36)	−425								
18Cr-8Ni pipe	A 312	8	TP304	(26)(28)	−425								
Type 304 A 240	A 358	8	304	(26)(28)(31)(36)	−425	75	30	20.0	*20.0*	*20.0*	18.7	17.5	16.4
18Cr-8Ni pipe	A 376	8	TP304	(20)(26)(28)(31)(36)	−425								
18Cr-8Ni pipe	A 376	8	TP304H	(26)(31)(36)	−325								
18Cr-8Ni pipe	A 409	8	TP304	(26)(28)(31)(36)	−425								
18Cr-8Ni pipe	A 312	8	TP304H	(26)	−325	75	30	20.0	*20.0*	*20.0*	18.7	17.5	16.4
18Cr-8Ni	A 452	8	TP304H	(26)	−325	75	30	20.0	*20.0*	*20.0*	18.7	17.4	16.5
18Cr-10Ni-Mo	A 451	8	CPF8M	(26)(28)	−425	70	30	20.0	*20.0*	*20.0*	19.4	18.1	17.1
18Cr-10Ni-Cb	A 452	8	TP347H	...	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
20Cr-Cu tube	A 268	10	TP443										
27Cr tube	A 268	10I	TP446	(35)	−20	70	40	23.3	23.3	21.4	20.4	19.4	18.4
25-10Ni-N	A 451	8	CPE20N	(35)(39)	−325	80	40	26.7	26.2	24.9	23.3	22.0	21.4
23Cr-4Ni-N	A 789												
23Cr-4Ni-N	A 790	10H	S32304	(25)	−60	87	58	29.0	27.9	26.3	25.3	24.9	24.5
12¾Cr	A 426	6	CPCA-15	(10)(35)	−20	90	65	30.0	...	...	...	...	...
22Cr-5Ni-3Mo	A 789												
22Cr-5Ni-3Mo	A 790	10H	S31803	(25)	−60	90	65	30.0	30.0	28.9	27.9	27.2	26.9
26Cr-4Ni-Mo	A 789												
26Cr-4Ni-Mo	A 790	10H	S32900	(25)	−20	90	70	30.0	...	...	...	...	...
25Cr-8Ni-3Mo-W-Cu-N	A 789												
25Cr-8Ni-3Mo-W-Cu-N	A 790	S-10H	S32760	(25)	−60	109	80	36.3	34.4	34.0	34.0	34.0	...
25Cr-7Ni-4Mo-N	A 789												
25Cr-7Ni-4Mo-N	A 790	10H	S32750	(25)	−20	116	80	38.7	35.0	33.1	31.9	31.4	31.2
Plates and Sheets													
18Cr-10Ni	A 240	8	305	(26)(36)(39)	−325	70	25	16.7	...	...	...	...	...
12Cr-Al	A 240	7	405	(35)	−20	60	25	16.7	15.3	14.8	14.5	14.3	14.0
18Cr-8Ni	A 240	8	304L	(36)	−425	70	25	16.7	*16.7*	*16.7*	15.6	14.8	14.0
16Cr-12Ni-2Mo	A 240	8	316L	(36)	−425	70	25	16.7	*16.7*	*16.7*	15.5	14.4	13.5
18Cr-Ti-Al	A 240	...	X8M	(35)	−20	65	30	20.0	...	...	...	...	...
18Cr-8Ni	A 167	S-8	302B	(26)(28)(31)(36)(39)	−325	75	30	20.0	*20.0*	*20.0*	18.7	17.4	16.4
18Cr-Ni	A 240	8	302	(26)(36)	−325	75	30	20.0	*20.0*	*20.0*	18.7	17.4	16.4

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																			
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Grade	Spec. No.
																		Stainless Steel (3) (4) (Cont'd) Pipes and Tubes (2) (Cont'd)	
																		FP304	A 430
																		FP304H	A 430
																		TP304	A 269
																		TP304	A 312
16.2	16.0	15.6	15.2	14.9	14.6	14.4	*13.8*	*12.2*	9.7	7.7	6.0	4.7	3.7	2.9	2.3	1.8	1.4	304	A 358
																		TP304	A 376
																		TP304H	A 376
																		TP304	A 409
16.2	16.0	15.6	15.2	14.9	14.6	14.4	*13.8*	*12.2*	9.7	7.7	6.0	4.7	3.7	2.9	2.3	1.8	1.4	TP304H	A 312
16.2	15.9	15.5	15.1	14.9	14.6	14.3	*13.8*	*12.2*	9.8	7.6	6.0	4.7	3.6	2.8	2.2	1.8	1.4	TP304H	A 452
16.7	16.2	15.8	15.5	*14.7*	*14.4*	*14.0*	*13.4*	11.4	9.3	8.0	6.8	5.3	4.0	3.0	2.3	1.9	1.4	CPF8M	A 451
18.9	18.6	18.5	18.2	18.1	18.1	18.1	*18.0*	*17.7*	*14.2*	10.5	7.9	5.9	4.3	3.2	2.5	1.8	1.4	TP347H	A 452
18.0	17.5	16.9	16.2	15.1	13.0	6.9	4.5	...	...	...	...	...	...	...	...	...	...	TP443	A 268
																		TP446	A 268
21.3	21.2	21.1	21.0	20.8	20.5	...	...	...	...	...	...	...	...	...	...	...	...	CPE20N	A 451
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S32304	A 789, A 790
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CPCA-15	A 426
...	...	...	...	...	...	...	...	...	..	...	...	...	...	...	...	...	...	S31803	A 789, A 790
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S32900	A 789, A 790
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S32760	A 789, A 790
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S32750	A 789, A 790
																		Plates and Sheets	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	305	A 240
13.8	13.5	11.6	11.1	10.4	9.6	8.4	4.0	...	...	...	...	...	...	...	...	...	...	405	A 240
13.7	13.5	13.3	13.0	12.8	*11.9*	*9.9*	7.8	6.3	5.1	4.0	3.2	2.6	2.1	1.7	1.1	1.0	0.9	304L	A 240
13.2	12.9	12.6	12.4	12.1	11.8	11.5	11.2	10.8	*10.2*	*8.8*	6.4	4.7	3.5	2.5	1.8	1.3	1.0	316L	A 240
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	X8M	A 240
16.1	15.9	15.6	15.2	14.9	14.3	*13.7*	...	...	...	...	...	...	...	...	...	...	...	302B	A 167
16.1	15.9	15.6	15.2	14.9	14.6	14.3	*13.7*	...	...	...	...	...	...	...	...	...	...	302	A 240

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200	300	400	500	600
						Tensile	Yield						
Stainless Steel (3) (4) (Cont'd) Plates and Sheets (Cont'd)													
13Cr	A 240	7	410S	(35)(50)	−20	60	30	20.0	18.4	17.7	17.4	17.2	16.8
13Cr	A 240	6	410	(35)	−20	65	30	20.0	18.4	17.7	17.4	17.2	16.8
15Cr	A 240	6	429										
17Cr	A 240	7	420	(35)	−20	65	30	20.0	18.4	17.7	17.4	17.2	16.8
18Cr-13Ni-3Mo	A 240	8	317L	(36)	−325	75	30	20.0	*20.0*	*20.0*	18.9	17.7	16.8
25Cr-20Ni	A 167	S-8	310	(28)(35)(36)(39)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
25Cr-20Ni	A 240	8	310S	(28)(35)(36)									
18Cr-10Ni-Ti	A 240	8	321	(30)(36)	−325	75	30	20.0	*20.0*	*20.0*	20.0	19.3	18.3
20Cr-10Ni	A 167	S-8	308	(6)(26)(31)(39)	−325	75	30	20.0	16.7	15.0	13.6	12.5	11.6
23Cr-12Ni	A 167	S-8	309	(12)(28)(31)(35)(36)(39)									
23Cr-12Ni	A 240	8	309S	(28)(35)(36)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
18Cr-10Ni-Cb	A 240	8	347	(36)	−425	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-10Ni-Cb	A 240	8	348	(36)	−325								
25Cr-20Ni	A 167	S-8	310	(28)(29)(35)(36)(39)									
25Cr-20Ni	A 240	8	310S	(28)(29)(35)(36)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
18Cr-10Ni-Ti	A 240	8	321	(28)(30)(36)									
18Cr-10Ni-Ti	A 240	8	321H	(36)	−325	75	30	20.0	*20.0*	*20.0*	20.0	19.3	18.3
16Cr-12Ni-2Mo	A 240	8	316	(26)(28)(36)	−425								
18Cr-13Ni-3Mo	A 240	8	317	(26)(28)(36)	−325	75	30	20.0	*20.0*	*20.0*	19.3	17.9	17.0
18Cr-10Ni-Cb	A 167	8	347	(28)(30)(36)									
18Cr-10Ni-Cb	A 240	8	347	(28)(36)	−425								
18Cr-10Ni-Cb	A 167	8	348	(28)(30)(36)		75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-10Ni-Cb	A 240	8	348	(28)(36)	−325								
18Cr-8Ni	A 240	8	304	(26)(28)(36)	−426	75	30	20.0	*20.0*	*20.0*	18.7	17.5	16.4
25Cr-8Ni-3Mo-W-Cu-N	A 240	S-10H	S32760	(25)	−60	109	80	36.3	35.9	34.4	34.0	34.0	34.0

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																			
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Grade	Spec. No.
																		Stainless Steel (3) (4) (Cont'd) Plates and Sheets (Cont'd)	
16.5	16.2	15.7	15.1	10.4	9.6	8.4	6.4	4.4	2.9	1.7	1.0	...	...	...	...	...	...	410S	A 240
16.5	16.2	15.7	15.1	11.2	10.4	8.8	6.4	4.4	2.9	1.7	1.0	...	...	...	...	...	...	410	A 240
16.5	16.2	15.7	15.1	11.2	10.4	9.2	9.5	4.5	3.2	2.4	1.7	...	...	...	...	...	...	429	A 240
																		430	A 240
16.6	16.2	15.8	15.5	15.2	...	...	...	...	...	...	...	...	...	...	...	...	...	317L	A 240
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	11.0	7.1	5.0	3.6	2.5	1.5	0.8	0.5	0.4	0.3	0.2	310	A 167
																		310S	A 240
17.9	17.5	17.2	16.9	16.7	16.6	16.4	*16.2*	9.6	6.9	5.0	3.6	2.6	1.7	1.1	0.8	0.5	0.3	321	A 240
11.2	10.8	10.4	10.0	9.7	9.4	9.1	8.8	8.5	7.5	5.7	4.5	3.2	2.4	1.8	1.4	1.0	0.7	308	A 167
																		309	A 167
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	10.5	8.5	6.5	5.0	3.8	2.9	2.3	1.8	1.3	0.9	0.7	309S	A 240
19.0	18.6	18.5	18.4	*18.2*	*18.1*	*18.1*	*13.0*	*12.1*	9.1	6.1	4.4	3.3	2.2	1.5	1.2	0.9	0.8	347	A 240
																		348	A 240
																		310	A 167
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	11.0	9.8	8.5	7.3	6.0	4.8	3.5	2.3	1.6	1.1	0.8	310S	A 240
17.9	17.5	17.2	16.9	16.7	16.6	16.4	*16.2*	*11.7*	9.1	6.9	5.4	4.1	3.2	2.5	1.9	1.5	1.1	321	A 240
																		321H	A 240
16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	*14.5*	*12.4*	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	316	A 240
																		317	A 240
19.0	18.6	18.5	18.4	18.2	18.1	18.1	18.0	17.1	14.2	10.5	7.9	5.9	4.9	3.2	2.5	1.8	1.3	347	A 167
																		347	A 240
																		348	A 167
																		348	A 240
16.2	16.0	15.6	15.2	14.9	14.6	14.4	*13.8*	*12.2*	9.7	7.7	6.0	4.7	3.7	2.9	2.3	1.8	1.4	304	A 240
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S32760	A 240

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200	300	400	500	600
						Tensile	Yield						
Stainless Steel (3) (4) (Cont'd) Forgings and Fittings (2)													
18Cr-13Ni-3Mo ≤ 5 in. thk.	A 182	8	F317L	(9)(21a)	−325	70	25	16.7	*16.7*	16.0	15.6	14.8	14.0
18Cr-8Ni	A 182	8	F304L	(9)(21a)	−425	70	25	16.7	*16.7*	*16.7*	15.8	14.8	14.0
18Cr-8Ni	A 403	8	WP304L	(32)(37)	−425								
16Cr-12Ni-2Mo	A 182	8	F316L	(9)(21a)	−425	70	25	16.7	*16.7*	*16.7*	15.5	14.4	13.5
16Cr-12Ni-2Mo	A 403	8	WP316L	(32)(37)	−425								
20Ni-8Cr	A 182	8	F10	(26)(28)(39)	−325	80	30	20.0	...	...	...	...	...
18Cr-13Ni-3Mo	A 403	8	WP317L	(32)(37)	−325	75	30	20.0	*20.0*	*20.0*	18.9	17.7	16.8
25Cr-20Ni	A 182	8	F310	(9)(21)(28)(35)(39)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
25Cr-20Ni	A 403	8	WP310	(28)(32)(35)(37)(39)	−325								
18Cr-10Ni-Ti	A 182	8	F321	(9)(21)	−325	75	30	20.0	*20.0*	*20.0*	20.0	19.3	18.3
18Cr-10Ni-Ti	A 403	8	WP321	(32)(37)	−325								
23Cr-12Ni	A 403	8	WP309	(28)(32)(35)(37)(39)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
25Cr-20Ni	A 182	8	F310	(9)(21)(28)(29)(35)(39)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
25Cr-20Ni	A 403	8	WP310	(28)(29)(32)(35)(37)(39)	−325								
18Cr-10Ni-Cb	A 182	8	F347	(9)(21)	−425	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-10Ni-Cb	A 403	8	WP347	(32)(37)	−425								
18Cr-10Ni-Cb	A 182	8	F348	(9)(21)	−325								
18Cr-10Ni-Cb	A 403	8	WP348	(32)(37)	−325								
18Cr-10Ni-Ti	A 182	8	F321	(9)(21)(28)(30)	−325	75	30	20.0	*20.0*	*20.0*	20.0	19.3	18.3
18Cr-10Ni-Ti	A 182	8	F321H	(9)(21)									
18Cr-10Ni-Ti	A 403	8	WP321	(28)(30)(32)(37)									
18Cr-10Ni-Ti	A 403	8	WP321H	(32)(37)	−325								
16Cr-12Ni-2Mo	A 403	8	WP316H	(26)(32)(37)	−325	75	30	20.0	*20.0*	*20.0*	19.3	17.9	17.0
16Cr-12Ni-2Mo	A 182	8	F316	(9)(21)(26)	−325	75	30	20.0	*20.0*	*20.0*	19.3	17.9	17.0
18Cr-10Ni-Cb	A 403	8	WP347H	(32)(37)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	19.3
18Cr-10Ni-Cb	A 182	8	F347	(9)(21)(28)	−425								
18Cr-10Ni-Cb	A 403	8	WP347	(28)(32)(37)	−425								
18Cr-10Ni-Cb	A 182	8	F348	(9)(21)(28)	−325								
18Cr-10Ni-Cb	A 403	8	WP348	(28)(32)(37)	−325								
18Cr-10Ni-Cb	A 182	8	F347H	(9)(21)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*19.9*	*19.3*
18Cr-10Ni-Cb	A 182	8	F348H										

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																			
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Grade	Spec. No.
																		Stainless Steel (3) (4) (Cont'd) Forgings and Fittings (2)	
13.8	13.5	13.2	13.0	12.7	...	...	...	...	...	...	...	...	...	...	...	...	...	F317L	A 182
13.7	13.5	13.3	13.0	12.8	*11.9*	*9.9*	7.8	6.3	5.1	4.0	3.2	2.6	2.1	1.7	1.1	1.0	0.9	F304L	A 182
																		WP304L	A 403
13.2	12.9	12.6	12.4	12.1	11.8	11.5	11.2	10.8	*10.2*	*8.8*	6.4	4.7	3.5	2.5	1.8	1.3	1.0	F316L	A 182
																		WP316L	A 403
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	F10	A 182
16.6	16.2	15.8	15.5	15.2	...	...	...	...	...	...	...	...	...	...	...	...	...	WP317L	A 403
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	11.0	7.1	5.0	3.6	2.5	1.5	0.8	0.5	0.4	0.3	0.2	F310	A 182
																		WP310	A 403
17.9	17.5	17.2	16.9	16.7	16.6	16.4	*16.2*	9.6	6.9	5.0	3.6	2.6	1.7	1.1	0.8	0.5	0.3	F321	A 182
																		WP321	A 403
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	10.5	8.5	6.5	5.0	3.8	2.9	2.3	1.7	1.3	0.9	0.7	WP309	A 403
18.8	18.3	18.0	17.5	*14.6*	*13.9*	*12.5*	11.0	9.8	8.7	7.3	6.0	4.8	3.5	2.3	1.6	1.1	0.8	F310	A 182
																		WP310	A 403
19.0	18.6	18.5	18.4	*18.2*	*18.1*	*18.1*	*18.0*	*12.1*	9.1	6.1	4.4	3.3	2.2	1.5	1.2	0.9	0.8	F347	A 182
																		WP347	A 403
																		F348	A 182
																		WP348	A 403
17.9	17.5	17.2	16.9	16.7	16.6	16.4	*16.2*	*11.7*	9.1	6.9	5.4	4.1	3.2	2.5	1.9	1.5	1.1	F321	A 182
																		F321H	A 182
																		WP321	A 403
																		WP321H	A 403
16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	*14.5*	*12.4*	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	WP316H	A 403
16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	*14.5*	*12.4*	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	F316	A 182
19.0	18.6	18.5	18.4	18.2	18.1	18.1	18.0	*17.1*	14.2	10.5	7.9	5.9	4.4	3.2	2.5	1.8	1.3	WP347H	A 403
																		F347	A 182
																		WP347	A 403
																		F348	A 182
																		WP348	A 403
19.0	18.6	18.5	18.4	18.2	18.1	18.1	18.0	*17.1*	*14.2*	10.5	7.9	5.9	4.4	3.2	2.5	1.8	1.3	F347H	A 182
																		F348H	A 182

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.					
						Tensile	Yield	to 100	200	300	400	500	600
Stainless Steel (3) (4) (Cont'd)													
Forgings and Fittings (2) (Cont'd)													
16Cr-12Ni-2Mo	A 182	8	F316	(9)(21)(26)(28)	−325	75	30	20.0	*20.0*	*20.0*	19.3	17.9	17.0
16Cr-12Ni-2Mo	A 403	8	WP316	(26)(28)(32)(37)	−425								
18Cr-13Ni-3Mo	A 403	8	WP317	(26)(28)(32)	−325								
18Cr-8Ni	A 182	8	F304	(9)(21)(26)(28)	−425	75	30	20.0	*20.0*	*20.0*	18.7	17.5	16.4
18Cr-8Ni	A 403	8	WP304	(26)(28)(32)(37)	−425								
18Cr-8Ni	A 403	8	WP304H	(26)(32)(37)	−325	75	30	20.0	*20.0*	*20.0*	18.7	17.5	16.4
18Cr-8Ni	A 182	8	F304H	(9)(21)(26)	−325								
13Cr	A 182	6	F6a Cl. 1	(35)	−20	70	40	23.3	23.3	22.6	22.4	22.0	21.5
13Cr	A 182	6	F6a Cl. 2	(35)	−20	85	55	28.3	28.3	27.8	27.2	26.8	26.1
25Cr-8Ni-3Mo-W-Cu-N	A 182	S-10H	S32760	(25)	−60	109	80	36.3	35.9	34.4	34.0	34.0	34.0
25Cr-8Ni-3Mo-W-Cu-N	A 815												
13Cr	A 182	S-6	F6a Cl.3	(35)	−20	110	85	36.6	...	...	...	...	...
13Cr-½Mo	A 182	6	F6b	(35)	...	110–135	90	36.6	...	...	...	...	...
13Cr	A 182	S-6	F6a Cl. 4	(35)	−20	130	110	43.3	...	...	...	...	...
Bar													
18Cr-8Ni	A 479	8	304	(26)(28)(31)	−425	75	30	20.0	20.0	20.0	18.7	17.5	16.4
Castings (2)													
28Ni-20Cr-2Mo-3Cb	A 351	45	CN7M	(9)(30)	−325	62	25	16.6	...	...	...	...	...
35Ni-15Cr-Mo	A 351	S-45	HT30	(36)(39)	−325	65	28	18.6	...	...	...	...	...
25Cr-13Ni	A 351	8	CH8	(9)(31)	−325	65	28	18.6	*18.6*	*18.6*	*18.6*	*18.6*	18.0
25Cr-20Ni	A 351	8	CK20	(9)(27)(31)(35)(39)	−325	65	28	18.6	*18.6*	*18.6*	*18.6*	*18.6*	18.0
15Cr-15Ni-2Mo-Cb	A 351	S-8	CF10MC	(30)	−325	70	30	20.0	...	...	...	...	...
18Cr-8Ni	A 351	8	CF3	(9)	−425	70	30	20.0	*20.0*	19.7	17.6	16.4	15.6
17Cr-10Ni-2Mo	A 351	8	CF3M	(9)	−425	70	30	20.0	18.0	17.4	16.6	16.0	15.4
18Cr-8Ni	A 351	8	CF8	(9)(26)(27)(31)	−425	70	30	20.0	*20.0*	20.0	18.7	17.4	16.4
25Cr-13Ni	A 351	S-8	CH10	(27)(31)(35)									
25Cr-13Ni	A 351	8	CH20	(9)(27)(31)(35)(39)	−325	70	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.2
20Cr-10Ni-Cb	A 351	8	CF8C	(9)(27)(30)	−325	70	30	20.0	*20.0*	*20.0*	*19.3*	18.6	18.5
18Cr-10Ni-2Mo	A 351	8	CF8M	(9)(26)(27)(30)	−425	70	30	20.0	*20.0*	*20.0*	19.4	18.1	17.1
25Cr-20Ni	A 351	S-8	HK40	(35)(36)(39)	−325	62	35	20.6	...	...	...	...	...
25Cr-20Ni	A 351	8	HK30	(35)(39)	−325	65	35	21.6	...	...	...	...	...
18Cr-8Ni	A 351	8	CF3A	(9)(56)									
18Cr-8Ni	A 351	8	CF8A	(9)(26)(56)	−425	77	35	23.3	23.3	22.6	21.8	20.5	19.3
25Cr-10Ni-N	A 351	8	CE20N	(35)(39)	−325	80	40	26.7	26.2	24.9	23.3	22.0	21.4
12Cr	A 217	6	CA15	(35)	−20	90	65	30.0	21.5	20.8	20.0	19.3	18.8
24Cr-10Ni-Mo-N	A 351	10H	CE8MN	(9)	−60	95	65	31.7	31.6	29.3	28.2	28.2	28.2
25Cr-8Ni-3Mo-W-Cu-N	A 351	S-20H	CD3M-W-Cu-N	(9)(25)	−60	100	65	33.3	33.3	31.9	31.9	31.1	31.1
13Cr-4Ni	A 487	6	CA6NM Cl.A	(9)(35)	−20	110	80	36.7	36.7	35.4	35.0	34.4	33.7

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																			
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Grade	Spec. No.
																		Stainless Steel (3) (4) (Cont'd) Forgings and Fittings (2) (Cont'd)	
16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	*14.5*	*12.4*	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	F316	A 182
																		WP316	A 403
																		WP317	A 403
16.2	16.0	15.6	15.2	14.9	14.6	14.4	13.8	*12.2*	9.7	7.7	6.0	4.7	3.7	2.9	2.3	1.8	1.4	F304	A 182
																		WP304	A 403
16.2	16.0	15.6	15.2	14.9	14.6	14.4	*13.8*	*12.2*	9.7	7.7	6.0	4.7	3.7	2.9	2.3	1.8	1.4	WP304H	A 403
																		F304H	A 182
21.1	20.6	19.9	19.1	11.2	10.4	8.8	6.4	...	...	...	...	...	...	...	...	...	...	F6a Cl. 1	A 182
25.7	25.0	24.4	23.2	14.4	12.3	8.8	6.4	4.4	2.9	1.8	1.0	...	...	...	...	...	...	F6a Cl. 2	A 182
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S32760	A 182
																		S32760	A 815
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	F6a Cl. 3	A 182
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	F6b	A 182
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	F6a Cl. 4	A 182
																			Bar
16.2	16.0	15.6	15.2	14.9	14.7	14.4	14.1	12.4	9.8	7.7	6.1	4.7	3.7	2.9	2.3	1.8	1.4	304	A 479
																			Castings (2)
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CN7M	A 351
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	HT30	A 351
18.0	17.1	16.7	16.4	*12.7*	*12.5*	*11.7*	10.5	8.5	6.5	5.5	3.7	2.9	2.0	1.7	1.2	0.9	0.7	CH8	A 351
17.5	17.1	16.7	16.4	*12.7*	*12.5*	*11.9*	11.0	9.7	8.5	7.2	6.0	4.7	3.5	2.4	1.6	1.1	0.7	CK20	A 351
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CF10MC	A 351
15.2	15.1	14.9	14.7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CF3	A 351
15.0	14.6	14.4	14.0	13.2	...	...	...	...	...	...	...	...	...	...	...	...	...	CF3M	A 351
16.1	15.9	15.5	15.1	*14.4*	*14.2*	*13.9*	*12.2*	9.5	7.5	6.0	4.8	3.9	3.3	2.7	2.3	2.0	1.7	CF8	A 351
18.7	18.2	18.0	17.5	*13.6*	*13.2*	*12.5*	10.5	8.5	8.5	5.0	3.7	2.9	2.0	1.7	1.2	0.9	0.7	CH10	A 351
																		CH20	A 351
18.4	18.2	18.2	18.2	*18.1*	*18.1*	*18.1*	*18.0*	*17.1*	*14.2*	10.5	7.9	5.4	4.4	3.2	2.5	1.8	1.3	CF8C	A 351
16.7	16.2	15.7	15.6	*14.7*	*14.5*	*14.0*	*13.1*	11.5	9.4	8.0	6.7	5.2	4.0	3.0	2.4	1.9	1.5	CF8M	A 351
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	HK40	A 351
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	HK30	A 351
18.9	17.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CF3A	A 351
																		CF8A	A 351
21.3	21.2	21.1	21.0	20.8	20.5	...	...	...	...	...	...	...	...	...	...	...	...	CE20N	A 351
18.4	18.1	17.5	16.8	14.9	11.0	7.6	5.0	3.3	2.3	1.5	1.0	...	...	...	...	...	...	CA15	A 217
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CE8MN	A 351
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CD3M-W-Cu-N	A 351
33.2	32.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CA6NM Cl.A	A 487

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)(46)	Class	Temper	Size Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.	
								Tensile	Yield	to 100	150
Cooper and Copper Alloy Pipes and Tubes (2)											
Cu pipe	B 42	31	C10200, C12000, C12200, C14200	061	...	...					
Cu tube	B 75	31	C10200, C12000, C12200, C14200	050, 060	...	...					
Cu tube	B 68										
Cu tube	B 88	S-31	C10200, C12000, C12200	050, 060	...	(24)	−452	30	9	6.0	5.1
Cu tube	B 280	S-31	C10200, C12000, C12200	060	...	(24)					
Red brass pipe	B 43	32	C23000	061	...	...	−452	40	12	8.0	8.0
90Cu-10Ni	B 467	34	C70600	W050, W061	> 4.5 O.D.						
90Cu-10Ni	B 466	34	C70600	Annealed	...	(14)	−452	38	13	8.7	8.4
90Cu-10Ni	B 467	34	C70600	W050, W061	≤ 4.5 O.D.	(14)	−452	40	15	10.0	9.7
70Cu-30Ni	B 467	34	C71500	W050, W061	> 4.5 O.D.	(14)	−452	45	15	10.0	9.6
80Cu-20Ni	B 466	34	C71000	Annealed	≤ 4.5 O.D.	(14)	−452	45	16	10.7	10.6
Cu pipe	B 42	31	C10200, C12000, C12200	H55	NPS 2 ½ thru 12						
Cu tube	B 75	31	C10200, C12000, C12200, C14200	H58	...	(14)(34)	−452	36	30	12.0	12.0
Cu tube	B 88	S-31	C10200, C12000, C12200	H	...	(14)(24) (34)					
70Cu-30Ni	B 466	34	C71500	Annealed	...	(14)	− 452	50	18	12.0	11.6
70Cu-30Ni	B 467	34	C71500	W050, W061	≤ 4.5 O.D.	(14)	−452	50	20	13.3	12.7
Cu pipe	B 42	31	C10200, C12000, C12200	H80	NPS ⅛ thru 2						
Cu tube	B 75	31	C10200, C12000, C12200, C14200	H80	...	(14)(34)	−452	45	40	15.0	15.0
Plates and Sheets											
Cu	B 152	31	C10200, C10400, C10500, C10700 C12200, C12300	025	...	(14)(24)	−452	30	10	6.7	5.8
90Cu-10Ni	B 171	34	C70600	...	≤ 2.5 thk.	(14)	−452	40	15	10.0	9.7
Cu-Si	B 96	33	C65500	061	...	...	−452	50	18	12.0	12.0
70Cu-30Ni	B 171	34	C71500	...	≤ 2.5 thk.	(14)	−452	50	20	13.3	12.7
Al-bronze	B 169	35	C61400	025, 060	≤ 2.0 thk.	(13)	−452	70	30	20.0	20.0

Symbols in Temper Column

025 = hot-rolled, annealed
050 = light annealed
060 = soft annealed
061 = annealed
W050 = welded, annealed
W061 = welded, fully finished, annealed
H = drawn
H55 = light drawn
H58 = drawn, general purpose
H80 = hard drawn

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)												
200	250	300	350	400	450	500	550	600	650	700	Class	Spec. No.
											Copper and Copper Alloy Pipes and Tubes (2)	
4.8	4.8	4.7	4.0	3.0	1.5	0.8	...	...	...	...	C10200, C12000, C12200, C14200	B 42
											C10200, C12000, C12200, C14200	B 75
											C10200, C12000, C12200	B 68
											C10200, C12000, C12200	B 88
											C10200, C12000, C12200	B 280
8.0	8.0	8.0	7.0	5.0	2.0	...	...	...	...	...	C23000	B 43
											C70600	B 467
8.3	8.0	7.8	7.7	7.6	7.5	7.3	7.0	6.0	...	...	C70600	B 466
9.5	9.3	9.0	8.7	8.7	8.6	8.0	7.0	6.0	...	...	C70600	B 467
9.5	9.2	9.1	8.8	8.6	8.4	8.2	8.1	8.0	7.9	7.8	C71500	B 467
10.5	10.4	10.3	10.1	9.9	9.6	9.3	8.9	8.4	7.7	7.0	C71000	B 466
											C10200, C12000, C12200	B 42
12.0	12.0	11.6	11.4	10.5	...	...	...	...	...	...	C10200, C12000, C12200, C14200	B 75
											C10200, C12000, C12200	B 88
11.3	11.0	10.8	10.6	10.3	10.1	9.9	9.8	9.6	9.5	9.4	C71500	B 466
12.3	12.1	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	10.4	C71500	B 467
											C10200, C12000, C12200	B 42
15.0	15.0	14.7	13.7	4.3	...	...	...	...	...	...	C10200, C12000, C12200, C14200	B 75
											Plates and Sheets	
5.5	5.2	5.1	4.0	3.0	1.5	0.8	...	...	...	...	C10200, C10400, C10500, C10700, C12200, C12300	B 152
9.5	9.3	9.0	8.7	8.7	8.6	8.0	7.0	6.0	...	...	C70600	B 171
11.9	11.7	10.0	5.0	...	...	...	...	...	...	...	C65500	B 96
12.3	12.1	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	10.4	C71500	B 171
19.9	19.8	19.6	19.4	19.2	19.1	19.0	...	...	...	...	C61400	B 169

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)(46)	Class	Temper	Size Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.	
								Tensile	Yield	to 100	150
Copper and Copper Alloy (Cont'd)											
Forgings											
Cu	B 283	S-31	C11000	...	...	(14)	−452	33	11	7.3	6.7
High Si bronze (A)	B 283	S-33	C65500	...	...	(14)	−452	52	18	12.0	10.0
Forging brass	B 283	a	C37700	...	...	(14)	−325	58	23	15.3	12.5
Leaded naval brass	B 283	a	C48500	...	...	(14)	−325	62	24	16.0	15.2
Naval brass	B 283	S-32	C46400	...	...	(14)	−425	64	26	17.3	15.8
Mn-bronze (A)	B 283	S-32	C67500	...	...	(14)	−325	72	34	22.7	12.9
Al-Si-bronze	B 283	35	C63900	...	...	(14)	−325	83	41	27.3	17.5
Castings(2)											
Composition bronze	B 62	a	C83600	...	...	(9)	−325	30	14	9.4	9.4
Leaded Ni-bronze	B 584	a	C97300	...	...	...	−325	30	15	10.0	...
Leaded Ni-bronze	B 584	a	C97600	...	...	...	−325	40	17	10.0	7.5
Leaded Sn-bronze	B 584	a	C92300	...	...	...	−325	36	16	10.6	9.0
Leaded Sn-bronze	B 584	a	C92200	...	...	...	−325	34	16	10.6	10.6
Steam bronze	B 61	a	C92200	...	...	(9)	−325	34	16	10.6	10.6
Sn-bronze	B 584	b	C90300	...	...	...	−325	40	18	12.0	10.0
Sn-bronze	B 584	b	C90500	...	...	...	−325	40	18	12.0	12.0
Leaded Mn-bronze	B 584	a	C86400	...	...	(9)	−325	60	20	13.3	12.8
Leaded Ni-bronze	B 584	a	C97800	...	...	...	−325	50	22	14.6	10.4
No. 1 Mn-bronze	B 584	b	C86500	...	...	...	−325	65	25	16.6	14.8
Al-bronze	B 148	S-35	C95200	...	...	(9)					
Al-bronze	B 148	S-35	C95300	...	...	...	−425	65	25	16.3	15.7
Si-Al-bronze	B 148	S-35	C95600	...	...	...	−325	60	28	18.8	...
Al-bronze	B 148	S-35	C95400	...	...	...	−325	75	30	20.0	18.8
Mn-bronze	B 584	a	C86700	...	...	...	−325	80	32	21.3	17.5
Al-bronze	B 148	S-35	C95500	...	...	...	−452	90	40	26.6	22.5
High strength Mn-bronze	B 584	b	C86200	...	...	...	−325	90	45	30.0	19.5
High strength Mn-bronze	B 584	b	C86300	...	...	...	−325	110	60	36.6	23.3

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)												
200	250	300	350	400	450	500	550	600	650	700	Class	Spec. No.
												Copper and Copper Alloy (Cont'd) Forgings
6.5	6.3	5.0	3.8	2.5	1.5	0.8	...	...	...	...	C11000	B 283
10.0	10.0	10.0	5.0	2.0	...	...	...	...	...	...	C65500	B 283
12.0	11.2	10.5	7.5	2.0	...	...	...	...	...	...	C37700	B 283
15.0	14.1	13.0	8.5	2.0	...	...	...	...	...	...	C48500	B 283
15.3	14.2	13.0	9.0	2.0	...	...	...	...	...	...	C46400	B 283
12.0	11.2	10.5	7.5	2.0	...	...	...	...	...	...	C67500	B 283
17.3	17.1	17.1	17.0	16.8	...	...	...	...	...	...	C63900	B 283
												Castings (2)
9.4	9.4	9.1	8.9	8.6	8.5	...	...	...	...	...	C83600	B 62
...	...	...	...	...	...	...	...	...	...	...	C97300	B 584
7.3	6.9	6.3	...	...	...	...	...	...	...	...	C97600	B 584
9.0	9.0	8.5	8.0	7.0	...	...	...	...	...	...	C92300	B 584
10.6	10.6	10.6	10.6	10.3	...	...	...	...	...	...	C92200	B 584
10.6	10.6	10.6	10.6	10.3	9.6	9.0	6.3	...	...	...	C92200	B 61
9.5	9.3	8.5	8.0	7.0	...	...	...	...	...	...	C90300	B 584
12.0	12.0	12.0	11.9	11.0	...	...	...	...	...	...	C90500	B 584
12.0	11.3	10.5	7.5	...	...	...	...	...	...	...	C86400	B 584
9.4	8.5	7.5	7.0	...	...	...	...	...	...	...	C97800	B 584
13.4	12.0	10.5	7.5	...	...	...	...	...	...	...	C86500	B 584
											C95200	B 148
15.2	14.7	14.5	14.2	14.2	14.2	14.2	11.7	7.4	...	...	C95300	B 148
...	...	...	...	...	...	...	...	...	...	...	C95600	B 148
18.0	17.3	16.3	15.6	14.8	12.9	11.0	...	...	...	...	C95400	B 148
15.3	12.9	10.5	7.5	...	...		...	...	...	...	C86700	B 584
21.0	19.5	18.0	16.5	15.0	13.5	12.0	...	...	...	...	C95500	B 148
17.3	16.5	10.5	7.5	...	...	...	...	...	...	...	C86200	B 584
19.0	14.8	10.5	7.5	...	...	...	...	...	...	...	C86300	B 584

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	UNS No.	Class	Size Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200	300	400	500	600	650	700	750
								Tensile	Yield									
Nickel and Nickel Alloy (4) Pipes and Tubes (2)																		
Low C Ni	B 161	41																
Low C Ni	B 725	S41	N02201	Annealed	> 5 O.D.	...	−325	50	10	6.7	6.4	6.3	6.2	6.2	6.2	6.2	6.2	6.1
Ni	B 161	41																
Ni	B 725	S41	N02200	Annealed	> 5 O.D.	...	−325	55	12	8.0	8.0	8.0	8.0	8.0	8.0	...	...	...
Low C Ni	B 161	41																
Low C Ni	B 725	S41	N02201	Annealed	≤ 5 O.D.	...	−325	50	12	8.0	7.7	7.5	7.5	7.5	7.5	7.5	7.4	7.3
Ni	B 161	41																
Ni	B 725	S41	N02200	Annealed	≤ 5 O.D.	...	−325	55	15	10.0	10.0	10.0	10.0	10.0	10.0	...	...	...
Ni-Cu	B 165	42																
Ni-Cu	B 725	S42	N04400	Annealed	> 5 O.D.	...	−325	70	25	16.7	14.7	13.7	13.2	13.2	13.2	13.2	13.2	13.0
Ni-Fe-Cr	B 407	45	N08800	H.F. or H.F. ann.	...	(76)	−325	65	25	16.7	*16.7*	*16.7*	*15.8*	*14.9*	*14.6*	*14.4*	*14.3*	*14.2*
Ni-Cr-Fe	B 167	43	N06600	H.F. or H.F. ann.	> 5 O.D.	...	−325	75	25	16.7	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*
Ni-Fe-Cr	B 407	45	N08810	C.D. sol. ann. or H.F. ann.	...	(62)(76)												
Ni-Fe-Cr	B 514	45	N08810	Annealed	...	(62)(76)	−325	65	25	16.7	16.7	16.7	16.7	16.7	16.5	16.0	15.7	15.4
Ni-Fe-Cr	B 407	45	N08811	C.D. sol. ann. or H.F. ann.	...	(62)(76)	−325	65	25	16.7	16.7	16.7	16.7	16.7	16.5	16.0	15.7	15.4
Ni-Cu	B 165	42																
Ni-Cu	B 725	S42	N04400	Annealed	≤ 5 O.D.	...	−325	70	28	18.7	16.4	15.4	14.8	14.8	14.8	14.8	14.8	14.6
Ni-Fe-Cr-Mo	B 619	45	N08320	Sol. ann.	...	(76)												
Ni-Fe-Cr-Mo	B 622	45	N08320	Sol. ann.	...	...	−325	75	28	18.7	*18.7*	*18.6*	*17.9*	*17.6*	*17.5*	*17.5*	*17.5*	*17.4*
Low C Ni	B 161	41																
Low C Ni	B 725	S41	N02201	Str. rel.	...	...	−325	60	30	20.0	15.0	15.0	14.8	14.7	14.2	...	...	...
Ni-Fe-Cr	B 514	45	N08800	Annealed	...	(76)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
Ni-Cr-Fe	B 167	43	N06600	H.F. or H.F. ann.	≤ 5 O.D.													
Ni-Cr-Fe	B 167	43	N06600	C.D. ann.	> 5 O.D.	...	−325	80	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
Ni-Fe-Cr	B 407	45	N08800	C.D. ann.	...	(61)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	20.0	20.0
Ni	B 161	41	N02200	Str. rel.	...	...	−325	65	40	21.6	16.3	16.3	16.3	16.0	15.4	...	...	...
Ni	B 725																	
Ci-Ni-Fe-Mo-Cu -Cb	B 464																	
Cr-Ni-Fe-Mo-Cu -Cb	B 729	45	N08020	Annealed	...	(76)	−325	80	35	23.3	*20.0*	*19.8*	*19.4*	*19.3*	*19.3*	19.2	19.2	19.2
Ni-Cr-Fe-Mo-Cu	B 619	45	N06007	Sol. ann.	...	(76)	−325	90	35	23.3	*23.3*	*23.3*	*23.3*	*23.3*	22.7	22.5	22.3	22.0
Ni-Cr-Fe-Mo-Cu	B 622	45	N06007	Sol. ann.	...	...	−325	90	35	23.3	*23.3*	*23.3*	*23.3*	*23.3*	22.7	22.5	22.3	22.0
Ni-Cr-Fe	B 167	43	N06600	C.D. ann.	≤ 5 O.D.	...												
Ni-Cr-Fe	B 517	43	N06600	C.D. ann.	...	(76)	−325	80	35	23.3	23.3	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*
Ni-Mo-Cr	B 619	44	N06455	Sol. ann.	...	(76)	−325	100	40	26.7	*24.9*	*24.9*	*24.9*	*24.7*	*24.4*	*24.2*	*24.0*	*23.8*

Abbreviations in Class Column:

ann	annealed	H.R.	hot rolled	sol.	solution
C.D.	cold worked	plt.	plate	str.	stress
forg.	forged	R.	rolled		
H.F.	hot worked	rel.	relieved		

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																		UNS No.	Spec. No.
800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650		
																		Nickel and Nickel Alloy (4) Pipes and Tubes (2)	
5.9	5.8	4.5	3.7	3.0	2.4	2.0	1.5	1.2	...	...	...	...	...	...	...	...	...	N02201	B 161 B 725
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 161 B 725
7.2	5.8	4.5	3.7	3.0	2.4	2.0	1.5	1.2	...	...	...	...	...	...	...	...	...	N02201	B 161 B 725
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 161 B 725
12.7	11.8	8.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	B 165 B 725
14.0	*13.2*	*13.1*	*12.9*	*12.8*	*12.7*	*12.7*	10.0	7.0	6.0	4.6	3.6	2.8	2.1	1.7	...	...	...	N08800	B 407
16.7	*16.5*	*15.9*	*15.9*	7.0	4.5	3.0	2.2	2.0	...	...	...	...	...	...	...	...	...	N06600	B 167
15.3	*15.1*	*14.8*	*14.6*	*14.4*	*13.7*	*11.6*	9.3	7.4	5.9	4.7	3.8	3.0	2.4	1.9	1.5	1.2	1.0	N08810	B 407 B 514
15.3	*15.1*	*14.8*	*14.6*	*14.4*	*13.7*	12.9	10.4	8.3	6.7	5.4	4.3	3.4	2.7	2.2	1.7	1.4	1.1	N08811	B 407
14.2	11.0	8.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	B 165 B 725
17.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08320	B 619 B 622
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02201	B 161 B 725
20.0	18.3	18.2	17.9	17.6	17.0	13.0	9.8	6.6	4.6	2.0	1.6	1.1	1.0	0.6	...	...	...	N08800	B 514
20.0	*19.6*	*16.0*	10.6	7.0	4.5	3.0	2.2	2.0	...	...	...	...	...	...	...	...	...	N06600	B 167 B 167
20.0	*18.3*	*18.2*	*17.9*	*17.6*	*17.0*	13.0	9.8	6.6	4.2	2.0	1.6	1.1	1.0	0.8	...	...	...	N08800	B 407
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 161 B 725
19.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08020	B 464 B 729
21.8	*20.2*	*20.0*	*19.5*	*18.9*	...	...	...	...	...	...	...	...	...	...	...	...	...	N06007	B 619
21.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06007	B 622
23.3	*20.0*	16.0	10.6	7.0	4.5	3.0	2.2	2.0	...	...	...	...	...	...	...	...	...	N06600	B 167 B 517
22.9	...	...	...	...	..	...	...	...	...	...	...	...	...	...	...	...	...	N06455	B 619

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	UNS No.	Class	Size Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi Tensile	Yield	Min. Temp. to 100	200	300	400	500	600	650	700
Nickel and Nickel Alloy (4) (Cont'd)																	
Pipes and Tubes (2) (Cont'd)																	
Ni-Cr-Mo-Fe	B 619	43	N06002	Sol. ann.	...	(76)											
Ni-Cr-Mo-Fe	B 622	43	N06002	Sol. ann.	...	...	−325	100	40	26.7	23.3	23.3	22.9	22.2	21.1	20.7	20.3
Low C Ni-Fe-Cr-Mo-Cu	B 619	45	N08031	Annealed	...	(76)											
Low C Ni-Fe-Cr-Mo-Cu	B 622	45	N08031	Annealed	...	...	−325	94	40	26.7	26.7	26.6	24.8	23.2	22.1	21.8	21.2
Ni-Mo-Cr	B 622	44	N06455	Sol. ann.	...	...	−325	100	40	26.8	26.7	26.7	26.7	26.7	26.7	26.7	26.5
Ni-Mo-Cr	B 619	44	N10276	Sol. ann.	...	(76)											
Ni-Mo-Cr	B 622	44	N10276	Sol. ann.	...	...	−325	100	41	27.3	27.3	27.3	27.3	26.9	25.4	24.7	24.0
Ni-Cu	B 165	42															
Ni-Cu	B 725	S42	N04400	Str. rel.	...	(54)	−325	85	55	28.3	21.2	21.2	21.0	21.0	...	...	...
Cr-Ni-Mo	B 675	45	N08367	Annealed	...	(76)											
Cr-Ni-Mo	B 804	45	N08367	Annealed	...	...	−325	95	45	30.0	30.0	30.0	28.6	27.5	26.3	25.5	25.1
Ni-Cr-Mo	B 619	44	N06022	Sol. ann.	...	(76)											
Ni-Cr-Mo	B 622	44	N06022	Sol. ann.	...	...	−325	100	45	30.0	30.0	30.0	30.0	28.6	27.1	26.5	25.9
Low C-Ni-Cr-Mo	B 619	44	N06059	Sol. ann.	...	(76)											
Low C-Ni-Cr-Mo	B 622	44	N06059	Sol. ann.	...	...	−325	100	45	30.0	30.0	30.0	30.0	29.6	28.1	27.5	26.7
Ni-Mo	B 619	44	N10001	Sol. ann.	...	...	−325	100	45	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Ni-Mo	B 622																
Cr-Ni-Mo	B 690	45	N08367	Annealed	...	...	−325	104	46	30.7	30.7	30.7	30.6	28.2	26.9	26.1	25.7
Ni-Mo	B 619	44	N10665	Sol. ann.	...	(76)											
Ni-Mo	B 622	44	N10665	Sol. ann.	...	...	−325	110	51	34.0	34.0	34.0	34.0	34.0	34.0	34.0	34.0
Ni-Cr-Mo-Cb	B 444	43	N06625	Annealed	...	(64) (70)	−325	120	60	40.0	40.0	40.0	40.0	38.9	38.0	37.7	37.4
Plates and Sheets																	
Low C Ni	B 162	41	N02201	H.R. plt. ann.	...	...	−325	50	12	8.0	7.7	7.5	7.5	7.5	7.5	7.5	7.4
Low C Ni	B 162	41	N02201	H.R. plt as R.													
Ni	B 162	41	N02200	H.R. plt. ann.	...	...	−325	55	15	10.0	10.0	10.0	10.0	10.0	10.0	...	...
Ni	B 162	41	N02200	H.R. plt. as R.	...	...	−325	55	20	13.3	13.3	13.3	13.3	12.5	11.5	...	..
Ni-Fe-Cr	B 409	45	N08810	Annealed	All	...	−325	65	25	16.7	16.7	16.7	16.7	16.7	16.7	16.0	15.7
Ni-Fe-Cr	B 409	45	N08811	Annealed	All	...	−325	65	25	16.7	16.7	16.7	16.7	16.7	16.7	16.0	15.7

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																				
750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	UNS No.	Spec. No.
																			Nickel and Nickel Alloy (4) (Cont'd) Pipes and Tubes (2) (Cont'd)	
20.1	*19.8*	*19.7*	*19.6*	*19.5*	*19.3*	*19.3*	*17.5*	14.1	11.3	9.3	7.7	6.1	4.8	3.8	3.0	...	...	...	N06002	B 619 B 622
20.9	20.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08031	B 619 B 622
26.1	25.8	..	..	..	..	..	..	...	...	...	...	...	...	...	...	...	...	...	N06455	B 622
23.5	23.0	*22.6*	*22.3*	*22.1*	*21.8*	*18.5*	*15.0*	*12.2*	*9.8*	*7.8*	...	...	...	...	...	...	...	...	N10276	B 619 B 622
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	B 165 B 725
24.7	24.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08367	B 675 B 804
25.5	25.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06022	B 619 B 622
26.1	25.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06059	B 619 B 622
30.0	29.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N10001	B 619 B 622
25.3	24.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08367	B 690
34.0	*34.0*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N10665	B 619 B 622
37.4	*37.4*	*37.4*	*37.4*	*37.4*	*37.4*	*37.4*	27.7	21.0	13.2	...	...	...	...	...	...	...	...	...	N06625	B 444
																			Plates and Sheets	
7.3	7.2	5.8	4.5	3.7	3.0	2.4	2.0	1.5	1.2	...	...	...	...	...	...	...	...	...	N02201	B 162 B 162
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 162
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 162
15.4	15.3	15.1	14.8	14.6	14.4	13.7	11.6	9.3	7.4	5.9	4.7	3.8	3.0	2.4	1.9	1.5	1.2	1.0	N08810	B 409
15.4	15.3	15.1	14.8	14.6	14.4	13.7	12.9	10.4	8.3	6.7	5.4	4.3	3.4	2.7	2.2	1.7	1.4	1.1	N08811	B 409

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	UNS No.	Class	Size Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.	Stress Values, ksi						
								Tensile	Yield	to 100	200	300	400	500	600	650	700
Nickel and Nickel Alloy (4) Cont'd																	
Plates and Sheets (Cont'd)																	
Ni-Fe-Cr-Mo	B 620	45	N08320	Sol. ann.	All	...	−325	75	28	18.7	*18.7*	*18.6*	*17.9*	*17.6*	*17.5*	*17.5*	*17.5*
Ni-Cu	B 127	42	N04400	H.R. plt. ann.	...	...	−325	70	28	18.7	16.4	*15.4*	14.8	14.8	14.8	14.8	14.8
Ni-Cr-Fe-Mo-Cu	B 582	45	N06007	Sol. ann.	> 3/4	...	−325	85	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.4	19.2	19.0
Ni-Fe-Cr	B 409	45	N08800	Annealed	All	...	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
Cr-Ni-Fe-Mo-Cu-Cb	B 463	45	N08020	Annealed	All	...	−325	80	35	23.3	*20.0*	*19.8*	*19.4*	*19.3*	*19.3*	*19.2*	*19.2*
Ni-Cr-Fe-Mo-Cu	B 582	45	N06007	Sol. ann.	−3/4	...	−325	90	35	23.3	*23.3*	*23.3*	*23.3*	*23.3*	*22.7*	*22.5*	*22.3*
Ni-Cr-Fe-Mo	B 435	43	N06002	H.R. Sol. ann.	All	...	−325	95	35	23.3	21.1	18.9	16.6	16.0	15.5	15.5	15.5
Ni-Cr-Fe	B 168	43	N06600	H.R. plt. ann.	...	...	−325	80	35	23.3	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*
Ni-Cr-Fe	B 168	43	N06600	H.R. plt. as R.	...	...	−325	85	35	23.3	*21.2*	*21.2*	*21.2*	*21.2*	*21.2*	*21.2*	*21.2*
Ni-Cu	B 127	42	N04400	H.R. plt. as R.	...	...	−325	75	40	25.0	23.5	21.9	21.2	21.2	21.2	21.2	21.2
Low C-Ni-Fe-Cr-Mo-Cu	B 625	...	N08031	Annealed	All	...	−325	94	40	26.7	*26.7*	26.6	24.8	23.2	22.1	21.8	21.2
Low C-Ni-Mo-Cr	B 575	44	N06455	Sol. ann.	All	...	−325	100	40	26.7	*26.7*	*26.7*	*26.7*	*26.7*	*26.7*	*26.7*	26.5
Low C-Ni-Mo-Cr	B 575	44	N10276	Sol. ann.	All	...	−325	100	41	27.3	*27.3*	*27.3*	*27.3*	26.9	25.4	24.7	24.0
Ni-Cr-Mo-Cb	B 443	43	N06625	Annealed Plt.	All	(64) (70)	−325	110	55	36.7	36.7	36.7	36.7	35.6	34.8	34.6	34.3
Ni-Cr-Mo-Cb	B 575	44	N06022	Sol ann. sheet	< 3/16	...	−325	100	45	30.0	*30.0*	*30.0*	*30.0*	28.6	27.1	26.5	25.9
Ni-Fe-Cr-Mo	B 688	45	N08367	Annealed	> 3/4	...	−325	95	45	30.0	*30.0*	*30.0*	28.6	27.5	26.3	25.5	25.1
Ni-Fe-Cr-Mo	B 688	45	N08367	Annealed	≥ 3/16, ≤ 3/4	...	−325	100	45	30.0	*30.0*	*30.0*	30.0	27.5	26.3	25.5	25.1
Low C-Ni-Cr-Mo	B 575	...	N06059	Sol. ann.	All	...	−325	100	45	30.0	*30.0*	*30.0*	*30.0*	29.6	28.1	27.5	26.7
Ni-Mo	B 333	44	N10001	Sol. ann. plt.	≥ 3/16, ≤ 2 1/2	...	−325	100	45	30.0	*30.0*	*30.0*	*30.0*	*30.0*	*30.0*	*30.0*	*30.0*
Ni-Fe-Cr-Mo	B 688	45	N08367	Annealed	< 3/16	...	−325	104	46	30.7	*30.7*	30.7	30.6	28.2	26.9	26.1	25.7
Ni-Mo	B 333	44	N10001	Sol. ann. sheet	< 3/16	...	−325	115	50	33.3	*33.3*	*33.3*	*33.3*	*33.3*	*33.3*	*33.3*	*33.3*
Ni-Mo	B 333	44	N10665	Sol. ann.	All	...	−325	110	51	34.0	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	34.0
Forgings and Fittings (2)																	
Low C-Ni	B 160	41	N02201	Annealed	All	(9) (9a)											
Low C-Ni	B 366	41	N02201	...	...												
Low C-Ni	B 366	41	N02201	...	...	(32) (74)	−325	50	10	6.7	6.4	6.3	6.2	6.2	6.2	6.2	6.2

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																				
750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	UNS No.	Spec. No.
																			Nickel and Nickel Alloy (4) (Cont'd) Plates and Sheets (Cont'd)	
17.4	17.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08320	B 620
14.6	14.2	11.0	8.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	B 127
18.8	18.6	*18.5*	*18.4*	*18.3*	*18.3*	...	...	...	...	...	...	...	...	...	...	...	...	...	N06007	B 582
20.0	*20.0*	18.3	18.2	17.9	17.6	17.0	13.0	9.8	6.6	4.2	2.0	1.6	1.1	1.0	0.8	...	...	...	N08800	B 409
19.2	19.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08020	B 463
22.0	*21.8*	*20.3*	*20.0*	*19.5*	*19.0*	...	...	...	...	...	...	...	...	...	...	...	...	...	N06007	B 582
15.5	15.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06002	B 435
23.3	*23.3*	*20.0*	16.0	10.6	7.0	4.5	3.0	2.2	2.0	...	...	...	...	...	...	...	...	...	N06600	B 168
21.2	*21.2*	*21.2*	*21.2*	*21.2*	14.5	10.3	7.2	5.8	5.5	...	...	...	...	...	...	...	...	...	N06600	B 168
20.9	20.3	8.2	4.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	B 127
20.9	20.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08031	B 625
26.1	25.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06455	B 575
23.5	23.0	*22.6*	*22.3*	*22.1*	*21.1*	*18.5*	*15.0*	*12.2*	*9.8*	*7.8*	...	...	...	...	...	...	...	...	N10276	B 575
34.3	34.3	34.3	34.3	34.3	34.3	34.3	25.4	21.0	13.2	...	...	...	...	...	...	...	...	...	N06625	B 443
25.5	25.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06022	B 575
24.7	24.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08367	B 688
24.7	24.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08367	B 688
26.1	25.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06059	B 575
30.0	29.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N10001	B 333
25.3	24.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08367	B 688
33.3	33.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N10001	B 333
34.0	34.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N10665	B 333
																			Forgings and Fittings (2)	
																			N02201	B 160
																			N02201	B 366
6.1	5.9	5.8	4.8	3.7	3.0	2.4	2.0	1.5	1.2	...	...	...	...	...	...	...	...	...	N02201	B 366

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	UNS No.	Class	Size Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.	Stress Values, ksi						
								Tensile	Yield	to 100	200	300	400	500	600	650	700
Nickel and Nickel Alloy (4) (Cont'd)																	
Forgings and Fittings (2) (Cont'd)																	
Ni	B 366	S-41															
Ni	B 564	S-41	N02200	...	...	(32)(74)	−325	55	12	8.0	8.0	8.0	8.0	8.0	...	...	
Ni	B 564	S-41	N02200	Annealed	All	(9)	−325	55	15	10.0	10.0	10.0	10.0	10.0	10.0	...	...
Ni-Fe-Cr	B 564	45	N08810														
Ni-Fe-Cr	B 564	S-45	N08814	Annealed	...	(9)	−325	65	25	16.2	16.2	16.2	16.2	16.0	16.0	16.0	15.7
Ni-Cu	B 564	42	N04400	Annealed	...	(9)											
Ni-Cu	B 366	42	N04400	...	...	(32)(74)	−325	70	25	16.7	14.7	13.7	13.2	13.2	13.2	13.2	13.2
Ni-Cr-Fe	B 366	S-43	N06600	...	...	(32)(74)	−325	75	25	16.7	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*
Ni-Fe-Cr	B 366	45	N08800	Annealed	...	...											
Ni-Fe-Cr	B 564	45	N08800	Annealed	...	(9)	−325	75	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*
Cr-Ni-Fe-Mo-Cu-Cb	B 366	45	N08020	Annealed	...	...											
Cr-Ni-Fe-Mo-Cu-Cb	B 462	45	N08020	Annealed	...	(9)	−325	80	35	23.3	*20.0*	*19.8*	*19.4*	19.3	*19.3*	*19.2*	19.2
Ni-Cr-Fe	B 564	43	N06600	Annealed	All	(9)	−325	80	35	23.3	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*
Ni-Cr-Mo-Fe	B 366	S-43	N06002	...	...	(32)(74)	−325	100	40	26.7	*23.3*	*23.3*	*22.9*	*22.3*	*21.1*	*20.7*	*20.3*
Low C-Ni-Fe-Cr-Mo-Cu	B 366																
Low C-Ni-Fe-Cr-Mo-Cu	B 564	S45	N08031	Annealed H.W.	All	...	−325	94	40	26.7	*26.7*	26.6	24.8	23.2	22.1	21.8	21.2
Ni-Mo-Cr	B 366	44	N10276	Sol. ann.	All	...											
Ni-Mo-Cr	B 564	44	N10276	Sol. ann.	All	(9)	−325	100	41	27.3	*27.3*	*27.3*	*27.3*	26.9	25.4	24.7	24.0
Ni-Mo	B 366	44	N10001	...	...	(32)(74)	−325	100	45	30.0	*25.0*	*25.0*	*24.7*	*24.3*	*24.2*	*24.1*	*24.0*
Ni-Mo-Cr	B 366	44	N06022	...	...	(32)(74)											
Ni-Cr-Mo	B 564	44	N06022	...	...	...	−325	100	45	30.0	*30.0*	*30.0*	*30.0*	28.6	27.1	26.5	25.9
Low C-Ni-Cr-Mo	B 366																
Low C-Ni-Cr-Mo	B 564	S44	N06059	H.W. Sol. ann.	All	...	−325	100	45	30.0	*30.0*	*30.0*	*30.0*	29.6	28.1	27.5	26.7
Ni-Cr-Mo-Cb	B 564	43	N06625	Annealed	≤ 4	(9)(64)	−325	120	60	40.0	*40.0*	*40.0*	*40.0*	38.3	38.0	37.7	37.4
Ni-Mo	B 366	44	N10665	Sol. ann.	All	...	−325	110	51	34.0	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*	*34.0*

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																				
750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	UNS No.	Spec. No.
																			Nickel and Nickel Alloy (4) (Cont'd) Forgings and Fittings (2) (Cont'd)	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 366
																			N02200	B 564
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 564
15.4	15.3	15.1	14.8	14.6	14.4	13.7	11.6	9.3	7.4	5.9	4.7	3.8	3.0	2.4	1.9	1.5	1.2	1.0	N08810	B 564
																			N08811	B 564
13.0	12.7	11.0	8.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	B 564
																				B 366
16.7	*16.7*	*16.5*	*15.9*	10.6	7.0	4.5	3.0	2.2	2.0	...	...	...	...	...	...	...	...	...	N06600	B 366
20.0	*20.0*	18.3	18.2	17.9	17.6	17.0	13.0	9.8	6.6	4.2	2.0	1.6	1.1	1.0	0.8	...	...	...	N08800	B 366
																				B 564
19.2	19.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08020	B 366
																			N08020	B 462
23.3	*23.3*	20.0	16.0	10.6	7.0	4.5	3.0	2.2	2.0	...	...	...	...	...	...	...	...	...	N06600	B 564
20.1	*19.8*	*19.7*	*19.6*	*19.5*	*19.3*	*18.4*	*17.5*	14.1	11.3	9.5	7.7	6.1	4.3	3.8	3.0	...	...	...	N06002	B 366
20.9	20.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08031	B 366
																				B 564
23.5	23.0	22.6	*22.3*	*22.1*	*21.8*	*18.5*	*15.0*	*12.2*	*9.8*	*7.8*	...	...	...	...	...	...	...	...	N10276	B 366
																				B 564
23.9	*23.8*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N10001	B 366
25.5	25.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06022	B 366
																				B 564
26.1	25.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06059	B 366
																				B 564
37.4	37.4	37.4	37.4	37.4	37.4	37.4	23.4	21.0	13.2	...	...	...	...	...	...	...	...	...	N06625	B 564
34.0	*34.0*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N10665	B 366

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	UNS No. or Grade	Class	Size Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.							
								Tensile	Yield	to 100	200	300	400	500	600	650	700
Nickel and Nickel Alloy (4) (Cont'd)																	
Rod and Bar																	
Ni	B 160	41	N02200	H.W.	All	(9)	−325	60	15	10.0	10.0	10.0	10.0	9.5	8.3	...	...
Ni	B 160	41	N02200	Annealed	All	(9)	−325	55	15	10.0	10.0	10.0	10.0	10.0	10.0	...	...
Ni-Cu	B 164	42	N04400	Ann. forg.	All	(13)	−325	70	25	16.7	14.7	13.7	13.2	13.2	13.2	13.2	13.2
Ni-Fe-Cr-Mo	B 621	45	N08320	Sol. ann.	All	...	−325	75	28	18.7	*18.7*	*18.6*	*17.9*	*17.6*	*17.5*	*17.5*	*17.5*
Ni-Cr-Fe-Mo-Cu	B 581	45	N06007	Sol. ann.	> 3/4	...	−325	85	30	20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.4	19.2	19.0
Ni-Cr-Fe-Mo-Cu	B 581	45	N06007	Sol. ann.	≤ 3/4	...	−325	90	35	23.3	*22.3*	*22.3*	*22.3*	*22.3*	22.7	22.5	*22.3*
Low C-Ni-Fe-Cr-Mo-Cu	B 649	S-45	N08031	Annealed	All	...	−325	94	40	26.7	*26.7*	*26.6*	*24.8*	23.2	22.1	21.8	21.2
Ni-Cu	B 164	42	N04400	H.W.	All except hex. > 2 1/8	...	−325	80	40	26.6	20.0	20.0	20.0	20.0	20.0	20.0	19.2
Ni-Mo-Cr	B 574	44	N06455	Sol. ann.	All	(9)	−325	100	40	26.7	*26.7*	*26.7*	*26.7*	*26.7*	*26.7*	*26.7*	*26.5*
Ni-Cr-Mo-Cb	B 446	43	N06625	Annealed	> 4 to 10	(9)(64) (70)	−325	110	50	33.3	*33.3*	*33.3*	*33.3*	32.4	31.7	31.4	31.2
					≤ 4	(9)(64) (70)	−325	120	60	40.0	*40.0*	*40.0*	*40.0*	38.3	38.0	37.7	37.4
Low C-Ni-Cr-Mo	B 574	S-44	N06059	Sol. ann.	All	...	−325	100	45	30.0	*30.0*	*30.0*	*30.0*	29.6	28.1	27.5	26.7
Castings (2)																	
Ni-Mo-Cr	A 494	...	CW-12MW	...		(9)(46)	−325	72	40	24.0	17.1	16.2	16.2	16.2	16.2	16.1	16.1
Ni-Mo-Cr	A 494	S-44	CW-6M	...	...	(9)											
Ni-Cr-Mo	A 494	S-44	CX-2MW	Sol. ann.	...	(9)	−325	80	45	26.7	25.9	25.3	24.9	23.6	...	...	...

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)																			UNS No. or Grade	Spec. No.
750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650		
																			Nickel and Nickel Alloy (4) (Cont'd) Rod and Bar	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 160
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 160
13.0	12.7	11.0	8.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	B 164
17.4	*17.2*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08320	B 621
18.8	18.6	18.5	18.4	18.3	18.3	...	...	...	...	...	...	...	...	...	...	...	...	...	N06007	B 581
22.0	*21.8*	*20.3*	*20.0*	*19.5*	*19.0*	...	...	...	...	...	...	...	...	...	...	...	...	...	N06007	B 581
20.9	20.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N08031	B 649
18.5	14.5	8.5	4.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	B 164
26.1	*25.8*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06455	B 574
31.2	31.2	31.2	31.2	31.2	31.2	31.2	23.1	23.1	21.0	13.2	...	...	...	...	...	...	...	...	N06625	B 446
37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	27.7	21.0	13.2	...	...	...	...	...	...	...	...		
26.1	25.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06059	B 574
																			Castings (2)	
15.7	15.2	14.8	14.4	14.1	13.8	...	...	...	...	...	...	...	...	...	...	...	...	...	CW-12MW	A 494
																			CW-6M	A 494
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CX-2MW	A 494

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Basic Allowable Stress *S*, ksi (1) at Metal Temperature, °F (7)		
						Tensile	Yield	Min. Temp. to 100	150	200
Titanium and Titanium Alloy Pipes and Tubes (2)										
Ti	B 337	51	1	(17)	−75	35	25	11.7	10.8	9.7
Ti	B 337	51	2	(17)	−75	50	40	16.7	16.7	16.7
Ti-0.2Pd	B 337	51	7	(17)	−75	50	40	16.7	16.7	16.7
Ti	B 337	52	3	(17)	−75	65	55	21.7	20.8	19.0
Plates and Sheets										
Ti	B 265	51	1	...	−75	35	25	11.6	10.8	9.7
Ti	B 265	51	2	...	−75	50	40	16.7	16.7	16.7
Ti	B 265	52	3	...	−75	65	55	21.7	20.8	19.0
Forgings										
Ti	B 381	51	F1	...	−75	35	25	11.7	10.8	9.7
Ti	B 381	51	F2	...	−75	50	40	16.7	16.7	16.7
Ti	B 381	52	F3	...	−75	65	55	21.7	20.8	19.0
Zirconium and Zirconium Alloy Pipes and Tubes (2)										
Zr	B 523	61	R60702	...	−75	55	30	17.3	16.0	14.7
Zr	B 658	61	R60702	...	−75	55	30	17.3	16.0	14.7
Zr + Cb	B 523	62	R60705	(73)	−75	80	55	26.7	24.6	22.1
Zr + Cb	B 658	62	R60705	(73)	−75	80	55	26.7	24.6	22.1
Plates and Sheets										
Zr	B 551	61	R60702	...	−75	55	30	17.3	16.0	14.7
Zr + Cb	B 551	62	R60705	(73)	−75	80	55	26.7	24.6	22.1
Forgings and Bar										
Zr	B 493	61	R60702	...	−75	55	30	17.3	16.0	14.7
Zr	B 550	61	R60702	...	−75	55	30	17.3	16.0	14.7
Zr + Cb	B 493	62	R60705	(73)	−75	70	55	23.3	...	...
Zr + Cb	B 550	62	R60705	(73)	−75	80	55	26.7	24.6	22.1

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

(99)

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)											
250	300	350	400	450	500	550	600	650	700	Grade	Spec. No.
										Titanium and Titanium Alloy Pipes and Tubes (2)	
8.6	7.7	6.9	6.4	6.0	5.3	4.7	4.2	...	...	1	B 337
13.7	12.3	10.9	9.8	8.8	8.0	7.5	7.3	...	...	2	B 337
										7	B 337
17.3	15.6	13.9	12.3	11.1	9.9	8.9	8.0	...	...	3	B 337
										Plates and Sheets	
8.6	7.7	6.9	6.4	6.0	5.3	4.7	4.2	...	...	1	B 265
13.7	12.3	10.9	9.8	8.8	8.0	7.5	7.3	...	...	2	B 265
17.3	15.6	13.9	12.3	11.1	9.9	8.9	8.0	...	...	3	B 265
										Forgings	
8.6	7.7	6.9	6.4	6.0	5.3	4.7	4.2	...	...	F1	B 381
13.7	12.3	10.9	9.8	8.8	8.0	7.5	7.3	...	...	F2	B 381
17.3	15.6	13.9	12.3	11.1	9.9	8.9	8.0	...	...	F3	B 381
										Zirconium and Zirconium Alloy Pipes and Tubes (2)	
13.5	12.4	11.5	9.3	8.9	8.1	8.0	7.9	7.2	6.4	R60702	B 523, B 658
20.5	18.6	17.7	16.7	16.2	15.6	14.8	13.9	13.6	13.2	R60705	B 523, B 658
										Plates and Sheets	
13.5	12.4	11.5	9.3	8.9	8.1	8.0	7.9	7.2	6.4	R60702	B 551
20.5	18.6	17.7	16.7	16.2	15.6	14.8	13.9	13.6	13.2	R60705	B 551
										Forgings and Bar	
13.5	12.4	11.5	9.3	8.9	8.1	8.0	7.9	7.2	6.4	R60702	B 493, B 550
...	...	...	...	...	...	...	...	...	...	R60705	B 493
20.5	18.6	17.7	16.7	16.2	15.6	14.8	13.9	13.6	13.3	R60705	B 550

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Spec. No.	P-No. or S-No. (5)	Grade	Temper	Size or Thickness Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Basic Allowable Stress S, ksi (1), at Metal Temperature, °F (7)						
							Tensile	Yield	Min. Temp. to 100	150	200	250	300	350	400
Aluminum Alloy															
Seamless Pipes and Tubes															
B 210, B 241	21	1060	0, H112,	...	(14)(33)	−452	8.5	2.5	1.7	1.7	1.6	1.5	1.3	1.1	0.8
B 345	S-21		H113												
B 210	21	1060	H14	...	(14)(33)	−452	12	10	4.0	4.0	4.0	3.0	2.6	1.8	1.1
B 241	21	1100	0, H112	...	(14)(33)	−452	11	3	2.0	2.0	2.0	1.9	1.7	1.3	1.0
B 210	21	1100	H113	...	(14)(33)	−452	11	3.5	2.3	2.3	2.3	2.3	1.7	1.3	1.0
B 210	21	1100	H14	...	(14)(33)	−452	16	14	5.3	5.3	5.3	4.9	2.8	1.9	1.1
B 210, B 214	21														
B 345, B 491	S-21	3003	0, H112	...	(14)(33)	−452	14	5	3.3	3.3	3.3	3.1	2.4	1.8	1.4
B 210	21	3003	H14	...	(14)(33)	−452	20	17	6.7	6.7	6.7	4.8	4.3	3.0	2.3
B 210, B 241	21														
B 345	S-21	3003	H18	...	(14)(33)	−452	27	24	9.0	9.0	8.9	6.3	5.4	3.5	2.5
B 210, B 241	21	Alclad	0, H112	..	(14)(33)	−452	13	4.5	3.0	3.0	3.0	2.8	2.2	1.6	1.3
B 345	S-21	3002													
B 210	21	Alclad 3003	H14	...	(14)(33)	−452	19	16	6.0	6.0	6.0	4.3	3.9	2.7	2.1
B 210	21	Alclad 3003	H18	...	(14)(33)	−452	26	23	8.1	8.1	8.0	5.7	4.9	3.2	2.2
B 210, B 241	22	5052	0	...	(14)	−452	25	10	6.7	6.7	6.7	6.2	5.6	4.1	2.3
B 210	22	5052	H32	...	(14)(33)	−452	31	23	10.3	10.3	10.3	7.5	6.2	4.1	2.3
B 210	22	5052	H34	...	(14)(33)	−452	34	26	11.3	11.3	11.3	8.4	6.2	4.1	2.3
B 241	25														
B 210, B 345	S-25	5083	0, H112	...	(33)	−452	39	16	10.7	10.7	...	...	...	...	...
B 241	25	5086	0, H112	...	(33)	−452	35	14	9.3	9.3	...	...	...	...	...
B 210, B 345	S-25														
B 210	S-25	5086	H32	...	(33)	−452	40	28	13.3	13.3	...	...	...	...	...
B 210	S-25	5086	H34	...	(33)	−452	44	34	14.7	14.7	...	...	...	...	...
B 210	22	5154	0	...	...	−452	30	11	7.3	7.3	...	...	...	...	...
B 210	22	5154	H34	...	(33)	−452	39	29	13.3	13.0	...	...	...	...	...
B 241	22	5454	0, H112	...	(33)	−452	31	12	8.0	8.0	8.0	7.4	5.5	4.1	3.0
B 210	25	5456	0, H112	...	(33)	−452	41	19	12.7	12.7	...	...	...	...	..
B 241	S-25														

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

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Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Spec. No.	P-No. or S-No. (5)	Grade	Temper	Size or Thickness Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Basic Allowable Stress S, ksi (1), at Metal Temperature, °F (7)						
							Tensile	Yield	Min. Temp. to 100	150	200	250	300	350	400
Aluminum Alloy (Cont'd)															
Seamless Pipes and Tubes (Cont'd)															
B 241	22	5652	0, H112	...	(33)	−452	25	10	6.7	6.7	6.7	6.2	5.6	4.1	2.3
B 210	23	6061	T4	...	(33)	−452	30	16	10.0	10.0	10.0	9.8	9.2	7.9	5.6
B 241, B 345	23, S-23	6061	T4	...	(33)(63)	−452	26	16	8.7	8.7	8.7	8.5	8.0	7.9	5.6
B 210	23	6061	T6	...	(33)	−452	42	35	14.0	14.0	14.0	13.2	11.3	7.9	5.6
B 241, B 345	23, S-23	6061	T6	Pipe	(13)(33)(63)	−452	38	35	12.7	12.7	12.7	12.1	10.6	7.9	5.6
B 210, B 241, B 345	23, S-23	6061	T4, T6 wld.	...	(22)(63)	−452	24	...	8.0	8.0	8.0	7.9	7.4	6.1	4.3
B 210	23	6063	T4	...	(33)	−452	22	10	6.7	6.7	6.7	6.7	6.7	3.4	2.0
B 241, B 345	23, S-23	6063	T4	≤ 0.500	(33)	−452	19	10							
B 241, B 345	23, S-23	6063	T5	≤ 0.500	(33)	−452	22	16	7.3	7.3	7.2	6.8	6.1	3.4	2.0
B 210	23	6063	T6	...	(33)	−452	33	28	11.0	11.0	10.5	9.5	7.0	3.4	2.0
B 241, B 345	23, S-23	6063	T6	...	(33)	−452	30	25	10.0	10.0	9.8	9.0	6.6	3.4	2.0
B 210, B 241, B 345	23, S-23	6063	T4, T5, T6 wld.	...	...	−452	17	...	5.7	5.7	5.7	5.6	5.2	3.0	2.0
Structural Tubes															
B 221	21	1060	0, H112	...	(33)(69)	−452	8.5	2.5	1.7	1.7	1.6	1.5	1.3	1.1	0.8
B 221	21	1100	0, H112	...	(33)(69)	−452	11	3	2.0	2.0	2.0	1.9	1.7	1.3	1.0
B 221	21	3003	0, H112	...	(33)(69)	−452	14	5	3.3	3.3	3.3	3.1	2.4	1.8	1.4
B 221	21	Alclad 3003	0, H112	...	(33)(69)	−452	13	4.5	3.0	3.0	3.0	2.8	2.2	1.6	1.3
B 221	22	5052	0	...	(69)	−452	25	10	6.7	6.7	6.7	6.2	5.6	4.1	2.3
B 221	25	5083	0	...	(69)	−452	39	16	10.7	10.7	...	...	...	...	...
B 221	25	5086	0	...	(69)	−452	35	14	9.3	9.3	...	...	...	...	...
B 221	22	5154	0	...	(69)	−452	30	11	7.3	7.3	...	...	...	...	...
B 221	22	5454	0	...	(69)	−452	31	12	8.0	8.0	8.0	7.4	5.5	4.1	3.0
B 221	25	5456	0	...	(69)	−452	41	19	12.7	12.7	...	...	...	...	...
B 221	23	6061	T4	...	(33)(63)(69)	−452	26	16	8.7	8.7	8.7	8.5	8.0	7.7	5.3
B 221	23	6061	T6	...	(33)(63)(69)	−452	38	35	12.7	12.7	12.7	12.1	10.6	7.9	5.6
B 221	23	6061	T4, T6 wld.	...	(22)(63)(69)	−452	24	...	8.0	8.0	8.0	7.9	7.4	6.1	4.3

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Spec. No.	P-No. or S-No. (5)	Grade	Temper	Size or Thickness Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Basic Allowable Stress S, ksi (1), at Metal Temperature, °F (7)						
							Tensile	Yield	Min. Temp. to 100	150	200	250	300	350	400
Aluminum Alloy (Cont'd)															
Structural Tubes (Cont'd)															
B 221	23	6063	T4	≤ 0.500	(13)(33)(69)	−452	19	10	6.4	6.4	6.4	6.4	6.4	3.4	2.0
B 221	23	6063	T5	≤ 0.500	(13)(33)(69)	−452	22	16	7.3	7.3	7.2	6.8	6.1	3.4	2.0
B 221	23	6063	T6	...	(33)(69)	−452	30	25	10.0	10.0	9.8	9.0	6.6	3.4	2.0
B 221	23	6063	T4, T5, T6 wld.	...	(69)	−452	17	...	5.7	5.7	5.7	5.6	5.2	3.0	2.0
Plates and Sheets															
B 209	21	1060	0	...	...	−452	8	2.5	1.7	1.7	1.6	1.5	1.3	1.1	0.8
B 209	21	1060	H112	0.500–1.000	(13)(33)	−452	10	5	3.3	3.2	2.9	1.9	1.7	1.4	1.0
B 209	21	1060	H12	...	(33)	−452	11	9	3.7	3.7	3.4	2.3	2.0	1.8	1.1
B 209	21	1060	H14	...	(33)	−452	12	10	4.0	4.0	4.0	3.0	2.6	1.8	1.1
B 209	21	1100	0	...	...	−452	11	3.5	2.3	2.3	2.3	2.3	1.7	1.3	1.0
B 209	21	1100	H112	0.500–2.000	(13)(33)	−452	12	5	3.3	3.3	3.3	2.5	2.2	1.7	1.0
B 209	21	1100	H12	...	(33)	−452	14	11	4.7	4.7	4.7	3.2	2.8	1.9	1.1
B 209	21	1100	H14	...	(33)	−452	16	14	5.3	5.3	5.3	3.7	2.8	1.9	1.1
B 209	21	3003	0	...	...	−452	14	5	3.3	3.3	3.3	3.1	2.4	1.8	1.4
B 209	21	3003	H112	0.500–2.000	(13)(33)	−452	15	6	4.0	4.0	3.9	3.1	2.4	1.8	1.4
B 209	21	3003	H12	...	(33)	−452	17	12	5.7	5.7	5.7	4.0	3.6	3.0	2.3
B 209	21	3003	H14	...	(33)	−452	20	17	6.7	6.7	6.7	4.8	4.3	3.0	2.3
B 209	21	Alclad 3003	0	0.006–0.499	(66)	−452	13	4.5							
B 209	21	Alclad 3003	0	0.500–3.000	(68)	−452	14	5	3.0	3.0	3.0	2.8	2.2	1.6	1.3
B 209	21	Alclad 3003	H112	o.500–2.000	(33)(66)	−452	15	6	3.6	3.6	3.5	2.8	2.2	1.6	1.3
B 209	21	Alclad 3003	H12	0.017–0.499	(33)(66)	−452	16	11							
B 209	21	Alclad 3003	H12	0.500–2.000	(33)(68)	−452	17	12	5.1	5.1	5.1	3.6	3.2	2.7	2.1
B 209	21	Alclad 3003	H14	0.009–0.499	(33)(66)	−452	19	16							
B 209	21	Alclad 3003	H14	0.500–1.000	(33)(68)	−452	20	17	6.0	6.0	6.0	4.3	3.9	2.7	2.1
B 209	22	3004	0	...	...	−452	22	8.5	5.7	5.7	5.7	5.7	5.7	3.8	2.3
B 209	22	3004	H112	...	(33)	−452	23	9	6.0	6.0	6.0	6.0	5.8	3.8	2.3
B 209	22	3004	H32	...	(33)	−452	28	21	9.3	9.3	9.3	7.0	5.8	3.8	2.3
B 209	22	3004	H34	...	(33)	−452	32	25	10.7	10.7	10.7	8.0	5.8	3.8	2.3

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Spec. No.	P-No. or S-No. (5)	Grade	Temper	Size or Thickness Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Basic Allowable Stress S, ksi (1), at Metal Temperature, °F (7)						
							Tensile	Yield	Min. Temp. to 100	150	200	250	300	350	400
Aluminum Alloy (Cont'd) Plates and Sheets (Cont'd)															
B 209	22	Alclad 3004	0	0.006–0.499	(66)	−452	21	8							
B 209	22	Alclad 3004	0	0.500–3.000	(68)	−452	22	8.5	5.1	5.1	5.1	5.1	5.1	3.4	2.1
B 209	22	Alclad 3004	H112	0.250–0.499	(33)(66)	−452	22	8.5							
B 209	22	Alclad 3004	H112	0.500–3.000	(33)(68)	−452	23	9	5.4	5.4	5.4	5.4	5.2	3.4	2.1
B 209	22	Alclad 3004	H32	0.017–0.499	(33)(66)	−452	27	20							
B 209	22	Alclad 3004	H32	0.500–2.000	(33)(68)	−452	28	21	8.4	8.4	8.4	6.3	5.2	3.4	2.1
B 209	22	Alclad 3004	H34	0.009–0.499	(33)(66)	−452	31	24							
B 209	22	Alclad 3004	H34	0.500–1.000	(33)(68)	−452	32	25	9.6	9.6	9.6	7.2	5.2	3.4	2.1
B 209	S-21	5050	0	...	...	−452	18	6	4.0	4.0	4.0	4.0	4.0	2.8	1.4
B 209	S-21	5050	H112	...	(33)	−452	20	8	5.3	5.3	5.3	5.3	5.3	2.8	1.4
B 209	S-21	5050	H32	...	(33)	−452	22	16	7.3	7.3	7.3	5.5	5.3	2.8	1.4
B 209	S-21	5050	H34	...	(33)	−452	25	20	8.3	8.3	8.3	6.3	5.3	2.8	1.4
B 209	22	5052 & 5652	0	...	...										
B 209	22	5052 & 5652	H112	0.500–3.00	(13)(33)	−452	25	9.5	6.3	6.3	6.3	6.2	5.6	4.1	2.3
B 209	22	5052 & 5652	H32	...	(33)	−452	31	23	10.3	10.3	10.3	7.5	6.2	4.1	2.3
B 209	22	5052 & 5652	H34	...	(33)	−452	34	26	11.3	11.3	11.3	8.4	6.2	4.1	2.3
B 209	25	5083	0	0.051–1.500	(13)	−452	40	18	12.0	12.0	...	...	...	...	...
B 209	25	5083	H321	0.188–1.500	(13)(33)	−452	44	31	14.7	14.7	...	...	...	...	...
B 209	25	5086	0	...	...	−452	35	14							
B 209	25	5086	H112	0.500–1.000	(13)(33)	−452	35	16	9.3	9.3	...	...	...	...	...
B 209	25	5086	H32	...	(33)	−452	40	28	13.3	13.3	...	...	...	...	...
B 209	25	5086	H34	...	(33)	−452	44	34	14.7	14.7	...	...	...	...	...
B 209	22	5154 & 5254	0	...	...										
B 209	22	5154 & 5254	H112	0.500–3.000	(13)(33)	−452	30	11	7.3	7.3	...	...	...	...	...
B 209	22	5154 & 5254	H32	...	(33)	−452	36	26	12.0	12.0	...	...	...	...	...
B 209	22	5154 & 5254	H34	...	(33)	−452	39	29	13.0	13.0	...	...	...	...	...

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Spec. No.	P-No. or S-No. (5)	Grade	Temper	Size or Thickness Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi Tensile	Yield	Basic Allowable Stress S, ksi (1), at Metal Temperature, °F (7) Min. Temp. to 100	150	200	250	300	350	400
Aluminum Alloy (Cont'd)															
Plates and Sheets (Cont'd)															
B 209	22	5454	0	...	...										
B 209	22	5454	H112	0.500–3.000	(13)(33)	−452	31	12	8.0	8.0	8.0	7.4	5.5	4.1	3.0
B 209	22	5454	H32	...	(33)	−452	36	26	12.0	12.0	12.0	7.5	5.5	4.1	3.0
B 209	22	5454	H34	...	(33)	−452	39	29	13.0	13.0	13.0	7.5	5.5	4.1	3.0
B 209	25	5456	0	0.051–1.500	(13)	−452	42	19	12.7	12.7	...	...	...	...	...
B 209	25	5456	H321	0.188–0.499	(13)(33)	−452	46	33	15.3	15.3	...	...	...	...	...
B 209	23	6061	T4	...	(33)(63)	−452	30	16	10.0	10.0	10.0	9.8	9.2	7.9	5.6
B 209	23	6061	T6	...	(33)										
B 209	23	6061	T651	0.250–4.000	(13)(33)	−452	42	35	14.0	14.0	14.0	13.2	11.2	7.9	5.6
B 209	23	6061	T4, T6 wld.	...	(22)(63)	−452	24	...	8.0	8.0	8.0	7.9	7.4	6.1	4.3
B 209	23	Alclad 6061	T4	...	(33)(66)	−452	27	14							
B 209	23	Alclad 6061	T451	0.250–0.499	(33)(66)	−452	27	14	9.0	9.0	9.0	8.8	8.3	7.1	5.0
B 209	23	Alclad 6061	T451	0.500–3.000	(33)(68)	−452	30	16							
B 209	23	Alclad 6061	T6	...											
B 209	23	Alclad 6061	T651	0.250–0.499	(33)(66)	−452	38	32	12.6	12.6	12.6	11.9	10.1	7.1	5.0
B 209	23	Alclad 6061	T651	0.500–4.000	(33)(68)	−452	42	35							
B 209	23	Alclad 6061	T4, T6 wld.	...	(22)(63)	−452	24	...	8.0	8.0	8.0	7.9	7.4	6.1	4.3
Forgings and Fittings (2)															
B 247	21	3003	H112, H112 wld.	...	(9)(45)	−452	14	5	3.3	3.3	3.3	3.1	2.4	1.8	1.4
B 247	25	5083	O, H112, H112 wld.	...	(9)(32)(33)	−452	38	16	10.7	10.7	...	..	...	...	...
B 247	23	6061	T6	...	(9)(33)	−452	38	35	12.7	12.7	12.7	12.1	10.6	7.9	5.6
B 247	23	6061	T6 wld.	...	(9)(22)	−452	24	...	8.0	8.0	8.0	7.9	7.4	6.1	4.3
B 361	S-21	WP1060	O, H112	...	(13)(14)(23)(32)(33)	−452	8	2.5	1.7	1.7	1.6	1.5	1.3	1.1	0.8

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TABLE A-1 (CONT'D)
BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Spec. No.	P-No. or S-No. (5)	Grade	Temper	Size or Thickness Range, in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7)						
							Tensile	Yield	Min. Temp. to 100	150	200	250	300	350	400
Aluminum Alloy (Cont'd)															
Forgings and Fittings (2) (Cont'd)															
B 361	S-21	WP1100	O, H112	...	(13)(14)(23)(32)(33)	−452	11	3	2.0	2.0	2.0	1.9	1.7	1.3	1.0
B 361	S-21	WP3003	O, H112	...	(13)(14)(23)(32)(33)	−452	14	5	3.3	3.3	3.3	3.1	2.4	1.8	1.4
B 361	S-21	WP Alclad 3003	O, H112	...	(13)(14)(23)(32)(33)(66)	−452	13	4.5	3.0	3.0	3.0	2.8	2.2	1.6	1.3
B 361	S-25	WP5083	O, H112	...	(13)(23)(32)(33)	−452	39	16	10.7	10.7	...	...	...	...	...
B 361	S-22	WP5154	O, H112	...	(23)(32)(33)	−452	30	11	7.3	7.3	...	...	...	...	...
B 361	S-23	WP6061	T4	...	(13)(23)(32)(33)(63)	−452	26	16	8.7	8.7	8.7	8.5	8.0	7.7	5.6
B 361	S-23	WP6061	T6	...	(13)(23)(32)(33)(63)	−452	38	35	12.7	12.7	12.7	12.1	10.6	7.9	5.6
B 361	S-23	WP6061	T4, T6 wld.	...	(22)(23)(32)(63)	−452	24	...	8.0	8.0	8.0	7.9	7.4	6.1	4.3
B 361	S-23	WP6063	T4	...	(13)(23)(32)(33)	−452	18	9	6.0	6.0	6.0	6.0	6.0	3.4	2.0
B 361	S-23	WP6063	T6	...	(13)(23)(32)(33)	−452	30	25	10.0	10.0	9.8	9.0	6.6	3.4	2.0
B 361	S-23	WP6063	T4, T6 wld.	...	(23)(32)	−452	17	...	5.7	5.7	5.7	5.6	5.2	3.0	2.0
Castings (2)															
B 26	...	443.0	F	...	(9)(43)	−452	17	6	4.0	4.0	4.0	4.0	4.0	4.0	3.0
B 26	...	356.0	T6	...	(9)(43)	−452	30	20	10.0	10.0	10.0	8.4	...	...	...
B 26	...	356.0	T71	...	(9)(43)	−452	25	18	8.3	8.3	8.3	8.1	7.3	5.5	2.4

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TABLE A-1A
BASIC CASTING QUALITY FACTORS E_c

These quality factors are determined in accordance with para. 302.3.3(b). See also para. 302.3.3(c) and Table 302.3.3C for increased quality factors applicable in special cases. Specifications are ASTM.

Spec. No.	Description	E_c (2)	Appendix A Notes
Iron			
A 47	Malleable iron castings	1.00	(9)
A 48	Gray iron castings	1.00	(9)
A 126	Gray iron castings	1.00	(9)
A 197	Cupola malleable iron castings	1.00	(9)
A 278	Gray iron castings	1.00	(9)
A 395	Ductile and ferritic ductile iron castings	0.80	(9)(40)
A 571	Austenitic ductile iron castings	0.80	(9)(40)
Carbon Steel			
A 216	Carbon steel castings	0.80	(9)(40)
A 352	Ferritic steel castings	0.80	(9)(40)
Low and Intermediate Alloy Steel			
A 217	Martensitic stainless and alloy castings	0.80	(9)(40)
A 352	Ferritic steel castings	0.80	(9)(40)
A 426	Centrifugally cast pipe	1.00	(10)
Stainless Steel			
A 351	Austenitic steel castings	0.80	(9)(40)
A 451	Centrifugally cast pipe	0.90	(10)(40)
A 452	Centrifugally cast pipe	0.85	(40)
A 487	Steel castings	0.80	(9)(40)
Copper and Copper Alloy			
B 61	Steam bronze castings	0.80	(9)(40)
B 62	Composition bronze castings	0.80	(9)(40)
B 148	Al-Bronze and Si-Al-Bronze castings	0.80	(9)(40)
B 584	Copper alloy castings	0.80	(9)(40)
Nickel and Nickel Alloy			
A 494	Nickel and nickel alloy castings	0.80	(9)(40)
Aluminum Alloy			
B 26, Temper F	Aluminum alloy castings	1.00	(9)(10)
B 26, Temper T6, T71	Aluminum alloy castings	0.80	(9)(40)

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TABLE A-1B
BASIC QUALITY FACTORS FOR LONGITUDINAL WELD JOINTS IN PIPES, TUBES, AND FITTINGS E_j

These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

Spec. No.	Class (or Type)	Description	E_j (2)	Appendix A Notes
Carbon Steel				
API 5L	...	Seamless pipe	1.00	...
	...	Electric resistance welded pipe	0.85	...
	...	Electric fusion welded pipe, double butt, straight or spiral seam	0.95	...
	...	Furnace butt welded	0.60	...
A 53	Type S	Seamless pipe	1.00	...
	Type E	Electric resistance welded pipe	0.85	...
	Type F	Furnace butt welded pipe	0.60	...
A 105	...	Forgings and fittings	1.00	(9)
A 106	...	Seamless pipe	1.00	...
A 134	...	Electric fusion welded pipe, single butt, straight or spiral seam	0.80	...
A 135	...	Electric resistance welded pipe	0.85	...
A 139	...	Electric fusion welded pipe, straight or spiral seam	0.80	...
A 179	...	Seamless tube	1.00	...
A 181	...	Forgings and fittings	1.00	(9)
A 234	...	Seamless and welded fittings	1.00	(16)
A 333	...	Seamless pipe	1.00	...
	...	Electric resistance welded pipe	0.85	...
A 334	...	Seamless tube	1.00	...
A 350	...	Forgings and fittings	1.00	(9)
A 369	...	Seamless pipe	1.00	...
A 381	...	Electric fusion welded pipe, 100% radiographed	1.00	(18)
	...	Electric fusion welded pipe, spot radiographed	0.90	(19)
	...	Electric fusion welded pipe, as manufactured	0.85	...
A 420	...	Welded fittings, 100% radiographed	1.00	(16)
A 524	...	Seamless pipe	1.00	...
A 587	...	Electric resistance welded pipe	0.85	...
A 671	12, 22	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23	Electric fusion welded pipe, double butt seam	0.85	...
A 672	12, 22	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23	Electric fusion welded pipe, double butt seam	0.85	...
A 691	12, 22	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23	Electric fusion welded pipe, double butt seam	0.85	...

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TABLE A-1B (CONT'D)
BASIC QUALITY FACTORS FOR LONGITUDINAL WELD JOINTS IN PIPES, TUBES, AND FITTINGS E_j

These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

Spec. No.	Class (or Type)	Description	E_j (2)	Appendix A Notes
Low and Intermediate Alloy Steel				
A 182	...	Forgings and fittings	1.00	(9)
A 234	...	Seamless and welded fittings	1.00	(16)
A 333	...	Seamless pipe	1.00	...
	...	Electric resistance welded pipe	0.85	...
A 334	...	Seamless tube	1.00	...
A 335	...	Seamless pipe	1.00	...
A 350	...	Forgings and fittings	1.00	...
A 369	...	Seamless pipe	1.00	...
A 420	...	Welded fittings, 100% radiographed	1.00	(16)
A 671	12, 22	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23	Electric fusion welded pipe, double butt seam	0.85	...
A 672	12, 22	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23	Electric fusion welded pipe, double butt seam	0.85	...
A 691	12, 22	Electric fusion welded pipe, 100% radiographed	1.00	...
	13, 23	Electric fusion welded pipe, double butt seam	0.85	...
Stainless Steel				
A 182	...	Forgings and fittings	1.00	...
A 268	...	Seamless tube	1.00	...
	...	Electric fusion welded tube, double butt seam	0.85	...
	...	Electric fusion welded tube, single butt seam	0.80	...
A 269	...	Seamless tube	1.00	...
	...	Electric fusion welded tube, double butt seam	0.85	...
	...	Electric fusion welded tube, single butt seam	0.80	...
A 312	...	Seamless tube	1.00	...
	...	Electric fusion welded tube, double butt seam	0.85	...
	...	Electric fusion welded tube, single butt seam	0.80	...
A 358	1, 3, 4	Electric fusion welded pipe, 100% radiographed	1.00	...
	5	Electric fusion welded pipe, spot radiographed	0.90	...
	2	Electric fusion welded pipe, double butt seam	0.85	...
A 376	...	Seamless pipe	1.00	...
A 403	...	Seamless fittings	1.00	...
	...	Welded fitting, 100% radiographed	1.00	(16)
	...	Welded fitting, double butt seam	0.85	...
	...	Welded fitting, single butt seam	0.80	...

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TABLE A-1B (CONT'D)
BASIC QUALITY FACTORS FOR LONGITUDINAL WELD JOINTS IN PIPES, TUBES, AND FITTINGS E_j

These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

Spec. No.	Class (or Type)	Description	E_j (2)	Appendix A Notes
Stainless Steel (Cont'd)				
A 409	...	Electric fusion welded pipe, double butt seam	0.85	...
	...	Electric fusion welded pipe, single butt seam	0.80	...
A 430	...	Seamless pipe	1.00	...
A 487	...	Steel castings	0.80	(9)(40)
A 789	...	Seamless tube	1.00	...
	...	Electric fusion welded, 100% radiographed	1.00	...
	...	Electric fusion welded, double butt	0.85	...
	...	Electric fusion welded, single butt	0.80	...
A 790	...	Seamless pipe	1.00	...
	...	Electric fusion welded, 100% radiographed	1.00	...
	...	Electric fusion welded, double butt	0.85	...
	...	Electric fusion welded, single butt	0.80	...
A 815	...	Seamless fittings	1.00	...
	...	Welded fittings, 100% radiographed	1.00	(16)
	...	Welded fittings, double butt seam	0.85	...
	...	Welded fittings, single butt seam	0.80	...
Copper and Copper Alloy				
B 42	...	Seamless pipe	1.00	...
B 43	...	Seamless pipe	1.00	...
B 68	...	Seamless tube	1.00	...
B 75	...	Seamless tube	1.00	...
B 88	...	Seamless water tube	1.00	...
B 280	...	Seamless tube	1.00	...
B 466	...	Seamless pipe and tube	1.00	...
B 467	...	Electric resistance welded pipe	0.85	...
	...	Electric fusion welded pipe, double butt seam	0.85	...
	...	Electric fusion welded pipe, single butt seam	0.80	...
Nickel and Nickel Alloy				
B 160	...	Forgings and fittings	1.00	(9)
B 161	...	Seamless pipe and tube	1.00	...
B 164	...	Forgings and fittings	1.00	(9)
B 165	...	Seamless pipe and tube	1.00	...
B 167	...	Seamless pipe and tube	1.00	...
B 366	...	Seamless and welded fittings	1.00	(16)
B 407	...	Seamless pipe and tube	1.00	...
B 444	...	Seamless pipe and tube	1.00	...
B 464	...	Welded pipe	0.80	...
B 514	...	Welded pipe	0.80	...
B 517	...	Welded pipe	0.80	...
B 564	...	Nickel alloy forgings	1.00	(9)

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TABLE A-1B (CONT'D)
BASIC QUALITY FACTORS FOR LONGITUDINAL WELD JOINTS IN PIPES, TUBES, AND FITTINGS E_j

These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

Spec. No.	Class (or Type)	Description	E_j (2)	Appendix A Notes
Nickel and Nickel Alloy (Cont'd)				
B 619	...	Electric resistance welded pipe	0.85	...
	...	Electric fusion welded pipe, double butt seam	0.85	...
	...	Electric fusion welded pipe, single butt seam	0.80	...
B 622	...	Seamless pipe and tube	1.00	...
B 675	All	Welded pipe	0.80	...
B 690	...	Seamless pipe	1.00	...
B 705	...	Welded pipe	0.80	...
B 725	...	Electric fusion welded pipe, double butt seam	0.85	...
	...	Electric fusion welded pipe, single butt seam	0.80	...
B 729	...	Seamless pipe and tube	1.00	...
B 804	1, 3, 5	Welded pipe, 100% radiographed	1.00	...
	2, 4	Welded pipe, double fusion welded	0.85	...
	6	Welded pipe, single fusion welded	0.80	...
Titanium and Titanium Alloy				
B 337	...	Seamless pipe	1.00	...
	...	Electric fusion welded pipe, double butt seam	0.85	...
Zirconium and Zirconium Alloy				
B 523	...	Seamless tube	1.00	...
	...	Electric fusion welded tube	0.80	...
B 658	...	Seamless pipe	1.00	...
	...	Electric fusion welded pipe	0.80	...
Aluminum Alloy				
B 210	...	Seamless tube	1.00	...
B 241	...	Seamless pipe and tube	1.00	...
B 247	...	Forgings and fittings	1.00	(9)
B 345	...	Seamless pipe and tube	1.00	...
B 361	...	Seamless fittings	1.00	...
	...	Welded fittings, 100% radiograph	1.00	(18)(23)
	...	Welded fittings, double butt	0.85	(23)
	...	Welded fittings, single butt	0.80	(23)

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Table A-2 begins on the next page

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TABLE A-2
DESIGN STRESS VALUES FOR BOLTING MATERIALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM

Material	Spec. No.	Grade	Size Range, Diam., in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.					
						Tensile	Yield	to 100	200	300	400	500	600
Carbon Steel													
...	A 675	45	...	(8f)(8g)	−20	45	22.5	11.2	11.2	11.2	11.2	11.2	11.2
...	A 675	50	...	(8f)(8g)	−20	50	25	12.5	12.5	12.5	12.5	12.5	12.5
...	A 675	55	...	(8f)(8g)	−20	55	27.5	13.7	13.7	13.7	13.7	13.7	13.7
...	A 307	B	...	(8f)(8g)	−20	60	...	13.7	13.7	13.7	13.7	13.7	...
...	A 675	60	...	(8f)(8g)	−20	60	30	15.0	15.0	15.0	15.0	15.0	15.0
...	A 675	65	...	(8g)	−20	65	32.5	16.2	16.2	16.2	16.2	16.2	16.2
...	A 675	70	...	(8g)	−20	70	35	17.5	17.5	17.5	17.5	17.5	17.5
...	A 325	...	...	(8g)	−20	105	81	19.3	19.3	19.3	19.3	19.3	19.3
...	A 675	80	...	(8g)	−20	80	40	20.0	20.0	20.0	20.0	20.0	20.0
Nuts	A 194	1, 2	...	(42)	−20	...	...	...	...	...	...	...	...
Nuts	A 194	2H	...	(42)	−50	...	...	...	...	...	...	...	...
...	A 194	2HM	...	(42)	−50	...	...	...	...	...	...	...	...
Nuts	A 563	A, Hvy Hex	...	(42b)	−20	...	...	...	...	...	...	...	...
Alloy Steel													
Cr-0.2Mo	A 193	B7M	≤ 4	...	−50	100	80	20.0	20.0	20.0	20.0	20.0	20.0
Cr-0.20Mo	A 320	L7M	≤ 2½	...	−100	100	80	20.0	20.0	20.0	20.0	20.0	20.0
5Cr	A 193	B5	≤ 4	(15)	−20	100	80	20.0	20.0	20.0	20.0	20.0	20.0
Cr-Mo-V	A 193	B16	> 2½, ≤ 4	(15)	−20	110	95	22.0	22.0	22.0	22.0	22.0	22.0
...	A 354	BC	...	(15)	0	115	99	23.0	23.0	23.0	23.0	23.0	23.0
Cr-Mo	A 193	B7	> 2½, ≤ 4	(15)(38)	−40	115	95	23.0	23.0	23.0	23.0	23.0	23.0
Ni-Cr-Mo	A 320	L43	≤ 4	(15)	−150	125	105	25.0	25.0	25.0	25.0	25.0	25.0
Cr-Mo	A 320	L7	≤ 2½	(15)	−150	125	105	25.0	25.0	25.0	25.0	25.0	25.0
Cr-Mo	A 320	L7A, L7B, L7C	≤ 2½	(15)	−150	125	105	25.0	25.0	25.0	25.0	25.0	25.0
Cr-Mo	A 193	B7	≤ 2½	...	−50	125	105	25.0	25.0	25.0	25.0	25.0	25.0
Cr-Mo-V	A 193	B16	≤ 2½	(15)	−20	125	105	25.0	25.0	25.0	25.0	25.0	25.0
...	A 354	BD	≤ 2½	(15)	20	150	130	30.0	30.0	30.0	30.0	30.0	30.0
5Cr nuts	A 194	3	...	(42)	−20	...	...	...	...	...	...	...	...
C-Mo nuts	A 194	4	...	(42)	−150	...	...	...	...	...	...	...	...
Cr-Mo nuts	A 194	7	...	(42)	−150	...	...	...	...	...	...	...	...
Cr-Mo nuts	A 194	7M	...	(42)	−150	...	...	...	...	...	...	...	...
Stainless Steel													
316	A 193	B8M Cl. 2	> 1¼, ≤ 1½	(15)(60)	−325	90	50	18.8	16.2	16.2	16.2	16.2	16.2
316	A 320	B8M Cl. 2	> 1¼, ≤ 1½	(15)(60)	−325	90	50	18.8	16.2	16.2	16.2	16.2	16.2
304	A 193	B8 Cl. 2	> 1¼, ≤ 1½	(15)(60)	−325	100	50	18.8	17.2	16.0	15.0	14.0	13.4
304	A 320	B8 Cl. 2	> 1¼, ≤ 1½	(15)(60)	−325	100	50	18.8	17.2	16.0	15.0	14.0	13.4
321	A 193	B8C Cl. 2	> 1¼, ≤ 1¼	(15)(60)	−325	100	50	18.8	16.7	16.3	16.3	16.3	16.3
321	A 320	B8C Cl. 2	> 1¼, ≤ 1¼	(15)(60)	−325	100	50	18.8	16.7	16.3	16.3	16.3	16.3
347	A 193	B8T Cl. 2	> 1¼, ≤ 1½	(15)(60)	−325	100	50	18.8	17.8	16.5	16.3	16.3	16.3
347	A 320	B8T Cl. 2	> 1¼, ≤ 1½	(15)(60)	−325	100	50	18.8	17.8	16.5	16.3	16.3	16.3
303 sol. trt.	A 320	B8F Cl. 1	...	(8f)(15)(39)	−325	75	30	18.8	13.0	12.0	10.9	10.0	9.3
19Cr-9Ni	A 453	651B	> 3	(15)(35)	−20	95	50	19.0	19.0	19.0	19.0	19.0	19.0
19Cr-9Ni	A 453	651B	≤ 3	(15)(35)	−20	95	60	19.0	19.0	19.0	19.0	19.0	19.0
19Cr-9Ni	A 453	651A	> 3	(15)(35)	−20	100	60	20.0	20.0	20.0	20.0	20.0	20.0
19Cr-9Ni	A 453	651A	≤ 3	(15)(35)	−20	100	70	20.0	20.0	20.0	20.0	20.0	20.0

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TABLE A-2
DESIGN STRESS VALUES FOR BOLTING MATERIALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM

Design Stress, ksi (1), at Metal Temperature, °F (7)																			
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Grade	Spec. No.
																			Carbon Steel
11.2	11.0	10.2	9.0	7.7	6.5	...	...	...	...	...	...	...	...	...	...	...	...	45	A 675
12.5	12.1	11.1	9.6	8.0	6.5	...	...	...	...	...	...	...	...	...	...	...	...	50	A 675
13.7	13.2	12.0	10.2	8.3	6.5	...	...	...	...	...	...	...	...	...	...	...	...	55	A 675
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B	A 307
15.0	14.3	12.9	10.8	8.6	6.5	...	...	...	...	...	...	...	...	...	...	...	...	60	A 675
16.2	15.5	13.8	11.5	8.9	6.5	4.5	2.5	...	...	...	...	...	...	...	...	...	...	65	A 675
17.5	16.6	14.7	12.0	9.2	6.5	4.5	2.5	...	...	...	...	...	...	...	...	...	...	70	A 675
19.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	A 325
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	80	A 675
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1, 2	A 194
																		2H	A 194
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2HM	A 194
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	A, Hvy Hex	A 563
																			Alloy Steel
																		B7M	A 193
20.0	20.0	20.0	18.5	16.2	12.5	8.5	4.5	...	...	...	...	...	...	...	...	...	...	L7M	A 320
20.0	20.0	20.0	18.5	14.5	10.4	7.6	5.6	4.2	3.1	2.0	1.3	...	...	...	...	...	...	B5	A 193
22.0	22.0	22.0	22.0	21.0	18.5	15.3	11.0	6.3	2.8	...	...	...	...	...	...	...	...	B16	A 193
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	BC	A 354
23.0	23.0	22.2	20.0	16.3	12.5	8.5	4.5	...	...	...	...	...	...	...	...	...	...	B7	A 193
																		L43	A 320
25.0	25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	L7	A 320
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	L7A, L7B, L7C	A 320
25.0	25.0	23.6	21.0	17.0	12.5	8.5	4.5	...	...	...	...	...	...	...	...	...	...	B7	A 193
25.0	25.0	25.0	25.0	23.5	20.5	16.0	11.0	6.3	2.8	...	...	...	...	...	...	...	...	B16	A 193
30.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	BD	A 354
																		3	A 194
																		4	A 194
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7	A 194
																		7M	A 194
																			Stainless Steel
12.5	12.5	12.5	12.5	10.9	10.8	10.7	10.6	...	...	...	...	...	...	...	...	...	...	B8M Cl. 2	A 193, A 320
12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	...	...	...	...	...	...	...	...	...	...	B8 Cl. 2	A 193, A 320
13.1	12.9	12.8	12.7	12.6	12.6	12.5	12.5	...	...	...	...	...	...	...	...	...	...	B8C Cl. 2	A 193, A 320
13.3	12.9	12.7	12.5	12.5	12.5	12.5	12.5	...	...	...	...	...	...	...	...	...	...	B8T Cl. 2	A 193, A 320
8.9	8.6	8.3	8.0	...	...	..	...	...	...	...	...	...	...	...	...	...	...	B8F Cl. 1	A 320
																		651B	A 453
19.0	19.0	19.0	19.0	19.0	19.0	18.9	18.2	...	...	...	...	...	...	...	...	...	...	651B	A 453
																		651A	A 453
20.0	20.0	20.0	20.0	20.0	20.0	19.8	19.2	...	...	...	...	...	...	...	...	...	...	651A	A 453

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TABLE A-2 (CONT'D)
DESIGN STRESS VALUES FOR BOLTING MATERIALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM

Material	Spec. No.	Grade	Size Range, Diam., in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp. to 100	200	300	400	500	600
						Tensile	Yield						
Stainless Steel (Cont'd)													
316	A 193 / A 320	B8M Cl. 2	> 1, ≤ 1¼	(15)(60)	−325	105	65	18.8	16.2	16.2	16.2	16.2	16.2
347	A 193 / A 320	B8C Cl. 2	> 1, ≤ 1¼	(15)(60)	−325	105	65	18.8	17.2	16.0	15.0	14.0	13.4
304	A 193 / A 320	B8 Cl. 2	> 1, ≤ 1¼	(15)(60)	−325	105	65	18.8	16.7	16.3	16.3	16.3	16.3
321	A 193 / A 320	B8T Cl. 2	> 1, ≤1 ¼	(15)(60)	−325	105	65	18.8	17.8	16.5	16.3	16.3	16.3
321	A 193	B8T Cl. 1	...	(8f)(15)(28)	−325	75	30	18.8	17.8	16.5	15.3	14.3	13.5
304	A 320	B8 Cl. 1	...	(8f)(15)(28)	−425	75	30	18.8	16.7	15.0	13.8	12.9	12.1
347	A 193	B8C Cl. 1	...	(8f)(15)(28)	−425	75	30	18.8	17.9	16.4	15.5	15.0	14.3
316	A 193	B8M Cl. 1	...	(8f)(15)(28)	−325	75	30	18.8	17.7	15.6	14.3	13.3	12.6
316 str. hd.	A 193 / A 320	B8M Cl. 2	> ¾, ≤ 1	(15)(60)	−325	100	80	20.0	20.0	20.0	20.0	20.0	20.0
347 str. hd	A 193 / A 320	B8C Cl. 2	> ¾, ≤ 1	(15)(60)	−325	115	80	20.0	17.2	16.0	15.0	14.0	13.4
304 str. hd.	A 193 / A 320	B8 Cl. 2	> ¾, ≤ 1	(15)(60)	−325	115	80	20.0	20.0	20.0	20.0	20.0	20.0
321 str. hd.	A 193 / A 320	B8T Cl. 2	> ¾, ≤ 1	(15)(60)	−325	115	80	20.0	20.0	20.0	20.0	20.0	20.0

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TABLE A-2 (CONT'D)
DESIGN STRESS VALUES FOR BOLTING MATERIALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM

Design Stress, ksi (1), at Metal Temperature, °F (7)																			
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Grade	Spec. No.
																		Stainless Steel (Cont'd)	
16.2	16.2	16.2	16.2	10.9	10.8	10.7	10.6	...	...	...	...	...	...	...	...	...	...	B8M, Cl. 2	A 193 A 320
13.8	12.9	12.8	12.7	12.6	12.6	12.5	12.5	...	...	...	...	...	...	...	...	...	...	B8C, Cl. 2	A 193 A 320
16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	...	...	...	...	...	...	...	...	...	...	B8, Cl. 2	A 193 A 320
16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	...	...	...	...	...	...	...	...	...	...	B8T, Cl. 2	A 193 A 320
13.3	12.9	12.7	12.5	12.4	12.3	12.1	12.1	9.6	6.9	5.0	3.6	2.5	1.7	1.1	0.7	0.5	0.3	B8T, Cl. 1	A 193
12.0	11.8	11.5	11.2	11.0	10.8	10.6	10.4	10.1	9.8	7.7	6.0	4.7	3.7	2.9	2.3	1.8	1.4	B8, Cl. 1	A 320
14.1	13.8	13.7	13.6	13.5	13.5	13.4	13.4	12.1	9.1	6.1	4.4	3.3	2.2	1.5	1.2	0.9	0.8	B8C, Cl. 1	A 193
12.3	12.1	11.9	11.7	11.6	11.5	11.4	11.3	11.2	11.0	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	B8M, Cl. 1	A 193
20.0	20.0	20.0	20.0	10.9	10.8	10.7	10.6	...	...	...	...	...	...	...	...	...	...	B8M, Cl. 2	A 193 A 320
13.1	12.9	12.8	12.7	12.6	12.6	12.5	12.5	...	...	...	...	...	...	...	...	...	...	B8C, Cl. 2	A 193 A 320
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	...	...	...	...	...	...	...	...	...	...	B8, Cl. 2	A 193 A 320
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	...	...	...	...	...	...	...	...	...	...	B8T, Cl. 2	A 193 A 320

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TABLE A-2 (CONT'D)
DESIGN STRESS VALUES FOR BOLTING MATERIALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM

Material	Spec. No.	Grade	Size Range, Diam., in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.					
						Tensile	Yield	to 100	200	300	400	500	600
Stainless Steel (Cont'd)													
12Cr	A 437	B4C	...	(35)	−20	115	85	21.2	21.2	21.2	21.2	21.2	21.2
13Cr	A 193	B6	≤ 4	(15)(35)	−20	110	85	21.2	21.2	21.2	21.2	21.2	21.2
14Cr-24Ni	A 453	660A/B	...	(15)(35)	−20	130	85	21.3	20.7	20.5	20.4	20.3	20.2
316 str. hd.	A 193 / A 320	B8M Cl. 2	≤ 3/4	(15)(60)	−325	110	95	22.0	22.0	22.0	22.0	22.0	22.0
347	A 193 / A 320	B8C Cl. 2	≤ 3/4	(15)(60)	−325	125	100	25.0	25.0	25.0	25.0	25.0	25.0
304	A 193 / A 320	B8 Cl. 2	≤ 3/4	(15)(60)	−325	125	100	25.0	17.2	16.0	15.0	14.0	13.4
321	A 193 / A 320	B8T Cl. 2	≤ 3/4	(15)(60)	−325	125	100	25.0	25.0	25.0	25.0	25.0	25.0
12Cr	A 437	B4B	...	(35)	−20	145	105	26.2	26.2	26.2	26.2	26.2	26.2
12Cr nuts	A 194	6	...	(35)(42)	−20	...	...	...	...	...	...	...	...
303 nuts	A 194	8FA	...	(42)	−20	...	...	...	...	...	...	...	...
316 nuts	A 194	8MA	...	(42)	−325	...	...	...	...	...	...	...	...
321 nuts	A 194	8TA	...	(42)	−325	...	...	...	...	...	...	...	...
304 nuts	A 194	8	...	(42)	−425	...	...	...	...	...	...	...	...
304 nuts	A 194	8A	...	(42)	−425	...	...	...	...	...	...	...	...
347 nuts	A 194	8CA	...	(42)	−425	...	...	...	...	...	...	...	...

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STD·ASME B31·3-ENGL 1999 ■ 0759670 0608008 T9T ■

TABLE A-2 (CONT'D)
DESIGN STRESS VALUES FOR BOLTING MATERIALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM

Design Stress, ksi (1), at Metal Temperature, °F (7)																			
650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Grade	Spec. No.
																		Stainless Steel (Cont'd)	
21.2	21.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B4C	A 437
21.2	21.2	21.2	19.6	15.6	12.0	...	...	...	...	...	...	...	...	...	...	...	...	B6	A 193
20.2	20.1	20.0	19.9	19.9	19.9	19.8	19.8	...	...	...	...	...	...	...	...	...	...	660A/B	A 453
22.0	22.0	22.0	22.0	10.9	10.8	10.7	10.6	...	...	...	...	...	...	...	...	...	...	B8M C1. 2	A 193 A 320
25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	...	...	...	...	...	...	...	...	...	...	B8 C1. 2	A 193 A 320
13.1	11.0	10.8	10.5	10.3	10.1	9.9	9.7	...	...	...	...	...	...	...	...	...	...	B8 C1. 2	A 193 A 320
25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	...	...	...	...	...	...	...	...	...	...	B8T C1. 2	A 193 A 320
26.2	26.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B4B	A 437
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6	A 194
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8FA	A 194
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8MA 8TA	A 194 A 194
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8 8A 8CA	A 194 A 194 A 194

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TABLE A-2 (CONT'D)
DESIGN STRESS VALUES FOR BOLTING MATERIALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM

Material	Spec. No.	UNS No. or Grade	Temper	Size Range, Diam., in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.			
							Tensile	Yield	to 100	200	300	400
Copper and Copper Alloy												
Naval brass	B 21	C46400, C48200, C48500	060	...	(8f)	−325	50	20	5.0	4.8	4.2	...
Cu	B 187	C10200, C11000, C12000, C12200	060	...	(8f)	−325	30	10	6.7	5.5	5.1	...
Cu-Si	B 98	C65100	060	...	(8f)(52)	−325	40	12	8.0	8.0	7.9	...
Cu-Si	B 98	C65500, C66100	060	...	(8f)(52)	−325	52	15				
Cu-Si	B 98	C65500, C66100	H01	...	(8f)	−325	55	24				
Cu-Si	B 98	C65500, C66100	H02	≤ 2	...	−325	70	38	10.0	10.0	10.0	...
Cu-Si	B 98	C65100	H06	> 1, ≤ 1½	...	−325	75	40				
Cu-Si	B 98	C65100	H06	>½, ≤ 1	...	−325	75	45	11.3	11.3	11.3	...
Cu-Si	B 98	C65100	H06	≤ ½	...	−325	85	55	13.7	13.7	13.7	...
Al-Si-Bronze	B 150	C64200	HR50	> 1, ≤ 2	...	−325	80	42				
Al-Si-Bronze	B 150	C64200	HR50	> ½, ≤ 1	...	−325	85	42	16.7	14.0	13.5	11.0
Al-Si-Bronze	B 150	C64200	HR50	≤ ½	...	−325	90	42				
Al-Bronze	B 150	C61400	HR50	> 1, ≤ 2	...	−325	70	32				
Al-Bronze	B 150	C61400	HR50	> ½, ≤1	...	−325	75	35	17.5	17.5	17.5	17.5
Al-Bronze	B 150	C61400	HR50	≤ ½	...	−325	80	40				
Al-Bronze	B 150	C6300	HR50	> 2, ≤ 3								
Al-Bronze	B 150	C6300	M20	> 3, ≤ 4	...	−325	85	42.5				
Al-Bronze	B 150	C6300	HR50	> 1, ≤ 2	...	−325	90	45	20.0	20.0	20.0	20.0
Al-Bronze	B 150	C6300	HR50	> ½, ≤ 1	...	−325	100	50				
Nickel and Nickel Alloy												
Low C-Ni	B 160	N02201	Ann. hot fin.	...	(8f)	−325	50	10	6.7	6.4	6.3	6.2
Ni	B 160	N02200	Hot fin.	...	(8f)	−325	60	15	10.0	10.0	10.0	10.0
Ni	B 160	N02200	Annealed	...	(8f)	−325	55	15				
Ni	B 160	N02200	Cold drawn	...	...	−325	65	40	10.0	10.0	10.0	10.0
Ni-Cu	B 164	N04400	C.D./Str. rel.	...	(54)	−325	84	50				
Ni-Cu	B 164	N04405	Cold drawn	...	(54)	−325	85	50	12.5	12.5	12.5	12.5
Ni-Cu	B 164	N04400	Cold drawn	...	(54)	−325	85	55	13.7	13.7	13.7	13.7
Ni-Cu	B 164	N04400/N04405	Annealed	...	(8f)	−325	70	25	16.6	14.6	13.6	13.2
Ni-Cu	B 164	N04405	Hot fin.	Rod ≤ 3	...	−325	75	35	18.7	18.7	18.7	18.7
Ni-Cu	B 164	N04400	Hot fin.	2⅛ ≤ Hex. ≤ 4	(8f)	−325	75	30	18.7	18.7	18.7	18.7
Ni-Cu	B 164	N04400	Hot fin.	All except hex. > 2⅛	...	−325	80	40	20.0	20.0	20.0	20.0

Symbols in Temper Column

060 = soft anneal
H01 = quarter-hard
H02 = half-hard
H06 = extra hard
HR50 = drawn, stress-relieved

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TABLE A-2 (CONT'D)
DESIGN STRESS VALUES FOR BOLTING MATERIALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM

Design Stress, ksi (1), at Metal Temperature, °F (7)																UNS No. or Grade	Spec. No.
500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300		
																Copper and Copper Alloy	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C46400, etc.	B 21
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C10200, etc.	B 187
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C65100	B 98
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C65500, etc.	B 98
																C65500, etc.	B 98
																C65500, etc.	B 98
																C65100	B 98
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C65100	B 98
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C65100	B 98
5.2	1.7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C64200	B 150
																C64200	B 150
																C64200	B 150
16.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C61400	B 150
																C61400	B 150
																C61400	B 150
19.4	12.0	8.5	6.0	...	...	...	...	...	...	...	...	...	...	...	...	C63000	B 150
																C63000	B 150
																C63000	B 150
																C63000	B 150
																Nickel and Nickel Alloy	
6.2	6.2	6.2	6.2	6.0	5.9	5.8	4.8	3.7	3.0	2.4	2.0	1.5	1.2	...	...	N02201	B 160
9.5	8.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 160
																N02200	B 160
10.0	10.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N02200	B 160
																N04400	B 164
12.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04405	B 164
13.7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N04400	B 164
13.1	13.1	13.1	13.1	13.0	12.7	11.0	8.0	...	...	...	...	...	...	...	...	N04400, etc.	B 164
18.7	18.7	18.7	18.0	17.2	14.5	8.5	4.0	...	...	...	...	...	...	...	...	N04405	B 164
17.8	17.4	17.2	17.0	16.8	14.5	8.5	4.0	...	...	...	...	...	...	...	...	N04400	B 164
20.0	20.0	20.0	19.2	18.5	14.5	8.5	4.0	...	...	...	...	...	...	...	...	N04400	B 164

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TABLE A-2 (CONT'D)
DESIGN STRESS VALUES FOR BOLTING MATERIALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM

Material	Spec. No.	UNS No. or Grade	Temper	Size Range, Diam., in.	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.			
							Tensile	Yield	to 100	200	300	400
Nickel and Nickel Alloy (Cont'd)												
Ni-Cr-Fe	B 166	N06600	Cold drawn	Rod ≤ 3	(41)(54)	−325	105	80	10.0	9.5	9.2	9.1
Ni-Cr-Fe	B 166	N06600	Hot fin.	Rod ≤ 3	...	−325	90	40	10.0	9.5	9.2	9.1
Ni-Cr-Fe	B 166	N06600	Annealed	...	...	−325	80	35	20.0	20.0	20.0	20.0
Ni-Cr-Fe	B 166	N06600	Hot fin.	Rod > 3	...	−325	85	35	21.2	21.2	21.2	21.2
Ni-Mo	B 335	N10001	Annealed	...	...	−325	100	46	25.0	25.0	25.0	24.7
Ni-Mo-Cr	B 574	N10276	Sol. Ann.	...	...	−325	100	41	25.0	25.0	25.0	21.2
Aluminum Alloy												
...	B 211	6061	T6, T651 wld.	≥ 1/8, ≤ 8	(8f)(43)(63)	−452	24	...	4.8	4.8	4.8	3.5
...	B 211	6061	T6, T651	≥ 1/8, ≤ 8	(43)(63)	−452	42	35	8.4	8.4	8.4	4.4
...	B 211	2024	T4	> 6 1/2, ≤ 8	(43)(63)	−452	58	38	9.5	9.5	9.5	4.2
...	B 211	2024	T4	> 4 1/2, ≤ 6 1/2	(43)(63)	−452	62	40	10.0	10.0	10.0	4.5
...	B 211	2024	T4	≥ 1/2, ≤ 4 1/2	(43)(63)	−452	62	42	10.5	10.5	10.4	4.5
...	B 211	2024	T4	≥ 1/8, < 1/2	(43)(63)	−452	62	45	11.3	11.3	10.4	4.5
...	B 211	2014	T6, T651	≥ 1/8, ≤ 8	(43)(63)	−452	65	55	13.0	13.0	11.4	3.9

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TABLE A-2 (CONT'D)
DESIGN STRESS VALUES FOR BOLTING MATERIALS[1]
Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM

Design Stress, ksi (1), at Metal Temperature, °F (7)																UNS No. or Grade	Spec. No.
500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300		
																Nickel and Nickel Alloy (Cont'd)	
9.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N06600	B 166
9.1	9.1	9.0	8.9	8.9	8.8	8.7	8.6	8.5	8.3	7.8	7.3	6.4	5.5	...	...	N06600	B 166
20.0	20.0	19.8	19.6	19.4	19.1	18.7	16.0	10.6	7.0	4.5	3.0	2.2	2.2	...	...	N06600	B 166
21.2	21.2	21.1	21.1	21.0	20.4	20.2	19.5	19.3	14.5	10.3	7.3	5.8	5.5	...	...	N06600	B 166
24.3	23.7	23.4	23.0	22.8	22.5	...	...	...	...	...	...	...	...	...	...	N10001	B 335
20.0	18.8	18.3	17.8	17.4	17.1	16.8	16.6	16.5	16.5	...	...	...	...	...	...	N10276	B 574
																Aluminum Alloy	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6061	B 211
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6061	B 211
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2024	B 211
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2024	B 211
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2024	B 211
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2024	B 211
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2014	B 211

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APPENDIX B
STRESS TABLES AND ALLOWABLE PRESSURE TABLES FOR NONMETALS

The data and Notes in Appendix B are requirements of this Code.

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D 3035	PE Plastic Pipe (SDR-PR), Based on Controlled Outside Diameter	228
D 3309	PB Plastic Hot-Water Distribution Systems.	228
D 3517	Fiberglass RTR Pressure Pipe [Note (3)].	229
D 3754	Fiberglass RTR Sewer and Industrial Pressure Pipe [Note (3)]	229
F 441	CPVC Plastic Pipe	228
F 442	CPVC Plastic Pipe, (SDR-PR).	228
AWWA		
C300	Reinforced Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids	229
C301	Prestressed Concrete Pressure, Pipe Steel Cylinder Type, for Water and Other Liquids.	229
C302	Reinforced Concrete Pressure Pipe, Steel Non-Cylinder Type, for Water and Other Liquids	229
C950	Glass-Fiber-Reinforced Thermosetting-Resin Pressure Pipe.	229

NOTES:

(1) It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.

(2) For names of plastics identified only by abbreviation, see para. A326.3.

(3) The term *fiberglass RTR* takes the place of the ASTM designation: *"fiberglass" (glass-fiber-reinforced thermosetting resin).*

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NOTES FOR APPENDIX B TABLES

NOTES:

(1) These recommended limits are for low pressure applications with water and other fluids that do not significantly affect the properties of the thermoplastic. The upper temperature limits are reduced at higher pressures, depending on the combination of fluid and expected service life. Lower temperature limits are affected more by the environment, safeguarding, and installation conditions than by strength.

(2) These recommended limits apply only to materials listed. Manufacturers should be consulted for temperature limits on specific types and kinds of materials not listed.

(3) Use these hydrostatic design stress (HDS) values at all lower temperatures.

(4) The intent of listing in this Table is to include all the types, grades, classes, and hydrostatic design bases in the listed specifications.

(5) Mean short term burst stresses are based on values listed in applicable ASTM Specifications, excluding the lower confidence limit multiplier of 0.85 applied to the mean stress value.

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TABLE B-1
HYDROSTATIC DESIGN STRESSES (HDS) AND RECOMMENDED TEMPERATURE LIMITS FOR THERMOPLASTIC PIPE

ASTM Spec. No.	Material	Recommended Temperature Limits [Notes (1), (2)]				Hydrostatic Design Stress at						Mean Short-Term Burst Stress at 23°C [Note (5)]	
		Minimum		Maximum		23°C [Note (3)]	73°F [Note (3)]	38°C	100°F	82°C	180°F		
		°C	°F	°C	°F	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi
...	ABS55535	−40	−40	80	176	...	...	...	...	...	...	...	...
...	AP	−18	0	77	170	...	...	...	...	...	...	...	...
D 2846 F 441 F 442	CPVC4120	−18	0	99	210	13.8	2.0	11.0	1.6	3.4	0.5	51.9	7.53
...	ECTFE	−40	−40	149	300	...	...	...	...	...	...	...	...
...	ETFE	−40	−40	149	300	...	...	...	...	...	...	...	...
D 2513 D 2662 D 2666 D 3000 D 3309	PB2110	−18	0	99	210	6.9	1.0	5.5	0.8	3.4	0.5	17.9	2.59
D 2104 D 2239 D 2447 D 2513 D 2737 D 3035	PE3408	−34	−30	82	180	5.51	0.80	3.4	0.5	...	...	20.4	2.96
...	PEEK	−40	−40	250	450	...	...	...	...	...	...	...	...
...	PFA	−40	−40	250	450	...	...	...	...	...	...	...	...
...	POP2125	−1	30	99	210	...	...	...	...	...	...	...	...
...	PP	−1	30	99	210	...	...	...	...	...	...	...	...
D 1785	PVC1120	−18	0	66	150	13.8	2.0	11.0	1.6	...	...	51.9	7.53
D 2241	PVC1220	−18	0	66	150	13.8	2.0	11.0	1.6	...	...	51.9	7.53
D 2513	PVC2110	−18	0	54	130	6.9	1.0	5.5	0.8	...	...	40.5	5.88
D 2672	PVC2120	−18	0	66	150	13.8	2.0	11.0	1.6	...	...	51.9	7.53
...	PVDC	4	40	71	160	...	...	...	...	...	...	...	...
...	PVDF	−18	0	135	275	...	...	...	...	...	...	...	...

Notes for this Table are on p.233

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TABLE B-2
LISTED SPECIFICATIONS[4] FOR LAMINATED REINFORCED THERMOSETTING RESIN PIPE

Spec. No.
ASTM C 582

TABLE B-3
LISTED SPECIFICATIONS[4] FOR FILAMENT WOUND AND CENTRIFUGALLY CAST REINFORCED THERMOSETTING RESIN AND REINFORCED PLASTIC MORTAR PIPE

Spec. Nos. (ASTM Except as Noted)		
D 2517	D 2997	D 3754
D 2996	D 3517	AWWA C950

TABLE B-4
ALLOWABLE PRESSURES AND RECOMMENDED TEMPERATURE LIMITS FOR CONCRETE PIPE

Spec. No.	Material	Class	Allowable Gage Pressure		Recommended Temperature Limits [Note (2)]			
					Minimum		Maximum	
			kPa	psi	°C	°F	°C	°F
ASTM C361	Reinforced concrete	25	69	10	...	...	...	...
		50	138	20				
		75	205	30				
		100	275	40				
		125	345	50				
AWWA C300	Reinforced concrete	...	1795	260	...	...	...	...
AWWA C301	Reinforced concrete	Lined cylinder	1725	250	...	...	...	...
AWWA C301	Reinforced concrete	Embedded cylinder	2415	350	...	...	...	...
AWWA C302	Reinforced concrete	...	310	45	...	...	...	...

Notes for this Table are on p.233

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TABLE B-5
ALLOWABLE PRESSURES AND RECOMMENDED TEMPERATURE LIMITS FOR BOROSILICATE GLASS PIPE

ASTM Spec. No.	Material	Size Range DN	Size Range NPS	Allowable Gage Pressure kPa	Allowable Gage Pressure psi	Recommended Temperature Limits [Note (2)] Minimum °C	Minimum °F	Maximum °C	Maximum °F
C 599	Borosilicate glass	8–15	¼–½	690	100	...	...	232	450
		20	¾	515	75				
		25–80	1–3	345	50				
		100	4	240	35				
		150	6	138	20				

Notes for this Table are on p. 233

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APPENDIX C
PHYSICAL PROPERTIES OF PIPING MATERIALS

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NOTES FOR APPENDIX C TABLES

GENERAL NOTES: Tables C-2, C-4, and C-7 containing data in SI units are not included at this time. To convert data in U.S. customary units to SI metric units:

(a) determine the Fahrenheit equivalent of the given Celsius temperature;

(b) interpolate in the desired table to calculate the expansion or modulus value in U.S. units;

(c)(1) for Table C-1, multiply the value (in./100 ft) by 0.833 to obtain the total linear thermal expansion (mm/m) between 21°C and the given temperature;

(2) for Table C-3, multiply the value (μin./in.-°F) by 1.80 to obtain the mean coefficient of linear thermal expansion (μm/m-°C) between 21°C and the given temperature;

(3) for Table C-6, multiply the value in Msi by 6.895 to obtain the modulus of elasticity in MPa at the given temperature.

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Table C-1 begins on the next page

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TABLE C-1
TOTAL THERMAL EXPANSION, U.S. UNITS, FOR METALS[1]
Total Linear Thermal Expansion Between 70°F and Indicated Temperature, in./100 ft

	Material							
Temp., °F	Carbon Steel Carbon-Moly-Low-Chrome (Through 3Cr-Mo)	5Cr-Mo Through 9Cr-Mo	Austenitic Stainless Steels 18Cr-8Ni	12Cr, 17Cr, 27Cr	25Cr-20Ni	UNS N04400 Monel 67Ni-30Cu	$3\frac{1}{2}$Ni	Copper and Copper Alloys
−450	...	...	...	...	...	...	...	−3.93
−425	...	...	...	...	...	...	...	−3.93
−400	...	...	...	...	...	...	...	−3.91
−375	...	...	...	...	...	...	...	−3.87
−350	...	...	...	...	...	...	...	−3.79
−325	−2.37	−2.22	−3.85	−2.04	...	−2.62	−2.25	−3.67
−300	−2.24	−2.10	−3.63	−1.92	...	−2.50	−2.17	−3.53
−275	−2.11	−1.98	−3.41	−1.80	...	−2.38	−2.07	−3.36
−250	−1.98	−1.86	−3.19	−1.68	...	−2.26	−1.96	−3.17
−225	−1.85	−1.74	−2.96	−1.57	...	−2.14	−1.86	−2.97
−200	−1.71	−1.62	−2.73	−1.46	...	−2.02	−1.76	−2.76
−175	−1.58	−1.50	−2.50	−1.35	...	−1.90	−1.62	−2.53
−150	−1.45	−1.37	−2.27	−1.24	...	−1.79	−1.48	−2.30
−125	−1.30	−1.23	−2.01	−1.11	...	−1.59	−1.33	−2.06
−100	−1.15	−1.08	−1.75	−0.98	...	−1.38	−1.17	−1.81
−75	−1.00	−0.94	−1.50	−0.85	...	−1.18	−1.01	−1.56
−50	−0.84	−0.79	−1.24	−0.72	...	−0.98	−0.84	−1.30
−25	−0.68	−0.63	−0.98	−0.57	...	−0.77	−0.67	−1.04
0	−0.49	−0.46	−0.72	−0.42	...	−0.57	−0.50	−0.77
25	−0.32	−0.30	−0.46	−0.27	...	−0.37	−0.32	−0.50
50	−0.14	−0.13	−0.21	−0.12	...	−0.20	−0.15	−0.22
70	0	0	0	0	0	0	0	0
100	0.23	0.22	0.34	0.20	0.32	0.28	0.23	0.34
125	0.42	0.40	0.62	0.36	0.58	0.52	0.42	0.63
150	0.61	0.58	0.90	0.53	0.84	0.75	0.61	0.91
175	0.80	0.76	1.18	0.69	1.10	0.99	0.81	1.20
200	0.99	0.94	1.46	0.86	1.37	1.22	1.01	1.49
225	1.21	1.13	1.75	1.03	1.64	1.46	1.21	1.79
250	1.40	1.33	2.03	1.21	1.91	1.71	1.42	2.09
275	1.61	1.52	2.32	1.38	2.18	1.96	1.63	2.38
300	1.82	1.71	2.61	1.56	2.45	2.21	1.84	2.68
325	2.04	1.90	2.90	1.74	2.72	2.44	2.05	2.99
350	2.26	2.10	3.20	1.93	2.99	2.68	2.26	3.29
375	2.48	2.30	3.50	2.11	3.26	2.91	2.47	3.59
400	2.70	2.50	3.80	2.30	3.53	3.25	2.69	3.90
425	2.93	2.72	4.10	2.50	3.80	3.52	2.91	4.21
450	3.16	2.93	4.41	2.69	4.07	3.79	3.13	4.51
475	3.39	3.14	4.71	2.89	4.34	4.06	3.35	4.82
500	3.62	3.35	5.01	3.08	4.61	4.33	3.58	5.14
525	3.86	3.58	5.31	3.28	4.88	4.61	3.81	5.45
550	4.11	3.80	5.62	3.49	5.15	4.90	4.04	5.76

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TABLE C-1
TOTAL THERMAL EXPANSION, U.S. UNITS, FOR METALS[1]
Total Linear Thermal Expansion Between 70°F and Indicated Temperature, in./100 ft

Material								
Aluminum	Gray Cast Iron	Bronze	Brass	70Cu-30Ni	UNS N08XXX Series Ni-Fe-Cr	UNS N06XXX Series Ni-Cr-Fe	Ductile Iron	Temp., °F
...	...	...	...	...	...	...	...	−450
...	...	...	...	...	...	...	...	−425
...	...	...	...	...	...	...	...	−400
...	...	...	...	...	...	...	...	−375
...	...	...	...	...	...	...	...	−350
−4.68	...	−3.98	−3.88	−3.15	...	...	...	−325
−4.46	...	−3.74	−3.64	−2.87	...	...	...	−300
−4.21	...	−3.50	−3.40	−2.70	...	...	...	−275
−3.97	...	−3.26	−3.16	−2.53	...	...	...	−250
−3.71	...	−3.02	−2.93	−2.36	...	...	...	−225
−3.44	...	−2.78	−2.70	−2.19	...	...	−1.51	−200
−3.16	...	−2.54	−2.47	−2.12	...	...	−1.41	−175
−2.88	...	−2.31	−2.24	−1.95	...	...	−1.29	−150
−2.57	...	−2.06	−2.00	−1.74	...	...	−1.16	−125
−2.27	...	−1.81	−1.76	−1.53	...	...	−1.04	−100
−1.97	...	−1.56	−1.52	−1.33	...	...	−0.91	−75
−1.67	...	−1.32	−1.29	−1.13	...	...	−0.77	−50
−1.32	...	−1.25	−1.02	−0.89	...	...	−0.62	−25
−0.97	...	−0.77	−0.75	−0.66	...	...	−0.46	0
−0.63	...	−0.49	−0.48	−0.42	...	...	−0.23	25
−0.28	...	−0.22	−0.21	−0.19	...	...	−0.14	50
0	0	0	0	0	0	0	0	70
0.46	0.21	0.36	0.35	0.31	0.28	0.26	0.21	100
0.85	0.38	0.66	0.64	0.56	0.52	0.48	0.39	125
1.23	0.55	0.96	0.94	0.82	0.76	0.70	0.57	150
1.62	0.73	1.26	1.23	1.07	0.99	0.92	0.76	175
2.00	0.90	1.56	1.52	1.33	1.23	1.15	0.94	200
2.41	1.08	1.86	1.83	1.59	1.49	1.38	1.13	225
2.83	1.27	2.17	2.14	1.86	1.76	1.61	1.33	250
3.24	1.45	2.48	2.45	2.13	2.03	1.85	1.53	275
3.67	1.64	2.79	2.76	2.40	2.30	2.09	1.72	300
4.09	1.83	3.11	3.08	2.68	2.59	2.32	1.93	325
4.52	2.03	3.42	3.41	2.96	2.88	2.56	2.13	350
4.95	2.22	3.74	3.73	3.24	3.18	2.80	2.36	375
5.39	2.42	4.05	4.05	3.52	3.48	3.05	2.56	400
5.83	2.62	4.37	4.38	...	3.76	3.29	2.79	425
6.28	2.83	4.69	4.72	...	4.04	3.53	3.04	450
6.72	3.03	5.01	5.06	...	4.31	3.78	3.28	475
7.17	3.24	5.33	5.40	...	4.59	4.02	3.54	500
7.63	3.46	5.65	5.75	...	4.87	4.27	3.76	525
8.10	3.67	5.98	6.10	...	5.16	4.52	3.99	550

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TABLE C-1 (CONT'D)
TOTAL THERMAL EXPANSION, U.S. UNITS, FOR METALS[1]
Total Linear Thermal Expansion Between 70°F and Indicated Temperature, in./100 ft

Temp., °F	Material							
	Carbon Steel Carbon-Moly-Low-Chrome (Through 3Cr-Mo)	5Cr-Mo Through 9Cr-Mo	Austenitic Stainless Steels 18Cr-8Ni	12Cr, 17Cr, 27Cr	25Cr-20Ni	UNS N04400 Monel 67Ni-30Cu	$3^1/_2$Ni	Copper and Copper Alloys
575	4.35	4.02	5.93	3.69	5.42	5.18	4.27	6.07
600	4.60	4.24	6.24	3.90	5.69	5.46	4.50	6.09
625	4.86	4.47	6.55	4.10	5.96	5.75	4.74	...
650	5.11	4.69	6.87	4.31	6.23	6.05	4.98	...
675	5.37	4.92	718	4.52	6.50	6.34	5.22	...
700	5.63	5.14	7.50	4.73	6.77	6.64	5.46	...
725	5.90	5.38	7.82	4.94	7.04	6.94	5.70	...
750	6.16	5.62	8.15	5.16	7.31	7.25	5.94	...
775	6.43	5.86	8.47	5.38	7.58	7.55	6.18	...
800	6.70	6.10	8.80	5.60	7.85	7.85	6.43	...
825	6.97	6.34	9.13	5.82	8.15	8.16	6.68	...
850	7.25	6.59	9.46	6.05	8.45	8.48	6.93	...
875	7.53	6.83	9.79	6.27	8.75	8.80	7.18	...
900	7.81	7.07	10.12	6.49	9.05	9.12	7.43	...
925	8.08	7.31	10.46	6.71	9.35	9.44	7.68	...
950	8.35	7.56	10.80	6.94	9.65	9.77	7.93	...
975	8.62	7.81	11.14	7.17	9.95	10.09	8.17	...
1000	8.89	8.06	11.48	7.40	10.25	10.42	8.41	...
1025	9.17	8.30	11.82	7.62	10.55	10.75	...	...
1050	9.46	8.55	12.16	7.95	10.85	11.09	...	...
1075	9.75	8.80	12.50	8.18	11.15	11.43	...	...
1100	10.04	9.05	12.84	8.31	11.45	11.77	...	...
1125	10.31	9.28	13.18	8.53	11.78	12.11	...	...
1150	10.57	9.52	13.52	8.76	12.11	12.47	...	...
1175	10.83	9.76	13.86	8.98	12.44	12.81	...	...
1200	11.10	10.00	14.20	9.20	12.77	13.15	...	...
1225	11.38	10.26	14.54	9.42	13.10	13.50	...	...
1250	11.66	10.53	14.88	9.65	13.43	13.86	...	...
1275	11.94	10.79	15.22	9.88	13.76	14.22	...	...
1300	12.22	11.06	15.56	10.11	14.09	14.58	...	...
1325	12.50	11.30	15.90	10.33	14.39	14.94	...	...
1350	12.78	11.55	16.24	10.56	14.69	15.30	...	...
1375	13.06	11.80	16.58	10.78	14.99	15.66	...	...
1400	13.34	12.05	16.92	11.01	15.29	16.02	...	...
1425	...	...	17.30	...	...	...	...	...
1450	...	...	17.69	...	...	...	...	...
1475	...	...	18.08	...	...	...	...	...
1500	...	...	18.47	...	...	...	...	...

NOTE:
(1) For Code references to this Appendix, see para. 319.3.1. These data are for use in the absence of more applicable data. It is the designer's responsibility to verify that materials are suitable for the intended service at the temperatures shown.

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TABLE C-1 (CONT'D)
TOTAL THERMAL EXPANSION, U.S. UNITS, FOR METALS[1]
Total Linear Thermal Expansion Between 70°F and Indicated Temperature, in./100 ft

Material								
Aluminum	Gray Cast Iron	Bronze	Brass	70Cu-30Ni	UNS N08XXX Series Ni-Fe-Cr	UNS N06XXX Series Ni-Cr-Fe	Ductile Iron	Temp., °F
8.56	3.89	6.31	6.45	...	5.44	4.77	4.22	575
9.03	4.11	6.64	6.80	...	5.72	5.02	4.44	600
...	4.34	6.96	7.16	...	6.01	5.27	4.66	625
...	4.57	7.29	7.53	...	6.30	5.53	4.90	650
...	4.80	7.62	7.89	...	6.58	5.79	5.14	675
...	5.03	7.95	8.26	...	6.88	6.05	5.39	700
...	5.26	8.28	8.64	...	7.17	6.31	5.60	725
...	5.50	8.62	9.02	...	7.47	6.57	5.85	750
...	5.74	8.96	9.40	...	7.76	6.84	6.10	775
...	5.98	9.30	9.78	...	8.06	7.10	6.35	800
...	6.22	9.64	10.17	...	8.35	...	6.59	825
...	6.47	9.99	10.57	...	8.66	...	6.85	850
...	6.72	10.33	10.96	...	8.95	...	7.09	875
...	6.97	10.68	11.35	...	9.26	...	7.35	900
...	7.23	11.02	11.75	...	9.56	...	7.64	925
...	7.50	11.37	12.16	...	9.87	...	7.86	950
...	7.76	11.71	12.57	...	10.18	...	8.11	975
...	8.02	12.05	12.98	...	10.49	...	8.35	1000
...	...	12.40	13.39	...	10.80	...	...	1025
...	...	12.76	13.81	...	11.11	...	...	1050
...	...	13.11	14.23	...	11.42	...	...	1075
...	...	13.47	14.65	...	11.74	...	...	1100
...	...	...	...	...	12.05	...	...	1125
...	...	...	...	...	12.38	...	...	1150
...	...	...	...	...	12.69	...	...	1175
...	...	...	...	...	13.02	...	...	1200
...	...	...	...	...	13.36	...	...	1225
...	...	...	...	...	13.71	...	...	1250
...	...	...	...	...	14.04	...	...	1275
...	...	...	...	...	14.39	...	...	1300
...	...	...	...	...	14.74	...	...	1325
...	...	...	...	...	15.10	...	...	1350
...	...	...	...	...	15.44	...	...	1375
...	...	...	...	...	15.80	...	...	1400
...	...	...	...	...	16.16	...	...	1425
...	...	...	...	...	16.53	...	...	1450
...	...	...	...	...	16.88	...	...	1475
...	...	...	...	...	17.25	...	...	1500

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TABLE C-3
THERMAL COEFFICIENTS, U.S. UNITS, FOR METALS[1]
Mean Coefficient of Linear Thermal Expansion Between 70°F and Indicated Temperature, μin./in.-°F

	Material							
Temp., °F	Carbon Steel Carbon-Moly-Low-Chrome (Through 3Cr-Mo)	5Cr-Mo Through 9Cr-Mo	Austenitic Stainless Steels 18Cr-8Ni	12Cr, 17Cr, 27Cr	25Cr-20Ni	UNS N04400 Monel 67Ni-30Cu	$3\frac{1}{2}$Ni	Copper and Copper Alloys
−450	...	...	...	...	...	...	...	6.30
−425	...	...	...	...	...	...	...	6.61
−400	...	...	...	...	...	...	...	6.93
−375	...	...	...	...	...	...	...	7.24
−350	...	...	...	...	...	...	...	7.51
−325	5.00	4.70	8.15	4.30	...	5.55	4.76	7.74
−300	5.07	4.77	8.21	4.36	...	5.72	4.90	7.94
−275	5.14	4.84	8.28	4.41	...	5.89	5.01	8.11
−250	5.21	4.91	8.34	4.47	...	6.06	5.15	8.26
−225	5.28	4.98	8.41	4.53	...	6.23	5.30	8.40
−200	5.35	5.05	8.47	4.59	...	6.40	5.45	8.51
−175	5.42	5.12	8.54	4.64	...	6.57	5.52	8.62
−150	5.50	5.20	8.60	4.70	...	6.75	5.59	8.72
−125	5.57	5.26	8.66	4.78	...	6.85	5.67	8.81
−100	5.65	5.32	8.75	4.85	...	6.95	5.78	8.89
−75	5.72	5.38	8.83	4.93	...	7.05	5.83	8.97
−50	5.80	5.45	8.90	5.00	...	7.15	5.88	9.04
−25	5.85	5.51	8.94	5.05	...	7.22	5.94	9.11
0	5.90	5.56	8.98	5.10	...	7.28	6.00	9.17
25	5.96	5.62	9.03	5.14	...	7.35	6.08	9.23
50	6.01	5.67	9.07	5.19	...	7.41	6.16	9.28
70	6.07	5.73	9.11	5.24	...	7.48	6.25	9.32
100	6.13	5.79	9.16	5.29	...	7.55	6.33	9.39
125	6.19	5.85	9.20	5.34	...	7.62	6.36	9.43
150	6.25	5.92	9.25	5.40	...	7.70	6.39	9.48
175	6.31	5.98	9.29	5.45	...	7.77	6.42	9.52
200	6.38	6.04	9.34	5.50	8.79	7.84	6.45	9.56
225	6.43	6.08	9.37	5.54	8.81	7.89	6.50	9.60
250	6.49	6.12	9.41	5.58	8.83	7.93	6.55	9.64
275	6.54	6.15	9.44	5.62	8.85	7.98	6.60	9.68
300	6.60	6.19	9.47	5.66	8.87	8.02	6.65	9.71
325	6.65	6.23	9.50	5.70	8.89	8.07	6.69	9.74
350	6.71	6.27	9.53	5.74	8.90	8.11	6.73	9.78
375	6.76	6.30	9.56	5.77	8.91	8.16	6.77	9.81
400	6.82	6.34	9.59	5.81	8.92	8.20	6.80	9.84
425	6.87	6.38	9.62	5.85	8.92	8.25	6.83	9.86
450	6.92	6.42	9.65	5.89	8.92	8.30	6.86	9.89
475	6.97	6.46	9.67	5.92	8.92	8.35	6.89	9.92
500	7.02	6.50	9.70	5.96	8.93	8.40	6.93	9.94
525	7.07	6.54	9.73	6.00	8.93	8.45	6.97	9.97
550	7.12	6.58	9.76	6.05	8.93	8.49	7.01	9.99

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TABLE C-3
THERMAL COEFFICIENTS, U.S. UNITS, FOR METALS[1]
Mean Coefficient of Linear Thermal Expansion Between 70°F and Indicated Temperature, μin./in.-°F

Material								
Aluminum	Gray Cast Iron	Bronze	Brass	70Cu-30Ni	UNS N08XXX Series Ni-Fe-Cr	UNS N06XXX Series Ni-Cr-Fe	Ductile Iron	Temp., °F
...	...	...	...	...	...	...	...	−450
...	...	...	...	...	...	...	...	−425
...	...	...	...	...	...	...	...	−400
...	...	...	...	...	...	...	...	−375
...	...	...	...	...	...	...	...	−350
9.90	...	8.40	8.20	6.65	...	...	...	−325
10.04	...	8.45	8.24	6.76	...	...	...	−300
10.18	...	8.50	8.29	6.86	...	...	...	−275
10.33	...	8.55	8.33	6.97	...	...	...	−250
10.47	...	8.60	8.37	7.08	...	...	...	−225
10.61	...	8.65	8.41	7.19	...	...	4.65	−200
10.76	...	8.70	8.46	7.29	...	...	4.76	−175
10.90	...	8.75	8.50	7.40	...	...	4.87	−150
11.08	...	8.85	8.61	7.50	...	...	4.98	−125
11.25	...	8.95	8.73	7.60	...	...	5.10	−100
11.43	...	9.05	8.84	7.70	...	...,	5.20	−75
11.60	...	9.15	8.95	7.80	...	...	5.30	−50
11.73	...	9.23	9.03	7.87	...	...	5.40	−25
11.86	...	9.32	9.11	7.94	...	...	5.50	0
11.99	...	9.40	9.18	8.02	...	...	5.58	25
12.12	...	9.49	9.26	8.09	...	...	5.66	50
12.25	...	9.57	9.34	8.16	...	7.13	5.74	70
12.39	...	9.66	9.42	8.24	...	7.20	5.82	100
12.53	...	9.75	9.51	8.31	...	7.25	5.87	125
12.67	..	9.85	9.59	8.39	...	7.30	5.92	150
12.81	...	9.93	9.68	8.46	...	7.35	5.97	175
12.95	5.75	10.03	9.76	8.54	7.90	7.40	6.02	200
13.03	5.80	10.05	9.82	8.58	8.01	7.44	6.08	225
13.12	5.84	10.08	9.88	8.63	8.12	7.48	6.14	250
13.20	5.89	10.10	9.94	8.67	8.24	7.52	6.20	275
13.28	5.93	10.12	10.00	8.71	8.35	7.56	6.25	300
13.36	5.97	10.15	10.06	8.76	8.46	7.60	6.31	325
13.44	6.02	10.18	10.11	8.81	8.57	7.63	6.37	350
13.52	6.06	10.20	10.17	8.85	8.69	7.67	6.43	375
13.60	6.10	10.23	10.23	8.90	8.80	7.70	6.48	400
13.68	6.15	10.25	10.29	...	8.82	7.72	6.57	425
13.75	6.19	10.28	10.35	...	8.85	7.75	6.66	450
13.83	6.24	10.30	10.41	...	8.87	7.77	6.75	475
13.90	6.28	10.32	10.47	...	8.90	7.80	6.85	500
13.98	6.33	10.35	10.53	...	8.92	7.82	6.88	525
14.05	6.38	10.38	10.58	...	8.95	7.85	6.92	550

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TABLE C-3 (CONT'D)
THERMAL COEFFICIENTS, U.S. UNITS, FOR METALS[1]
Mean Coefficient of Linear Thermal Expansion Between 70°F and Indicated Temperature, μin./in.-°F

	Material							
Temp., °F	Carbon Steel Carbon-Moly-Low-Chrome (Through 3Cr-Mo)	5Cr-Mo Through 9Cr-Mo	Austenitic Stainless Steels 18Cr-8Ni	12Cr, 17Cr, 27Cr	25Cr-20Ni	UNS N04400 Monel 67Ni-30Cu	$3\frac{1}{2}$Ni	Copper and Copper Alloys
575	7.17	6.62	9.79	6.09	8.93	8.54	7.04	10.1
600	7.23	6.66	9.82	6.13	8.94	8.58	7.08	10.04
625	7.28	6.70	9.85	6.17	8.94	8.63	7.12	...
650	7.33	6.73	9.87	6.20	8.95	8.68	7.16	...
675	7.38	6.77	9.90	6.23	8.95	8.73	7.19	...
700	7.44	6.80	9.92	6.26	8.96	8.78	7.22	...
725	7.49	6.84	9.95	6.29	8.96	8.83	7.25	...
750	7.54	6.88	9.99	6.33	8.96	8.87	7.29	...
775	7.59	6.92	10.02	6.36	8.96	8.92	7.31	...
800	7.65	6.96	10.05	6.39	8.97	8.96	7.34	...
825	7.70	7.00	10.08	6.42	8.97	9.01	7.37	...
850	7.75	7.03	10.11	6.46	8.98	9.06	7.40	...
875	7.79	7.07	10.13	6.49	8.99	9.11	7.43	...
900	7.84	7.10	10.16	6.52	9.00	9.16	7.45	...
925	7.87	7.13	10.19	6.55	9.05	9.21	7.47	...
950	7.91	7.16	10.23	6.58	9.10	9.25	7.49	...
975	7.94	7.19	10.26	6.60	9.15	9.30	7.52	...
1000	7.97	7.22	10.29	6.63	9.18	9.34	7.55	...
1025	8.01	7.25	10.32	6.65	9.20	9.39	...	...
1050	8.05	7.27	10.34	6.68	9.22	9.43	...	...
1075	8.08	7.30	10.37	6.70	9.24	9.48	...	...
1100	8.12	7.32	10.39	6.72	9.25	9.52	...	...
1125	8.14	7.34	10.41	6.74	9.29	9.57	...	...
1150	8.16	7.37	10.44	6.75	9.33	9.61	...	...
1175	8.17	7.39	10.46	6.77	9.36	9.66	...	...
1200	8.19	7.41	10.48	6.78	9.39	9.70	...	...
1225	8.21	7.43	10.50	6.80	9.43	9.75	...	...
1250	8.24	7.45	10.51	6.82	9.47	9.79	...	...
1275	8.26	7.47	10.53	6.83	9.50	9.84	...	...
1300	8.28	7.49	10.54	6.85	9.53	9.88	...	...
1325	8.30	7.51	10.56	6.86	9.53	9.92	...	...
1350	8.32	7.52	10.57	6.88	9.54	9.96	...	...
1375	8.34	7.54	10.59	6.89	9.55	10.00	...	...
1400	8.36	7.55	10.60	6.90	9.56	10.04	...	...
1425	...	...	10.64	...	...	...	...	...
1450	...	...	10.68	...	...	...	...	...
1475	...	...	10.72	...	...	...	...	...
1500	...	...	10.77	...	...	...	...	...

NOTE:
(1) For Code references to this Appendix, see para. 319.3.1. These data are for use in the absence of more applicable data. It is the designer's responsibility to verify that materials are suitable for the intended service at the temperatures shown.

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TABLE C-3 (CONT'D)
THERMAL COEFFICIENTS, U.S. UNITS, FOR METALS[1]
Mean Coefficient of Linear Thermal Expansion Between 70°F and Indicated Temperature, μin./in.-°F

Material								
Aluminum	Gray Cast Iron	Bronze	Brass	70Cu-30Ni	UNS N08XXX Series Ni-Fe-Cr	UNS N06XXX Series Ni-Cr-Fe	Ductile Iron	Temp., °F
14.13	6.42	10.41	10.64	...	8.97	7.88	6.95	575
14.20	6.47	10.44	10.69	...	9.00	7.90	6.98	600
...	6.52	10.46	10.75	...	9.02	7.92	7.02	625
...	6.56	10.48	10.81	...	9.05	7.95	7.04	650
...	6.61	10.50	10.86	...	9.07	7.98	7.08	675
...	6.65	10.52	10.92	...	9.10	8.00	7.11	700
...	6.70	10.55	10.98	...	9.12	8.02	7.14	725
...	6.74	10.57	11.04	...	9.15	8.05	7.18	750
...	6.79	10.60	11.10	...	9.17	8.08	7.22	775
...	6.83	10.62	11.16	...	9.20	8.10	7.25	800
...	6.87	10.65	11.22	...	9.22	...	7.27	825
...	6.92	10.67	11.28	...	9.25	...	7.31	850
...	6.96	10.70	11.34	...	9.27	...	7.34	875
...	7.00	10.72	11.40	...	9.30	...	7.37	900
...	7.05	10.74	11.46	...	9.32	...	7.41	925
...	7.10	10.76	11.52	...	9.35	...	7.44	950
...	7.14	10.78	11.57	...	9.37	...	7.47	975
...	7.19	10.80	11.63	...	9.40	...	7.50	1000
...	...	10.83	11.69	...	9.42	...	...	1025
...	...	10.85	11.74	...	9.45	...	...	1050
...	...	10.88	11.80	...	9.47	...	...	1075
...	...	10.90	11.85	...	9.50	...	...	1100
...	...	10.93	11.91	...	9.52	...	...	1125
...	...	10.95	11.97	...	9.55	...	...	1150
...	...	10.98	12.03	...	9.57	...	...	1175
...	...	11.00	12.09	...	9.60	...	...	1200
...	...	...	...	...	9.64	...	...	1225
...	...	...	...	...	9.68	...	...	1250
...	...	...	...	...	9.71	...	...	1275
...	...	...	...	...	9.75	...	...	1300
...	...	...	...	...	9.79	...	...	1325
...	...	...	...	...	9.83	...	...	1350
...	...	...	...	...	9.86	...	...	1375
...	...	...	...	...	9.90	...	...	1400
...	...	...	...	...	9.94	...	...	1425
...	...	...	...	...	9.98	...	...	1450
...	...	...	...	...	10.01	...	...	1475
...	...	...	...	...	10.05	...	...	1500

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TABLE C-5
THERMAL EXPANSION COEFFICIENTS, NONMETALS[1, 2]

Material Description	Mean Coefficients (Divide Table Values by 10^6)			
	in./in., °F	Range, °F	mm/mm, °C	Range, °C
Thermoplastics				
Acetal AP2012	2	...	3.6	...
Acrylonitrile-butadiene-styrene				
ABS 1208	60	...	108	...
ABS 1210	55	45–55	99	7–13
ABS 1316	40	...	72	...
ABS 2112	40	...	72	...
Cellulose acetate butyrate				
CAB MH08	80	...	144	...
CAB S004	95	...	171	...
Chlorinated poly(vinyl chloride)				
CPVC 4120	35	...	63	...
Polybutylene PB 2110	72	...	130	...
Polyether, chlorinated	45	...	81	...
Polyethylene				
PE 1404	100	46–100	180	8–38
PE 2305	90	46–100	162	8–38
PE 2306	80	46–100	144	8–38
PE 3306	70	46–100	126	8–38
PE 3406	60	46–100	108	8–38
Polyphenylene POP 2125	30	...	54	...
Polypropylene				
PP1110	48	33–67	86	1–19
PP1208	43	...	77	...
PP2105	40	...	72	...
Poly(vinyl chloride)				
PVC 1120	30	23–37	54	−5 to +3
PVC 1220	35	34–40	63	1–4
PVC 2110	50	...	90	...
PVC 2112	45	...	81	...
PVC 2116	40	37–45	72	3–7
PVC 2120	30	...	54	...
Poly(vinylidene fluoride)	79	...	142	...
Poly(vinylidene chloride)	100	...	180	...
Polytetrafluoroethylene	55	73–140	99	23–60
Poly(fluorinated ethylenepropylene)	46–58	73–140	83–104	23–60
Poly(perfluoroalkoxy alkane)	67	70–212	121	21–100
Poly(perfluoroalkoxy alkane)	94	212–300	169	100–149
Poly(perfluoroalkoxy alkane)	111	300–408	200	149–209

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TABLE C-5 (CONT'D)
THERMAL EXPANSION COEFFICIENTS, NONMETALS[1, 2]

Material Description	Mean Coefficients (Divide Table Values by 10^6)			
	in./in., °F	Range, °F	mm/mm, °C	Range, °C
Reinforced Thermosetting Resins and Reinforced Plastic Mortars				
Glass-epoxy, centrifugally cast	9–13	...	16–23.5	...
Glass-polyester, centrifugally cast	9–15	...	16–27	...
Glass-polyester, filament-wound	9–11	...	16–20	...
Glass-polyester, hand lay-up	12–15	...	21.5–27	...
Glass-epoxy, filament-wound	9–13	...	16–23.5	...
Other Nonmetallic Materials				
Borosilicate glass	1.8	...	3.25	...

NOTES:
(1) For Code references to this Appendix, see para. A319.3.1. These data are for use in the absence of more applicable data. It is the designer's responsibility to verify that materials are suitable for the intended service at the temperatures shown.
(2) Individual compounds may vary from the values shown. Consult manufacturer for specific values for products.

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TABLE C-6
MODULUS OF ELASTICITY, U.S. UNITS, FOR METALS

Material	E = Modulus of Elasticity, Msi (Millions of psi), at Temperature, °F									
	−425	−400	−350	−325	−200	−100	70	200	300	400
Ferrous Metals										
Gray cast iron	...	...	...	...	...	...	13.4	13.2	12.9	12.6
Carbon steels, C ≤ 0.3%	31.9	...	...	31.4	30.8	30.2	29.5	28.8	28.3	27.7
Carbon steels, C > 0.3%	31.7	...	...	31.2	30.6	30.0	29.3	28.6	28.1	27.5
Carbon-moly steels	31.7	...	...	31.1	30.5	29.9	29.2	28.5	28.0	27.4
Nickel steels, Ni 2%–9%	30.1	...	...	29.6	29.1	28.5	27.8	27.1	26.7	26.1
Cr-Mo steels, Cr ½%–2%	32.1	...	...	31.6	31.0	30.4	29.7	29.0	28.5	27.9
Cr-Mo steels, Cr 2¼%–3%	33.1	...	...	32.6	32.0	31.4	30.6	29.8	29.4	28.8
Cr-Mo steels, Cr 5%–9%	33.4	...	...	32.9	32.3	31.7	30.9	30.1	29.7	29.0
Chromium steels, Cr 12%, 17%, 27%	31.8	...	...	31.2	30.7	30.1	29.2	28.5	27.9	27.3
Austenitic steels (TP304, 310, 316, 321, 347)	30.8	...	...	30.3	29.7	29.0	28.3	27.6	27.0	26.5
Copper and Copper Alloys (UNS Nos.)										
Comp. and leaded Sn-bronze (C83600, C92200)	...	...	...	14.8	14.6	14.4	14.0	13.7	13.4	13.2
Naval brass, Si- & Al-bronze (C46400, C65500, C95200, C95400)	...	...	...	15.9	15.6	15.4	15.0	14.6	14.4	14.1
Copper (C11000)	...	...	...	16.9	16.6	16.5	16.0	15.6	15.4	15.0
Copper, red brass, Al-bronze (C10200, C12000, C12200, C12500, C14200, C23000, C61400)	...	...	...	18.0	17.7	17.5	17.0	16.6	16.3	16.0
90Cu-10Ni (C70600)	...	...	...	19.0	18.7	18.5	18.0	17.6	17.3	16.9
Leaded Ni-bronze	...	...	...	20.1	19.8	19.6	19.0	18.5	18.2	17.9
80Cu-20Ni (C71000)	...	...	...	21.2	20.8	20.6	20.0	19.5	19.2	18.8
70Cu-30Ni (C71500)	...	...	...	23.3	22.9	22.7	22.0	21.5	21.1	20.7
Nickel and Nickel Alloys (UNS Nos.)										
Monel 400 N04400	28.3	...	...	27.8	27.3	26.8	26.0	25.4	25.0	24.7
Alloys N06007, N08320	30.3	...	...	29.5	29.2	28.6	27.8	27.1	26.7	26.4
Alloys N08800, N08810, N06002	31.1	...	...	30.5	29.9	29.4	28.5	27.8	27.4	27.1
Alloys N06455, N10276	32.5	...	...	31.6	31.3	30.6	29.8	29.1	28.6	28.3
Alloys N02200, N02201, N06625	32.7	...	...	32.1	31.5	30.9	30.0	29.3	28.8	28.5
Alloy N06600	33.8	...	...	33.2	32.6	31.9	31.0	30.2	29.9	29.5
Alloy N10001	33.9	...	...	33.3	32.7	32.0	31.1	30.3	29.9	29.5
Alloy N10665	34.2	...	...	33.3	33.0	32.3	31.4	30.6	30.1	29.8
Unalloyed Titanium										
Grades 1, 2, 3, and 7	...	...	...	...	...	...	15.5	15.0	14.6	14.0

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TABLE C-6
MODULUS OF ELASTICITY, U.S. UNITS, FOR METALS

E = Modulus of Elasticity, MSI (Millions of psi), at Temperature, °F											
500	600	700	800	900	1000	1100	1200	1300	1400	1500	Material
											Ferrous Metals
12.2	11.7	11.0	10.2	...	...	...	...	...	...	...	Gray cast iron
27.3	26.7	25.5	24.2	22.4	20.4	18.0	...	...	...	...	Carbon steels, C ≤ 0.3%
27.1	26.5	25.3	24.0	22.2	20.2	17.9	15.4	...	...	...	Carbon steels, C > 0.3%
27.0	26.4	25.3	23.9	22.2	20.1	17.8	15.3	...	...	...	Carbon-moly steels
25.7	25.2	24.6	23.0	...	...	...	...	...	...	...	Nickel steels, Ni 2%–9%
27.5	26.9	26.3	25.5	24.8	23.9	23.0	21.8	20.5	18.9	...	Cr-Mo steels, Cr ½%–2%
28.3	27.7	27.1	26.3	25.6	24.6	23.7	22.5	21.1	19.4	...	Cr-Mo steels, Cr 2¼%–3%
28.6	28.0	27.3	26.1	24.7	22.7	20.4	18.2	15.5	12.7	...	Cr-Mo steels, Cr 5%–9%
26.7	26.1	25.6	24.7	22.2	21.5	19.1	16.6	...	...	...	Chromium steels, Cr 12%, 17%, 27%
25.8	25.3	24.8	24.1	23.5	22.8	22.1	21.2	20.2	19.2	18.1	Austenitic steels (TP304, 310, 316, 321, 347)
											Copper and Copper Alloys (UNS Nos.)
12.9	12.5	12.0	...	...	...	...	...	...	...	...	Comp. and leaded Sn-bronze (C83600, C92200)
13.8	13.4	12.8	...	...	...	...	...	...	...	...	Naval brass, Si- & Al-bronze (C46400, C65500, C95200, C95400)
14.7	14.2	13.7	...	...	...	...	...	...	..	...	Copper (C11000)
15.6	15.1	14.5	...	...	...	...	...	...	...	...	Copper, red brass, Al-bronze (C10200, C12000, C12200, C12500, C14200, C23000, C61400)
16.6	16.0	15.4	...	...	...	...	...	...	...	...	90Cu-10Ni (C70600)
17.5	16.9	16.2	...	...	...	...	...	...	...	...	Leaded Ni-bronze
18.4	17.8	17.1	...	...	...	...	...	...	...	...	80Cu-20Ni (C71000)
20.2	19.6	18.8	...	...	...	...	...	...	...	...	70Cu-30Ni (C71500)
											Nickel and Nickel Alloys (UNS Nos.)
24.3	24.1	23.7	23.1	22.6	22.1	21.7	21.2	...	...	...	Monel 400 N04400
26.0	25.7	25.3	24.7	24.2	23.6	23.2	22.7	...	...	...	Alloys N06007, N08320
26.6	26.4	25.9	25.4	24.8	24.2	23.8	23.2	...	...	...	Alloys N08800, N08810, N06002
27.9	27.6	27.1	26.5	25.9	25.3	24.9	24.3	...	...	...	Alloys N06455, N10276
28.1	27.8	27.3	26.7	26.1	25.5	25.1	24.5	...	...	...	Alloys N02200, N02201, N06625
29.0	28.7	28.2	27.6	27.0	26.4	25.9	25.3	...	...	...	Alloy N06600
29.1	28.8	28.3	27.7	27.1	26.4	26.0	25.3	...	...	...	Alloy N10001
29.4	29.0	28.6	27.9	27.3	26.7	26.2	25.6	...	...	...	Alloy N10665
											Unalloyed Titanium
13.3	12.6	11.9	11.2	...	...	...	...	...	...	...	Grades 1, 2, 3, and 7

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TABLE C-6 (CONT'D)
MODULUS OF ELASTICITY, U.S. UNITS, FOR METALS

Material	E = Modulus of Elasticity, Msi (Millions of psi), at Temperature, °F									
	-425	-400	-350	-325	-200	-100	70	200	300	400
Aluminum and Aluminum Alloys (UNS Nos.)										
Grades 443, 1060, 1100, 3003, 3004, 6061, 6063 (A24430, A91060, A91100, A93003, A93004, A96061, A96063)	11.4	...	...	11.1	10.8	10.5	10.0	9.6	9.2	8.7
Grades 5052, 5154, 5454, 5652 (A95052, A95154, A95454, A95652)	11.6	...	...	11.3	11.0	10.7	10.2	9.7	9.4	8.9
Grades 356, 5083, 5086, 5456 (A03560, A95083, A95086, A95456)	11.7	...	...	11.4	11.1	10.8	10.3	9.8	9.5	9.0

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TABLE C-8
MODULUS OF ELASTICITY, NONMETALS[1]

Material Description	*E*, ksi (73.4°F)	*E*, MPa (23°C)
Thermoplastics [Note (2)]		
Acetal	410	2,830
ABS, Type 1210	250	1,725
ABS, Type 1316	340	2,345
CAB	120	825
PVC, TYPE 1120	420	2,895
PVC, Type 1220	410	2,825
PVC, Type 2110	340	2,345
PVC, Type 2116	380	2,620
Chlorinated PVC	420	2,895
Chlorinated polyether	160	1,105
PE, Type 2306	90	620
PE, Type 3306	130	895
PE, Type 3406	150	1,035
Polypropylene	120	825
Poly(vinylidene chloride)	100	690
Poly(vinylidene fluoride)	194	1,340
Poly(tetrafluorethylene)	57	395
Poly(fluorinated ethylenepropylene)	67	460
Poly(perfluoroalkoxy alkane)	100	690
Thermosetting Resins, Axially Reinforced		
Epoxy-glass, centrifugally cast	1200–1900	8,275–13,100
Epoxy-glass, filament-wound	1100–2000	7,585–13,790
Polyester-glass, centrifugally cast	1200–1900	8,275–13,100
Polyester-glass, hand lay-up	800–1000	5,515–6,895
Other		
Borosilicate glass	9800	67,570

NOTES:
(1) For Code references to this Appendix, see para. A319.3.2. These data are for use in the absence of more applicable data. It is the designer's responsibility to verify that materials are suitable for the intended service at the temperatures shown.
(2) The modulus of elasticity data shown for thermoplastics are based on short term tests. The manufacturer should be consulted to obtain values for use under long term loading.

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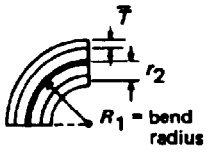
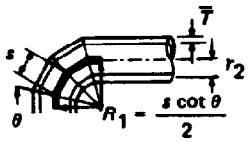
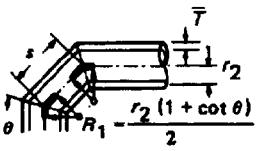
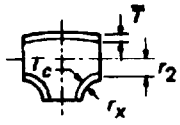
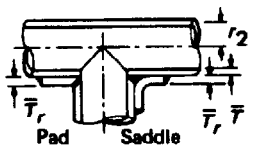
APPENDIX D
FLEXIBILITY AND STRESS INTENSIFICATION FACTORS

TABLE D300[1]
FLEXIBILITY FACTOR, k AND STRESS INTENSIFICATION FACTOR, i

Description	Flexibility Factor, k	Stress Intensification Factor [Notes (2), (3)] Out-of-Plane, i_o	Stress Intensification Factor [Notes (2), (3)] In-Plane, i_i	Flexibility Characteristic, h	Sketch
Welding elbow or pipe bend [Notes (2), (4)-(7)]	$\frac{1.65}{h}$	$\frac{0.75}{h^{2/3}}$	$\frac{0.9}{h^{2/3}}$	$\frac{\overline{T}R_1}{r_2^2}$	
Closely spaced miter bend $s < r_2 (1 + \tan \theta)$ [Notes (2), (4), (5), (7)]	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.9}{h^{2/3}}$	$\frac{\cot \theta}{2}\left(\frac{s\overline{T}}{r_2^2}\right)$	
Single miter bend or widely spaced miter bend $s \geq r_2 (1 + \tan \theta)$ [Notes (2), (4), (7)]	$\frac{1.52}{h^{5/6}}$	$\frac{0.9}{h^{2/3}}$	$\frac{0.9}{h^{2/3}}$	$\frac{1 + \cot \theta}{2}\left(\frac{\overline{T}}{r_2}\right)$	
Welding tee per ASME B16.9 with $r_x \geq \frac{1}{8} D_b$ $T_c \geq 1.5\,\overline{T}$ [Notes (2), (4), (6), (11), (13)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4} i_o + \frac{1}{4}$	$4.4\,\frac{\overline{T}}{r_2}$	
Reinforced fabricated tee with pad or saddle [Notes (2), (4), (8), (12), (13)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4} i_o + \frac{1}{4}$	$\frac{(\overline{T} + \frac{1}{2}\overline{T}_r)^{2.5}}{\overline{T}^{1.5} r_2}$	

Notes to this Table follow on p. 258

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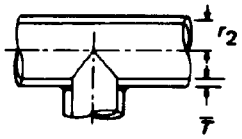
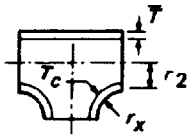
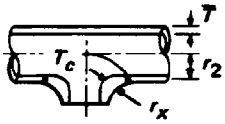
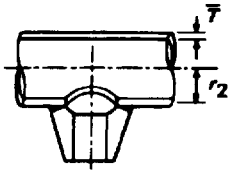
TABLE D300[1] (CONT'D)
FLEXIBILITY FACTOR, k AND STRESS INTENSIFICATION FACTOR, i

Description	Flexibility Factor, k	Stress Intensification Factor [Notes (2), (3)] Out-of-Plane, i_o	Stress Intensification Factor [Notes (2), (3)] In-Plane, i_i	Flexibility Characteristic, h	Sketch
Unreinforced fabricated tee [Notes (2), (4), (12), (13)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4}i_o + \frac{1}{4}$	$\frac{\overline{T}}{r_2}$	
Extruded welding tee with $\frac{r_x}{T_c} \geq 0.05\frac{D_b}{\overline{T}}$ $T_c < 1.5\,\overline{T}$ [Notes (2), (4), (13)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4}i_o + \frac{1}{4}$	$\left(1 + \frac{r_x}{r_2}\right)\frac{\overline{T}}{r_2}$	
Welded-in contour insert with $r_x \geq \frac{1}{8}\,D_b$ $T_c \geq 1.5\,\overline{T}$ [Notes (2), (4), (11), (13)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{3}{4}i_o + \frac{1}{4}$	$4.4\,\frac{\overline{T}}{r_2}$	
Branch welded-on fitting (integrally reinforced) [Notes (2), (4), (9), (12)]	1	$\frac{0.9}{h^{2/3}}$	$\frac{0.9}{h^{2/3}}$	$3.3\,\frac{\overline{T}}{r_2}$	

Description	Flexibility Factor, k	Stress Intensification Factor, i [Note (1)]
Butt welded joint, reducer, or weld neck flange	1	1.0
Double-welded slip-on flange	1	1.2
Fillet welded joint, or socket weld flange or fitting	1	Note (14)
Lap joint flange (with ASME B16.9 lap joint stub)	1	1.6
Threaded pipe joint, or threaded flange	1	2.3
Corrugated straight pipe, or corrugated or creased bend [Note (10)]	5	2.5

Notes to this Table follow on p. 258

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TABLE D300[1] (CONT'D)
FLEXIBILITY FACTOR, k AND STRESS INTENSIFICATION FACTOR, i

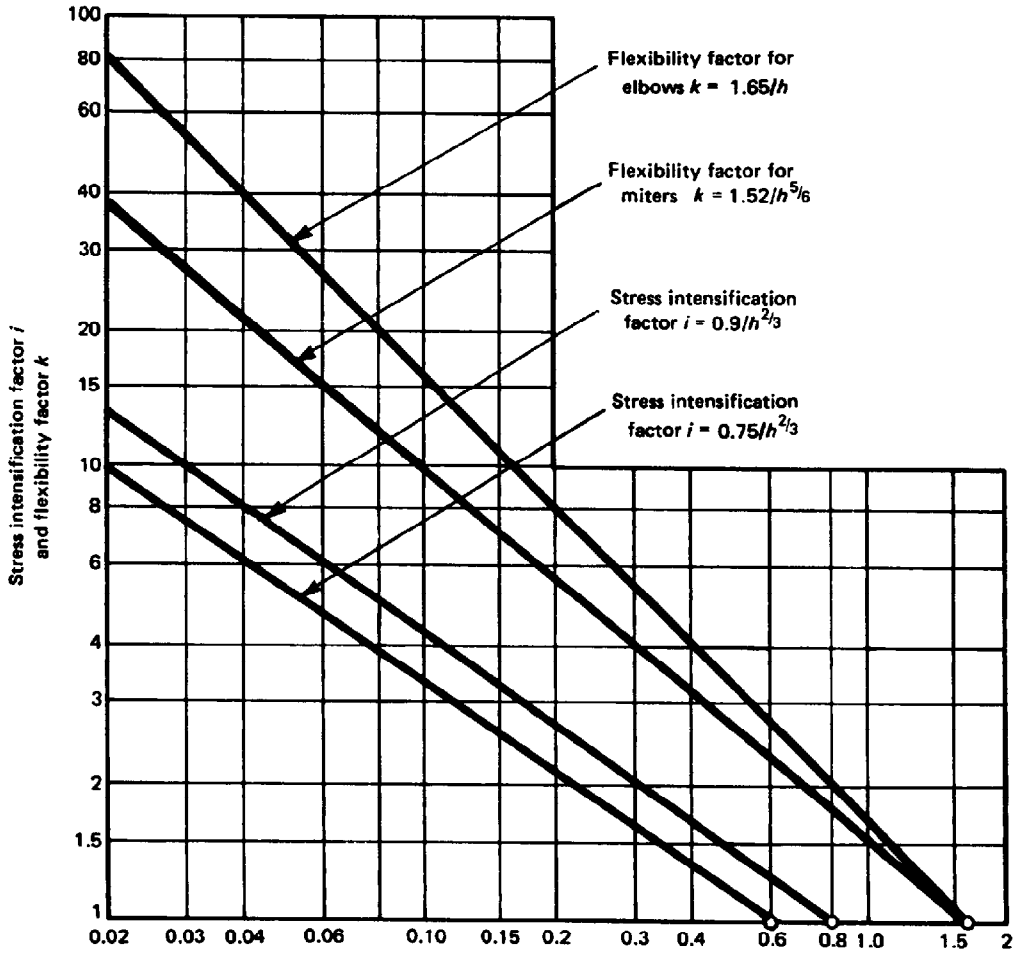

Chart A

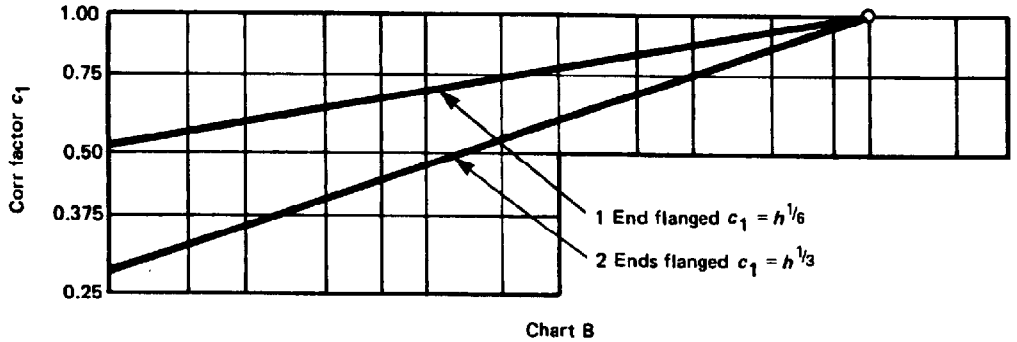

Chart B

Notes to this Table follow on next page

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TABLE D300 (CONT'D)

NOTES:

(1) Stress intensification and flexibility factor data in Table D300 are for use in the absence of more directly applicable data (see para. 319.3.6). Their validity has been demonstrated for $D/\overline{T} \leq 100$.

(2) The flexibility factor k in the Table applies to bending in any plane. The flexibility factors k and stress intensification factors i shall not be less than unity; factors for torsion equal unity. Both factors apply over the effective arc length (shown by heavy center lines in the sketches) for curved and miter bends, and to the intersection point for tees.

(3) A single intensification factor equal to $0.9/h^{2/3}$ may be used for both i_i and i_o if desired.

(4) The values of k and i can be read directly from Chart A by entering with the characteristic h computed from the formulas given above. Nomenclature is as follows:

$\overline{T}$ = for elbows and miter bends, the nominal wall thickness of the fitting
= for tees, the nominal wall thickness of the matching pipe
$\overline{T}_c$ = the crotch thickness of tees
$\overline{T}_r$ = pad or saddle thickness
θ = one-half angle between adjacent miter axes
r_2 = mean radius of matching pipe
R_1 = bend radius of welding elbow or pipe bend
r_x = see definition in para. 304.3.4(c)
s = miter spacing at center line
D_b = outside diameter of branch

(5) Where flanges are attached to one or both ends, the values of k and i in the Table shall be corrected by the factors C_1, which can be read directly from Chart B, entering with the computed h.

(6) The designer is cautioned that cast buttwelded fittings may have considerably heavier walls than that of the pipe with which they are used. Large errors may be introduced unless the effect of these greater thicknesses is considered.

(7) In large diameter thin-wall elbows and bends, pressure can significantly affect the magnitudes of k and i. To correct values from the Table, divide k by

$$\left[1 + 6\left(\frac{P}{E}\right)\left(\frac{r_2}{\overline{T}}\right)^{7/3}\left(\frac{R_1}{r_2}\right)^{1/3}\right]$$

divide i by

$$\left[1 + 3.25\left(\frac{P}{E}\right)\left(\frac{r_2}{\overline{T}}\right)^{5/2}\left(\frac{R_1}{r_2}\right)^{2/3}\right]$$

For consistency, use kPa and mm for SI metric, and psi and in. for US customary notation.

(8) When $\overline{T}_r$ is $> 1\frac{1}{2}\ \overline{T}$, use $h = 4\ \overline{T}/r_2$.

(9) The designer must be satisfied that this fabrication has a pressure rating equivalent to straight pipe.

(10) Factors shown apply to bending. Flexibility factor for torsion equals 0.9.

(11) When the radius and thickness limits are not met for this component, and in the absence of more directly applicable data (see para. 319.3.6), the flexibility characteristic h shall be $\overline{T}/r_2$.

(12) The out-of-plane stress intensification factor (SIF) for a reducing branch connection with branch-to-run diameter ratio of $0.5 < d/D < 1.0$ may be nonconservative. A smooth concave weld contour has been shown to reduce the SIF. Selection of the appropriate SIF is the designer's responsibility.

(13) Stress intensification factors for branch connections are based on tests with at least two diameters of straight run pipe on each side of the branch center line. More closely loaded branches may require special consideration.

(14) 2.1 max. or $2.1\ \overline{T}/C_x$, but not less than 1.3. C_x is the fillet weld leg length (see Fig. 328.5.2C. For unequal leg lengths, use the smaller leg for C_x.

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APPENDIX E
REFERENCE STANDARDS[1, 2]

(99)

Standards incorporated in this Code by reference, and the names and addresses of the sponsoring organizations are shown in this Appendix. It is not practical to refer to a specific edition of each standard throughout the Code text; instead, the specific edition reference dates are shown here. Subsequent issues and revisions of these referenced standards and any new standards incorporated in the Code by reference in Code Addenda will be listed (after review and acceptance by the Code Committee) in revisions of this Appendix E.

A component ordinarily is not marked to indicate the edition date of the standard to which it is manufactured. It is therefore possible that an item taken from inventory was produced in accordance with a superseded edition, or an edition not yet approved by the Code (because it is of later date than that listed and is in use). If compliance with a specific edition is a requirement of the intended service, it usually will be necessary to state the specific requirement in the purchase specification and to maintain identification of the component until it is put in service.

ASTM Specifications

A 20-96a
A 36-96
A 47-90 (R1996)
A 48-94a
A 53-96
A 105-96
A 106-95
A 126-95
A 134-93
A 135-96
A 139-93a
A 167-96
A 179-90a
A 181-95b
A 182-97c
A 193-96b
A 194-96
A 197-87 (R1992)
A 202-93
A 203-97
A 204-93
A 210-95
A 216-93
A 217-95
A 234-97
A 240-96a
A 263-94a
A 264-94a
A 265-94a
A 268-96
A 269-96
A 276-96
A 278-93
A 283-93a
A 285-90 (R1996)
A 299-90 (R1996)

ASTM Specifications (Cont'd)

A 302-97
A 307-94
A 312-95a
A 320-95
A 325-97
A 333-94
A 334-96
A 335-95a
A 350-96c
A 351-94a
A 352-93
A 353-93
A 354-95
A 358-95a
A 369-92
A 370-97
A 376-96
A 381-93
A 387-92
A 395-88 (R1993)
A 403-96
A 409-95a
A 420-96a
A 426-92
A 430-91
A 437-95
A 451-93
A 452-88
A 453-96
A 479-96
A 487-93
A 494-94
A 508-95
A 515-92
A 516-90 (R1996)
A 524-93
A 530-96
A 537-95

ASTM Specifications (Cont'd)

A 553-95
A 563-94
A 570-96
A 571-84 (R1992)
A 587-93
A 645-97
A 671-94
A 672-94
A 675-95
A 691-93
A 723-94
A 789-95
A 790-95
A 815-94
B 21-96
B 26-97
B 42-93
B 43-94
B 61-93
B 62-93
B 68-92a
B 75-95
B 88-95a
B 96-93
B 98-93
B 127-93a
B 148-93a
B 150-95
B 152-94
B 160-93
B 161-93
B 162-93a
B 164-93
B 165-93
B 166-97a
B 167-97a

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REFERENCE STANDARDS (CONT'D)

ASTM Specifications (Cont'd)

B 168-97a
B 169-95
B 171-95
B 187-94
B 209-96
B 210-95
B 211-95a
B 221-96
B 241-96
B 247-95a
B 265-95a

B 280-95
B 283-94

B 333-97
B 335-97
B 337-95
B 338-95
B 345-96

B 361-95
B 363-95
B 366-97
B 381-95a

B 407-96
B 409-96a
B 435-97
B 443-93
B 444-94
B 446-93

B 462-95
B 463-93
B 464-93
B 466-92a
B 467-88
B 491-92a
B 493-83 (R1993)

B 514-95
B 517-97
B 523-92
B 550-92

B 551-92
B 564-97a
B 574-97
B 575-97
B 581-97
B 582-97
B 584-93b

B 619-97
B 620-93

ASTM Specifications (Cont'd)

B 621-95a
B 622-97
B 625-95
B 649-95

B 658-92
B 675-96
B 688-96
B 690-96
B 705-94
B 725-93
B 729-95
B 804-96

C 14-82
C 301-79
C 361-90

C 582-87
C 599-70 (R1984)

D 1527-89
D 1600-90
D 1694-87
D 1785-89

D 2104-89a
D 2235-88
D 2239-89
D 2241-89
D 2282-89
D 2310-80 (R1986)
D 2321-89
D 2447-89
D 2464-90
D 2466-90a
D 2467-90
D 2468-89

D 2513-90b
D 2517-81 (R1987)
D 2564-88
D 2609-90
D 2657-90
D 2662-89
D 2666-89
D 2672-89
D 2683-90
D 2737-89
D 2837-90
D 2846-90
D 2855-90
D 2992-87
D 2996-88
D 2997-90

ASTM Specifications (Cont'd)

D 3000-89

D 3035-89a
D 3139-89
D 3140-90
D 3261-90
D 3309-89a

D 3517-88
D 3754-88
D 3839-89
D 3840-88

D 4024-87
D 4161-86

D 5421-93

E 112-85
E 114-85
E 125-63 (R1985)
E 142-86
E 155-85
E 165-80 (R1983)
E 186-84
E 213-93
E 272-75 (R1984)
E 280-84
E 310-75 (R1984)
E 446-84

E 709-80 (R1985)
F 336-92
F 423-95
F 437-96a
F 438-96a
F 439-96a
F 441/441M-96b
F 442/F 442M-96b
F 491-95
F 492-95
F 493-96

F 546-95
F 599-95
F 781-95
F 1055-95a
F 1290-93

F 1545-95

ASCE Standard

7-95

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REFERENCE STANDARDS (CONT'D)

ASME Codes

ASME Boiler and PressureVessel Code, 1995 Ed. (A1997)
* Section II, Part D
* Section V
* Section VIII, Division 1
* Section VIII, Division 2
* Section IX

ASME Standards

B1.1-1989
* B1.20.1-1983 (1992)
B1.20.3-1976 (R1991)
B1.20.7-1991

* B16.1-1989
* B16.3-1992
* B16.4-1992
* B16.5-1996
* B16.9-1993
* B16.10-1992
* B16.11-1991
* B16.14-1991
* B16.15-1985 (R1994)
* B16.20-1993

* B16.21-1992
* B16.22-1995
* B16.24-1991
* B16.25-1992
* B16.26-1988
* B16.28-1994
* B16.34-1996
* B16.36-1996
* B16.39-1986 (R1994)

* B16.42-1987
* B16.47-1996

* B18.2.1-1996
* B18.2.2-1987 (R1993)

* B36.10M-1996
* B36.19M-1985 (R1994)

* B46.1-1995

*American National Standards

A21.14-1984
A21.52-1982

B16.18-1984 (R1994)

B93.11-1981

API Specifications

5B, 1996
5L, 41st Ed., 1995
15LE, 3rd Ed., 1995
15LP, 5th Ed., 1981
15LR, 6th Ed., 1990

API Standards

* 526, 1995
594, 4th Ed., 1991
599, 1994
600, 1997

602, 6th Ed., 1993
603, 5th Ed., 1991

608, 1995
609, 4th Ed., 1991

API Recommended Practice

RP 941, 5th Ed., 1997

ASNT Standard

SNT TC-1A-1996

AWS Standards

* A3.0-1994
* A5.1-1992
* A5.4-1992
* A5.5-1996
A5.9-1993
A5.11-1990
A5.14-1989
A5.22-1995

AWWA Standards

* C110-1993
* C111-1995
* C115-1994
* C150-1996
* C151-1996
* C200-1991
* C207-1994
C208-1996
* C300-1997
* C301-1992

AWWA Standards (Cont'd)

* C302-1995
* C500-1993

* C504-1994
* C900-1989
* C950-1995

CDA Publication

Copper Tabe Handbook, 1980

CGA Publication

G-4.1-1996

CSA Publication

Z245.1-1998

EJMA Publication

EJMA Standards, 6th Ed., (A1995)

ICBO Publication

Uniform Building Code, 1994 Edition

MSS Standard Practices

SP-6-1996
SP-9-1997
SP-25-1993

SP-42-1990 (R1995)
SP-43-1991 (R1996)
SP-44-1996
SP-45-1992
SP-51-1991 (R1995)
SP-53-1995
SP-55-1996
* SP-58-1993
SP-65-1994
SP-70-1990

SP-71-1997
SP-72-1992
SP-73-1991 (R1996)

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REFERENCE STANDARDS (CONT'D)

MSS Standard Practices (Cont'd)

SP-75-1993
SP-79-1992
SP-80-1997
SP-81-1995
SP-83-1995
SP-85-1994
SP-88-1993
SP-95-1986 (R1991)
SP-97-1995
SP-105-1990

NACE Publication

Corrosion Data Survey, 1985
MR 0175-97
RP 0170-93 (R1997)
RP 0472-95

NBS Publication

NFPA Specification

* 1963-1993

PFI Standard

ES-7-1994

PPI Technical Report

TR-21-1974

SAE Specifications

* J 513-1996
* J 514-1996
* J 518-1993

NOTES:
(1) The issue date shown immediately following the hyphen after the number of the standard (e.g., B16.9-1978, C207-1978, and A 47-77) is the effective date of the issue (edition) of the standard. Any additional number shown following the issue date and prefixed by the letter "R" is the latest date of reaffirmation [e.g., C101-1967 (R1977)]. Any edition number prefixed by the letter "A" is the date of the latest addenda accepted [e.g., B16.36-1975 (A1979)].
(2) * Indicates that the standard has been approved as an American National Standard by the American National Standards Institute.

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Specifications and standards of the following organizations, appear in Appendix E:

API American Petroleum Institute
Publications and Distribution Section
1220 L Street, NW
Washington, DC 20005-4070
202 682-8375

ASCE The American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia 20191-4400
703 295-6000 or 800 548-2773

ASME ASME International
Three Park Avenue
New York, New York 10016-5990
212 591-8500

ASME Order Department
22 Law Drive
Box 2300
Fairfield, New Jersey 07007-2300
201 882-1167 or 800 843-2763

ASNT American Society for Nondestructive Testing, Inc.
P.O. Box 28518
1711 Arlingate Lane
Columbus, Ohio 43228-0518
614 274-6003 or 800 222-2768

ASTM American Society for Testing and Materials
100 Barr Harbor Drive
West Conshohocken, Pennsylvania
19428-2959
610 832-9500

AWWA American Water Works Association
6666 W. Quincy Avenue
Denver, Colorado 80235
303 794-7711 or 800 926-7337

AWS American Welding Society
550 NW LeJeune Road
Miami, Florida 33126
305 443-9353 or 800 443-9353

CDA Copper Development Association, Inc.
260 Madison Avenue, 16th Floor
New York, New York 10016
212 251-7200 or 800 232-3282

CGA Compressed Gas Association, Inc.
1725 Jefferson Davis Highway; Suite 1004
Arlington, Virginia 22202-4102
703 412-0900

CSA Canadian Standards Association
178 Rexdale Boulevard
Etobicoke (Toronto), Ontario
M9W 1R3, Canada

EJMA Expansion Joint Manufacturers Association
25 North Broadway
Tarrytown, New York 10591
914 332-0040

ICBO International Conference of Building Officials
5360 South Workman Mill Road
Whittier, California 90601-2298
562 692-4226 or 800 284-4406

MSS Manufacturers Standardization Society ofthe Valve and Fittings Industry, Inc.
127 Park Street, NE
Vienna, Virginia 22180-4602
703 281-6613

NACE NACE International
P.O. Box 218340
Houston, Texas 77218-8340
281 228-6200

NFPA National Fire Protection Association
11 Tracy Drive
Avon, Massachusetts 02322
617 770-3000 or 800 344-3555

NIST National Institute of Standards and Technology
Publications available from
Superintendent of Documents
United States Government Printing Office
Washington, DC 20402-9325
202 512-1800

PFI Pipe Fabrication Institute
P.O. Box 173
612 Lenore Avenue
Springdale, Pennsylvania 15144
412 274-4722

PPI Plastics Pipe Institute
1801 K Street NW; Suite 600K
Washington, DC 20006-1301
202 974-5200 or 800 541-0786

SAE Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, Pennsylvania 15096-0001
412 776-4970 or 800 832-6723

GENERAL NOTE TO LIST OF ORGANIZATIONS:
Some of the organizations listed above publish standards which have been approved as American National Standards. Copies of these standards may also be obtained from:

ANSI American National Standards Institute, Inc.
11 West 42nd Street
New York, New York 10036
212 642-4900

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APPENDIX F
PRECAUTIONARY CONSIDERATIONS

F300 GENERAL

This Appendix provides guidance for the designer in the form of precautionary considerations relating to particular fluid services and piping applications. These are not Code requirements but should be taken into account as applicable in the engineering design. Further information on these subjects can be found in the literature.

F301 DESIGN CONDITIONS

Selection of pressures, temperatures, and various forces that may apply to the design of piping can be influenced by unusual requirements which should be considered when they occur. These include but are not limited to the following.

F301.4 Ambient Effects

Where fluids can be trapped (e.g., in double seated valves) and subjected to heating and consequent expansion, means of pressure relief should be considered to avoid excessive pressure buildup.

F301.5 Dynamic Effects

geysering: an effect that can occur in piping handling fluids at or near their boiling temperatures under conditions when rapid evolution of vapor within the piping causes rapid expulsion of liquid. In such cases a pressure surge can be generated that may be destructive to the piping. (Geysering usually is associated with vertical pipelines but may occur in inclined lines under certain conditions.)

F301.7 Thermal Expansion and Contraction Effects

bowing during cooldown: an effect that can occur, usually in horizontal piping, on introduction of a fluid at or near its boiling temperature and at a flow rate that allows stratified two-phase flow, causing largecircumferential temperature gradients and possibly unacceptable stresses at anchors, supports, guides, and within pipe walls. (Two-phase flow can also generate excessive pressure oscillations and surges that may damage the piping.)

F304 PRESSURE DESIGN

F304.7 Pressure Design of Other Metallic Components

F304.7.4 Expansion Joints. The following are specific considerations to be evaluated by the designer when specifying expansion joint requirements, in addition to the guidelines given in EJMA Standards:

(a) susceptibility to stress corrosion cracking of the materials of construction, considering specific alloy content, method of manufacture, and final heat treated condition;

(b) consideration of not only the properties of the flowing medium but also the environment external to the expansion joint and the possibility of condensation or ice formation due to the operation of the bellows at a reduced temperature;

(c) consideration of specifying a minimum bellows or ply thickness. The designer is cautioned that requiring excessive bellows thickness may reduce the fatigue life of the expansion joint and increase end reactions.

(d) accessibility of the expansion joint for maintenance and inspection;

(e) need for leak tightness criteria for mechanical seals on slip type joints;

(f) specification of installation procedures and shipping or preset bars so that the expansion joint will not be extended, compressed, or offset to compensate for improper alignment of piping, other than the intentional offset specified by the piping designer;

(g) need to request data from the expansion joint manufacturer, including:

(1) effective thrust area;

(2) lateral, axial, and rotational stiffness (spring constant);

(3) calculated design cycle life under specified design conditions;

(4) friction force in hinges, tie rods, etc.;

(5) installed length and weight;

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(6) requirements for additional support or restraint in the piping;

(7) expansion joint elements that are designed to be uninsulated during operation;

(8) certification of pressure containing and/or restraining materials of construction;

(9) maximum test pressure;

(10) design calculations.

F307 VALVES

(a) Extended bonnet valves are recommended where necessary to establish a temperature differential between the valve stem packing and the fluid in the piping, to avoid packing leakage and external icing or other heat flux problems. The valve should be positioned to provide this temperature differential. Consideration should be given to possible packing shrinkage in low temperature fluid service.

(b) The effect of external loads on valve operability and leak tightness should be considered.

F308 FLANGES AND GASKETS

F308.2 Specific Flanges

Slip-On Flanges. The need for venting the space between the welds in double-welded slip-on flanges should be considered for fluid services (including vacuum) that require leak testing of the inner fillet weld, or when fluid handled can diffuse into the enclosed space, resulting in possible failure.

F308.4 Gaskets

(a) Gasket materials not subject to cold flow should be considered for use with raised face flanges for fluid services at elevated pressures with temperatures significantly above or below ambient.

(b) Use of full face gaskets with flat faced flanges should be considered when using gasket materials subject to cold flow for low pressure and vacuum services at moderate temperatures. When such gasket materials are used in other fluid services, the use of tongue-and-groove or other gasket-confining flange facings should be considered.

(c) The effect of flange facing finish should be considered in gasket material selection.

F309 BOLTING

F309.1 General

The use of controlled bolting procedures should be considered in high, low, and cycling temperature services, and under conditions involving vibration or fatigue, to reduce:

(a) the potential for joint leakage due to differential thermal expansion;

(b) the possibility of stress relaxation and loss of bolt tension.

F312 FLANGED JOINTS

F312.1 General

Three distinct elements of a flanged joint must act together to provide a leak-free joint: the flanges, the gasket, and the bolting. Factors that affect performance include:

(a) *Selection and Design*

(1) consideration of service conditions (including external loads, bending moments, and application of thermal insulation);

(2) flange rating, type, material, facing, and facing finish (see para. F308.2);

(3) gasket type, material, thickness, and design (see para. F308.4);

(4) bolt material, strength (cold and at temperature), and specifications for tightening of bolts (see para. F309.1); and

(5) design for access to the joint.

(b) *Installation*

(1) condition of flange mating surfaces;

(2) joint alignment and gasket placement before boltup; and

(3) implementation of specified bolting procedures.

F322 DESIGN CONSIDERATIONS FOR SPECIFIC SYSTEMS

F322.6 Pressure Relief Piping

Stop Valves in Pressure Relief Piping. If stop valves are located in pressure relief piping in accordance with para. 322.6.1(a), and if any of these stop valves are to be closed while the equipment is in operation, an authorized person should be present. The authorized person should remain in attendance at a location where

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the operating pressure can be observed and should have access to means for relieving the system pressure in the event of overpressure. Before leaving the station the authorized person should lock or seal the stop valves in the open position.

F323 MATERIALS

(a) Selection of materials to resist deterioration in service is not within the scope of this Code. However, suitable materials should be specified or selected for use in piping and associated facilities not covered by this Code but which affect the safety of the piping. Consideration should be given to allowances made for temperature and pressure effects of process reactions, for properties of reaction or decomposition products, and for hazards from instability of contained fluids.

(b) Information on material performance in corrosive environments can be found in publications, such as "The Corrosion Data Survey" published by the National Association of Corrosion Engineers.

F323.1 General Considerations

Following are some general considerations which should be evaluated when selecting and applying materials in piping (see also para. FA323.4):

(a) the possibility of exposure of the piping to fire and the melting point, degradation temperature, loss of strength at elevated temperature, and combustibility of the piping material under such exposure;

(b) the susceptibility to brittle failure or failure from thermal shock of the piping material when exposed to fire or to fire-fighting measures, and possible hazards from fragmentation of the material in the event of failure;

(c) the ability of thermal insulation to protect piping against failure under fire exposure (e.g., its stability, fire resistance, and ability to remain in place during a fire);

(d) the susceptibility of the piping material to crevice corrosion under backing rings, in threaded joints, in socket welded joints, and in other stagnant, confined areas;

(e) the possibility of adverse electrolytic effects if the metal is subject to contact with a dissimilar metal;

(f) the compatibility of lubricants or sealants used on threads with the fluid service;

(g) the compatibility of packing, seals, and O-rings with the fluid service;

(h) the compatibility of materials, such as cements, solvents, solders, and brazing materials, with the fluid service;

(i) the chilling effect of sudden loss of pressure on highly volatile fluids as a factor in determining the lowest expected service temperature;

(j) the possibility of pipe support failure resulting from exposure to low temperatures (which may embrittle the supports) or high temperatures (which may weaken them);

(k) the compatibility of materials, including sealants, gaskets, lubricants, and insulation, used in strong oxidizer fluid service (e.g., oxygen or fluorine).

F323.4 Specific Material Considerations — Metals

Following are some specific considerations which should be evaluated when applying certain metals in piping.

(a) Irons — Cast, Malleable, and High Silicon (14.5%). Their lack of ductility and their sensitivity to thermal and mechanical shock.

(b) Carbon Steel, and Low and Intermediate Alloy Steels

(1) the possibility of embrittlement when handling alkaline or strong caustic fluids;

(2) the possible conversion of carbides to graphite during long time exposure to temperatures above 427°C (800°F) of carbon steels, plain nickel steel, carbon-manganese steel, manganese-vanadium steel, and carbon-silicon steel;

(3) the possible conversion of carbides to graphite during long time exposure to temperatures above 468°C (875°F) of carbon-molybdenum steel, manganese-molybdenum-vanadium steel, and chromium-vanadium steel;

(4) the advantages of silicon-killed carbon steel (0.1% silicon minimum) for temperatures above 482°C (900°F);

(5) the possibility of damage due to hydrogen exposure at elevated temperature (see API RP 941); hydrogen damage (blistering) may occur at lower temperatures under exposure to aqueous acid solutions;[1]

---

[1] Titles of referenced documents are:
API RP 941, Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants
NACE MR 0175, Sulfide Stress-Cracking Resistant Metallic Materials for Oil Field Equipment
NACE RP 0472, Methods and Controls to Prevent In-Service Cracking of Carbon Steel (P-1) Welds in Corrosive Petroleum Refining Environments
NACE RP 0170, Protection of Austenitic Stainless Steel in Refineries Against Stress Corrosion Cracking by Use of Neutralizing Solutions During Shutdown

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(6) the possibility of stress corrosion cracking when exposed to cyanides, acids, acid salts, or wet hydrogen sulfide; a maximum hardness limit is usually specified (see NACE MR 0175 and RP 0472);[1]

(7) the possibility of sulfidation in the presence of hydrogen sulfide at elevated temperatures.

(c) High Alloy (Stainless) Steels

(99) *(1)* the possibility of stress corrosion cracking of austenitic stainless steels exposed to media such as chlorides and other halides either internally or externally; the latter can result from improper selection or application of thermal insulation, or from use of marking inks, paints, labels, tapes, adhesives, and other accessory materials containing chlorides or other halides;

(2) the susceptibility to intergranular corrosion of austenitic stainless steels sensitized by exposure to temperatures between 427°C and 871°C (800°F and 1600°F); as an example, stress corrosion cracking of sensitized metal at room temperature by polythionic acid (reaction of oxidizable sulfur compound, water, and air); stabilized or low carbon grades may provide improved resistance (see NACE RP 0170);[1]

(3) the susceptibility to intercrystalline attack of austenitic stainless steels on contact with liquid metals (including aluminum, antimony, bismuth, cadmium, gallium, lead, magnesium, tin, and zinc) or their compounds;

(4) the brittleness of ferritic stainless steels at room temperature after service at temperature above 371°C (700°F).

(d) Nickel and Nickel Base Alloys

(1) the susceptibility to grain boundary attack of nickel and nickel base alloys not containing chromium when exposed to small quantities of sulfur at temperatures above 316°C (600°F);

(2) the susceptibility to grain boundary attack of nickel base alloys containing chromium at temperatures above 593°C (1100°F) under reducing conditions and above 760°C (1400°F) under oxidizing conditions;

(3) the possibility of stress corrosion cracking of nickel-copper Alloy 400 in hydrofluoric acid vapor in the presence of air, if the alloy is highly stressed (including residual stresses from forming or welding).

(e) Aluminum and Aluminum Alloys

(1) the compatibility with aluminum of thread compounds used in aluminum threaded joints to prevent seizing and galling;

(2) the possibility of corrosion from concrete, mortar, lime, plaster, or other alkaline materials used in buildings or structures;

(3) the susceptibility of Alloy Nos. 5083, 5086, 5154, and 5456 to exfoliation or intergranular attack; and the upper temperature limit of 66°C (150°F) shown in Appendix A to avoid such deterioration.

(f) Copper and Copper Alloys

(1) the possibility of dezincification of brass alloys;

(2) the susceptibility to stress-corrosion cracking of copper-based alloys exposed to fluids such as ammonia or ammonium compounds;

(3) the possibility of unstable acetylide formation when exposed to acetylene.

(g) Titanium and Titanium Alloys. The possibility of deterioration of titanium and its alloys above 316°C (600°F);

(h) Zirconium and Zirconium Alloys. The possibility of deterioration of zirconium and zirconium alloys above 316°C (600°F);

(i) Tantalum. Above 299°C (570°F), the possibility of reactivity of tantalum with all gases except the inert gases. Below 299°C, the possibility of embrittlement of tantalum by nascent (monatomic) hydrogen (but not molecular hydrogen). Nascent hydrogen is produced by galvanic action, or as a product of corrosion by certain chemicals.

(j) Metals With Enhanced Properties. The possible loss of strength, in a material whose properties have been enhanced by heat treatment, during long-continued exposure to temperatures above its tempering temperature.

(k) The desirability of specifying some degree of production impact testing, in addition to the weld procedure qualification tests, when using materials with limited low temperature service experience below the minimum temperature stated in Table A-1.

F331 HEAT TREATMENT

F331.1 Heat Treatment Considerations

Heat treatment temperatures listed in Table 331.1.1 for some P-No. 4 and P-No. 5 materials may be higher than the minimum tempering temperatures specified in the ASTM specifications for the base material. For higher-strength normalized and tempered materials, there is consequently a possibility of reducing tensile properties of the base material, particularly if long holding times at the higher temperatures are used.

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F335 ASSEMBLY AND ERECTION

F335.9 Cleaning of Piping

Following are some general considerations which may be evaluated in determining the need for cleaning of piping:

(a) requirements of the service, including possible contaminants and corrosion products during fabrication, assembly, storage, erection, and testing;

(b) for low temperature service, removal of moisture, oil, grease, and other contaminants to prevent sticking of valves or blockage of piping and small cavities; and

(c) for strong oxidizer fluid service (e.g., oxygen or fluorine), special cleaning and inspection. Reference may be made to the Compressed Gas Association's Pamphlet G-4.1 Cleaning Equipment for Oxygen Service.

FA323.4 Material Considerations — Nonmetals

Following are some considerations to be evaluated when applying nonmetals in piping. See also paras. F323 and F323.1.

(a) Static Charges. Because of the possibility of producing hazardous electrostatic charges in nonmetallic piping and metallic piping lined with nonmetals, consideration should be given to grounding the metallic components of such systems conveying nonconductive fluids.

(b) Thermoplastics. If thermoplastic piping is used above ground for compressed air or other compressed gases, special precautions should be observed. In determining the needed safeguarding for such services, the energetics and the specific failure mechanism need to be evaluated. Encasement of the plastic piping in shatter-resistant material may be considered.

(c) Borosilicate Glass. Take into account its lack of ductility and its sensitivity to thermal and mechanical shock.

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APPENDIX G
SAFEGUARDING

G300 SCOPE

(a) Safeguarding is the provision of protective measures to minimize the risk of accidental damage to the piping or to minimize the harmful consequences of possible piping failure.

(b) In most instances, the safeguarding inherent in the facility (the piping, the plant layout, and its operating practices) is sufficient without need for additional safeguarding. In some instances, however, engineered safeguards must be provided.

(c) Appendix G outlines some considerations pertaining to the selection and utilization of safeguarding. Where safeguarding is required by the Code, it is necessary to consider only the safeguarding that will be suitable and effective for the purposes and functions stated in the Code or evident from the designer's analysis of the application.

G300.1 General Considerations

In evaluating a piping installation design to determine what safeguarding may exist or is necessary, the following should be reviewed:

(a) the hazardous properties of the fluid, considered under the most severe combination of temperature, pressure, and composition in the range of expected operating conditions;

(b) the quantity of fluid which could be released by piping failure, considered in relation to the environment, recognizing the possible hazards ranging from large releases of otherwise innocuous fluids to small leakages of toxic fluids;

(c) expected conditions in the environment, evaluated for their possible effect on the hazards caused by a possible piping failure. This includes consideration of ambient or surface temperature extremes, degree of ventilation, proximity of fired equipment, etc.;

(d) the probable extent of operating, maintenance, and other personnel exposure, as well as reasonably probable sources of damage to the piping from direct or indirect causes;

(e) the probable need for grounding of static charges to prevent ignition of flammable vapors;

(f) the safety inherent in the piping by virtue of materials of construction, methods of joining, and history of service reliability.

G300.2 Safeguarding by Plant Layout and Operation

Representative features of plant layout and operation which may be evaluated and selectively utilized as safeguarding include:

(a) plant layout features, such as open-air process equipment structures; spacing and isolation of hazardous areas; slope and drainage; buffer areas between plant operations and populated communities; or control over plant access;

(b) protective installations, such as fire protection systems; barricades or shields; ventilation to remove corrosive or flammable vapors; instruments for remote monitoring and control; containment and/or recovery facilities; or facilities (e.g., incinerators) for emergency disposal of hazardous materials;

(c) operating practices, such as restricted access to processing areas; work permit system for hazardous work; or special training for operating, maintenance, and emergency crews;

(d) means for safe discharge of fluids released during pressure relief device operation, blowdown, cleanout, etc;

(e) procedures for startup, shutdown, and management of operating conditions, such as gradual pressurization or depressurization, and gradual warmup or cooldown, to minimize the possibility of piping failure, e.g., brittle fracture.

G300.3 Engineered Safeguards

Engineered safeguards which may be evaluated and selectively applied to provide added safeguarding include:

(a) means to protect piping against possible failures, such as:

(1) thermal insulation, shields, or process controls

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to protect from excessively high or low temperature and thermal shock;

(2) armor, guards, barricades, or other protection from mechanical abuse;

(3) damping or stabilization of process or fluid flow dynamics to eliminate or to minimize or protect against destructive loads (e.g., severe vibration pulsations, cyclic operating conditions).

(b) means to protect people and property against harmful consequences of possible piping failure, such as confining and safely disposing of escaped fluid by shields for flanged joints, valve bonnets, gages, or sight glasses; or for the entire piping system if of frangible material; limiting the quantity or rate of fluid escaping by automatic shutoff or excess flow valves, additional block valves, flow-limiting orifices, or automatic shutdown of pressure source; limiting the quantity of fluid in process at any time, where feasible.

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APPENDIX H
SAMPLE CALCULATIONS FOR BRANCH REINFORCEMENT

H300 INTRODUCTION

The following examples are intended to illustrate the application of the rules and definitions in para. 304.3.3 for welded branch connections. (No metric equivalents are given.)

H301 EXAMPLE 1

An NPS 8 run (header) in an oil piping system has an NPS 4 branch at right angles (see Fig. H301). Both pipes are Schedule 40 API 5L Grade A seamless. The design conditions are 300 psig at 400°F. The fillet welds at the crotch are minimum size in accordance with para. 328.5.4. A corrosion allowance of 0.10 in. is specified. Is additional reinforcement necessary?

Solution

From Appendix A, S = 16.0 ksi for API 5L Grade A (Table A-1); E = 1.00 for API 5L seamless (Table A-1B).

$$T_h = 0.322\,(0.875) = 0.282 \text{ in.}$$

$$T_b = 0.237\,(0.875) = 0.207 \text{ in.}$$

$$L_4 = 2.5\,(0.282 - 0.1) = 0.455 \text{ in.}$$

or $2.5\,(0.207 - 0.1) + 0 = 0.268$ in., whichever is less

$$= 0.268 \text{ in.}$$

$$d_1 = [4.5 - 2\,(0.207 - 0.1)]/\sin 90 \text{ deg} = 4.286 \text{ in.}$$

$$d_2 = (0.207 - 0.1) + (0.282 - 0.1) + 4.286/2 = 2.432 \text{ in.}$$

Use d_1 or d_2, whichever is greater.

$$d_1 = 4.286 \text{ in.}$$

$$t_h = \frac{300\,(8.625)}{2(16{,}000)\,(1.00) + 2(0.4)\,(300)} = 0.080 \text{ in.}$$

$$t_b = \frac{300\,(4.500)}{2(16{,}000)\,(1.00) + 2(0.4)\,(300)} = 0.042 \text{ in.}$$

$t_c = 0.7\,(0.237) = 0.166$ in., or 0.25, whichever is less

$$t_c = 0.166 \text{ in.}$$

Minimum leg dimension

of fillet weld = 0.166/0.707 = 0.235 in.

Thus, the required area

$$A_1 = 0.080\,(4.286)\,(2 - \sin 90 \text{ deg}) = 0.343 \text{ sq in.}$$

The reinforcement area in run wall

$$A_2 = 4.286\,(0.282 - 0.08 - 0.10) = 0.437 \text{ sq in.}$$

in branch wall

$$A_3 = 2(0.268)\,[(0.207 - 0.042) - 0.10] = 0.035 \text{ sq in.}$$

in branch welds

$$A_4 = 2(1/2)\,(0.235)^2 = 0.055 \text{ sq in.}$$

The total reinforcement area = 0.527 sq in.

This is more than 0.343 sq in. so that no additional reinforcement is required to sustain the internal pressure.

H302 EXAMPLE 2

There is an NPS 8 branch at right angles to an NPS 12 header (Fig. H301). Both run and branch are of

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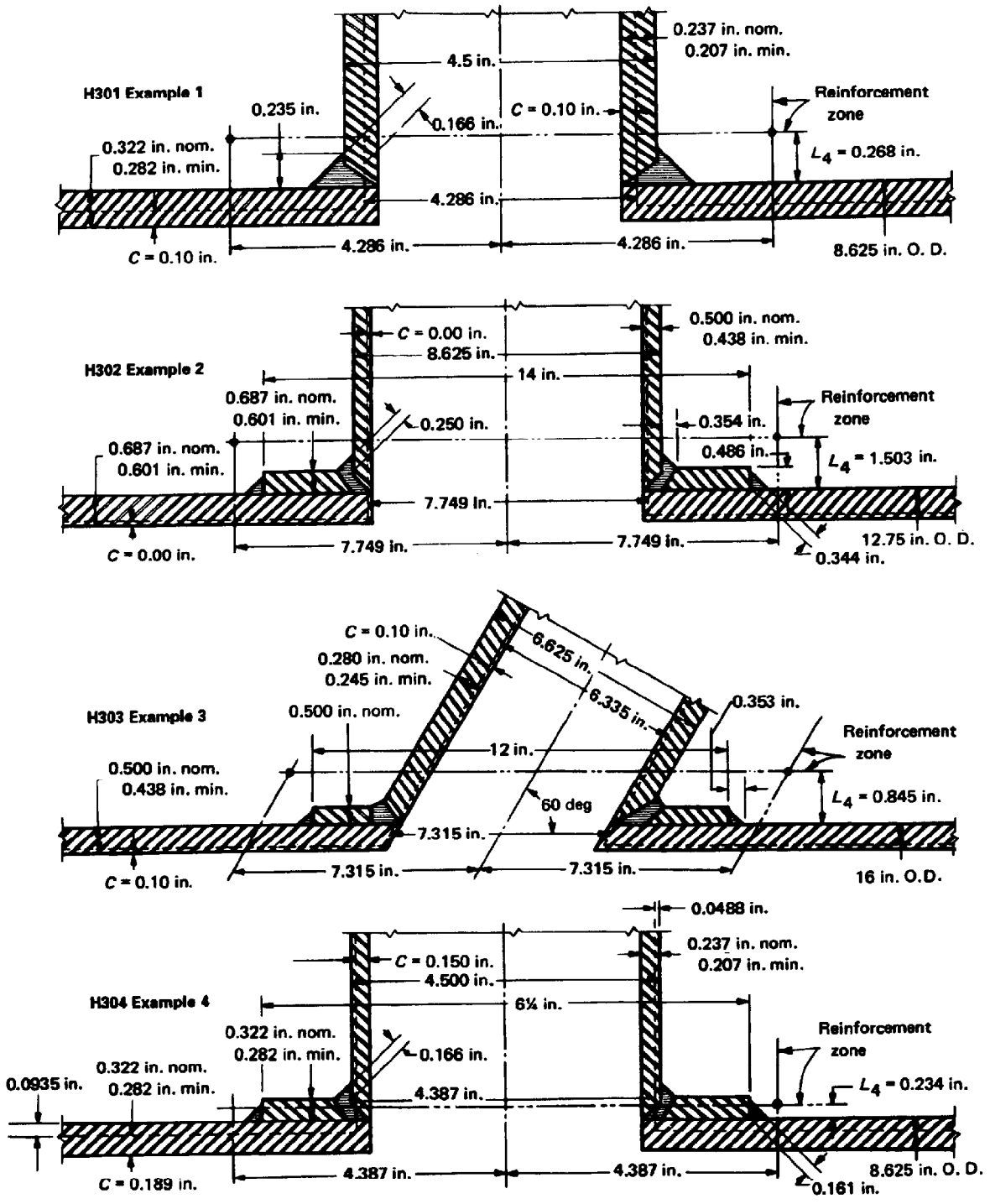

FIG. H301 ILLUSTRATIONS FOR EXAMPLES IN APPENDIX H

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aluminum alloy Schedule 80 ASTM B 241 6061-T6 seamless pipe. The connection is reinforced by a ring 14 in. O.D. (measured along the run) cut from a piece of NPS 12 Schedule 80 ASTM B 241 6063-T6 seamless pipe and opened slightly to fit over the run pipe. Allowable stresses for welded construction apply in accordance with Appendix A, Note (33). The fillet welds have the minimum dimensions permitted in para. 328.5.4. A zero corrosion allowance is specified. What is the maximum permissible design pressure if the design temperature is −320°F?

Solution

From Table A-1, S = 8.0 ksi for Grade 6061-T6 (welded) pipe and S = 5.7 ksi for Grade 6063-T6 (welded) pad, both at −320°F. From Table A-1B, E = 1.00 for ASTM B 241.

Leg dimensions of welds

$$\frac{t_c}{0.707} = \frac{0.250}{0.707} = 0.354 \text{ in.}$$

$$\frac{0.5\,(0.687)}{0.707} = 0.486 \text{ in.}$$

$$T_h = 0.687\,(0.875) = 0.601 \text{ in.}$$

$$T_b = 0.500\,(0.875) = 0.438 \text{ in.}$$

$$T_r = 0.687\,(0.875) = 0.601 \text{ in.}$$

$$L_4 = 2.5\,(0.601 - 0.00) = 1.503 \text{ in.}$$

[This is smaller than 2.5 (0.438 − 0.00) + 0.601 = 1.695 in.]

$$d_2 = d_1 = 8.625 - 2(0.438 - 0.00) = 7.749 \text{ in.}$$

$$t_h = \frac{12.75P}{2(8000)\,(1.00) + 2(0.4)\,(P)}$$

$$t_b = \frac{8.625P}{2(8000)\,(1.00) + 2(0.4)\,P}$$

Using the symbol

$$q = \frac{P}{16{,}000 + 0.8P}$$

we can briefly write

$$t_h = 12.75q \text{ and } t_b = 8.625q$$

The required area

$$A_1 = 7.749t_h = 98.80q$$

The reinforcement area in run wall

$$A_2 = 7.749\,(0.601 - 12.75q - 0.00)$$

$$= 4.657 - 98.80q$$

in branch wall

$$A_3 = 2(1.503)\,(0.438 - 8.625q - 0.00)$$

$$= 1.317 - 25.93q$$

in ring

$$A_4 = 0.601\,(14 - 8.625)\,(5700/8000) = 2.302$$

in fillet welds

$$A_4 = 2(\tfrac{1}{2})\,(0.354)^2 + 2(\tfrac{1}{2})\,(0.486)^2 = 0.362$$

The total reinforcement area = $8.638 - 124.73q$

At the maximum permissible normal operating pressure, the required area and the reinforcement area are equal; thus:

$$98.80q = 8.638 - 124.73q$$

$$223.53q = 8.638$$

$$q = 0.0386$$

But also

$$q = \frac{P}{16{,}000 + 0.8P}$$

Thus

$$P = 0.0386\,(16{,}000 + 0.8P) = 618.3 + 0.0309P$$

$$0.961P = 618.3$$

$$P = 643.1 \text{ psig}$$

which is the maximum permissible design pressure.

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H303 EXAMPLE 3

An NPS 6 Schedule 40 branch has its axis at a 60 deg angle to the axis of an NPS 16 Schedule 40 run (header) in an oil piping system (Fig. H301). Both pipes are API 5L Grade A seamless. The connection is reinforced with a ring 12 in. O.D. (measured along the run) made from ½ in. ASTM A 285 Grade C plate. All fillet welds are equivalent to 45 deg fillet welds with ⅜ in. legs. Corrosion allowance = 0.10 in. The design pressure is 500 psig at 700°F. Is the design adequate for the internal pressure?

Solution

From Appendix A, S = 14.4 ksi for API 5L Grade A and ASTM A 285 Grade C (Table A-1); E = 1.00 for API 5L seamless (Table A-1B).

$$T_h = 0.500\,(0.875) = 0.438 \text{ in.}$$

$$T_b = 0.280\,(0.875) = 0.245 \text{ in.}$$

$$T_r = 0.500 \text{ in.}$$

$$L_4 = 2.5\,(0.245 - 0.10) + 0.500 = 0.8625$$

This is greater than 2.5 (0.438 − 0.10) = 0.845 in.

$$t_h = \frac{500\,(16)}{2(14{,}400)\,(1.00) + 2(0.4)\,(500)} = 0.274 \text{ in.}$$

$$t_b = \frac{500\,(6.625)}{2(14{,}400)\,(1.00) + 2(0.4)\,(500)} = 0.113 \text{ in.}$$

$$d_2 = d_1 = \frac{6.625 - 2(0.245 - 0.10)}{\sin 60 \text{ deg}} = \frac{6.335}{0.866} = 7.315 \text{ in.}$$

The required area

$$A_1 = (0.274)\,(7.315)\,(2 - 0.866) = 2.27 \text{ sq in.}$$

The reinforcement area in run wall

$$A_2 = 7.315\,(0.438 - 0.274 - 0.10) = 0.468 \text{ sq in.}$$

in branch wall

$$A_3 = 2\left(\frac{0.845}{0.866}\right)(0.245 - 0.113 - 0.10) = 0.062 \text{ sq in.}$$

in ring

$$A_4 = 0.500\left(12 - \frac{6.625}{0.866}\right) = 2.175 \text{ sq in.}$$

in fillet welds

$$A_4 = 4(\tfrac{1}{2})(\tfrac{3}{8})^2 = 0.281 \text{ sq in.}$$

The total reinforcement area = 2.986 sq in.

This total is greater than 2.27 sq in., so that no additional reinforcement is required.

H304 EXAMPLE 4

An NPS 8 run (header) in an oil piping system has an NPS 4 branch at right angles (Fig. H301). Both pipes are Schedule 40 API 5L Grade A seamless. The design conditions are 350 psig at 400°F. It is assumed that the piping system is to remain in service until all metal thickness, in both branch and run, in excess of that required by Eq. (3a) of para. 304.1.2 has corroded away so that area A_2 as defined in para. 304.3.3(c)(1) is zero. What reinforcement is required for this connection?

Solution

From Appendix A, S = 16.0 ksi for API 5L Grade A (Table A-1); E = 1.00 for API 5L seamless (Table A-1B).

$$t_h = \frac{350\,(8.625)}{2(16{,}000)\,(1.00) + 2(0.4)\,(350)} = 0.0935 \text{ in.}$$

$$t_b = \frac{350\,(4.500)}{2(16{,}000)\,(1.00) + 2(0.4)\,(350)} = 0.0488 \text{ in.}$$

$$d_1 = 4.500 - 2(0.0488) = 4.402 \text{ in.}$$

Required reinforcement area

$$A_1 = 0.0935\,(4.402) = 0.412 \text{ sq in.}$$

Try fillet welds only.

$$L_4 = 2.5(0.0935) = 0.234 \text{ in.,}$$

$$\text{or } 2.5(0.0488) = 0.122 \text{ in.}$$

Use 0.122 in.

Due to limitation in the height at the reinforcement zone, no practical fillet weld size will supply enough

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reinforcement area; therefore, the connection must be further reinforced. Try a 6¼ in. O.D. reinforcing ring (measured along the run). Assume the ring to be cut from a piece of NPS 8 Schedule 40 API 5L Grade A seamless pipe and welded to the connection with minimum size fillet welds.

Minimum ring thickness

$$T_r = 0.322(0.875) = 0.282 \text{ in.}$$

$$\text{New } L_4 = 2.5(0.0488) + 0.282 = 0.404 \text{ in.,}$$

$$\text{or } 2.5(0.0935) = 0.234 \text{ in.}$$

Use 0.234 in.

Reinforcement area in the ring (considering only the thickness within L_4)

$$X_1 = 0.234\,(6.25 - 4.5) = 0.410 \text{ sq in.}$$

$$\text{Leg dimension of weld} = \frac{0.5(0.322)}{0.707} = 0.228 \text{ in.}$$

Reinforcement area in fillet welds

$$X_2 = 2(\tfrac{1}{2})\,(0.228)^2 = 0.052 \text{ sq in.}$$

Total reinforcement area

$$A_4 = X_1 + X_2 = 0.462 \text{ sq in.}$$

This total reinforcement area is greater than the required area; therefore, a reinforcing ring 6¼ in. O.D., cut from a piece of NPS 8 Schedule 40 API 5L Grade A seamless pipe and welded to the connection with minimum size fillet welds would provide adequate reinforcement for this connection.

H305 EXAMPLE 5 (Not Illustrated)

An NPS 1½ 3000 lb forged steel socket welding coupling has been welded at right angles to an NPS 8 Schedule 40 run (header) in oil service, using a weld conforming to sketch (1) of Fig. 328.5.4D. The run is ASTM A 53 Grade B seamless pipe. The design pressure is 400 psi and the design temperature is 450°F. The corrosion allowance is 0.10 in. Is additional reinforcement required?

Solution

No. According to para. 304.3.2(b) the design is adequate to sustain the internal pressure and no calculations are necessary. It is presumed, of course, that calculations have shown the run pipe to be satisfactory for the service conditions according to Eqs. (2) and (3).

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APPENDIX J
NOMENCLATURE[1]

Symbol	Definition	Units [Note (2)]		Reference		
		SI	U.S.	Paragraph	Table/Fig./App.	Equation
A	Factor for determining minimum value of R_1	...	...	304.2.3	...	(5)
A_1	Area required for branch reinforcement	mm^2	$in.^2$	304.3.3 304.3.4	304.3.3 304.3.4 H300	(6) (9)
A_2	Area available for branch reinforcement in run pipe	mm^2	$in.^2$	304.3.3 304.3.4	304.3.3 304.3.4 H300	(7) (10)
A_3	Area available for branch reinforcement in branch pipe	mm^2	$in.^2$	304.3.3 304.3.4	304.3.3 304.3.4 H300	(8) (11)
A_4	Area available for branch reinforcement in pad or connection	mm^2	$in.^2$	304.3.3 304.3.4	304.3.3 304.3.4 H300	(12)
c	Sum of mechanical allowances (thread or groove depth) plus corrosion and erosion allowances	mm	in.	302.3.5 302.4 304.1.1 304.2.3 304.4.1 304.5.2 304.5.3 A304.1.1 H300 K302.3.5 K304.1.1 K304.1.2 K304.5.2 K304.8.4	304.3.3 304.3.4 328.5.5 H301	(2) (4a) (4b) (4c) (7) (8) (13) (14) (15) (25) (33) (36) (37)
c_i	Sum of internal allowances	mm	in.	K304.1.1 K304.1.2	...	(34b) (35a) (35b)
c_o	Sum of external allowances	mm	in.	K304.1.1 K304.1.2	...	(34a) (35a) (35b)
C	Cold spring factor	...	...	319.5.1	...	(22) (23)
C	Material constant used in computing Larson-Miller parameter	...	...	V303.1.3 V303.1.4	...	(V2) (V3)
C_x	Size of fillet weld, socket welds other than flanges	mm	in.	...	328.5.2C	...
C_1	Estimated self-spring or relaxation factor	...	...	319.5.1	...	(23)

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Symbol	Definition	Units [Note (2)] SI	Units [Note (2)] U.S.	Reference Paragraph	Reference Table/Fig./App.	Reference Equation
d	Inside diameter of pipe (note differences in definition between paras. 304.1.1 and K304.1.1)	mm	in.	304.1.1 K304.1.1 K304.1.2	...	(34b) (35b)
d_b	Inside diameter of branch pipe	mm	in.	304.3.4	304.3.4	...
d_h	Inside diameter of header pipe	mm	in.	304.3.4	304.3.4	...
d_g	Inside or pitch diameter of gasket	mm	in.	304.5.3	304.5.3	(15)
d_x	Design inside diameter of extruded outlet	mm	in.	304.3.4	304.3.4	(9) (10)
d_1	Effective length removed from pipe at branch	mm	in.	304.3.3 H300	304.3.3	(6) (7)
d_2	Half-width of reinforcement zone	mm	in.	304.3.3 304.3.4 H300	304.3.3 304.3.4	(7)
D	Outside diameter of pipe as listed in tables of standards and specifications or as measured	mm	in.	304.1.1 304.1.2 304.1.3 319.4.1 A304.1.1 A328.2.5 K304.1.1 K304.1.2 K304.1.3 K304.8.4	304.1.1 304.2.3	(3a) (3b) (3c) (5) (16) (26) (27) (34a) (35a) (37)
D_b	Outside diameter of branch pipe	mm	in.	304.3.4	304.3.3 304.3.4 D300	...
D_h	Outside diameter of header pipe	mm	in.	304.3.3 304.3.4	304.3.3 304.3.4	...
E	Quality factor	...	...	302.3.1 304.1.1 304.1.2 304.2.3 304.3.3 304.4.1 304.5.1 304.5.2 304.5.3 305.2.3 306.1.3	H300	(3a) (3b) (3c) (4a) (4b) (4c) (15)
E	Modulus of elasticity (at specified condition)	MPa	ksi	A319.3.2	App. C D300	...
E_a	Reference modulus of elasticity at 21°C (70°F)	MPa	ksi	319.3.2 319.4.4 319.5 319.5.1	...	(22) (23)
E_c	Casting quality factor	...	...	302.3.1	302.3.3C	...

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Symbol	Definition	Units [Note (2)] SI	Units [Note (2)] U.S.	Reference Paragraph	Reference Table/Fig./App.	Reference Equation
E_c	Casting quality factor (Cont'd)			302.3.3 305.2.3 306.1.3 K302.3.3 K306.1.2	Table A-1A	
E_j	Joint quality factor	...	...	302.3.1 302.3.4 305.2.3 306.1.3 321.1.3 341.4.1 341.5.1 K302.3.4 K305.1 K306.1.2 K328.5.4	302.3.4 Table A-1B	...
E_m	Modulus of elasticity at maximum or minimum temperature	MPa	ksi	319.3.2 319.5.1	...	(22) (23)
E_t	Modulus of elasticity at test temperature	MPa	ksi	X302.2.3	...	(X2)
f	Stress range reduction factor	...	...	302.3.5	302.3.5	(1a) (1b) (1c)
F	Service (design) factor	...	...	A302.3.2 A304.1.1 A304.1.2	...	(26c)
g	Root gap for welding	mm	in.	K328.4.3	328.4.4 K328.5.4	...
h	Flexibility characteristic	...	...	...	D300	...
h_x	Height of extruded outlet	mm	in.	304.3.4	304.3.4	...
i	Stress intensification factor	...	...	319.3.6	D300	...
i_i	In-plane stress intensification factor	...	...	319.4.4	D300	(18) (19) (20)
i_o	Out-plane stress intensification factor	...	...	319.4.4	D300	(18) (19) (20)
k	Flexibility factor	...	...	319.3.6	D300	...
K	Factor determined by ratio of branch diameter to run diameter	...	...	304.3.4	304.3.4	(9)
K_1	Constant in empirical flexibility equation	...	...	319.4.1	...	(16)
K_s	Factor for statistical variation in test results (see para. X3.1.3)	...	...	X302.1.3	...	(X2)
L	Developed length of piping between anchors	m	ft	304.2.4 319.4.1 K304.2.4	...	(16)
L_4	Height of reinforcement zone outside run pipe	mm	in.	304.3.3 H300	304.3.3 H301	(8)

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Symbol	Definition	Units [Note (2)] SI	Units [Note (2)] U.S.	Reference Paragraph	Reference Table/Fig./App.	Reference Equation
L_5	Height of reinforcement zone for extruded outlet	mm	in.	304.3.4	304.3.4	(11)
LMP	Larson-Miller parameter, used to estimate design life	...	...	V303.1.3 V303.1.4	...	(V2) (V3)
m	Misfit of branch pipe	mm	in.	328.4.3 K328.4.3	328.4.4 K328.5.4	...
M	Length of full thickness pipe adjacent to miter bend	mm	in.	304.2.3	304.2.3	...
M_i	In-plane bending moment	N-mm	in.-lbf	319.4.4	319.4.4A 319.4.4B	(18) (19) (20)
M_o	Out-plane bending moment	N-mm	in.-lbf	319.4.4	319.4.4A 319.4.4B	(18) (19) (20)
M_t	Torsional moment	N-mm	in.-lbf	319.4.4	319.4.4A 319.4.4B	...
N	Equivalent number of full displacement cycles	...	...	300.2 302.3.5 319.4.5	302.3.5	(1c) (1d)
N_i	Number of cycles associated with displacement stress range $S_i (i = 1, 2, ...)$	...	...	302.3.5	...	(1d)
N_t	Number of fatigue tests performed to develop the material factor X_m	...	...	X302.1.3	...	(X2)
N_E	Number of cycles of maximum computed displacement stress range	...	...	302.3.5	...	(1d)
P	Design gage pressure	kPa	psi	304.1.1 304.1.2 304.4.1 304.5.1 304.5.2 304.5.3 345.4.2 A304.1.1 A304.1.2 A304.5.1 H300 K304.1.1 K304.1.2 K304.7.2 K304.8.4 K345.4.2	D300	(3a) (3b) (3c) (15) (24) (26) (34a) (34b) (35a) (35b) (37)
P_{a2}	See BPV Code, Section VIII, Division 1, UG-28	...	...	304.1.3	...	...
P_i	Gage pressure during service condition i	kPa	psi	V303.1.1	...	(V1)

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Symbol	Definition	Units [Note (2)] SI	Units [Note (2)] U.S.	Reference Paragraph	Reference Table/Fig./App.	Reference Equation
P_m	Maximum allowable internal pressure for miter bends	kPa	psi	304.2.3	...	(4a) (4b) (4c)
$P_{max.}$	Maximum allowable gage pressure for continuous operation of component at maximum design temperature	kPa	psi	V303.1.1	...	(V1)
P_S	Limiting design pressure based on column instability, for convoluted U-shaped bellows	kPa	psi	X302.2.3	...	(X3)
P_T	Minimum test gage pressure	kPa	psi	345.4.2 A382.2.5 X302.2.3	...	(24) (27) (X2)
r_i	Ratio of a lesser computed displacement stress range S_i to maximum computed stress range S_{Ei} ($i = 1, 2, \ldots$)	...	...	302.3.5	...	(1d)
r_2	Mean radius of pipe using nominal wall thickness $\overline{T}$	mm	in.	304.2.3 319.4.4	304.2.3 D300	(4a) (4b) (4c) (21)
r_x	External contour radius of extruded outlet	mm	in.	304.3.4	304.3.4 D300	(12)
R	Range of reaction forces or moments in flexibility analysis	N or N-mm	lbf or in.-lbf	319.5 319.5.1	...	(22)
R_a	Estimated instantaneous reaction force or moment at installation temperature	N or N-mm	lbf or in.-lbf	319.5.1	...	...
R_m	Estimated instantaneous maximum reaction force or moment at maximum or minimum metal temperature	N or N-mm	lbf or in.-lbf	319.5.1	...	(22)
$R_{min.}$	Minimum ratio of stress ranges (see para. X3.1.3 for further details)	...	...	X302.1.3	...	(X1) (X2)
R_1	Effective radius of miter bend	mm	in.	304.2.3	304.2.3	(4b) (5)
(99) R_1	Bend radius of welding elbow or pipe bend	mm	in.	...	D300	...
s	Miter spacing at pipe center line	mm	in.	...	D300	...
S	Basic allowable stress for metals	MPa	ksi	300.2 302.3.1 304.1.1 304.1.2 304.1.3 304.2.3 304.3.3 304.4.1 304.5.1 304.5.2 304.5.3 319.3.4 345.4.2 H300	A-1 K-1	(3a) (3b) (3c) (4a) (4b) (4c) (15) (24) (34a) (34b) (35a) (35b) (37)

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Symbol	Definition	Units [Note (2)] SI	Units [Note (2)] U.S.	Reference Paragraph	Reference Table/Fig./App.	Reference Equation
S	Basic allowable stress for metals (Cont'd)			K304.1.1 K304.1.2 K304.8.4 K345.4.2		
S	Bolt design stress	MPa	ksi	300.2 302.3.1	A-2	...
S	Design stress for nonmetals	...	...	A304.1.1 A304.1.2 A304.5.1 A304.5.2	B-1	(26)
S_a	Bolt design stress at atmospheric temperature	MPa	ksi	304.5.1 A304.5.1	...	...
S_b	Bolt design stress at design temperature	MPa	ksi	304.5.1 A304.5.1	...	...
S_b	Resultant bending stress	Mpa	ksi	319.4.4	...	(17) (18) (19) (20)
S_c	Basic allowable stress at minimum metal temperature expected during the displacement cycle under analysis	MPa	ksi	302.3.5 K302.3.5	...	(1a) (1b) (32)
S_d	Allowable stress from Table A-1 for the material at design temperature	MPa	ksi	V303.1.1	...	(V1)
S_f	Allowable stress for flange material or pipe	MPa	ksi	304.5.1 304.5.2	...	...
S_h	Basic allowable stress at maximum metal temperature expected during the displacement cycle under analysis	MPa	ksi	302.3.5 319.5.1 K302.3.5	...	(1a) (1b) (23) (32)
S_i	A computed displacement stress range smaller than S_E ($i = 1, 2, \ldots$)	MPa	ksi	302.3.5	...	(1d)
S_i	Equivalent stress during service condition i (the higher of S_{pi} and S_L)	MPa	ksi	V303.1.1 V303.1.2	...	...
S_{pi}	Equivalent stress for pressure during service condition i	MPa	ksi	V303.1.1	...	(V1)
S_t	Torsional stress	MPa	ksi	319.4.4	...	(17)
S_t	Total stress range for design fatigue curves applying to austenitic stainless steel expansion joints	...	psi	X302.1.3	X302.1.3	...
S_y	Yield stress (BPV Code)	MPa	ksi	302.2.4	...	...
S_A	Allowable stress range for displacement stress	MPa	ksi	300.2 302.3.5 319.2.3 319.3.4 319.4.4	...	(1a) (1b) (32)

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Symbol	Definition	Units [Note (2)] SI	Units [Note (2)] U.S.	Reference Paragraph	Reference Table/Fig./App.	Reference Equation
S_A	Allowable stress range for displacement stress (Cont'd)			319.4.5 K302.3.5		
S_E	Computed displacement stress range	MPa	ksi	300.2 302.3.5 319.2.3 319.4.4 319.4.5 319.5.1	...	(17) (23)
S_H	Mean long term hydrostatic strength (LTHS)	kPa	psi	A328.2.5	...	(27)
S_L	Sum of longitudinal stresses	MPa	ksi	302.3.5 302.3.6 K302.3.5 K302.3.6	...	(1b)
S_S	Mean short term burst stress	kPa	psi	A328.2.5	...	(27)
S_T	Allowable stress at test temperature	MPa	ksi	345.4.2 K345.4.2	...	(24) (38)
t	Pressure design thickness	mm	in.	304.1.1 304.1.2 304.1.3 304.3.3 304.4.1 304.5.2 A304.1.1 A304.1.2 A304.1.3 K304.1.1 K304.1.2 K304.1.3 k304.5.2	304.1.1 328.5.2C	(2) (3a) (3b) (3c) (3d) (13) (14) (25) (26) (33) (34a) (36)
t_b	Pressure design thickness of branch	mm	in.	304.3.3 304.3.4 H300	304.3.3 304.3.4	(8) (11)
t_c	Throat thickness of cover fillet weld	mm	in.	328.5.4 331.1.3 H300	328.5.4	...
t_h	Pressure design thickness of header	mm	in.	304.3.3 304.3.4 H300	304.3.3 304.3.4	(6) (7) (9) (10)
t_i	Total duration of service condition i, at pressure P_i and temperature T_i	hr	hr	V303.2	...	(V4)
t_m	Minimum required thickness, including mechanical, corrosion, and erosion allowances	mm	in.	304.1.1 304.2.1 304.4.1 304.5.2 304.5.3 328.4.2 A304.1.1	328.3.2 328.4.3 K328.4.2 K341.3.2	(2) (13) (14) (15) (25) (33) (36)

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Symbol	Definition	Units [Note (2)] SI	Units [Note (2)] U.S.	Reference Paragraph	Reference Table/Fig./App.	Reference Equation
t_m	Minimum required thickness, including mechanical, corrosion, and erosion allowances (Cont'd)			A304.2.1 K304.1.1 K304.2.1 K304.5.2 K328.4.2		
$t_{min.}$	For branch, the smaller of $\overline{T}_b$ or $\overline{T}_r$	mm	in.	328.5.4	328.5.4	...
t_{ri}	Rupture life of a component subjected to repeated service conditions i and stress S_i	hr	hr	V303.1.4 V303.2	...	(V3) (V4)
T	Pipe wall thickness (measured or minimum per purchase specification)	mm	in.	304.1.1 304.2.3 306.4.2 A304.1.1 A328.2.5 K304.1.1 K304.1.2	323.3.1 328.5.2B K323.3.1	(4a) (4b) (4c) (35a) (35b) (27)
T_b	Branch pipe wall thickness (measured or minimum per purchase specification)	mm	in.	304.3.3 304.3.4 H300	304.3.3 304.3.4	(8) (11) (12)
T_c	Crotch thickness of tees	mm	in.	...	D300	...
T_h	Header pipe wall thickness (measured or minimum per purchase specification)	mm	in.	304.3.3 304.3.4 H300	304.3.3 304.3.4	(7) (10)
T_i	Actual temperature during sevice condition i	°C	°F	V303.1.4	...	(V3)
T_r	Minimum thickness of reinforcing ring or saddle made from pipe (nominal thickness if made from plate)	mm	in.	304.3.3 H300	304.3.3	...
T_s	Effective branch wall thickness	mm	in.	319.4.4	...	(21)
T_x	Corroded finished thickness of extruded outlet	mm	in.	304.3.4	304.3.4	(12)
T_D	Design temperature during service condition i (temperature corresponding to S_i, Table A-1)	°C	°F	V303.1.2 V303.1.3	...	(V2)
T_2	Minimum thickness of fabricated lap	mm	in.	...	328.5.5	...
$\overline{T}$	Nominal wall thickness of pipe	mm	in.	302.3.5	328.5.2B 328.5.5 K302.3.3D D300	...
$\overline{T}_b$	Nominal branch pipe wall thickness	mm	in.	319.4.4 328.5.4 331.1.3	304.3.3 328.5.4D	...
$\overline{T}_h$	Nominal header pipe wall thickness	mm	in.	319.4.4 328.5.4 331.1.3	304.3.3 328.5.4D	...

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Symbol	Definition	Units [Note (2)] SI	Units [Note (2)] U.S.	Reference Paragraph	Reference Table/Fig./App.	Reference Equation
$\overline{T}_r$	Nominal thickness of reinforcing ring or saddle	mm	in.	328.5.4 331.1.3	328.5.4D D300	...
$\overline{T}_w$	Nominal wall thickness, thinner of components joined by butt weld	mm	in.	344.6.2	341.3.2 K341.3.2	...
u	Creep-rupture usage factor, summed up from individual usage factors, t_i/t_{ri}	...	...	V303.2 V303.3	...	(V4)
U	Straight line distance between anchors	m	ft	319.4.1	...	(16)
X	Factor for modifying the allowable stress range S_t for bellows expansion joint (see para. X302.1.3 for further details	...	...	X302.1.3	...	(X1) (X2)
X_1	Ring reinforcement area	mm^2	$in.^2$	H304		...
X_2	Fillet weld reinforcement area	mm^2	$in.^2$	H304		...
$x_{min.}$	Size of fillet weld to slip-on or socket welding flange	mm	in.	...	328.5.2B	...
y	Resultant of total displacement	mm	in.	319.4.1	...	(16)
Y	Coefficient for effective stressed diameter	...	...	304.1.1 304.1.2	304.1.1	(3a)
Z	Section modulus of pipe	mm^3	$in.^3$	319.4.4	...	(18) (19)
Z_e	Effective section modulus for branch	mm^3	$in.^3$	319.4.4	...	(20) (21)
α	Angle of change in direction at miter joint	deg	deg	304.2.3 306.3.2 306.3.3 M306.3	304.2.3	...
β	Smaller angle between axes of branch and run	deg	deg	304.3.3	304.3.3	(6) (8)
ΔT_n	Range of temperature change for lesser cycle ($n = 1, 2, ...$)	°C	°F	302.3.5	...	...
ΔT_e	Range of temperature change for full cycle	°C	°F	302.3.5	...	...
θ	Angle of miter cut	deg	deg	304.2.3	304.2.3 D300	(4a) (4c) (5)

NOTES:

(1) For Code reference to this Appendix, see para. 300.3.

(2) Note that the use of these units is not required by the Code. They represent sets of consistent units (except where otherwise stated) which may be used in computations, if stress values in ksi and MPa are multiplied by 1000 for use in equations that also involve pressure in psi and kPa values.

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APPENDIX K
ALLOWABLE STRESSES FOR HIGH PRESSURE PIPING

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NOTE:
(1) It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.

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NOTES FOR APPENDIX K TABLES

GENERAL NOTES:

(a) The allowable stress values and P-Number or S-Number assignments in Table K-1, together with the referenced Notes and double bars [see Note (7) of Notes for Appendix A Tables], are requirements of Chapter IX.

(b) Notes (1) through (7) and Notes (17) and (18) are referenced in Table headings and in headings for material type and product form; Notes (8) through (16) and (19) and (20) are referenced in the Notes column for specific materials.

(c) At this time, metric equivalents have not been provided in Table K-1. To convert stress values in Table K-1 to MPa at a given temperature in °C, determine the equivalent temperature in °F and interpolate to calculate the stress value in ksi at the given temperature. Multiply by 6.895 to determine allowable stress in MPa at the given temperature.

NOTES:

(1) The stress values in Table K-1 are allowable stresses in tension in accordance with para. K302.3.1(a). Stress values in shear and bearing are stated in para. K302.3.1(b), those in compression in para. K302.3.1(c).

(2) Samples representative of all piping components, as well as their fabrication welds, shall be impact tested in accordance with para. K323.3.

(3) Material minimum service temperature shall be in accordance with para. K323.2.2.

(4) The temperature limit for materials shall be in accordance with para. K323.2.1. A double bar (‖) after a tabled stress indicates that use of the material is prohibited above that temperature.

(5) Stress values printed in *italics* exceed two-thirds of the expected yield strength at temperature. Stress values in **boldface** are equal to 90% of yield strength at temperature. See para. K302.3.2.

(6) A product analysis of the material shall be performed. See para. K323.1.5.

(7) See para. 328.2.1(f) for a description of P-Number and S-Number groupings. P-Numbers are indicated by number or by a number followed by a letter (e.g., 8, or 5B, or 11A). S-Numbers are preceded by an S (e.g., S-1).

(8) This type or grade is permitted only in the seamless condition.

(9) If this grade is cold expanded, the most severely deformed portion of a representative sample shall be impact tested in accordance with para. K323.3.

(10) This material may require special consideration for welding qualification. See the BPV Code, Section IX, QW/QB-422. For use in this Code, a qualified WPS is required for each strength level of material.

(11) No welding is permitted on this material.

(12) Welds in components shall be of a design that permits fully interpretable radiographic examination; joint quality facter E_j shall be 1.00 per para. K302.3.4.

(13) Pipe furnished to this specification shall be supplied in the solution heat treated condition.

(14) This unstabilized grade of stainless steel increasingly tends to precipitate intergranular carbides as the carbon content increases above 0.03%. See also para. F323.4(c)(2).

(15) Stress values shown are for the lowest strength base material permitted by the specification to be used in the manufacture of this grade of fitting. If a higher strength base material is used, the higher stress values for that material may be used in design.

(16) Galvanized pipe furnished to this specification is not permitted for pressure containing service. See para. K323.4.2(b).

(17) Pipe and tubing shall be examined for longitudinal defects in accordance with Table K305.1.2.

(18) Material defects may be repaired by welding only in accordance with para. K323.1.6.

(19) For material thickness > 127 mm (5 in.), the specified minimum tensile strength is 448 MPa (65 ksi).

(20) For material thickness > 127 mm (5 in.), the specified minimum tensile strength is 483 MPa (70 ksi).

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TABLE K-1
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]

Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	Type or Grade	Notes	Specified Min. Strength, ksi Tensile	Yield
Carbon Steel Pipes and Tubes (17)						
...	A 53	1	B	(8)(16)	60	35
...	A 106	1	B	...		
...	A 333	1	6	(8)		
...	A 334	1	6	(8)		
...	API 5L	S-1	B	(8)(9)		
...	A 210	1	A-1	...	60	37
...	A 106	1	C	...	70	40
...	A 210					
...	API 5L	S-1	X42	(8)(9)	60	42
...	API 5L	S-1	X46	(8)(9)	63	46
...	API 5L	S-1	X52	(8)(9)	66	52
...	API 5L	S-1	X56	(8)(9)(10)	71	56
...	API 5L	S-1	X60	(8)(9)(10)	75	60
...	API 5L	S-1	X65	(8)(9)(10)	77	65
...	API 5L	S-1	X70	(8)(9)(10)	82	70
...	API 5L	S-1	X80	(8)(9)(10)	90	80
Forgings and Fittings						
...	A 234	1	WPB	(8)	60	35
...	A 420	1	WPL6			
...	A 350	1	LF2	...	70	36
...	A 105	1	...			
...	A 234	1	WPC	(8)	70	40
Low and Intermediate Alloy Steel Pipes and Tubes (17)						
C-½Mo	A 335	3	P1	...	55	30
1Cr-½Mo	A 335	4	P12	...	60	30
1¼Cr-½Mo	A 335	4	P11			
5Cr-½Mo	A 335	5A	P5	...	60	30
2¼Cr-1Mo	A 335	5A	P22	...	60	30

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TABLE K-1
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]
Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding								Type or Grade	Spec. No.
100	200	300	400	500	600	650	700		
									Carbon Steel Pipes and Tubes (17)
23.3	21.3	20.7	20.0	18.9	17.3	16.9	16.8	B	A 53
								B	A 106
								6	A 333
								6	A 334
								B	API 5L
24.7	22.5	21.9	21.1	20.0	18.3	17.9	17.8	A-1	A 210
26.7	24.3	23.7	22.9	21.6	19.7	19.4	19.2	C	A 106 / A 210
28.0	20.0	20.0	20.0	...	...	...	...	X42	API 5L
30.7	21.0	21.0	21.0	...	...	...	...	X46	API 5L
34.7	22.0	22.0	22.0	...	...	...	...	X52	API 5L
37.3	23.7	23.7	23.7	...	...	...	...	X56	API 5L
40.0	25.0	25.0	25.0	...	...	...	...	X60	API 5L
43.3	...	...	...	...	...	...	...	X65	API 5L
46.7	...	...	...	...	...	...	...	X70	API 5L
53.3	...	...	...	...	...	...	...	X80	API 5L
									Forgings and Fittings
23.3	21.3	20.7	20.0	18.9	17.3	16.9	16.8	WPB	A 234
								WPL6	A 420
								LF2	A 350
24.0	21.9	21.3	20.6	19.5	17.7	17.5	17.3	...	A 105
26.7	24.3	23.7	22.9	21.6	19.7	19.4	19.2	WPC	A 234
									Low and Intermediate Alloy Steel Pipes and Tubes (17)
20.0	18.8	18.1	17.4	16.9	16.4	16.1	15.7	P1	A 335
								P12	A 335
20.0	18.7	17.9	17.5	17.2	16.7	16.2	15.7	P11	A 335
20.0	18.1	17.4	17.2	17.1	16.8	16.6	16.3	P5	A 335
20.0	18.5	18.1	17.9	17.9	17.9	17.9	17.9	P22	A 335

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]

Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	Type or Grade	Notes	Specified Min. Strength, ksi	
					Tensile	Yield
Low and Intermediate Alloy Steel (Cont'd) Pipes and Tubes (17) (cont'd)						
3½Ni	A 333	9B	3	(8)	65	35
3½Ni	A 334	9B	3	(8)	65	36
9Ni	A 333	11A	8	(8)	100	75
9Ni	A 334	11A	8	(8)	100	75
Forgings and Fittings						
3½Ni	A 420	9B	WPL3	(8)	65	35
3½Ni	A 350	9B	LF3	...	70	37.5
1Cr-½Mo	A 182	4	F12, Cl. 2	...	70	40
1¼Cr-½Mo	A 182	4	F11, Cl. 2	...	70	40
C-½Mo	A 182	3	F1	...	70	40
5Cr-½Mo	A 182	5B	F5	...	70	40
2¼Cr-1Mo	A 182	5A	F22	...	75	45
9Ni	A 420	11A	WPL8	(8)	110	75
3½Ni-1¾Cr-½Mo	A 508	11A	4N, Cl. 2	...	115	100
Ni-Cr-Mo	A 723	...	1, 2, 3 Cl. 1	(11)	115	100
Ni-Cr-Mo	A 723	...	1, 2, 3 Cl. 2	(11)	135	120
Ni-Cr-Mo	A 723	...	1, 2, 3 Cl. 3	(11)	155	140
Stainless Steel (5) Pipes and Tubes (17)						
16Cr-12Ni-2Mo	A 312	8	TP316L	(12)	70	25
316L, A 240	A 358	8	316L, Cl. 1 & 3	(12)(13)	70	25
16Cr-12Ni-2Mo-N	A 312	8	TP316LN	(12)	75	30
316LN, A 240	A 358	8	316LN, Cl. 1 & 3	(12)(13)	75	30
18Cr-8Ni	A 312	8	TP304L	(12)	70	25
304L, A 240	A 358	8	304L, Cl. 1 & 3	(12)(13)	70	25
18Cr-8Ni-N	A 312	8	TP304LN	(12)	75	30
304LN, A 240	A 358	8	304L, Cl. 1 & 3	(12)(13)	75	30

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]
Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

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Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding								Type or Grade	Spec. No.
100	200	300	400	500	600	650	700		
								Low and Intermediate Alloy Steel (Cont'd) Pipes and Tubes (17) (Cont'd)	
23.3	19.6	19.6	18.7	17.8	16.8	16.3	15.5	3	A 333
24.0	19.6	19.6	18.7	17.8	16.8	16.3	15.5	3	A 334
50.0	31.7	...	...	...	...	...	...	8	A 333 A 334
								Forgings and Fittings	
23.3	...	...	...	...	...	...	...	WPL3	A 420
25.0	...	...	...	...	...	...	...	LF3	A 350
								F12, Cl. 2	A 182
26.7	24.6	23.4	22.5	21.7	20.9	20.5	20.1	F11, Cl. 2	A 182
26.7	25.1	24.1	23.2	22.5	21.8	21.4	21.0	F1	A 182
26.7	24.1	23.2	22.9	22.7	22.4	22.1	21.7	F5	A 182
30.0	27.5	26.1	25.5	24.8	24.3	24.0	23.7	F22	A 182
50.0	31.7	...	...	...	...	...	...	WPL8	A 420
66.7	62.8	60.8	59.5	58.5	57.4	56.7	...	4N, Cl. 2	A 508
66.7	64.0	62.3	61.3	60.3	59.3	58.5	57.3	1, 2, 3 Cl. 1	A 723
80.0	76.8	74.8	73.6	72.4	71.2	70.1	68.8	1, 2, 3 Cl. 2	A 723
93.3	89.6	87.3	85.9	84.5	83.1	81.9	80.3	1, 2, 3 Cl. 3	A 723
								Stainless Steel (5) Pipes and Tubes (17)	
16.7	*16.7*	*16.7*	15.6	14.4	14.0	13.2	12.9	TP316L 316L, Cl. 1 & 3	A 312 A 358
20	*20*	*20*	18.9	17.5	16.5	16.0	15.6	TP316LN 316LN, Cl. 1 & 3	A 312 A 358
16.7	*16.7*	*16.7*	15.8	14.7	14.0	13.7	13.4	TP304I 304I, Cl. 1 & 3	A 312 A 358
20.0	*20.0*	*20.0*	18.6	17.5	16.4	16.1	15.9	TP304LN 304LN, Cl. 1 & 3	A 312 A 358

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]

Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	Type or Grade	Notes	Specified Min. Strength, ksi	
					Tensile	Yield
Stainless Steel (5) (Cont'd)						
Pipes and Tubes (17) (Cont'd)						
18Cr-10Ni-Ti smls. > 3/8 in. thick	A 312	8	TP321	...	70	25
18Cr-10Ni-Ti smls. ≤ 3/8 in. thick or wld.	A 312	8	TP321	(12)		
321, A 240	A 358	8	321, Cl. 1 & 3	(12)(13)	75	30
18Cr-8Ni	A 312	8	TP304	(12)(14)		
304, A 240	A 358	8	304, Cl. 1 & 3	(12)(13)(14)	75	30
16Cr-12Ni-2Mo	A 312	8	TP316	(12)(14)		
316, A 240	A 358	8	316, Cl. 1 & 3	(12)(13)(14)	75	30
18Cr-13Ni-3Mo	A 312	8	TP317	(12)(14)		
18Cr-10Ni-Cb	A 312	8	TP347	(12)		
347, A 240	A 358	8	347, Cl. 1 & 3	(12)(13)	75	30
18Cr-8Ni-N	A 312	8	TP304N	(12)(14)		
304N, A 240	A 358	8	304N, Cl. 1 & 3	(12)(13)(14)	80	35
16Cr-12Ni-2Mo-N	A 312	8	TP316N	(12)(14)		
316N, A 240	A 358	8	316N, Cl. 1 & 3	(12)(13)(14)	80	35
Forgings and Fittings						
16Cr-12Ni-2Mo	A 182	8	F316L	(19)		
16Cr-12Ni-2Mo	A 403	8	WP316L, Cl. S & WX	(12)	70	25
16Cr-12Ni-2Mo-N	A 182	8	F316LN	(20)		
16Cr-12Ni-2Mo-N	A 403	8	WP316LN, Cl. S & WX	(12)	75	30
18Cr-8Ni	A 182	8	F304L	(19)		
18Cr-8Ni	A 403	8	WP304L, Cl. S & WX	(12)	70	25
18Cr-8Ni-N	A 182	8	F304LN	(20)		
18Cr-8Ni-N	A 403	8	WP304LN, Cl. S & WX	(12)	75	30

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TABLE K-1 (CONT'D) (99)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]
Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding								Type or Grade	Spec. No.
100	200	300	400	500	600	650	700		
								Stainless Steel (5) (Cont'd) Pipes and Tubes (17) (Cont'd)	
16.7	*16.7*	*16.7*	*16.7*	16.1	15.2	14.9	14.6	TP321 smls. > 3/8 in. thick	A 312
20.0	*20.0*	*20.0*	*20.0*	19.4	18.3	17.9	17.5	TP321 smls. ≤ 3/8 in. thick & wld. 321, Cl. 1 & 3	A 312 A 358
20.0	*20.0*	*20.0*	18.7	17.5	16.5	16.2	15.9	TP304 304, Cl. 1 & 3	A 312 A 358
20.0	*20.0*	*20.0*	19.3	18.0	17.0	16.7	16.3	TP316 316, Cl. 1 & 3 TP317	A 312 A 358 A 312
20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.3	18.9	18.5	TP347 347, Cl. 1 & 3	A 312 A 358
23.3	*23.3*	22.5	20.3	18.8	17.8	17.6	17.2	TP304N 304N, Cl. 1 & 3	A 312 A 358
23.3	*23.3*	*23.3*	*23.3*	22.2	21.1	20.5	20.1	TP316N 316N, Cl. 1 & 3	A 312 A 358
								Forgings and Fittings	
16.7	*16.7*	*16.7*	15.6	14.4	13.5	13.2	12.9	F316L WP316L, Cl. S & WX	A 182 A 403
20.0	*20.0*	*20.0*	18.9	17.5	16.5	16.0	15.6	F316LN WP316LN, Cl. S & WX	A 182 A 403
16.7	*16.7*	*16.7*	15.8	14.8	14.0	13.7	13.4	F304L WP304L, Cl. S & WX	A 182 A 403
20.0	*20.0*	*20.0*	18.6	17.5	16.4	16.1	15.9	F304LN WP304LN, Cl. S & WX	A 182 A 403

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]

Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	Type or Grade	Notes	Specified Min. Strength, ksi	
					Tensile	Yield
Stainless Steel (5) (Cont'd)						
Forgings and Fittings (Cont'd)						
18Cr-10Ni-Ti	A 182	8	F321	(20)	75	30
18Cr-10Ni-Ti	A 403	8	WP321, Cl. S & WX	(12)		
18Cr-8Ni	A 182	8	F304	(14)(20)	75	30
18Cr-8Ni	A 403	8	WP304, Cl. S & WX	(12)(14)		
16Cr-12Ni-2Mo	A 182	8	F316	(14)(20)	75	30
16Cr-12Ni-2Mo	A 403	8	WP316, Cl. S & WX	(12)(14)		
18Cr-13Ni-3Mo	A 403	8	WP317, Cl. S & WX	(12)(14)		
18Cr-10Ni-Cb	A 182	8	F347	(20)	75	30
18Cr-10Ni-Cb	A 403	8	WP347, Cl. S & WX	(12)		
18Cr-8Ni-N	A 182	8	F304N	(14)	80	35
18Cr-8Ni-N	A 403	8	WP304N, Cl. S & WX	(12)(14)		
16Cr-12Ni-2Mo-N	A 182	8	F316N	(14)	80	35
16Cr-12Ni-2Mo-N	A 403	8	WP316N, Cl. S & WX	(12)(14)		

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]

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Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding								Type or Grade	Spec. No.
100	200	300	400	500	600	650	700		
								Stainless Steel (5) (Cont'd) Forgings and Fittings (Cont'd)	
20.0	*20.0*	*20.0*	*20.0*	19.4	18.3	17.9	17.5	F321	A 182
								WP321, Cl. S & WX	A 403
20.0	*20.0*	*20.0*	18.7	17.5	16.5	16.2	15.9	F304	A 182
								WP304, Cl. S & WX	A 403
20.0	*20.0*	*20.0*	19.3	18.0	17.0	16.7	16.3	F316	A 182
								WP316, Cl. S & WX	A 403
								WP317, Cl. S & WX	A 403
20.0	*20.0*	*20.0*	*20.0*	*20.0*	19.4	19.0	18.6	F347	A 182
								WP347, Cl. S & WX	A 403
23.3	*23.3*	22.5	20.3	18.8	17.8	17.6	17.2	F304N	A 182
								WP304N, Cl. S & WX	A 403
23.3	*23.3*	*23.3*	*23.3*	22.2	21.0	20.5	20.1	F316N	A 182
								WP316N, Cl. S & WX	A 403

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]
Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	UNS Number	Condition	Size Range, in.	Notes	Specified Min. Strength, ksi Tensile	Yield
Nickel and Nickel Alloys (5)								
Pipes and Tubes (17)								
Ni-Cu	B 165	42	N04400	Annealed	> 5 O.D.	...	70	25
Ni-Cr-Fe	B 167	43	N06600	H.W.				
Ni-Cr-Fe	B 167	43	N06600	H.W. ann.	> 5 O.D.	...	75	25
Ni-Cu	B 165	42	N04400	Annealed	≤ 5 O.D.	...	70	28
Ni-Cr-Fe	B 167	43	N06600	H.W.	≤ 5 O.D.	...		
Ni-Cr-Fe	B 167	43	N06600	H.W. ann.	≤ 5 O.D.	...	80	30
Ni-Cr-Fe	B 167	43	N06600	C.W. ann.	> 5 O.D.	...		
Ni-Cr-Fe	B 167	43	N06600	C.W. ann.	≤ 5 O.D.	...	80	35
Ni-Mo-Cr	B 622	44	N10276	...	All	...	100	41
Ni-Cu	B 165	42	N04400	Str. rel.	All	...	85	55
Forgings and Fittings								
Ni-Cu	B 366	S-42	N04400	...	All	(12)(15)		
Ni-Cu	B 564	42	N04400	Annealed	All	...	70	25
Ni-Cr-Fe	B 366	S-43	N06600	...	All	(12)(15)	75	25
Ni-Cr-Fe	B 564	43	N06600	Annealed	All	...	80	35
Ni-Mo-Cr	B 366	44	N10276	...	All	(12)	100	41
Rod and Bar								
Ni-Cu	B 164	42	N04400	Annealed	All	...	70	25
Ni-Cr-Fe	B 166	43	N06600	C.W. ann. & H.W. ann.	All	...	80	35
Ni-Cr-Fe	B 166	43	N06600	H.W., A.W.	sq. rec., & hex.			
Ni-Cr-Fe	B 166	43	N06600	H.W., A.W.	> 3 rd.	...	85	35
Ni-Cu	B 164	42	N04400	H.W.	Rod, sq., & rec. ≤ 12 hex. ≤ $2\frac{1}{8}$	...	80	40
Ni-Cr-Fe	B 166	43	N06600	H.W., A.W.	$\frac{1}{2}$ to 3 rd.	...	90	40
Ni-Mo-Cr	B 574	44	N10276	...	All	...	100	41
Ni-Cr-Fe	B 166	S-43	N06600	H.W., A.W.	$\frac{1}{4}$ to $\frac{1}{2}$ rd.	...	95	45

Abbreviations in Condition and Size Range Columns:

ann.	annealed	rd.	rounds
A.W.	as worked	rec.	rectangle
C.W.	cold worked	rel.	relieved
H.W.	hot worked	sq.	squares
hex.	hexagons	str.	stress
O.D.	outside diameter		

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]
Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding								UNS Number	Spec. No.
100	200	300	400	500	600	650	700		
									Nickel and Nickel Alloy (5) Pipes and Tubes (17)
16.7	14.7	13.7	13.3	13.3	13.3	13.3	13.3	N04400	B 165
16.7	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	N06600	B 167
								N06600	B 167
18.7	16.5	15.4	14.8	14.8	14.8	14.8	14.8	N04400	B 165
20.0	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	*20.0*	N06600	B 167
								N06600	B 167
								N06600	B 167
23.3	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	N06600	B 167
27.3	*27.3*	*27.3*	*27.3*	26.9	25.4	24.6	24.0	N10276	B 622
36.7	32.3	30.1	29.1	29.1	...	...	...	N04400	B 165
									Forgings and Fittings
16.7	14.7	13.7	13.3	13.3	13.3	13.3	13.3	N04400	B 366
								N04400	B 564
16.7	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	*16.7*	N06600	B 366
23.3	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	N06600	B 564
27.3	*27.3*	*27.3*	*27.3*	26.9	25.4	24.6	24.0	N10276	B 366
									Rod and Bar
16.7	14.7	13.7	13.3	13.3	13.3	13.3	13.3	N04400	B 164
23.3	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	*23.3*	N06600	B 166
23.3	21.2	21.2	21.2	21.2	21.2	21.2	21.1	N06600	B 166
								N06600	B 166
26.7	20.0	20.0	20.0	20.0	20.0	20.0	19.2	N04400	B 164
26.7	21.2	21.2	21.2	21.2	21.2	21.2	21.1	N06600	B 166
27.3	*27.3*	*27.3*	*27.3*	26.9	25.4	*23.9*	23.9	N10276	B 574
30.0	21.2	21.2	21.2	21.2	21.2	21.2	21.1	N06600	B 166

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]
Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (7)	Grade	Notes	Specified Min. Strength, ksi	
					Tensile	Yield
Titanium and Titanium Alloy Pipes and Tubes (17)						
Ti	B 337	51	2	...	50	40
Ti	B 338					
Ti-0.2 Pd.	B 337	51	7			
Ti-0.2 Pd.	B 338					
Ti	B 337	52	3	(8)	65	55
Ti	B 338					
Forgings and Fittings						
Ti	B 363	51	WPT2	(12)	50	40
Ti	B 381	51	F2	...		
Ti-0.2 Pd	B 381	51	F7	...		
Ti	B 363	52	WPT3	(8)	65	55
Ti	B 381	52	F3	...		

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TABLE K-1 (CONT'D)
ALLOWABLE STRESSES IN TENSION FOR METALS FOR CHAPTER IX[1-6, 18]
Numbers in Parentheses Refer to Notes for Appendix K Tables; Specifications are ASTM Unless Otherwise Indicated

Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding									
100	200	300	400	500	600	650	700	Grade	Spec. No.
								Titanium and Titanium Alloy Pipes and Tubes (17)	
26.7	21.5	16.8	12.4	9.4	7.6	...	...	2	B 337
								2	B 338
								7	B 337
								7	B 338
36.7	29.8	23.6	17.7	12.4	8.4	...	...	3	B 337, B 338
								Forgings and Fittings	
26.7	21.5	16.8	12.4	9.4	7.6	...	...	WPT2	B 363
								F2	B 381
								F7	B 381
36.7	29.8	23.6	17.7	12.4	8.4	...	...	WPT3	B 363
								F3	B 381

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APPENDIX L
ALUMINUM ALLOY PIPE FLANGES

L300 GENERAL

This Appendix covers pressure-temperature ratings, materials, dimensions, and marking of forged aluminum alloy flanges, as an alternative to applying the rules in paras. 304.5.1(b) and 304.5.2(b). DN 15 (NPS ½) through DN 600 (NPS 24) flanges may be welding neck, slip-on, socket welding, lapped, or blind in ratings PN 20, 50, and 110 (Classes 150, 300, and 600).

Requirements and recommendations regarding bolting and gaskets are included.

L301 PRESSURE-TEMPERATURE RATINGS

L301.1 Ratings Basis

Ratings are maximum allowable working gage pressures at the temperatures shown in Tables L301.2M and L301.2U for the applicable material and pressure Class. For intermediate temperatures, linear interpolation is permitted.

L301.2 Ratings of Flanged Joints

(a) In addition to the considerations in para. F312.1, consideration must be given to the low modulus of elasticity of aluminum alloys. External moments should be limited, and controlled bolt tightening or other techniques may be necessary to achieve and maintain a leak-free joint.

(b) For ratings of slip-on and socket welding flanges made of Alloy 6061-T6, see Tables L301.2M and L301.2U, Note (3).

L301.3 Temperature Considerations

Application of the ratings in this Appendix to flanged joints at both high and low temperatures shall take into consideration the risk of leakage due to forces and moments developed in the connected piping or equipment. The following provisions are intended to minimize these risks.

L301.3.1 Flange Attachment. Slip-on and socket welding flanges are not recommended for service below −50°F if flanges are subject to thermal cycling.

L301.3.2 Differential Thermal Expansion and Conductivity. Because aluminum alloys have thermal expansion coefficients approximately twice those for steel, and thermal conductivity approximately three times that of steel, it may be necessary to provide for differential expansion and expansion rates between components of the flanged joint. Consideration shall be given to thermal transients (e.g., startup, shutdown, and upset) in addition to the operating temperature of the joint.

L301.4 Hydrostatic Test

A flange shall be capable of withstanding a hydrostatic test at 1.5 times its 100°F pressure rating.

L302 MARKING

Marking shall be in accordance with MSS SP-25, except as follows. Marking shall be stamped on the edge of each flange.

L302.1 Name

The manufacturer's name or trademark shall be applied.

L302.2 Material

The marking ASTM B 247 shall be applied, followed by the applicable Alloy and Temper designations.

L302.3 Rating

The marking shall be the applicable rating Class: 150, 300, or 600.

L302.4 Designation

The marking B31.3L shall be applied.

L302.5 Size

The marking of NPS shall be applied. A reducing size shall be designated by its two nominal pipe sizes.

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TABLE L301.2M
PRESSURE-TEMPERATURE RATINGS
Pressures Are in kPa; Temperatures Are in °C

Material ASTM B 247 Alloy, Temper	PN 20 Temperature [Note (1)]				PN 50 Temperature [Note (1)]				PN 110 Temperature [Note (1)]			
	38	66	93	121	38	66	93	121	38	66	93	121
3003-H112	275	275	240	240	725	690	655	655	1415	1380	1345	1275
6061-T6 [Note (2)]	1895	1860	1825	1795	4965	4895	4825	4655	9930	9790	9655	9345
6061-T6 [Note (3)]	1265	1240	1215	1195	3310	3265	3215	3105	6620	6525	6435	6230

NOTES:
(1) The minimum temperature is −269°C (−425°F). The maximum rating below 38°C (100°F) shall be the rating shown for 38°C.
(2) Ratings apply to welding neck, lapped, and blind flanges.
(3) Ratings apply to slip-on and socket welding flanges.

TABLE L301.2U
PRESSURE-TEMPERATURE RATINGS
Pressures Are in psig; Temperatures Are in °F

Material ASTM B 247 Alloy and Temper	Class 150 Temperature [Note (1)]				Class 300 Temperature [Note (1)]				Class 600 Temperature [Note (1)]			
	100	150	200	250	100	150	200	250	100	150	200	250
3003-H112	40	40	35	35	105	100	95	95	205	200	195	185
6061-T6 [Note (2)]	275	270	265	260	720	710	700	675	1440	1420	1400	1355
6061-T6 [Note (3)]	185	180	175	175	480	475	465	450	960	945	935	905

NOTES:
(1) The minimum temperature is −269°C (−425°F). The maximum rating below 38°C (100°F) shall be the rating shown for 38°C.
(2) Ratings apply to welding neck, lapped, and blind flanges.
(3) Ratings apply to slip-on and socket welding flanges.

See examples in Note (4) of Table 7, ASME B16.5.

L303 MATERIALS

L303.1 Flange Material

Flanges shall be forgings conforming to ASTM B 247. For specific alloys and tempers, see Tables L301.2M and L301.2U. For precautions in use, see para. 323.5 and Appendix F, para. F323.

(99) **L303.1.1 Repair Welding of Flanges.** Repair welding of flanges manufactured to this Appendix shall be restricted to any damaged areas of the weld bevel of welding neck flanges unless specifically approved by the Purchaser after consideration of the extent, location, and effect on temper and ductility. Repair welding of any area other than the weld bevel on 6061-T6 welding neck flanges shall restrict the pressure/temperature ratings to those specified for slip-on and socket welding flanges in Tables L301.2M and L301.2U. Any repair welding shall be performed in accordance with para. 328.6.

TABLE L303.2
ALUMINUM BOLTING MATERIALS[1]

ASTM Specification	Alloy	Temper
B 211	2014	T6, T261
B 211	2024	T4
B 211	6061	T6, T261

NOTE:
(1) Repair welding of bolting material is prohibited.

L303.2 Bolting Materials

Bolting listed in Table L303.2 and in ASME B16.5, Table 1B, may be used subject to the following limitations.

(99) **L303.2.1 High Strength Bolting.** Bolting materials listed as high strength in ASME B16.5, Table 1B, may be used in any flanged joints. See para. L305.

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(99) **L303.2.2 Intermediate Strength Bolting.** Bolting materials in Table L303.2, and bolting listed as intermediate strength in ASME B16.5, Table 1B, may be used in any flanged joints. See para. L305.

(99) **L303.2.3 Low Strength Bolting.** Bolting materials listed as low strength in ASME B16.5, Table 1B, may be used in PN 20 and PN 50 (Class 150 and 300) flanged joints. See para. L305.

L303.3 Gaskets

Gaskets listed in ASME B16.5, Annex E, Fig. E1, Group 1a may be used with any rating Class and bolting.

L303.3.1 Gaskets for Low Strength Bolting. If bolting listed as low strength (see para. L303.2.3) is used, gaskets listed in ASME B16.5, Annex E, Fig. E1, Group 1a shall be used.

L303.3.2 Gaskets for PN 20 (Class 150) Flanged Joints. It is recommended that only gaskets listed in ASME B16.5, Annex E, Fig. E1, Group 1a be used.

L303.3.3 Gaskets for Class 300 and Higher Flanged Joints. It is recommended that only gaskets listed in ASME B16.5, Annex E, Fig. E1, Group 1 be used. For gaskets in Group 1b, line flanges should be of the welding neck or lapped joint type; controlled-torque tightening practices should be used.

L304 DIMENSIONS AND FACINGS

(a) Flanges shall meet the dimensional and tolerance requirements of ASME B16.5.

(b) Flange facing and facing finish shall be in accordance with ASME B16.5, except that small male and female facings (on ends of pipe) shall not be used.

L305 DESIGN CONSIDERATIONS (99)

The following design considerations are applicable to all flanged joints which incorporate a flange manufactured to this Appendix:

(a) The differential expansion within a flanged joint must be considered; also, see para. F312.

(b) Where a gasket other than those recommended in para. L303.3 is specified, the designer shall verify by calculations the ability of the selected bolting to seat the selected gasket and maintain a sealed joint under the expected operating conditions without overstressing the components.

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APPENDIX M
GUIDE TO CLASSIFYING FLUID SERVICES[1, 2]

(See Fig. M300)

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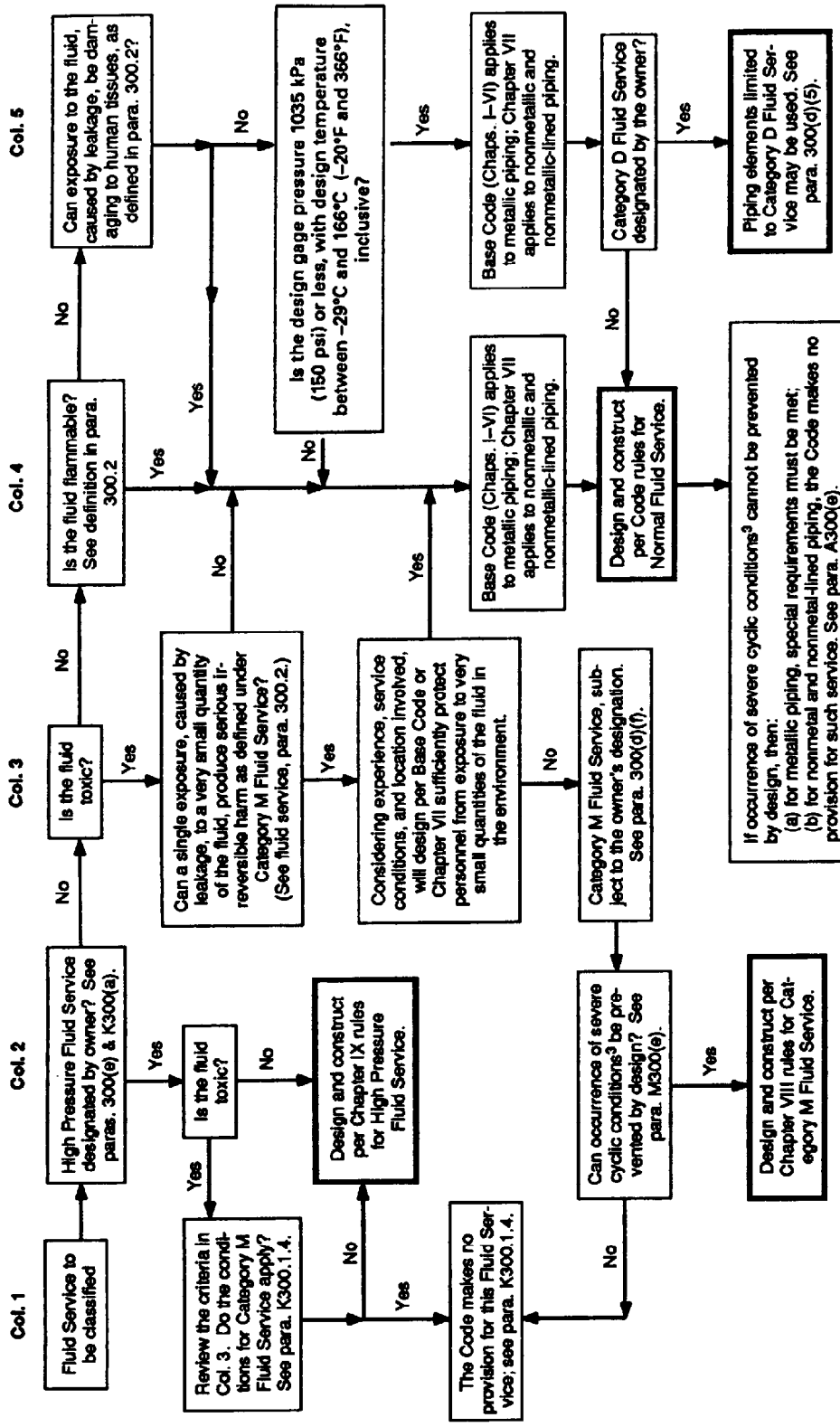

NOTES:
(1) See paras. 300(b)(1), 300(d)(4) and (5), and 300(e) for decisions the owner must make. Other decisions are the designer's responsibility; see para. 300(b)(2).
(2) The term "fluid service" is defined in para. 300.2
(3) Severe cyclic conditions are defined in para. 300.2. Requirements are found in Chapter II, Parts 3 and 4, and in paras. 323.4.2 and 341.4.3.

FIG. M300 GUIDE TO CLASSIFYING FLUID SERVICES

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APPENDIX V
ALLOWABLE VARIATIONS IN ELEVATED TEMPERATURE SERVICE

V300 APPLICATION

(a) This Appendix covers application of the Linear Life Fraction Rule, which provides a method for evaluating variations above design conditions at elevated temperatures where material creep properties [see para. V302(c)] control design. This Appendix is a Code requirement only when specified by the owner in accordance with the last sentence of para. 302.2.4(f)(1).

(b) Life Fraction analysis addresses only the gross strength of piping components; it does not consider local stress effects. It is the designer's responsibility to provide construction details suitable for elevated temperature design.

V300.1 Definitions

operating condition: any condition of pressure and temperature under which the design conditions are not exceeded

excursion: any condition under which pressure or temperature, or both, exceed the design conditions

service condition: any operating condition or excursion

duration

(a) the extent of any service condition, hours;

(b) the cumulative extent of all repetitions of a given service condition during service life, hours.

service life: the life assigned to a piping system for design purposes, hours

V301 DESIGN BASIS

Life Fraction analysis shall be performed in accordance with one of the following design basis options selected by the owner.[1]

(a) All service conditions and their durations are included.

(b) The most severe operating condition (representing all operating conditions and the sum of their durations) and all excursions and their durations are included.

(c) If operating conditions are unknown or are not considered reliable, the most severe design condition (representing all operating conditions and the sum of their durations), and all excursions and their durations, shall be used as the design basis.

V302 CRITERIA

(a) All of the criteria in para. 302.2.4 shall be met.

(b) Only carbon steels, low and intermediate alloy steels, austenitic stainless steels, and high nickel alloys are included.

(c) Excursions are considered only when the allowable stress at temperature in Table A-1 is based on the creep criteria stated in para. 302.3.2. (99)

(d) Creep-fatigue interaction effects shall be considered when the number of cycles exceeds 100.

V303 PROCEDURE

The cumulative effect of all service conditions during the service life of the piping is determined by the

[1] In selecting the design basis, the owner should be guided by the following.

Option (a) yields the most accurate estimation of creep-rupture effects, but requires the greatest detail in estimating operating cycles and variations.

Option (b) yields a more conservative (larger) estimate of creep-rupture effects, but requires less detailed estimation of operating conditions.

Option (c), required if neither of the other options is selected, yields the most conservative results and requires only the estimation of expected excursions.

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Linear Life Fraction Rule in accordance with the following procedure.

V303.1 Calculations for Each Service Condition *i*

The following steps shall be repeated for each service condition considered.

V303.1.1 Equivalent Stress for Pressure

(a) Using Eq. (V1), compute a pressure-based equivalent stress S_{pi}:

$$S_{pi} = S_d P_i / P_{\max.} \quad \text{(V1)}$$

where

S_{pi} = pressure-based equivalent stress, MPa (ksi)
P_i = gage pressure, kPa (psi), during service condition i
S_d = allowable stress, MPa (ksi) at design temperature, °C (°F)
$P_{\max.}$ = maximum allowable gage pressure, kPa (psi), for continuous operation of pipe or component at design temperature

(b) Compute the maximum longitudinal stress S_L during service condition i, in accordance with para. 302.3.5(c).

(c) The equivalent stress S_i for use in para. V303.1.2, is the greater of the values calculated in (a) and (b) above.

V303.1.2 Design Temperature. From Table A-1 find the temperature corresponding to the equivalent stress S_i using linear interpolation if necessary. This temperature T_D is the effective design temperature for service condition i.

V303.1.3 Larson-Miller Parameter. Compute the *LMP* for the basic design life for service condition i, using Eq. (V2):

$$\left.\begin{aligned} &\text{SI metric:} \quad LMP = (C + 5)(T_D + 273) \\ &\text{U.S.:} \quad LMP = (C + 5)(T_D + 460) \end{aligned}\right\} \quad \text{(V2)}$$

where

T_D = design temperature, °C (°F); see para. V303.1.2
C = 20 (carbon, low, and intermediate alloy steels)
C = 15 (austenitic stainless steel and high nickel alloys)

V303.1.4 Rupture Life. Compute the rupture life t_{ri}, hr, using Eq. (V3):

$$t_{ri} = 10^a \quad \text{(V3)}$$

where

$$\text{SI metric:} \quad a = \frac{LMP}{T_i + 273} - \text{C}$$

$$\text{U.S.:} \quad a = \frac{LMP}{T_i + 460} - \text{C}$$

and

t_{ri} = allowable rupture life, hr, associated with a given service condition i and stress S_i
T_i = actual temperature, °C (°F), during service condition i

LMP and C are as defined in para. V303.1.3

V303.2 Determine Creep-Rupture Usage Factor

The usage factor u is the summation of individual usage factors t_i/t_{ri} for all service conditions considered in para. V303.1. See Eq. (V4):

$$u = \sum(t_i/t_{ri}) \quad \text{(V4)}$$

where

i = as a subscript, 1 for the prevalent operating condition [or design condition if option (c) in para. V301 is used]; i = 2, 3, etc. for each of the other service conditions considered
t_i = total duration, hr, associated with any service condition i, at pressure P_i and temperature T_i
t_{ri} = as defined in para. V303.1.4

V303.3 Evaluation

The calculated value of u indicates the nominal amount of creep-rupture life expended during the service life of the piping system. If $u \leq 1.0$, the usage factor is acceptable including excursions. If $u > 1.0$, the designer shall either increase the design conditions (selecting piping system components of a higher allowable working pressure if necessary) or reduce the number and/or severity of excursions until the usage factor is acceptable.

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APPENDIX X
METALLIC BELLOWS EXPANSION JOINTS

Design requirements of Appendix X are dependent on and compatible with EJMA standards. There are no metric equivalents and no basis for introducing them at this time.

X300 GENERAL

The intent of this Appendix is to set forth design, manufacturing, and installation requirements and considerations for bellows type expansion joints, supplemented by the EJMA Standards. It is intended that applicable provisions and requirements of Chapters I through VI of this Code shall be met, except as modified herein. This Appendix does not specify design details. The detailed design of all elements of the expansion joint is the responsibility of the manufacturer. This Appendix is not applicable to expansion joints in piping designed in accordance with Chapter IX.

X301 PIPING DESIGNER RESPONSIBILITIES

The piping designer shall specify the design conditions and requirements necessary for the detailed design and manufacture of the expansion joint in accordance with para. X301.1 and the piping layout, anchors, restraints, guides, and supports required by para. X301.2.

X301.1 Expansion Joint Design Conditions

The piping designer shall specify all necessary design conditions including the following.

X301.1.1 Static Design Conditions. The design conditions shall include any possible variations of pressure or temperature, or both, above operating levels. Use of a design metal temperature other than the fluid temperature for any component of the expansion joint shall be verified by computation, using accepted heat transfer procedures, or by test or measurement on similarly designed equipment in service under equivalent operating conditions.

X301.1.2 Cyclic Design Conditions. These conditions shall include coincident pressure, temperature, imposed end displacements and thermal expansion of the expansion joint itself, for cycles during operation. Cycles due to transient conditions (startup, shutdown, and abnormal operation) shall be stated separately. (See EJMA Standards, C-4.1.5.2 on cumulative fatigue analysis, for guidance in defining cycles.)

X301.1.3 Other Loads. Other loads, including dynamic effects (such as wind, thermal shock, vibration, seismic forces, and hydraulic surge); and static loads, such as weight (insulation, snow, ice, etc.), shall be stated.

X301.1.4 Fluid Properties. Properties of the flowing medium pertinent to design requirements, including the owner-designated fluid service category, flow velocity and direction, for internal liners, etc., shall be specified.

X301.1.5 Other Design Conditions. Other conditions that may affect the design of the expansion joint, such as use of shrouds, external or internal insulation, limit stops, other constraints, and connections in the body (e.g., drains or bleeds) shall be stated.

X301.2 Piping Design Requirements

X301.2.1 General. Piping layout, anchorage, restraints, guiding, and support shall be designed to avoid imposing motions and forces on the expansion joint other than those for which it is intended. For example, a bellows expansion joint is not normally designed to absorb torsion. Pipe guides, restraints, and anchorage shall conform to the EJMA Standards. Anchors and guides shall be provided to withstand expansion joint thrust forces when not self-restrained by tie rods, hinge bars, pins, etc. (See para. X302.1.) Column buckling of the piping (e.g., due to internal fluid pressure) shall also be considered.

X301.2.2 Design of Anchors

(a) Main Anchors. Main anchors shall be designed to withstand the forces and moments listed in X301.2.2(b),

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and pressure thrust, defined as the product of the effective thrust area of the bellows and the maximum pressure to which the joint will be subjected in operation. For convoluted, omega, or disk type joints, the effective thrust area recommended by the manufacturer shall be used. If this information is unavailable, the area shall be based on the mean diameter of the bellows.

(b) Intermediate Anchors. Anchors shall be capable of withstanding the following forces and moments:

(1) those required to compress, extend, offset, or rotate the joint by an amount equal to the calculated linear or angular displacement;

(2) static friction of the pipe in moving on its supports between extreme extended and contracted positions (with calculated movement based on the length of pipe between anchor and expansion joint);

(3) operating and transient dynamic forces caused by the flowing medium; and

(4) other piping forces and moments.

X302 EXPANSION JOINT MANUFACTURER RESPONSIBILITIES

The expansion joint manufacturer shall provide the detailed design and fabrication of all elements of the expansion joint in accordance with the requirements of the Code and the engineering design. This includes:

(a) all piping within the end connections of the assembly supplied by the manufacturer, including pipe, flanges, fittings, connections, bellows, and supports or restraints of piping;

(b) specifying the need for supports or restraints external to the assembly as required, and of the data for their design; and

(c) determining design conditions for all components supplied with the expansion joint which are not in contact with the flowing medium.

X302.1 Expansion Joint Design

The design of bellows type expansion joints shall be based on recognized and accepted analysis methods and the design conditions stated in para. X301.1. Convoluted type bellows shall be designed in accordance with the EJMA Standards, except as otherwise required or permitted herein. Design of other types of bellows shall be qualified as required by para. 304.7.2.

X302.1.1 Factors of Safety. The factor of safety on squirm pressure shall be not less than 2.25. The factor of safety on ultimate rupture pressure shall be not less than 3.0.

X302.1.2 Design Stress Limits. For convoluted type bellows, stresses shall be calculated either by the formulas shown in the EJMA Standards or by other methods acceptable to the owner.

(a) The circumferential and meridional membrane stress in the bellows, the tangent end, and reinforcing ring members (including tensile stress in fasteners) due to design pressure shall not exceed the allowable stress values given in Table A-1.

(b) Meridional membrane and bending stresses at design pressure shall be of a magnitude which will not result in permanent deformation of the convolutions at test pressure. Correlation with previous test data may be used to satisfy this requirement.

For an unreinforced bellows, annealed after forming, the meridional membrane plus bending stress in the bellows shall not exceed 1.5 times the allowable stress given in Table A-1.

(c) Direct tensile, bearing, and shear stresses in restraints (tie rods, hinge bars, pins, etc.), in self-restrained expansion joints, and in the attachments of the restraining devices to the pipe or flanges, shall not exceed the allowable stress limits stated in para. 302.3.1. Restraints shall be designed to withstand the full design pressure thrust.

(d) Pressure design of pipe sections, fittings, and flanges shall meet the requirements of paras. 303 and 304.

(e) When the operating metal temperature of the bellows element is in the creep range,[1] the design shall be given special consideration and, in addition to meeting the requirements of this Appendix, shall be qualified as required by para. 304.7.2.

X302.1.3 Fatigue Analysis

(a) A fatigue analysis[1] which takes into account all design cyclic conditions shall be performed and the calculated design cycle life shall be reported. The method of analysis for convoluted U-shaped bellows shall be in accordance with EJMA Standards.

(b) Material design fatigue curves for as-formed austenitic stainless steel bellows are provided in Fig. X302.1.3. The curves are for use only with the EJMA stress equations. Fatigue testing by individual manufacturers, in accordance with (d) below, is required to qualify use of the pertinent fatigue curve for bellows manufactured by them. Fatigue testing in accordance

[1] Consideration shall be given to the detrimental effects of creep-fatigue interaction when the operating metal temperature of the bellows element will be in the creep range. Creep-fatigue interaction may become significant at temperatures above 800°F for austenitic stainless steels.

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with (e) below is required to develop fatigue curves for bellows of materials other than as-formed stainless steel. Fatigue test and evaluation procedures are described in (c) below. The allowable stress range for a U-shaped bellows shall be determined by multiplying the total stress range from Fig. X302.1.3 by the product of X_f times X_m, factors determined in accordance with (c), (d), and (e) below.

(c) Fatigue testing to qualify either a fabrication process or a new material shall be performed in accordance with the following procedure. Test bellows shall have an inside diameter not less than $3\frac{1}{2}$ in. and shall have at least three convolutions. The bellows fatigue test data shall be compared with a reference fatigue curve to develop a fabrication factor, Eq. (X1), or material factor, Eq. (X2):

$$X_f = R^f_{\text{min.}} \tag{X1}$$

$$X_m = K_s R^m_{\text{min.}}/X_f \tag{X2}$$

where

X_f = factor (not greater than 1.0) representing effect of the manufacturing process on bellows fatigue strength

X_m = factor representing effect of material and its heat treatment on bellows fatigue strength. X_m for as-formed austenitic stainless steel bellows is 1.0. It shall not exceed 1.0 in other cases unless five or more fatigue tests have been performed on bellows fabricated from the same material.

$R^f_{\text{min.}}$ and $R^m_{\text{min.}}$ = minimum ratio of test stress range to reference stress range of all bellows tested. (Superscripts f and m refer to qualification of a fabrication process or a new material, respectively.) This ratio shall be determined for each fatigue test by dividing the test stress range (calculated in accordance with the EJMA stress equations) by the reference stress range. The reference stress range is taken from the lower-bound fatigue curve for the bellows fatigue test data used to develop the design fatigue curves, and for unreinforced bellows is:

$$(8.4 \times 10^6/\sqrt{N_{ct}}) + 38{,}300$$

and for reinforced bellow is:

$$(10.6 \times 10^6/\sqrt{N_{ct}}) + 48{,}500$$

K_s = factor (not greater than 1.0) for statistical variation in test results
$= 1.25/(1.470 - 0.044N_t)$

N_{ct} = number of cycles to failure in bellows fatigue test; failure is defined as development of a crack through thickness

N_t = number of bellows fatigue tests performed to develop the material factor X_m

(d) The manufacturer shall qualify the manufacturing process by correlation fatigue testing. A minimum of five tests (each, for reinforced and unreinforced bellows) of austenitic stainless steel bellows in the as-formed condition, manufactured by the organization making the tests, shall be performed. Testing shall consider the effects of all variables necessary to validate the correlation between the fatigue curves, design equations, and finished product, including, as applicable: bellows diameter, thickness, convolution profile, manufacturing process, and single versus multi-ply construction. The factor X_f shall be determined from the test data in accordance with (c) above.

(e) The allowable stress range S_r for U-shaped bellows, fabricated from material other than as-formed austenitic stainless steel, shall be developed from bellows fatigue test data. A minimum of two bellows fatigue tests, differing in stress range by a factor of at least 2.0, are required to develop a material factor X_m in accordance with (c) above. [The factor X_f in Eq. (X2) shall be for the bellows tested.] Materials used in the as-formed condition and those heat treated after forming are considered separate materials.

X302.1.4 Limitations

(a) Expansion joint bellows shall not be constructed from lap welded pipe or lap welded tubing.

(b) All pressure containing or pressure thrust restraining materials shall conform to the requirements of Chapter III and Appendix A.

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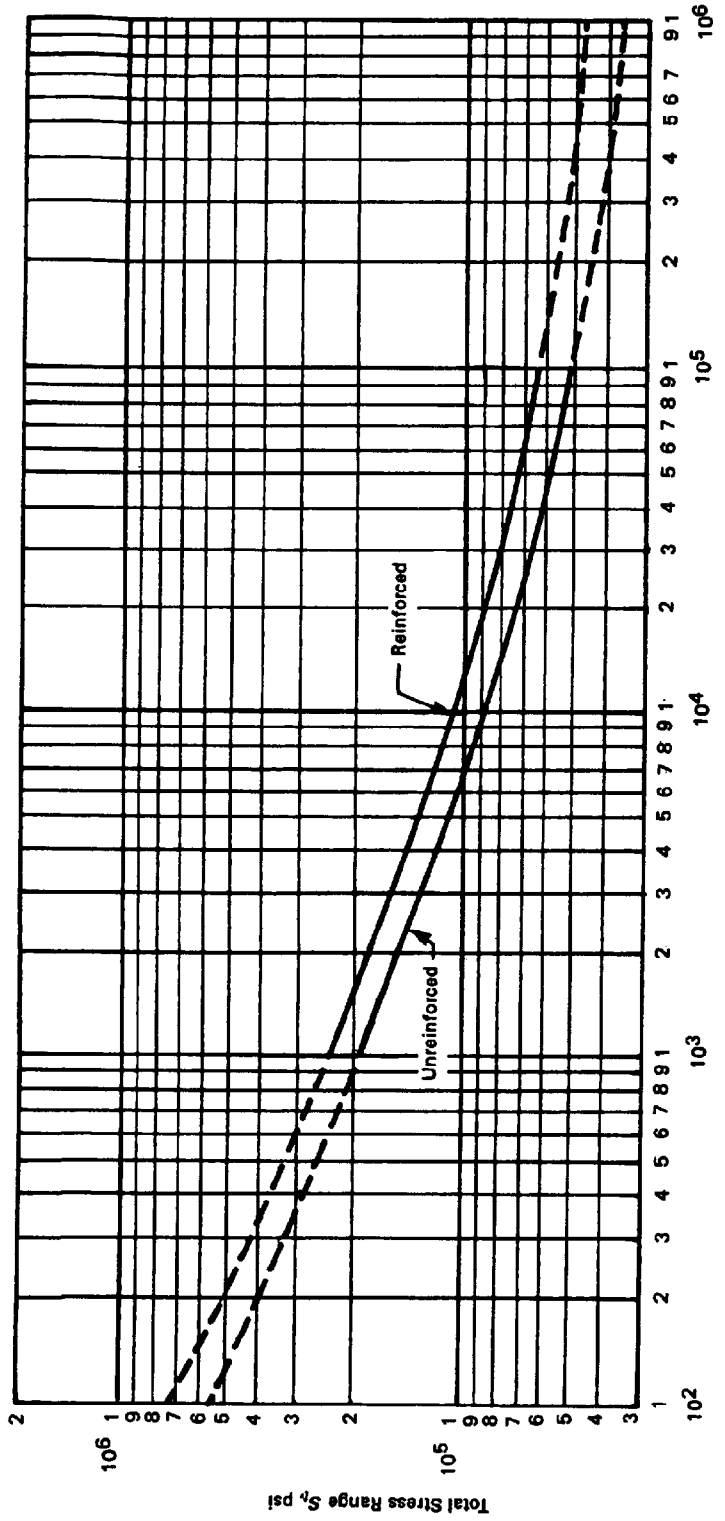

$$N_c = \left(\frac{A}{S_t - B}\right)^2$$

$$S_t = 0.7\,(S_3 + S_4) + S_5 + S_6$$

Bellows	Cycles	A	B
Unreinforced	≤ 40,000	5.2×10^6	38,300
	> 40,000	6.7×10^6	30,600
Reinforced	≤ 40,000	6.6×10^6	48,500
	> 40,000	8.5×10^6	38,800

GENERAL NOTES:

(a) These curves are intended to evaluate the design fatigue life at ambient temperature for austenitic stainless steel bellows which have not been heat treated. They are considered valid primarily in the range of 10^3 cycles to 10^5 cycles, due to the limited data available for the very low and very high cyclic ranges.

(b) The equations are of the form provided in "Design of Pressure Vessels for Low Cycle Fatigue" by B.F. Langer, ASME paper 61-WA-18. The constants were modified to reflect actual bellows test data reduced to a design curve in accordance with the rules of the BPV Code, Section VIII, Division 2, Appendix 8. The calculations of S_5 and S_6 shall be based on a modulus of elasticity equal to 28.3×10^6 psi.

(c) For nomenclature, refer to EJMA Standards.

(d) Factors have been included in these design fatigue curves to account for the normal effects of size, surface finish, and scatter of the data. Therefore, the design cycle life should realistically represent the estimated number of operating cycles. An overly conservative estimate of cycles can result in an increased number of convolutions and a joint more prone to instability.

FIG. X302.1.3 DESIGN FATIGUE CURVES FOR AUSTENITIC STAINLESS STEEL BELLOWS

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X302.2 Expansion Joint Manufacture

Expansion joints shall be produced in accordance with the manufacturer's specification, which shall include at least the following requirements.

X302.2.1 Fabrication

(a) All welds shall be made by qualified welders or welding operators using welding procedures qualified as required by para. 328.2.

(b) The longitudinal seam weld in the bellows element shall be a full penetration butt weld. Prior to forming, the thickness of the weld shall be not less than 1.00 nor more than 1.10 times the thickness of the bellows material.

(c) A full fillet weld may be used as a primary weld to attach a bellows element to an adjoining piping component.

X302.2.2 Examination. The following are minimum quality control requirements.

(a) Required examinations shall be in accordance with paras. 341 and 344.

(b) The longitudinal seam weld in the bellows tube shall be 100% examined prior to forming, either by radiography or, for material thickness $\leq {}^{3}/_{32}$ in. welded in a single pass, by liquid penetrant examination of both inside and outside surfaces. For the purposes of this Appendix, either examination is acceptable for design with a factor E_j of 1.00 when used within the stated thickness limits.

(c) After forming, a liquid penetrant examination shall be conducted on all accessible surfaces of the weld, inside and outside. Welds attaching the bellows to the piping, etc., shall be 100% liquid penetrant examined.

(d) Acceptance criteria for radiography shall be in accordance with Table 341.3.2. Acceptance criteria for liquid penetrant examination shall be that cracks, undercutting, and incomplete penetration are not permitted.

X302.2.3 Leak Test

(a) Each expansion joint shall be shop pressure tested by the manufacturer in accordance with para. 345, except that the test pressure shall be the lesser of that calculated by Eq. (24) (para. 345.4.2) or Eq. (X3), but not less than 1.5 times the design pressure. The test pressure shall be maintained for not less than 10 minutes.

$$P_T = 1.5 P_S E_t / E \qquad \text{(X3)}$$

where

P_T = minimum test gage pressure
P_S = limiting design pressure based on column instability (for convoluted U-shaped bellows, see C-4.2.1 and C-4.2.2 of the EJMA Standards)
E_t = modulus of elasticity at test temperature
E = modulus of elasticity at design temperature

(b) Expansion joints designed to resist the pressure thrust shall not be provided with any additional axial restraint during the leak test. Moment restraint simulating piping rigidity may be applied if necessary.

(c) In addition to examination for leaks and general structural integrity during the pressure test, the expansion joint shall be examined before, during, and after the test to confirm that no unacceptable squirm has occurred. Squirm shall be considered to have occurred if under the internal test pressure an initially symmetrical bellows deforms, resulting in lack of parallelism or uneven spacing of convolutions. Such deformation shall be considered unacceptable when the maximum ratio of bellows pitch under pressure to the pitch before applying pressure exceeds 1.15 for unreinforced bellows or 1.20 for reinforced bellows. Examination for leakage and deformation shall be performed at a pressure not less than two-thirds of the test pressure, after full test pressure has been applied.

(d) Examination for squirm shall be performed at full test pressure. For safety purposes, this may be accomplished by remote viewing (e.g., by optical magnification or video recording) of the changes in convolution spacing with respect to a temporarily mounted dimensional reference. Examination for leakage shall be performed at a pressure not less than two-thirds of test pressure, after application of full test pressure. For a pneumatic test, the precautions of para. 345.5.1 shall be observed.

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APPENDIX Z
PREPARATION OF TECHNICAL INQUIRIES

Z300 INTRODUCTION

The ASME B31 Committee, Code for Pressure Piping, will consider written requests for interpretations and revisions of the Code rules, and develop new rules if dictated by technological development. The Committee's activities in this regard are limited strictly to interpretations of the rules or to the consideration of revisions to the present rules on the basis of new data or technology. As a matter of published policy, ASME does not approve, certify, rate, or endorse any item, construction, proprietary device, or activity, and, accordingly, inquiries requiring such consideration will be returned. Moreover, ASME does not act as a consultant on specific engineering problems or on the general application or understanding of the Code rules. If, based on the inquiry information submitted, it is the opinion of the Committee that the inquirer should seek professional assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

An inquiry that does not provide the information needed for the Committee's full understanding will be returned.

The Introduction states that "it is the owner's responsibility to select the Code Section" for a piping installation. An inquiry requesting such a decision will be returned.

Z301 REQUIREMENTS

Inquiries shall be limited strictly to interpretations of the rules or to the consideration of revisions to the present rules on the basis of new data or technology. Inquiries shall meet the following requirements:

(a) Scope. Involve a single rule or closely related rules in the scope of the Code. An inquiry letter concerning unrelated subjects will be returned.

(b) Background. State the purpose of the inquiry, which may be either to obtain an interpretation of Code rules, or to propose consideration of a revision to the present rules. Provide concisely the information needed for the Committee's understanding of the inquiry, being sure to include reference to the applicable Code Section, Edition, Addenda, paragraphs, figures, and tables. If sketches are provided, they shall be limited to the scope of the inquiry.

(c) Inquiry Structure

(1) Proposed Question(s). The inquiry shall be stated in a condensed and precise question format, omitting superfluous background information, and, where appropriate, composed in such a way that "yes" or "no" (perhaps with provisos) would be an acceptable reply. The inquiry statement should be technically and editorially correct.

(2) Proposed Reply(ies). Provide a proposed reply stating what it is believed that the Code requires.

If in the inquirer's opinion, a revision to the Code is needed, recommended wording shall be provided in addition to information justifying the change.

Z302 SUBMITTAL

Inquiries should be submitted in typewritten form; however, legible handwritten inquiries will be considered. They shall include the name and mailing address of the inquirer, and be mailed to the following address:

Secretary
ASME B31 Committee
Three Park Avenue
New York, NY 10016-5990

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GENERAL NOTES TO INDEX:

(a) Reference is not made to a paragraph which merely states that a previous paragraph applies.

(b) To locate references with letter prefix:

Prefix	Location	Prefix	Location	Prefix	Location
A*	Chapter VII	G	App. G	M	Chapter VIII
B	App. B	H	App. H	MA	Chapter VIII
C	App. C	K	Chapter IX, App. K	X	Appendix X
D	App. D				
F	App. F				

*For Tables A-1, A-1A, A-1B, and A-2, see Appendix A.

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B31.1	Power Piping	1998
B31.2[1]	Fuel Gas Piping	1968
B31.3	Process Piping	1999
B31.4	Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids	1998
B31.5	Refrigeration Piping	1992
B31.8	Gas Transmission and Distribution Piping Systems	1995
B31.9	Building Services Piping	1996
B31.11	Slurry Transportation Piping Systems	1989 (R1998)
B31G-1991	Manual for Determining the Remaining Strength of Corroded Pipelines: A Supplement to ASME B31 Code for Pressure Piping	

NOTE:
(1) USAS B31.2-1968 was withdrawn as an American National Standard on February 18, 1988. ASME will continue to make available USAS B31.2-1968 as a historical document for a period of time.

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Designation: A 47/A 47M – 99

Standard Specification for Ferritic Malleable Iron Castings[1]

This standard is issued under the fixed designation A 47/A 47M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification[2] covers ferritic malleable castings for general engineering usage at temperatures from normal ambient to approximately 400°C (750°F).

1.2 No precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting and those of a test specimen cast from the same iron (see Appendix X1).

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware[3]

A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings[4]

A 644 Terminology Relating to Iron Castings[4]

E 8 Test Methods for Tension Testing of Metallic Materials[5]

E 10 Test Method for Brinell Hardness of Metallic Materials[5]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[5]

E 140 Hardness Conversion Tables for Metals[5]

2.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[6]

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Domestic Shipment (Civilian Agencies)[6]

3. Terminology

3.1 *Definitions*—Definitions for many terms common to iron are found in Terminology A 644.

4. Classification

4.1 Castings ordered and produced under this specification are classified under the following grades based on tests on separately cast test bars. Separately cast test bars shall be poured from the same lot of iron as the castings they represent and shall be heat treated with those castings except as provided in 7.2.3.

4.1.1 *Grade 32510 [Grade 22010]*:

4.1.1.1 The first three digits of the grade designation indicate the minimum yield strength (×100 psi [MPa]) and the last two digits indicate the minimum elongation (% in 2 in. [50 mm]).

5. Ordering Information

5.1 The purchase order for castings ordered under this specification shall state the specification designation, the year in which the specification was issued, and the grade of malleable iron to be supplied. Any option or special additions to the basic requirements of this specification shall be clearly and fully stipulated.

6. Chemical Composition

6.1 The chemical composition of the iron shall be such as to produce the structural and mechanical properties required by this specification.

7. Mechanical Properties

7.1 Factors influencing the properties of castings and their relationship to those of test specimens and separate test castings are discussed in Appendix X1.

7.2 *Tension Test Specimens*:

7.2.1 The tension test specimens shall be cast to the form and dimensions shown in Fig. 1 or Fig. 2, in the same kind of molding material used for the production castings. At least

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[1] This specification is under the jurisdiction of ASTM Committee A-4 on Iron Castings and is the direct responsibility of Subcommittee A04.02 on Malleable Iron Castings.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-47 in Section II of that code.

[3] *Annual Book of ASTM Standards*, Vol 01.06.

[4] *Annual Book of ASTM Standards*, Vol 01.02.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

[6] Available from Standardization Documents, Order Desk, Building 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111–5094, Attn: NPODS.

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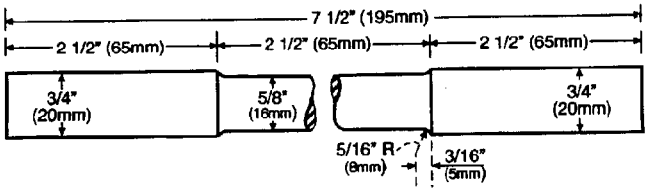
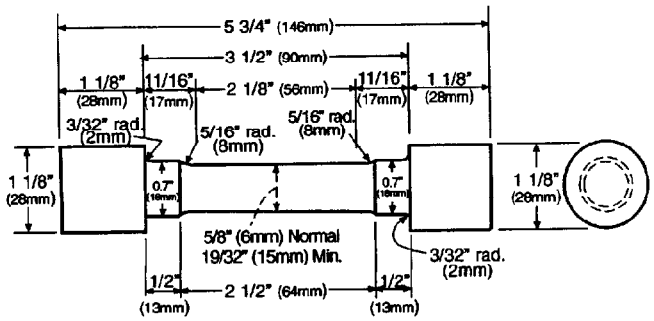
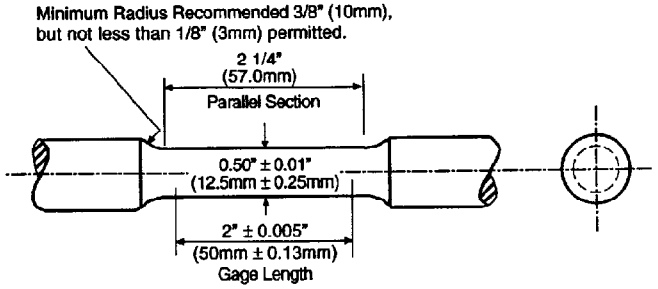


FIG. 1 Tension Test Specimen



NOTE 1—Modifications may be made in the dimensions indicated above for those details of the specimen outside of the gage length as required by testing procedure and equipment.

FIG. 2 Alternative Unmachined Tension Test Specimen



NOTE 1—The gage length and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. [0.08 to 0.13 mm] larger in diameter than the center.

FIG. 3 Machined Tension Test Specimen

three such specimens shall be cast from a representative ladle of iron either from each batch-melted heat or, in continuous melting, from each 4-h pour period during which the purchaser's castings were poured, or as otherwise agreed upon between manufacturer and purchaser.

7.2.2 All test specimens shall be suitably identified with the designation of either the batch-melted heat or the pour period of a continuous heat.

7.2.3 All test specimens shall be heat treated in the same production furnaces and in the same cycles as the castings they represent. However, in those instances wherein the critical sections of the production castings differ appreciably from that of the central portion of the test specimens, the time cycle for tempering the test specimens may be altered from that of the production lot in order to obtain similar microstructures or hardness, or both, in both specimen and castings. In such cases the hardness of the specimens shall be tested and reported along with the tensile test results.

7.2.4 The tension test is usually performed on unmachined specimens. However, for referee work, the specimen may be machined from the standard cast bar to the dimensions shown in Fig. 3.

7.3 *Tension Test Method*:

7.3.1 The gage length of the standard tension specimen shall be 2.00 ± 0.01 in. [50.0 ± 0.3 mm].

7.3.2 The diameter used to compute the cross-sectional area shall be the average between the largest and smallest diameters in that section of the 2-in. [50-mm] gage length having the smallest diameter and shall be measured to the nearest 0.001 in. [0.2 mm]. No cast bar having a mean diameter less than 0.590 in. [15.0 mm] shall be accepted for test.

7.3.3 After reaching a stress equivalent to approximately half of the anticipated yield stress, the speed of the moving head of the testing machine shall not exceed 0.50 in./min [12.5 mm/min] through the breaking load.

7.3.4 While the values for yield point and yield strength are not identical, they are sufficiently close for most applications of ferritic malleable irons to be used interchangeably. They may be determined by any of the approved techniques described in the paragraphs on Determination of Yield Strength and Yield Point of Test Methods E 8. If determined as yield strength, that stress producing an extension under load of 0.01 in. [0.25 mm] over the 2-in. [50-mm] gage length (for example, 0.5 % extension) or an offset of 0.2 % shall be taken as the yield stress, which shall be converted to yield strength by dividing by the original cross-sectional area of the gage length found in accordance with 7.3.2. It shall be reported to the nearest 100 psi [MPa]. In referee work, yield strength shall be determined as the stress that produces an extension under load of 0.5 % of the gage length.

7.3.5 The tensile strength shall be the maximum load carried by the specimen during the test divided by the original cross-sectional area of the gage length, as found in accordance with 7.3.2. It shall be reported to the nearest 100 psi [MPa].

7.3.6 The elongation is the increase in gage length after fracture of a tensile specimen, measured to the nearest 0.01 in. [0.25 mm], expressed as a percentage of the original gage length. It shall be reported to the nearest 0.5 %.

7.4 *Retesting*:

7.4.1 If, after testing, a specimen shows evidence of a defect, another tension test may be made on a companion specimen. Also, a retest shall be permitted whenever fracture occurs outside the central 50 % of the gage length.

7.4.2 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification, the castings represented by these test specimens shall be rejected. A valid test is

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one wherein the test specimen has been properly prepared and appears to be sound and on which the approved test procedure has been followed.

7.4.3 If sufficient companion test bars are unavailable, the manufacturer shall have the option of testing a specimen cut from a representative casting. Therefore, as stated in X1.3, the mechanical properties of such tension test specimen removed from a production casting will not necessarily correspond to those of a standard separately cast test specimen, the values in Table 1 do not apply. Instead, the mechanical properties of the test specimen from the casting must equal or exceed the average of those from similar test specimens removed from the same location from two castings of the same design where separately cast test bars meet the requirements of Table 1.

7.4.4 If the first test results indicate that a reheat treatment is needed to meet the test requirements, the entire lot of castings and the representative test specimens shall be reheat treated together. Testing shall then be repeated in accordance with 7.4.1-7.4.3.

7.4.5 The results of all tests, including retests, shall be posted in permanent record, which shall state any abnormalities observed during the test and in the fractured ends. Such records shall be kept for at least 1 year after shipment of the production castings and shall be available for examination by the purchaser or by his authorized representative.

7.4.6 If not covered in the purchase agreement, the frequency of tension testing shall be in accordance with 7.2.1 and sufficiently often to ensure uniformity of product and compliance with minimum test requirements.

7.4.7 Tension test results, obtained in accordance with the above subsections, must conform to the values of Table 1 for acceptance under this specification except as provided in 7.4.3.

7.4.8 When agreed upon between manufacturer and purchaser, tested specimens or unbroken test bars shall be preserved by the manufacturer for a period of three months after the date of the test report.

7.5 *Hardness Test*—If the purchase agreement requires hardness testing, the acceptable hardness range shall be stated and a test location clearly shown on the covering drawing(s).

7.5.1 *Hardness Test Method*—The Brinell method of hardness testing in accordance with Test Method E 10 shall be employed whenever possible.

7.5.2 For castings of such size or shape that do not permit Brinell testing with the standard 3000-kgf load, the 500 kgf may be employed, the hardness number being reported as HB 10/500/15. In very unusual cases where it is impossible to use the Brinell method, the Rockwell test may be substituted, using Test Methods E 18 with an appropriate Rockwell scale. Conversions of hardness values from one method to another according to Standard E 140, which does not specifically cover cast irons, are approximate only and, therefore, are generally inadvisable.

7.5.3 Sufficient material shall be removed from the cast surface to ensure that the measured surface is representative.

7.5.4 Sampling procedures and the frequency of hardness testing shall be fully detailed on the purchase agreement. Otherwise, hardness tests shall be performed at the discretion of the producer.

7.5.5 Castings failing to conform to the required hardness range may be reheat treated and retested. If after reheat treating they still fail the hardness requirements, they shall be rejected.

7.5.6 Typical hardness maximums for this grade of malleable iron are listed in Table 2.

TABLE 1 Tension Test Requirements

Inch-Pound Grades			
English Grade	Tensile Strength, min, psi	Yield Strength, min, psi	Elongation in 2 in, min, %
32510	50 000	32 500	10
Metric Grades			
Metric Grade	Tensile Strength, min, MPa	Yield Strength min, MPa	Elongation in 50 mm, min, %
22010	340	220	10

8. Microstructure Requirements

8.1 The microstructure of the malleable iron shall consist of temper carbon nodules distributed through a ferritic matrix and shall be free of excessive pearlite, massive carbides, and primary graphite.

8.2 When agreed upon by the purchaser and producer, the maximum decarburization at any as-cast surface after heat treatment may be stipulated in writing, as measured by visual depletion of combined carbon after polishing, etching in nital, and viewing at 100×.

8.3 In reference work, the metallographic practice recommended in Test Method A 247 shall be followed.

9. Soundness Requirements

9.1 All castings, on visual examination, shall be sound and free of obvious shrinkage and porosity.

9.2 If the purchaser requires soundness tests to be performed, it shall be so stated in the purchase agreement, and the method and soundness requirements shall be detailed.

10. Dimensional Requirements

10.1 The castings shall conform to the dimensions given on drawings furnished by the purchaser, or to the dimensions established by the pattern equipment supplied by the purchaser, or as agreed upon in specific cases to gages supplied by the purchaser. Variations in any solid dimensions will be permitted, as shown in Table 3, unless otherwise agreed upon by the foundry and purchaser.

11. Workmanship, Finish and Appearance

11.1 The surface of the casting shall be inspected visually, particularly in critical areas, for such surface defects as cracks, hot tears, adhering sand and scale, cold shuts, and gas holes.

11.2 No repairing, plugging, or welding of any kind shall be permitted unless written permission is granted by the purchaser.

11.3 Castings that have been repaired by welding shall be reannealed so that their microstructure will comply with Section 8.

TABLE 2 Typical Hardness

Inch-Pound Grade [Metric Grade]	Hardness, maximum HB	Indentation Value Diameters, mm
325 10 [22010]	156	4.8

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TABLE 3 Permissible Variation in Any Solid Dimension

Size, in. [mm]	Tolerance, ± in. [mm]
Up to 1 [up to 25]	0.03 [0.8]
1 to 6 [25 to 150]	0.06 [1.6]
6 to 12 [151 to 300]	0.12 [3.2]
12 to 18 [301 to 460]	0.15 [3.8]
18 to 24 [461 to 600]	0.19 [4.8]
24 to 36 [601 to 900]	0.22 [5.6]

12. Responsibility for Inspection

12.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspections required by this specification, using his own or other reliable facilities, and he shall maintain complete records of all such tests and inspections. Such records shall be available for review by the purchaser.

12.2 The purchaser reserves the right to perform any inspection set forth in the specification where such inspections are deemed necessary to ensure that supplies and services conform to the prescribed requirements.

13. Rejection and Rehearing

13.1 Any casting or lot of castings failing to comply with the requirements of this specification may, where possible, be reprocessed, retested, and reinspected. If the tests and inspections on the reprocessed casting(s) show compliance with this specification, the castings shall be acceptable; if they do not, they shall be rejected.

13.2 If the purchaser should find that a casting or lot of castings fails to comply with this specification subsequent to receipt at his facility, he shall so notify the manufacturer promptly and in no case later than six weeks after receipt of the shipment, stating clearly his basis for rejection. In case of dissatisfaction with the purchaser's claim, the manufacturer may apply for a hearing before final rejection of the shipment.

14. Certification

14.1 When specified by the purchaser's order or contract, a manufacturer's certification or compliance statement that the casting or lot of castings was made, sampled, tested, and inspected in accordance with this specification, including a report of test results signed by an authorized agent of the manufacturer, shall be furnished at the time of shipment, and such certification or compliance statement shall be the basis for acceptance of the casting or lot of castings.

15. Product Marking

15.1 When the size of the casting permits, each casting shall bear the identifying mark of the manufacturer and the part or pattern number at a location shown on the covering drawing and, if not shown on the drawing, at such a location at the discretion of the producer that the identification will not interfere with subsequent processing and service of the casting.

16. Packaging and Package Marking

16.1 Unless otherwise stated in the contract or order, the cleaning, preservation, and packing of castings for shipment shall be in accordance with the manufacturer's commercial practice. Packaging and marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

16.2 *U.S. Government Procurement*—When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Fed. Std. No. 123 and MIL-STD-129.

SUPPLEMENTARY REQUIREMENTS

S1. Special Conditions

S1.1 If agreed upon in writing by the foundry and purchaser, the malleable iron castings may be required to meet special conditions, hardness or other property dimensions, surface quality, or a combination of conditions.

S2. Test Lugs

S2.1 If requested in writing or if included on the pattern(s) or pattern drawing(s), test lugs may be cast on all castings of sufficient size to permit their incorporation. The size of such lugs shall be proportional to the thickness of the casting. On castings over 24 in. [600 mm] in length, a test lug shall be cast near each end such as not to interfere with any subsequent processing of the castings. The purchase order shall stipulate whether the foundry's inspector or the purchaser's inspector shall break, inspect, and pass judgment on the fracture quality of these test lugs.

S3. Destructive Tests

S3.1 At the option of the purchaser or his representative, a casting of each design ordered may be tested to destruction, or otherwise broken up, to determine the presence of any manufacturing condition that might be detrimental to the serviceability of the casting.

S4. Special Tension Specimens

S4.1 If tension specimens are to be machined from castings, their location in the casting, the specimen dimensions, and the required properties shall be agreed upon in writing by the foundry and purchaser.

S5. Zinc-Coated Castings

S5.1 When specified in the contract or purchase order, castings shall be zinc-coated by the hot-dip process in accordance with Specification A 153. Castings shall be of a composition that will preclude the possibility of galvanizing embrittlement, or shall be either cooled from the anneal or subsequently heat treated so as to be immunized against such embrittlement. If regalvanizing is required, procedures for regalvanizing castings and determining the effect on the casting performance must be agreed upon between the purchaser and the seller.

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S6. Marking of Casting for Government Procurement

S6.1 When castings are specified for government procurement, the location of the permanent markings specified in 15.1, as well as any special marking for mechanical or physical properties (either permanent or temporary), shall be as indicated on the government drawings or sketches.

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of malleable iron castings are influenced by a number of factors, including the cooling rate during solidification, chemical composition, the heat treatment, the design of the casting, section thickness, and the location and effectiveness of gates, risers, and chills.

X1.2 Because of the complexity of these factors in influencing the properties of the final product, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specific application, it may be determined by appropriate experimentation.

X1.3 The specimen specified in 7.2.1 as the standard tensile test bar for malleable iron has a ⅝-in. [16-mm] diameter test section that reasonably represents a typical section of the general run of malleable iron castings. Furthermore, the initial freezing of malleable irons as homogeneous white iron, together with the heat treatment that is inherent in the manufacture of malleable iron, tends to reduce the section-sensitivity effect. Therefore, where experimentation into precise properties within a given casting would be infeasible, this standard test bar, made like any typical casting, should provide a practical approximation of the properties that can be expected in average sound malleable iron casting.

X1.4 If malleable iron castings are welded, the microstructure of the iron is markedly affected, particularly in the heat-affected zone. Therefore, since this may adversely affect the properties of the casting, the welding of malleable iron castings should be done under strict metallurgical control, followed by appropriate post-weld heat treatment, to minimize the substantial reductions in ductility, impact resistance, and machinability that could result, particularly in the vicinity of the weldment. Nevertheless, it is generally considered inadvisable to join castings to similar castings or to other materials, by fusion welding out in the field, or in manufactured assemblies, without fully testing the entire completed part.

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Designation: A 105/A 105M – 01

An American National Standard

Endorsed by
Manufacturers Standardization Society
of the Valve and Fittings Industry
Used in USDOE-NE Standards

Standard Specification for Carbon Steel Forgings for Piping Applications[1]

This standard is issued under the fixed designation A 105/A 105M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification[2] covers forged carbon steel piping components for ambient- and higher-temperature service in pressure systems. Included are flanges, fittings, valves, and similar parts ordered either to dimensions specified by the purchaser or to dimensional standards such as the ASME and API specifications referenced in Section 2. Forgings made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. Larger forgings may be ordered to Specification A 266/A 266M. Tubesheets and hollow cylindrical forgings for pressure vessel shells are not included within the scope of this specification. Although this specification covers some piping components machined from rolled bar and seamless tubular products (see 4.2), it does not cover raw material produced in these product forms.

1.2 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.3 Specification A 266/A 266M covers other steel forgings and Specifications A 675, A 695, and A 696 cover other steel bars.

1.4 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A 961, the following list of standards apply to this specification:

2.2 *ASTM Standards:*

A 266/A 266M Specification for Carbon Steel Forgings for Pressure Vessel Components[3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3,4,5]

A 675/A 675M Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties[3]

A 695 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, for Fluid Power Applications[3]

A 696 Specification for Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components[3]

A 788 Specification for Steel Forgings, General Requirements[3]

A 961 Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications[4]

2.3 *MSS Standards:*

SP 44 Standard for Steel Pipe Line Flanges[6]

2.4 *ASME Standards:*

B16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings[7]

B16.9 Wrought Steel Buttwelding Fittings[7]

B16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves[7]

B16.11 Forged Steel Fittings, Socket Weld, and Threaded[7]

B16.34 Valves-Flanged, Threaded and Welding End[7]

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved Mar. 10, 2001. Published May 2001. Originally published as A 105 – 26 T. Last previous edition A 105/A 105M – 00.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-105 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.05.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

[5] *Annual Book of ASTM Standards*, Vol 01.03.

[6] Available from Manufacturers' Standardization Society of the Valve and Fittings Industry, 127 Park Street, NE Vienna, VA 22180–4602.

[7] Available from ASME International, Three Park Avenue, New York, NY 10016–5990.

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B16.47 Large Diameter Steel Flanges[7]
2.5 *ASME Boiler and Pressure Vessel Code:*
Section IX Welding Qualifications[7]
2.6 *API Standards:*
API-600 Flanged and Butt-Welding-End Steel Gate Valves[8]
API-602 Compact Design Carbon Steel Gate Valves for Refinery Use[8]

3. Ordering Information

3.1 See Specification A 961.
3.1.1 Additional requirements (see 12.2).

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 961, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 961 constitutes nonconformance with this specification. In case of a conflict between the requirements of this specification and Specification A 961, this specification shall prevail.

4.2 Except as permitted by Section 6 in Specification A 961, the finished product shall be a forging as defined in the Terminology Section of Specification A 788.

5. Heat Treatment

5.1 Heat treatment is not a mandatory requirement of this specification except for the following piping components:

5.1.1 Flanges above Class 300,[9]

5.1.2 Flanges of special design where the design pressure at the design temperature exceeds the pressure-temperature ratings of Class 300, Group 1.1,

5.1.3 Flanges of special design where the design pressure or design temperature are not known,

5.1.4 Piping components other than flanges which meet both of the following criteria: (*1*) over NPS 4 and (*2*) above Class 300, and

5.1.5 Piping components of Special Class[10] other than flanges which meet both of the following criteria: (*1*) over NPS 4 and (*2*) when the working pressure at the operating temperature exceeds the tabulated values for Special Class 300, Group 1.1.

5.2 Heat treatment, when required by 5.1 shall be annealing, normalizing, or normalizing and tempering or quenching and tempering in accordance with Specification A 961.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements specified in Table 1.

6.2 Steels to which lead has been added shall not be used.

7. Mechanical Properties

7.1 The material shall conform to the mechanical property requirements prescribed in Table 2 and Table 3.

TABLE 1 Chemical Requirements

NOTE—For each reduction of 0.01 % below the specified carbon maximum (0.35 %), an increase of 0.06 % manganese above the specified maximum (1.05 %) will be permitted up to a maximum of 1.35 %.

Element	Composition, %
Carbon	0.35 max
Manganese	0.60–1.05
Phosphorus	0.035 max
Sulfur	0.040 max
Silicon	0.10–0.35
Copper	0.40 max[A]
Nickel	0.40 max[A]
Chromium	0.30 max[A,B]
Molybdenum	0.12 max[A,B]
Vanadium	0.08 max
Columbium	0.02 max

[A] The sum of copper, nickel, chromium, molybdenum and vanadium shall not exceed 1.00 %.
[B] The sum of chromium and molybdenum shall not exceed 0.32 %.

TABLE 2 Mechanical Requirements[A]

Tensile strength, min, psi [MPa]	70 000 [485]
Yield strength, min, psi [MPa][B]	36 000 [250]
Elongation in 2 in. or 50 mm, min, %:	
Basic minimum elongation for walls 5/16 in. [7.9 mm] and over in thickness, strip tests.	30
When standard round 2-in. or 50-mm gage length or smaller proportionally sized specimen with the gage length equal to 4D is used	22
For strip tests, a deduction for each 1/32-in. [0.8-mm] decrease in wall thickness below 5/16 in. [7.9 mm] from the basic minimum elongation of the percentage points of Table 3	1.50[C]
Reduction of area, min, %[D]	30
Hardness, HB, max	187

[A] For small forgings, see 7.3.4.
[B] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.
[C] See Table 3 for computed minimum values.
[D] For round specimens only.

TABLE 3 Computed Minimum Values

Wall Thickness		Elongation in 2 in. or 50 mm, min, %
in.	mm	
5/16 (0.312)	7.9	30.00
9/32 (0.281)	7.1	28.50
1/4 (0.250)	6.4	27.00
7/32 (0.219)	5.6	25.50
3/16 (0.188)	4.8	24.00
5/32 (0.156)	4.0	22.50
1/8 (0.125)	3.2	21.00
3/32 (0.094)	2.4	19.50
1/16 (0.062)	1.6	18.00

Note—The above table gives the computed minimum elongation values for each 1/32-in. [0.8-mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

$$E = 48T + 15.00$$

where:
E = elongation in 2 in. or 50 mm, %, and
T = actual thickness of specimen, in. [mm].

7.2 For normalized, normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall correspond to the 1/4 T plane or deeper position, where T is the maximum heat-treated thickness of the represented

[8] Available from American Petroleum Institute, 2101 L St. N.W., Washington, DC 20037.
[9] For definition of Class 300, see ASME B16.5.
[10] For definition of special class, see ASME B16.34.

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forging. In addition, for quenched and tempered forgings, the midlength of the test specimen shall be at least T from any second heat-treated surface. When section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location.

7.3 *Tension Tests*:

7.3.1 One tension test shall be made for each heat of as-forged components.

7.3.2 One tension test shall be made from each heat-treating charge. If more than one heat is included in such a charge, each heat shall be tested.

7.3.2.1 When the heat-treating temperatures are the same and the furnaces (either batch or continuous type), are controlled within ±25°F [±14°C] and equipped with recording pyrometers so that complete records of heat treatment are available, then one tension test from each heat is required instead of one test from each heat in each heat-treatment charge. The test specimen material shall be included with a furnace charge.

7.3.3 Testing shall be performed in accordance with Test Methods and Definitions A 370. The largest feasible round specimen as described in Test Methods and Definitions A 370 shall be used except when hollow cylindrically shaped parts are machined from seamless tubulars. The gage length for measuring elongation shall be four times the diameter of the test section. When hollow cylindrically shaped parts are machined from seamless tubular materials, strip tests may be used.

7.3.4 Forgings too small to permit obtaining a subsize specimen of 0.250 in. [6.35 mm] diameter or larger (see Test Methods and Definitions A 370) parallel to the dimension of maximum working, and produced in equipment unsuitable for the production of a separately forged test bar such as an automatic or semi-automatic press, may be accepted on the basis of hardness only. One percent of the forgings per lot (see Note 2), or ten forgings, whichever is the lesser number, shall be selected at random, prepared, and tested using the standard Brinell test in Test Methods and Definitions A 370. The locations of the indentations shall be at the option of the manufacturer but shall be selected to be representative of the forging as a whole. One indentation per forging shall be required but additional indentations may be made to establish the representative hardness. The hardness of all forgings so tested shall be 137 to 187 HB inclusive.

NOTE 2—A lot is defined as the product from a mill heat or if heat treated, the product of a mill heat per furnace charge.

7.4 *Hardness Tests*—Except when only one forging is produced, a minimum of two forgings shall be hardness tested per batch or continuous run as defined in 7.3.2.1 to ensure that forgings are within the hardness limits given in Table 2. When only one forging is produced, it shall be hardness tested as defined in 7.3.2.1 to ensure it is within the hardness limits given in Table 2. Testing shall be in accordance with Test Methods and Definitions A 370. The purchaser may verify that the requirement has been met by testing at any location on the forging, provided such testing does not render the forging useless.

8. Hydrostatic Tests

8.1 Such tests shall be conducted by the forging manufacturer only when Supplementary Requirement S8 in Specification A 961 is specified.

9. Retreatment

9.1 If the results of the mechanical tests do not conform to the requirement specified, the manufacturer may heat treat or reheat treat the forgings as applicable and repeat the test specified in Section 7.

10. Repair by Welding

10.1 Repair of defects by the manufacturer is permissible for forgings made to dimensional standards such as those of ASME or for other parts made for stock by the manufacturer. Prior approval of the purchaser is required to repair-weld special forgings made to the purchaser's requirements.

10.2 Weld repairs shall be made by a process that does not produce undesirably high levels of hydrogen in the welded areas.

10.3 All forgings repaired by welding shall be post-weld heat treated between 1100°F [593°C] and the lower transformation temperature for a minimum of ½ h/in. [½ h/25.4 mm] of maximum section thickness, or alternatively annealed, normalized and tempered, or quenched and tempered. If the forging was not previously heat treated, the original tempering temperature was exceeded, or the forging was fully heat treated in the post weld cycle, then the forging shall be tested in accordance with Section 7 on completion of the cycle.

10.4 The mechanical properties of the procedure-qualification weldment shall, when tested in accordance with Section IX of the ASME Boiler and Pressure Vessel Code, conform with the requirements listed in Table 2 for the thermal condition of repair-welded forgings.

11. Rejection and Rehearing

11.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

12. Certification

12.1 *Identification Marking*—For forgings made to specified dimensions, when agreed upon by the purchaser, and for forgings made to dimensional standards, application of identification marks as required in Specification A 961 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification. The specification designation included on test reports shall include year of issue and revision letter, if any.

12.2 *Test Reports*—When test reports are required, the manufacturer shall also provide the following, where applicable:

12.2.1 Type heat treatment, Section 5,

12.2.2 Tensile property results, Section 7 (Table 2), report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent,

12.2.3 Chemical analysis results, Section 6 (Table 1). When the amount of an unspecified element is less than 0.02 %, then the analysis for that element may be reported as "< 0.02 %,"

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12.2.4 Hardness results, Section 7 (Table 2), and

12.2.5 Any supplementary testing required by the purchase order.

13. Product Marking

13.1 If the forgings have been quenched and tempered, the letters "QT" shall be stamped on the forgings following this specification number.

13.2 Forgings repaired by welding shall be marked with the letter "W" following this specification number.

13.3 When test reports are required for larger products, the markings shall consist of the manufacturer's symbol or name, this specification number, and such other markings as necessary to identify the part with the test report (13.1 and 13.2 shall apply). The specification number marked on the forgings need not include specification year of issue and revision letter.

13.4 *Bar Coding*—In addition to the requirements in Specification A 961 and 13.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

14. Keywords

14.1 pipe fittings, steel; piping applications; pressure containing parts; steel flanges; steel forgings, carbon; steel valves; temperature service applications, elevated; temperature service applications, high

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order.

S1. Hardness

S1.1 The purchaser may check the hardness of any or all forgings supplied at any location on the forging and the hardness shall be 137 to 187 HB. All forgings not within the specified hardness range shall be rejected.

S2. Heat Treatment

S2.1 All forgings shall be heat treated as specified by the purchaser.

S2.2 When forgings not requiring heat treatment by 5.1 are supplied heat treated by purchaser request, the basis for determining conformance with Table 2 and Table 3 shall be hardness testing per 7.4 and either (*1*) tensile testing of heat treated forgings per 7.2, or (*2*) tensile tests from as-forged forgings or separately forged test blanks, as agreed upon between the supplier and purchaser.

S2.3 When test reports are required, and tensile test results were obtained from as-forged forgings or as-forged test blanks, it shall be so indicated on the test report.

S2.4 In addition to the marking required by Section 13, this specification shall be followed by the letter: A for annealed, N for normalized, NT for normalized and tempered, or QT for quenched and tempered, as appropriate.

S3. Marking Small Forgings

S3.1 For small products where the space for marking is less than 1 in. [25 mm] in any direction, test reports are mandatory and marking may be restricted to only such symbols or codes as are necessary to identify the parts with test reports.

S3.2 When the configuration or size does not permit marking directly on the forging, the marking method shall be a matter of agreement between the manufacturer and the purchaser.

S4. Carbon Equivalent

S4.1 The maximum carbon equivalent, based on heat analysis, shall be 0.47 for forgings with a maximum section thickness of 2 in. or less, and 0.48 for forgings with a maximum section thickness of greater than 2 in.

S4.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S4.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

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Designation: A 106 – 99$^{\epsilon 1}$

An American National Standard
Used in USDOE-NE standards

Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service[1]

This standard is issued under the fixed designation A 106; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

ϵ^1 NOTE—Values in 14.5.1 were editorially corrected August 1999.

1. Scope

1.1 This specification[2] covers seamless carbon steel pipe for high-temperature service (Note 1) in NPS ⅛ to NPS 48 inclusive, with nominal (average) wall thickness as given in ANSI B 36.10. It shall be permissible to furnish pipe having other dimensions provided such pipe complies with all other requirements of this specification. Pipe ordered under this specification shall be suitable for bending, flanging, and similar forming operations, and for welding. When the steel is to be welded, it is presupposed that a welding procedure suitable to the grade of steel and intended use or service will be utilized (Note 2).

NOTE 1—It is suggested, consideration be given to possible graphitization.

NOTE 2—The purpose for which the pipe is to be used should be stated in the order. Grade A rather than Grade B or Grade C is the preferred grade for close coiling or cold bending. This note is not intended to prohibit the cold bending of Grade B seamless pipe.

1.2 Supplementary requirements (S1 to S7) of an optional nature are provided for seamless pipe intended for use in applications where a superior grade of pipe is required. These supplementary requirements call for additional tests to be made and when desired shall be so stated in the order.

1.3 When these products are to be used in applications conforming to ISO Recommendations for Boiler Construction, the requirements of Specification A 520 (Mechanical Property Requirements Section) shall supplement and supersede the requirements of this specification.

1.4 The values stated in inch-pound units are to be regarded as the standard.

NOTE 3—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.5 The following precautionary caveat pertains only to the test method portion, Sections 11, 12, 13, 14, and 15, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 520 Specification for Supplementary Requirements for Seamless and Electric-Resistance-Welded Carbon Steel Tubular Products for High-Temperature Service Conforming to ISO Recommendations for Boiler Construction[3]

A 530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe[3]

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing[4]

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation[4]

E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings[5]

E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products[4]

2.2 *ANSI Standard:*

ANSI B 36.10 Welded and Seamless Wrought Steel Pipe[6]

2.3 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[7]

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage[7]

2.4 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[7]

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products[7]

2.5 *Other Standards:*

[1] This specification is under the jurisdiction of Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.09 on Carbon Steel Tubular Products.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specifications SA-106 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

[6] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

[7] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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SSPC-SP 6 Surface Preparation Specification No. 6[8]

3. Ordering Information

3.1 The inclusion of the following, as required will describe the desired material adequately, when ordered under this specification:

3.1.1 Quantity (feet or number of lengths),

3.1.2 Name of material (seamless carbon steel pipe),

3.1.3 Grade (Table 1),

3.1.4 Manufacture (hot-finished or cold-drawn),

3.1.5 Size (NPS and weight class or schedule number, or both; outside diameter and nominal wall thickness; or inside diameter and nominal wall thickness),

3.1.6 Special outside diameter tolerance pipe (16.2.2),

3.1.7 Inside diameter tolerance pipe, over 10 in. (254 mm) ID (16.2.3),

3.1.8 Length (specific or random, Section 20),

3.1.9 Optional requirements (Section 9 and S1 to S4),

3.1.10 Test report required (Section on Certification of Specification A 530/A 530M),

3.1.11 Specification designation,

3.1.12 End use of material,

3.1.13 Hydrostatic test in accordance with Specification A 530/A 530M or 13.3 of this specification, or NDE in accordance with Section 14 of this specification.

3.1.14 Special requirements.

4. Process

4.1 The steel shall be killed steel, with the primary melting process being open-hearth, basic-oxygen, or electric-furnace, possibly combined with separate degassing or refining. If secondary melting, using electroslag remelting or vacuum-arc remelting is subsequently employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.2 Steel cast in ingots or strand cast is permissible. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

4.3 For pipe NPS 1½ and under, it shall be permissible to furnish hot finished or cold drawn.

4.4 Unless otherwise specified, pipe NPS 2 and over shall be furnished hot finished. When agreed upon between the manufacturer and the purchaser, it is permissible to furnish cold-drawn pipe.

5. Heat Treatment

5.1 Hot-finished pipe need not be heat treated. Cold-drawn pipe shall be heat treated after the final cold draw pass at a temperature of 1200°F (650°C) or higher.

6. General Requirements

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified in Section 7. If the secondary melting processes of 5.1 are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the manufacturer, if the latter has not manufactured the steel, shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 7.

9. Product Analysis

9.1 At the request of the purchaser, analyses of two pipes from each lot (Note 4) of 400 lengths or fraction thereof, of each size up to, but not including, NPS 6, and from each lot of 200 lengths or fraction thereof of each size NPS 6 and over, shall be made by the manufacturer from the finished pipe. The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Section 7.

9.2 If the analysis of one of the tests specified in 9.1 does not conform to the requirements specified in Section 7, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to requirements specified.

NOTE 4—A lot shall consist of the number of lengths specified in Sections 9 and 21 of the same size and wall thickness from any one heat of steel.

10. Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2. Computed elongation values are contained in Table 3 and Table 4.

[8] Available from Steel Structures Painting Council, 4400 5th Ave., Pittsburgh, PA 15213-2683.

TABLE 1 Chemical Requirements

	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max[A]	0.25	0.30	0.35
Manganese	0.27–0.93	0.29–1.06	0.29–1.06
Phosphorus, max	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035
Silicon, min	0.10	0.10	0.10
Chrome, max[B]	0.40	0.40	0.40
Copper, max[B]	0.40	0.40	0.40
Molybdenum, max[B]	0.15	0.15	0.15
Nickel, max[B]	0.40	0.40	0.40
Vanadium, max[B]	0.08	0.08	0.08

[A] For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted up to a maximum of 1.35 %.

[B] These five elements combined shall not exceed 1 %.

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TABLE 2 Tensile Requirements

	Grade A (Explanatory Note 2)		Grade B		Grade C	
Tensile strength, min, psi (MPa)	48 000 (330)		60 000 (415)		70 000 (485)	
Yield strength, min, psi (MPa)	30 000 (205)		35 000 (240)		40 000 (275)	
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
Elongation in 2 in. or 50 mm, min, %:						
Basic minimum elongation transverse strip tests, and for all small sizes tested in full section	35	25	30	16.5	30	16.5
When standard round 2-in. or 50-mm gage length test specimen is used	28	20	22	12	20	12
For longitudinal strip tests	[A,B]		[A,B]		[A,B]	
For transverse strip tests, a deduction for each 1/32-in. (0.8-mm) decrease in wall thickness below 5/16 in. (7.9 mm) from the basic minimum elongation of the following percentage shall be made		1.25[C]		1.00[C]		1.00[C]

[A]The minimum elogation in 2 in. (50.8 mm) shall be determined by the following equation:

$$e = 625\,000A^{0.2} / U^{0.9}$$

where:

e = minimum elongation in 2 in. (50.8 mm), %, rounded to the nearest 0.5%

A = cross-sectional area of the tension test specimen, in.^{2}, based on specified outside diameter or nominal specimen width and specified wall thickness rounded to the nearest 0.01 in.^{2}(if the area thus caluclated is greater than the value 0.75 in.^{2} shall be used), and

U = specified tensile strength, psi.

[B]See Table 4 for minimum elongation values for various size tension specimens and grades.

[C]Table 3 gives the computed minimum values:

TABLE 3 Computed Transverse Elongation[A]

Wall Thickness		Elongation in 2 in. or 50 mm, min, %	
in.	mm	Grade A, Transverse	Grades B and C, Transverse
5/16 (0.312)	7.9	25.00	16.50
9/32 (0.281)	7.1	23.75	15.50
1/4 (0.250)	6.4	22.50	14.50

[A]This table gives the computed minimum elongation values for each 1/32-in. (0.8-mm) decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

Grade	Direction of Test	Equation
A	Transverse	$E = 40t + 12.50$
B and C	Transverse	$E = 32t + 6.50$

where:

E = elongation in 2 in. or 50 mm, %, and

t = actual thickness of specimen, in.

TABLE 4 Elongation Values

					Elongation in 2 in. min., Specified Tensile Strength, psi		
	Tension Test Specimen Wall Thickness, in.[B]				*Grade A*	*Grade B*	*Grade C*
Area, in.^{2}[A]	1/2 in. Specimen	3/4 in. Specimen	1 in. Specimen	1 1/2 in. Specimen	48 000	60 000	70 000
≥ 0.75	≥ 1.491	≥ 0.994	≥ 0.746	≥ 0.497	36.0	29.5	25.5
0.74	1.470–1.490	0.980–0.993	0.735–0.745	0.490–0.496	36.0	29.5	25.5
0.73	1.451–1.469	0.967–0.979	0.726–0.734	0.484–0.489	36.0	29.5	25.5
0.72	1.430–1.450	0.954–0.966	0.715–0.725	0.477–0.483	36.0	29.5	25.5
0.71	1.411–1.429	0.941–0.953	0.706–0.714	0.471–0.476	35.5	29.0	25.5
0.70	1.390–1.410	0.927–0.940	0.695–0.705	0.464–0.470	35.5	29.0	25.5
0.69	1.371–1.389	0.914–0.926	0.686–0.694	0.457–0.463	35.5	29.0	25.5
0.68	1.350–1.370	0.900–0.913	0.675–0.685	0.450–0.456	35.5	29.0	25.0
0.67	1.331–1.349	0.887–0.899	0.666–0.674	0.444–0.449	35.5	29.0	25.0
0.66	1.310–1.330	0.874–0.886	0.655–0.665	0.437–0.443	35.0	29.0	25.0
0.65	1.291–1.309	0.861–0.873	0.646–0.654	0.431–0.436	35.0	28.5	25.0
0.64	1.270–1.290	0.847–0.860	0.635–0.645	0.424–0.430	35.0	28.5	25.0
0.63	1.251–1.269	0.834–0.846	0.626–0.634	0.417–0.423	35.0	28.5	25.0
0.62	1.230–1.250	0.820–0.833	0.615–0.625	0.410–0.416	35.0	28.5	25.0

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TABLE 4 *Continued*

Area, in.[2A]	Tension Test Specimen Wall Thickness, in.[B]				Elongation in 2 in. min., Specified Tensile Strength, psi		
	1/2 in. Specimen	3/4 in. Specimen	1 in. Specimen	1 1/2 in. Specimen	*Grade A* 48 000	*Grade B* 60 000	*Grade C* 70 000
0.61	1.211–1.229	0.807–0.819	0.606–0.614	0.404–0.409	34.5	28.5	24.5
0.60	1.190–1.210	0.794–0.806	0.595–0.605	0.397–0.403	34.5	28.5	24.5
0.59	1.171–1.189	0.781–0.793	0.586–0.594	0.391–0.396	34.5	28.0	24.5
0.58	1.150–1.170	0.767–0.780	0.575–0.585	0.384–0.390	34.5	28.0	24.5
0.57	1.131–1.149	0.754–0.766	0.566–0.574	0.377–0.383	34.0	28.0	24.5
0.56	1.110–1.130	0.740–0.753	0.555–0.565	0.370–0.376	34.0	28.0	24.5
0.55	1.091–1.109	0.727–0.739	0.546–0.554	0.364–0.369	34.0	28.0	24.9
0.54	1.070–1.090	0.714–0.726	0.535–0.545	0.357–0.363	34.0	27.5	24.0
0.53	1.051–1.069	0.701–0.713	0.526–0.534	0.351–0.356	33.5	27.5	24.0
0.52	1.030–1.050	0.687–0.700	0.515–0.525	0.344–0.350	33.5	27.5	24.0
0.51	1.011–1.029	0.674–0.686	0.506–0.514	0.337–0.343	33.5	27.5	24.0
0.50	0.990–1.010	0.660–0.673	0.495–0.505	0.330–0.336	33.5	27.0	23.5
0.49	0.971–0.989	0.647–0.659	0.486–0.494	0.324–0.329	33.0	27.0	23.5
0.48	0.950–0.970	0.634–0.646	0.475–0.485	0.317–0.323	33.0	27.0	23.5
0.47	0.931–0.949	0.621–0.633	0.466–0.474	0.311–0.316	33.0	27.0	23.5
0.46	0.910–0.930	0.607–0.620	0.455–0.465	0.304–0.310	33.0	27.0	23.5
0.45	0.891–0.909	0.594–0.606	0.446–0.454	0.297–0.303	32.5	26.5	23.0
0.44	0.870–0.890	0.580–0.593	0.435–0.445	0.290–0.296	32.5	26.5	23.0
0.43	0.851–0.869	0.567–0.579	0.426–0.434	0.284–0.289	32.5	26.5	23.0
0.42	0.830–0.850	0.554–0.566	0.415–0.425	0.277–0.283	32.0	26.5	23.0
0.41	0.811–0.829	0.541–0.553	0.406–0.414	0.271–0.276	32.0	26.0	23.0
0.40	0.790–0.810	0.527–0.540	0.395–0.405	0.264–0.270	32.0	26.0	22.5
0.39	0.771–0.789	0.514–0.526	0.386–0.394	0.257–0.263	31.5	26.0	22.5
0.38	0.750–0.770	0.500–0.513	0.375–0.385	0.250–0.256	31.5	26.0	22.5
0.37	0.731–0.749	0.487–0.499	0.366–0.374	0.244–0.249	31.5	25.5	22.5
0.36	0.710–0.730	0.474–0.486	0.355–0.365	0.237–0.243	31.0	25.5	22.0
0.35	0.691–0.709	0.461–0.473	0.346–0.354	0.231–0.236	31.0	25.5	22.0
0.34	0.670–0.690	0.447–0.460	0.335–0.345	0.224–0.230	31.0	25.0	22.0
0.33	0.651–0.669	0.434–0.446	0.326–0.334	0.217–0.223	30.5	25.0	22.0
0.32	0.630–0.650	0.420–0.433	0.315–0.325	0.210–0.216	30.5	25.0	21.5
0.31	0.611–0.629	0.407–0.419	0.306–0.314	0.204–0.209	30.5	25.0	21.5
0.30	0.590–0.610	0.394–0.406	0.295–0.305	0.197–0.203	30.0	24.5	21.5
0.29	0.571–0.589	0.381–0.393	0.286–0.294	0.191–0.196	30.0	24.5	21.5
0.28	0.550–0.570	0.367–0.380	0.275–0.285	0.184–0.190	29.5	24.5	21.0
0.27	0.531–0.549	0.354–0.366	0.266–0.274	0.177–0.183	29.5	24.0	21.0
0.26	0.510–0.530	0.340–0.353	0.255–0.265	0.170–0.176	29.0	24.0	21.0
0.25	0.491–0.509	0.327–0.339	0.246–0.254	0.164–0.169	29.0	23.5	20.5
0.24	0.470–0.490	0.314–0.326	0.235–0.245	0.157–0.163	29.0	23.5	20.5
0.23	0.451–0.469	0.301–0.313	0.226–0.234	0.151–0.156	28.5	23.5	20.5
0.22	0.430–0.450	0.287–0.300	0.215–0.225	0.144–0.150	28.5	23.0	20.0
0.21	0.411–0.429	0.274–0.286	0.206–0.214	0.137–0.143	28.0	23.0	20.0
0.20	0.390–0.410	0.260–0.273	0.195–0.205	0.130–0.136	27.5	22.5	19.5
0.19	0.371–0.389	0.247–0.259	0.186–0.194	0.124–0.129	27.5	22.5	19.5
0.18	0.350–0.370	0.234–0.246	0.175–0.185	0.117–0.123	27.0	22.0	19.5
0.17	0.331–0.349	0.221–0.233	0.166–0.174	0.111–0.116	27.0	22.0	19.0
0.16	0.310–0.330	0.207–0.220	0.155–0.165	0.104–0.110	26.5	21.5	19.0
0.15	0.291–0.309	0.194–0.206	0.146–0.154	0.097–0.103	26.0	21.5	18.5
0.14	0.270–0.290	0.180–0.193	0.135–0.145	0.091–0.096	26.0	21.0	18.5
0.13	0.251–0.269	0.167–0.179	0.126–0.134	0.084–0.090	25.5	21.0	18.0
0.12	0.230–0.250	0.154–0.166	0.115–0.125	0.077–0.083	25.0	20.5	18.0
0.11	0.211–0.229	0.141–0.153	0.106–0.114	0.071–0.076	24.5	20.0	17.5
0.10	0.190–0.210	0.127–0.140	0.095–0.105	0.064–0.070	24.0	19.5	17.0
0.09	0.171–0.189	0.114–0.126	0.086–0.094	0.057–0.063	23.5	19.5	17.0
0.08	0.150–0.170	0.100–0.113	0.075–0.085	0.050–0.056	23.0	19.0	16.5
0.07	0.131–0.149	0.087–0.099	0.066–0.074	0.044–0.049	22.5	18.5	16.0
0.06	0.110–0.130	0.074–0.086	0.055–0.065	0.037–0.043	22.0	18.0	15.5
0.05	0.091–0.109	0.061–0.073	0.046–0.054	0.031–0.036	21.0	17.0	15.0
0.04	0.070–0.090	0.047–0.060	0.035–0.045	0.024–0.030	20.0	16.5	14.5
0.03	0.051–0.069	0.034–0.046	0.026–0.034	0.017–0.023	19.0	15.5	13.5
0.02	0.030–0.050	0.020–0.033	0.015–0.025	0.010–0.016	17.5	14.5	12.5
≤0.01	≤ 0.029	≤ 0.019	≤ 0.014	≤ 0.009	15.0	12.5	11.0

[A] 1 in.^{2} = 645.16 mm^2.

[B] 1 in. = 25.4 mm.

11. Bending Requirements

11.1 For pipe NPS 2 and under a sufficient length of pipe shall stand being bent cold through 90° around a cylindrical mandrel, the diameter of which is twelve times the outside diameter (as shown in ANSI B 36.10) of the pipe, without developing cracks. When ordered for close coiling (Note 2),

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the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the outside diameter (as shown in ANSI B 36.10) of the pipe, without failure.

11.2 Subject to the approval of the purchaser, for pipe whose diameter exceeds 10 in. (254 mm), it shall be permissible for the bend test to be substituted for the flattening test described in Section 12. The bend test specimens shall be bent at room temperature through 180° with the inside diameter of the bend being 1 in. (25.4 mm), without cracking on the outside portion of the bent portion.

11.3 For pipe whose diameter exceeds 25 in. (635 mm) and whose diameter to wall thickness ratio is 7.0 or less, the bend test described in 11.2 shall be conducted instead of the flattening test.

NOTE 5—Diameter to wall thickness ratio = specified outside diameter/nominal wall thickness.

Example: For 28 in. diameter 5.000 in. thick pipe the diameter to wall thickness ratio = 28/5 = 5.6.

12. Flattening Tests

12.1 Except as allowed by 11.2, for pipe over NPS 2, a section of pipe not less than 2½ in. (63.5 mm) in length shall be flattened cold between parallel plates until the opposite walls of the pipe meet. Flattening tests shall be in accordance with Specification A 530/A 530M, except that in the formula used to calculate the "*H*" value, the following "*e*" constants shall be used:

0.08 for Grade A
0.07 for Grades B and C

12.2 When low *D*-to-*t* ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the *D*-to-*t* ratio is less than ten.

NOTE 6—The *H* values have been calculated for sizes from NPS 2½ to 24, inclusive, and are shown in Table X1.1 of this specification.

13. Hydrostatic Test

13.1 Each length of pipe shall withstand without leakage through the pipe wall, a hydrostatic test, except as provided for in 13.2, 13.3, and 13.4.

13.2 When specified by the purchaser, it shall be permissible for pipe to be tested by the nondestructive electric test described in Section 14 in lieu of the hydrostatic test.

13.3 When specified in the order, pipe shall be furnished without hydrostatic test and without the NDE in Section 14. In this case, each length so furnished shall include the mandatory marking of the letters "NH."

13.4 When the hydrostatic test and the NDE test are omitted and the lengths marked with the letters "NH," the certification, when required, shall clearly state "Not Hydro Statically Tested," the specification number and material grade, as shown on the certification, shall be followed by the letters "NH."

14. Nondestructive Electric Test

14.1 When allowed by 13.2, each pipe shall be tested with a nondestructive electric test in accordance with Practice E 213, Practice E 309, or Practice E 570. In such cases, the marking of each length of pipe so furnished shall include the letters "NDE." It is the intent of this test to reject pipe with imperfections that produce test signals equal or greater than that of the calibration standard.

14.2 When the nondestructive electric test is performed, the lengths shall be marked with the letters "NDE." The certification, when required, shall state "Nondestructive Electric Tested" and shall indicate which of the tests was applied. Also the letters "NDE" shall be appended to the product specification number and material grade shown on the certification.

14.3 The following information is for the benefit of the user of this specification:

14.3.1 The reference standards defined in 14.4 through 14.6 are convenient standards for calibration of nondestructive testing equipment. The dimensions of such standards are not to be construed as the minimum sizes of imperfections detectable by such equipment.

14.3.2 The ultrasonic testing referred to in this specification is capable of detecting the presence and location of significant longitudinally or circumferentially oriented imperfections: however, different techniques need to be employed for the detection of such differently oriented imperfections. Ultrasonic testing is not necessarily capable of detecting short, deep imperfections.

14.3.3 The eddy current examination referenced in this specification has the capability of detecting significant imperfections, especially of the short abrupt type.

14.3.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented imperfections: however, different techniques need to be employed for the detection of such differently oriented imperfections.

14.3.5 The hydrostatic test referred to in Section 13 has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. Hydrostatic testing is not necessarily capable of detecting very tight, through-the-wall imperfections or imperfections that extend an appreciable distance into the wall without complete penetration.

14.3.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific applications of these examinations is directed to discuss this with the manufacturer of the tubular product.

14.4 For ultrasonic testing, the calibration reference notches shall be, at the option of the producer, any one of the three common notch shapes shown in Practice E 213. The depth of notch shall not exceed 12½ % of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

14.5 For eddy current testing, the calibration pipe shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection:

14.5.1 *Drilled Hole*—The calibration pipe shall contain depending upon the pipe diameter three holes spaced 120° apart or four holes spaced 90° apart and sufficiently separated longitudinally to ensure separately distinguishable responses. The holes shall be drilled radially and completely through the

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pipe wall, care being taken to avoid distortion of the pipe while drilling. Depending upon the pipe diameter the calibration pipe shall contain the following hole:

≤½ in.	0.039 in. (1 mm)
>½ ≤ 1¼ in.	0.055 in. (1.4 mm)
>1¼ ≤ 2 in.	0.071 in. (1.8 mm)
>2 ≤ 5 in.	0.087 in. (2.2 mm)
>5 in.	0.106 in. (2.7 mm)

14.5.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼in. (6.4-mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding 12½ % of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

14.5.3 *Longitudinal Notch*—A notch 0.031 in. (0.787 mm) or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. (0.102 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

14.5.4 *Compatibility*—The discontinuity in the calibration pipe shall be compatible with the testing equipment and the method being used.

14.6 For flux leakage testing, the longitudinal calibration reference notches shall be straight-sided notches machined in a radial plane parallel to the pipe axis. For wall thickness under ½ in. (12.7 mm), outside and inside notches shall be used; for wall thickness equal and above ½ in. (12.7 mm), only an outside notch shall be used. Notch depth shall not exceed 12½ % of the specified wall thickness, or 0.004 in. (0.102 mm), whichever is greater. Notch length shall not exceed 1 in. (25.4 mm), and the width shall not exceed the depth. Outside diameter and inside diameter notches shall be located sufficiently apart to allow separation and identification of the signals.

14.7 Pipe containing one or more imperfections that produce a signal equal to or greater than the signal produced by the calibration standard shall be rejected or the area producing the signal shall be reexamined.

14.7.1 Test signals produced by imperfections which cannot be identified, or produced by cracks or crack-like imperfections shall result in rejection of the pipe, unless it is repaired and retested. To be accepted, the pipe must pass the same specification test to which it was originally subjected, provided that the remaining wall thickness is not decreased below that permitted by this specification. The OD at the point of grinding may be reduced by the amount so reduced.

14.7.2 Test signals produced by visual imperfections such as those listed below may be evaluated in accordance with the provisions of Section 18:

14.7.2.1 Dinges,

14.7.2.2 Straightener marks,

14.7.2.3 Cutting chips,

14.7.2.4 Scratches,

14.7.2.5 Steel die stamps,

14.7.2.6 Stop marks, or

14.7.2.7 Pipe reducer ripple.

14.8 The test methods described in this section are not necessarily capable of inspecting the end portion of pipes, a condition referred to as "end effect." The length of such end effect shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

15. Nipples

15.1 Nipples shall be cut from pipe of the same dimensions and quality described in this specification.

16. Dimensions, Weight, and Permissible Variations

16.1 *Weight*—The weight of any length of pipe shall not vary more than 10 % over and 3.5 % under that specified. Unless otherwise agreed upon between the manufacturer and the purchaser, pipe in NPS 4 and smaller may be weighed in convenient lots; pipe larger than NPS 4 shall be weighed separately.

16.2 *Diameter*—The tolerances for diameter shall be in accordance with the following:

16.2.1 Except for pipe ordered as special outside diameter tolerance pipe or as inside diameter tolerance pipe, variations in outside diameter shall not exceed those precribed in Table 5.

16.2.2 For pipe over 10 in. (254 mm) OD ordered as special outside diameter tolerance pipe, the outside diameter shall not vary more than 1 % over or 1 % under the specified outside diameter.

16.2.3 For pipe over 10 in. (254 mm) ID ordered as inside diameter tolerance pipe, the inside diameter shall not vary more than 1 % over or 1 % under the specified inside diameter.

16.3 *Thickness*—The minimum wall thickness at any point shall not be more than 12.5 % under the nominal wall thickness specified.

NOTE 7—The minimum wall thicknesses on inspection of some of the available sizes are shown in Table X2.1.

17. Lengths

17.1 Pipe lengths shall be in accordance with the following regular practice:

17.1.1 The lengths required shall be specified in the order, and

17.1.2 No jointers are permitted unless otherwise specified.

17.1.3 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft (4.8 to 6.7 m) with 5 % 12 to 16 ft (3.7 to 4.8 m), or in double random lengths with a minimum average of 35 ft (10.7 m) and a minimum length of 22 ft with 5 % 16 to 22 ft.

18. Workmanship, Finish and Appearance

18.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable

TABLE 5 Variations in Outside Diameter

NPS Designator	Permissible Variations in Outside Diameter			
	Over		Under	
	in.	mm	in.	mm
1/8 to 1½, incl	1/64 (0.015)	0.40	1/64 (0.015)	0.40
Over 1½ to 4, incl	1/32 (0.031)	0.79	1/32 (0.031)	0.79
Over 4 to 8, incl	1/16 (0.062)	1.59	1/32 (0.031)	0.79
Over 8 to 18, incl	3/32 (0.093)	2.38	1/32 (0.031)	0.79
Over 18 to 26, incl	1/8 (0.125)	3.18	1/32 (0.031)	0.79
Over 26 to 34, incl	5/32 (0.156)	3.97	1/32 (0.031)	0.79
Over 34 to 48, incl	3/16 (0.187)	4.76	1/32 (0.031)	0.79

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assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but consideration should be given to the necessity of exploring all surface imperfections to assure compliance with 18.2.

18.2 Surface imperfections that penetrate more than 12½ % of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

18.2.1 The defect shall be removed by grinding, provided that the remaining wall thickness is within the limits specified in 16.3.

18.2.2 Repaired in accordance with the repair welding provisions of 18.6.

18.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

18.2.4 Rejected.

18.3 To provide a workmanlike finish and basis for evaluating conformance with 18.2 the pipe manufacturer shall remove by grinding the following noninjurious imperfections:

18.3.1 Mechanical marks, abrasions (Note 8) and pits, any of which imperfections are deeper than 1/16 in. (1.58 mm).

18.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 18.1 to be deeper than 5 % of the nominal wall thickness.

18.4 At the purchaser's discretion, pipe shall be subjected to rejection if surface imperfections acceptable under 18.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

18.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding is permitted to be reduced by the amount so removed.

18.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

18.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 530/A 530M.

18.7 The finished pipe shall be reasonably straight.

NOTE 8—Marks and abrasions are defined as cable marks, dinges, guide marks, roll marks, ball scratches, scores, die marks, etc.

19. End Finish

19.1 The Pipe shall be furnished to the following practice, unless otherwise specified.

19.1.1 *NPS 1-1/2 and Smaller*—All walls shall be either plain-end square cut, or plain-end beveled at the option of the manufacturer.

19.1.2 *NPS 2 and Larger*—Walls through extra strong weights, shall be plain end-beveled.

19.1.3 *NPS 2 and Larger*—Walls over extra strong weights, shall be plain-end square cut.

NOTE 9—Plain-end beveled is defined as plain-end pipe having a bevel angle of 30°, +5° or -0°, as measured from a line drawn perpendicular to the axis of the pipe with a root face of 1/16 ± 1/32in. (1.5875 ± 0.7938 mm). Other bevel angles may be specified by agreement between the purchaser and the manufacturer.

20. Number of Tests

20.1 The tensile requirements specified in Section 7 shall be determined on one length of pipe from each lot (Note 4) of 400 lengths or fraction thereof of each size under NPS 6, and from each lot of 200 lengths or fraction thereof of each size NPS 6 and over.

20.2 For pipe NPS 2 and under, the bend test specified in 11.1 shall be made on one pipe from each lot of 400 lengths or fraction thereof of each size. The bend test, where used as permitted by 11.2 or required by 11.3, shall be made on one end of 5 % of the pipe from each lot. For small lots, at least one pipe shall be tested.

20.3 The flattening test specified in Section 12 shall be made on one length of pipe from each lot of 400 lengths or fraction thereof of each size over NPS 2, up to but not including NPS 6, and from each lot of 200 lengths or fraction thereof, of each size NPS 6 and over.

20.4 Each length of pipe shall be subjected to the hydrostatic test specified in Section 13.

20.5 If any test specimen shows defective machining or develops flaws, it is permissible to discard the flawed specimen and substitute another specimen.

21. Retests

21.1 If the percentage of elongation of any tension test specimen is less than that prescribed in Table 1 and any part of the fracture is more than ¾in. (19.0 mm) from the center of the gage length of a 2-in. (50-mm) specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed. If a specimen breaks in an inside or outside surface flaw, a retest shall be allowed.

21.2 Should a crop end of a finished pipe fail in the flattening test, one retest is permitted to be made from the failed end. Pipe shall be normalized either before or after the first test, but pipe shall be subjected to only two normalizing treatments.

22. Test Specimens and Test Methods

22.1 On NPS 8 and larger, specimens cut either longitudinally or transversely shall be acceptable for the tension test. On sizes smaller than NPS 8, the longitudinal test only shall be used.

22.2 When round tension test specimens are used for pipe wall thicknesses over 1.0 in. (25.40 mm), the mid–length of the longitudinal axis of such test specimens shall be from a location midway between the inside and outside surfaces of the pipe.

22.3 Test specimens for the bend test specified in Section 11 and for the flattening tests shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except when made on crop ends.

22.4 Test specimens for the bend test specified in 11.2 and 11.3 shall be cut from one end of the pipe and, unless otherwise

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specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either ½ by ½ in. (12.7 by 12.7 mm) in section or 1 by ½ in. (25.4 by 12.7 mm) in section with the corners rounded to a radius not over 1/16 in. (1.6 mm) and need not exceed 6 in. (152 mm) in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe respectively.

22.5 All routine check tests shall be made at room temperature.

23. Certification

23.1 When test reports are requested, in addition to the requirements of Specification A 530/A 530M, the producer or supplier shall furnish to the purchaser a chemical analysis report for the elements specified in Table 1.

24. Product Marking

24.1 In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include heat number, the information as per Table 6, an additional symbol" S" if one or more of the supplementary requirements apply; the length, OD 1 %, if ordered as special outside diameter tolerance pipe; ID 1 %, if ordered as special inside diameter tolerance pipe; the schedule number, weight class, or nominal wall thickness; and, for sizes larger than NPS 4, the weight. Length shall be marked in feet and tenths of a foot, or metres to two decimal places, depending on the units to which the material was ordered, or other marking subject to agreement. For sizes NPS 1½, 1¼, 1, and ¾, each length shall be marked as prescribed in Specification A 530/A 530M. These sizes shall be bundled in accordance with standard mill practice and the total bundle footage marked on the bundle tag; individual lengths of pipe need not be marked with footage. For sizes less than NPS ¾, all the required markings shall be on the bundle tag or on each length of pipe and shall include the total footage; individual lengths of pipe need not be marked with footage. If not marked on the bundle tag, all required marking shall be on each length.

TABLE 6 Marking

Hydro	NDE	Marking
Yes	No	Test Pressure
No	Yes	NDE
No	No	NH
Yes	Yes	Test Pressure/NDE

24.2 When pipe sections are cut into shorter lengths by a subsequent processor for resale as material, the processor shall transfer complete identifying information, including the name or brand of the manufacturer to each unmarked cut length, or to metal tags securely attached to bundles of unmarked small diameter pipe. The same material designation shall be included with the information transferred, and the processor's name, trademark, or brand shall be added.

24.3 *Bar Coding*—In addition to the requirements in 24.1 and 24.2, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used.

25. Government Procurement

25.1 When specified in the contract, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for the shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 or Fed. Std. No. 183 if continuous marking is required for military agencies.

25.2 *Inspection*—Unless otherwise specified in the contract, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the producer shall use his own, or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that the material conforms to the prescribed requirements.

26. Keywords

26.1 carbon steel pipe; seamless steel pipe; steel pipe

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Test

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 and over. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest.

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S3. Flattening Test

S3.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Metal Structure and Etching Test

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate sections of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Carbon Equivalent

S5.1 The steel shall conform to a carbon equivalent (CE) of 0.50 maximum as determined by the following formula:

$$CE = \%C + \frac{\%Mn}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Ni + \%Cu}{15}$$

S5.2 A lower CE maximum may be agreed upon between the purchaser and the producer.

S5.3 The CE shall be reported on the test report.

S6. Heat Treated Test Specimens

S6.1 At the request of the purchaser, one tensile test shall be performed by the manufacturer on a test specimen from each heat of steel furnished which has been either stress relieved at 1250°F or normalized at 1650°F, as specified by the purchaser. Other stress relief or annealing temperatures, as appropriate to the analysis, may be specified by agreement between the purchaser and the manufacturer. The results of this test shall meet the requirements of Table 1.

S7. Internal Cleanliness–Government Orders

S7.1 The internal surface of hot finished ferritic steel pipe and tube shall be manufactured to a free of scale condition equivalent to the visual standard listed in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

APPENDIXES

(Nonmandatory Information)

X1. CALCULATED H VALUES FOR SEAMLESS PIPE

X1.1 Tables X1.1 and X1.2 list values for H to be used for the test of Section 12.

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TABLE X1.1 Calculated "H" Values for Seamless Pipe

Inch-Pound Units

NPS Designator	Outside Diameter, in.	Wall Thickness, in.	Schedule Number	Distance, in inches, Between Plates "H" by Equation: $H = \frac{(1 + e)t}{e + t/D}$ Grade A	Distance, in inches, Between Plates "H" by Equation: $H = \frac{(1 + e)t}{e + t/D}$ Grades B & C
2½	2.875	0.203	40	1.456	1.545
		0.276	80	1.694	1.779
		0.375	160	1.925	2.002
3	3.500	0.216	40	1.646	1.755
		0.300	80	1.955	2.062
		0.438	160	2.306	2.398
3½	4.000	0.226	40	1.788	1.912
		0.318	80	2.153	2.276
4	4.500	0.237	40	1.929	2.067
		0.337	80	2.350	2.489
		0.438	120	2.687	2.818
		0.531	160	2.896	3.022
5	5.563	0.258	40	2.205	2.372
		0.375	80	2.747	2.920
		0.500	120	3.179	3.346
		0.625	160	3.509	3.667
6	6.625	0.280	40	2.473	2.669
		0.432	80	3.213	3.419
		0.562	120	3.682	3.884
		0.719	160	4.116	4.307
8	8.625	0.250	20	2.477	2.702
		0.277	30	2.668	2.902
		0.322	40	2.964	3.210
		0.406	60	3.451	3.711
		0.500	80	3.914	4.181
		0.593	100	4.305	4.573
		0.719	120	4.750	5.013
		0.812	140	5.036	5.293
		0.906	160	5.288	5.538
10	10.750	0.250	20	2.615	2.868
		0.307	30	3.054	3.333
		0.365	40	3.459	3.757
		0.500	60	4.268	4.592
		0.593	80	4.738	5.070
		0.719	100	5.320	5.621
		0.843	120	5.747	6.077
		1.000	140	6.242	6.564
		1.125	160	6.580	6.892
12	12.750	0.250	20	2.711	2.985
		0.330	30	3.366	3.683
		0.406	40	3.921	4.266
		0.562	60	4.892	5.271
		0.687	80	5.542	5.934
		0.843	100	6.231	6.627
		1.000	120	6.817	7.209
		1.125	140	7.222	7.607
		1.312	160	7.747	8.119
14	14.000	0.250	10	2.759	3.045
		0.312	20	3.294	3.617
		0.375	30	3.792	4.146
		0.438	40	4.669	5.125
		0.593	60	5.234	5.647
		0.750	80	6.064	6.494
		0.937	100	6.887	7.322
		1.093	120	7.479	7.902
		1.250	140	7.974	8.397
		1.406	160	8.416	8.827
16	16.000	0.250	10	2.284	3.124
		0.312	20	3.387	3.730
		0.375	30	3.915	4.294
		0.500	40	4.854	5.284
		0.656	60	5.855	6.324
		0.843	80	6.861	7.352
		1.031	100	7.709	8.206
		1.218	120	8.426	8.919
		1.438	140	9.141	9.625
		1.593	160	9.579	10.050
18	18.000	0.250	10	2.876	3.189
		0.312	20	3.462	3.823
		0.438	30	4.535	4.963
		0.562	40	5.457	5.941
		0.750	60	6.656	7.185
		0.937	80	7.663	8.214
		1.156	100	8.657	9.216
		1.375	120	9.495	10.043
		1.562	140	10.115	10.660
		1.781	160	10.665	11.198
20	20.000	0.250	10	2.919	3.242
		0.375	20	4.101	4.521
		0.500	30	5.143	5.632
		0.593	40	5.841	6.367
		0.812	60	7.272	7.856
		1.031	80	8.464	9.072
		1.281	100	9.601	10.221
		1.500	120	10.452	11.069
		1.750	140	11.284	11.889
		1.968	160	11.913	12.504
24	24.000	0.250	10	2.986	3.326
		0.375	20	4.236	4.686
		0.562	30	5.869	6.437
		0.687	40	6.831	7.454
		0.968	60	8.690	9.390
		1.218	80	10.061	10.793
		1.531	100	11.449	12.244
		1.812	120	12.585	13.32
		2.062	140	13.424	14.150
		2.343	160	14.248	14.958

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TABLE X1.2 Calculated "H" Values for Seamless Pipe Continued

SI Units

NPS Designator	Outside Diameter, mm	Wall Thickness, mm	Schedule Number	Distance, in mm, Between Plates "H" by Equation: $H = \frac{(1 + e)t}{e + t/D}$ Grade A	Distance, in mm, Between Plates "H" by Equation: $H = \frac{(1 + e)t}{e + t/D}$ Grades B & C
2 ½	73.0	5.16	40	37.0	39.2
		7.01	80	43.0	45.2
		9.52	160	48.9	50.8
3	88.9	5.49	40	41.8	44.6
		7.62	80	49.6	52.4
		11.13	160	58.6	60.9
3½	101.6	5.74	40	45.4	48.6
		8.08	80	54.7	57.8
4	114.3	6.02	40	49.0	52.5
		8.56	80	59.7	63.2
		11.13	120	67.0	71.6
		13.49	160	73.6	76.8
5	141.3	6.55	40	56.0	60.2
		9.52	80	69.8	74.2
		12.70	120	80.8	85.0
		15.88	160	89.1	93.1
6	168.3	7.11	40	62.8	67.8
		10.97	80	81.6	86.8
		14.27	120	93.5	98.6
		18.24	160	104.6	109.4
8	219.1	6.35	20	63.0	68.6
		7.04	30	67.8	73.7
		8.18	40	75.3	81.5
		10.31	60	87.7	94.3
		12.70	80	99.4	106.2
		15.06	100	109.4	116.2
		18.24	120	120.6	127.3
		20.62	140	127.9	134.4
		23.01	160	134.3	140.7
10	273.0	6.35	20	66.4	72.8
		7.80	30	77.6	84.7
		9.27	40	87.9	95.4
		12.70	60	108.4	116.6
		15.06	80	120.4	128.8
		18.24	100	135.1	142.8
		21.41	120	146.0	154.4
		25.40	140	158.6	166.7
		28.58	160	167.1	175.1
12	323.8	6.35	20	68.9	75.8
		8.38	30	85.5	93.6
		10.31	40	99.6	108.4
		14.27	60	124.3	133.9
		17.35	80	140.8	150.7
		21.41	100	158.3	168.3
		25.40	120	173.2	183.1
		28.58	140	183.4	193.2
		33.32	160	196.8	206.2
14	355.6	6.35	10	70.1	77.3
		7.92	20	83.7	91.8
		9.52	30	96.3	105.3
		11.13	40	118.6	130.2
		15.06	60	132.9	143.4
		19.05	80	154.0	165.0
		23.80	100	174.9	186.0
		27.76	120	190.0	200.7
		31.75	140	202.5	213.3
		35.71	160	213.8	224.2
16	406.4	6.35	10	71.7	79.4
		7.92	20	89.0	94.7
		9.52	30	99.4	109.1
		12.70	40	123.3	143.2
		16.66	60	148.7	160.6
		21.41	80	174.3	186.7
		26.19	100	195.8	208.4
		30.94	120	214.0	226.6
		36.53	140	232.2	244.5
		40.46	160	243.3	255.3
18	457.2	6.35	10	73.0	81.0
		7.92	20	87.9	97.1
		11.13	30	115.2	126.1
		14.27	40	139.5	150.9
		19.05	60	169.1	182.5
		23.80	80	194.6	208.6
		29.36	100	219.9	234.1
		34.92	120	241.2	255.1
		39.67	140	256.9	270.7
		45.24	160	270.9	284.4
20	508.0	6.35	10	74.1	82.4
		9.52	20	104.2	114.8
		12.70	30	130.6	143.0
		15.06	40	148.4	161.7
		20.62	60	184.7	199.5
		26.19	80	215.0	230.4
		32.54	100	243.9	259.6
		38.10	120	265.5	281.2
		44.45	140	286.6	302.0
		49.99	160	302.6	317.6
24	609.6	6.35	10	75.8	84.5
		9.52	20	107.6	119.0
		14.27	30	149.1	163.5
		17.35	40	173.5	189.3
		24.59	60	220.7	238.5
		30.94	80	255.6	274.1
		38.89	100	290.8	311.0
		46.02	120	319.7	338.6
		52.37	140	341.0	359.4
		59.51	160	361.9	379.9

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X2. MINIMUM WALL THICKNESS

X2.1 Table X2.1 lists minimum wall thicknesses for nominal pipe wall thickness.

TABLE X2.1 Mimimum Wall Thicknesses on Inspection for Nominal (Average) Pipe Wall Thicknesses

NOTE 1—The following equation, upon which this table is based, may be applied to calculate minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:

t_n = nominal (average) wall thickness, in. and

t_m = minimum wall thickness, in.

The wall thickness is expressed to three decimal places, the fourth decimal place being carried forward or dropped, in accordance with Practice E 29.

NOTE 2—This table covers some wall thicknesses associated with standard pipe sizes but is not meant to imply that these are the only thicknesses obtainable under this specification.

Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)	
in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.068	1.73	0.060	1.52	0.281	7.14	0.246	6.25	0.864	21.94	0.756	19.20
0.083	2.11	0.073	1.85	0.294	7.47	0.257	6.53	0.875	22.22	0.766	19.46
0.088	2.24	0.077	1.96	0.300	7.62	0.262	6.65	0.906	23.01	0.793	20.14
0.091	2.31	0.080	2.03	0.307	7.80	0.269	6.83	0.938	23.82	0.821	20.85
0.095	2.41	0.083	2.11	0.308	7.82	0.270	6.86	0.968	24.59	0.847	21.51
0.109	2.77	0.095	2.41	0.312	7.92	0.273	6.93	1.000	25.40	0.875	22.22
0.113	2.87	0.099	2.51	0.318	8.07	0.278	7.06	1.031	26.19	0.902	22.91
0.119	3.02	0.104	2.64	0.322	8.18	0.282	7.16	1.062	26.97	0.929	23.60
0.125	3.18	0.109	2.77	0.330	8.38	0.289	7.34	1.094	27.79	0.957	24.31
0.126	3.20	0.110	2.79	0.337	8.56	0.295	7.49	1.125	28.58	0.984	24.99
0.133	3.38	0.116	2.95	0.344	8.74	0.301	7.64	1.156	29.36	1.012	25.70
0.140	3.56	0.122	3.10	0.358	9.09	0.313	7.95	1.219	30.96	1.066	27.08
0.141	3.58	0.123	3.12	0.365	9.27	0.319	8.10	1.250	31.75	1.094	27.79
0.145	3.68	0.127	3.23	0.375	9.52	0.328	8.33	1.281	32.54	1.121	28.47
0.147	3.73	0.129	3.28	0.382	9.70	0.334	8.48	1.312	33.32	1.148	29.16
0.154	3.91	0.135	3.43	0.400	10.16	0.350	8.89	1.375	34.92	1.203	30.56
0.156	3.96	0.136	3.45	0.406	10.31	0.355	9.02	1.406	35.71	1.230	31.24
0.172	4.37	0.150	3.81	0.432	10.97	0.378	9.60	1.438	36.53	1.258	31.95
0.179	4.55	0.157	3.99	0.436	11.07	0.382	9.70	1.500	38.10	1.312	33.32
0.188	4.78	0.164	4.17	0.438	11.12	0.383	9.73	1.531	38.89	1.340	34.04
0.191	4.85	0.167	4.24	0.469	11.91	0.410	10.41	1.562	39.67	1.367	34.72
0.200	5.08	0.175	4.44	0.500	12.70	0.438	11.13	1.594	40.49	1.395	35.43
0.203	5.16	0.178	4.52	0.531	13.49	0.465	11.81	1.635	41.53	1.431	36.35
0.210	5.33	0.184	4.67	0.552	14.02	0.483	12.27	1.750	44.45	1.531	38.89
0.216	5.49	0.189	4.80	0.562	14.27	0.492	12.50	1.781	45.24	1.558	39.57
0.218	5.54	0.191	4.85	0.594	15.09	0.520	13.21	1.812	46.02	1.586	40.28
0.219	5.56	0.192	4.88	0.600	15.24	0.525	13.34	1.875	47.62	1.641	41.68
0.226	5.74	0.198	5.03	0.625	15.88	0.547	13.89	1.969	50.01	1.723	43.76
0.237	6.02	0.207	5.26	0.656	16.66	0.574	14.58	2.000	50.80	1.750	44.45
0.250	6.35	0.219	5.56	0.674	17.12	0.590	14.99	2.062	52.37	1.804	45.82
0.258	6.55	0.226	5.74	0.688	17.48	0.602	15.29	2.125	53.98	1.859	47.22
0.276	7.01	0.242	6.15	0.719	18.26	0.629	15.98	2.200	55.88	1.925	48.90
0.277	7.04	0.242	6.15	0.750	19.05	0.656	16.66	2.344	59.54	2.051	52.10
0.279	7.09	0.244	6.19	0.812	20.62	0.710	18.03	2.500	63.50	2.188	55.58
0.280	7.11	0.245	6.22	0.844	21.44	0.739	18.77				

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Designation: A 126 – 95 (Reapproved 2001)

Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings[1]

This standard is issued under the fixed designation A 126; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers three classes of gray iron for castings intended for use as valve pressure retaining parts, pipe fittings, and flanges.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

NOTE 1—The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 48 Specification for Gray Iron Castings[2]

A 438 Test Method for Transverse Testing of Gray Cast Iron[2]

A 644 Terminology Relating to Iron Castings[2]

E 8 Test Methods for Tension Testing of Metallic Materials[3]

3. Terminology

3.1 Definitions of many terms common to gray iron castings are found in Terminology A 644.

4. Classification

4.1 Castings produced to this specification are classified based upon the minimum tensile strength of the iron (see Table 1).

5. Ordering Information

5.1 Orders for material in this specification should include the following information:

5.1.1 ASTM designation and year date,

5.1.2 Class of iron required,

5.1.3 Quantity,

5.1.4 Transverse test, if required (see Section 8), and

5.1.5 Certification, if required (see Section 17).

TABLE 1 Tensile Requirements

	Class A	Class B	Class C
Tensile strength, min, ksi (MPa)	21 (145)	31 (214)	41 (283)

6. Workmanship, Finish, and Appearance

6.1 The castings shall be made in a workmanlike manner and the surface shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination.

7. Chemical Requirements

7.1 A chemical analysis shall be performed on each lot and shall conform to the following requirements for phosphorus and sulfur:

Phosphorus, max, %	0.75
Sulfur, max, %	0.15

7.2 The chemical analysis shall be performed on a sample obtained during the pouring of the lot.

8. Tensile Properties

8.1 One tension test shall be performed on each lot and shall conform to the mechanical properties specified in Table 1.

9. Transverse Test

9.1 When specified by the purchaser, one transverse test shall be performed on each lot and shall conform to the requirement specified in Table 2.

9.2 The test shall be performed with the bar resting on supports separated by 12 in. (305 mm) and the load applied midway between the supports. The load shall be applied at a rate that will produce 0.10 in. (2.5 mm) central deflection in 20 to 40 s.

9.3 In case the transverse test specimen varies from the specified diameter of 1.20 in. (30.5 mm), a correction factor conforming to the requirements for Test Bar B in Table 1 of Test Method A 438 shall apply.

10. Cast Test Bars

10.1 Separately cast 1⅛ in. (28.6 mm) diameter test bars shown in Fig. 1 shall be poured in sand molds from the same lot as the castings represented.

NOTE 2—The numbering on the test specimens shown in Fig. 1 and Fig.

[1] This specification is under the jurisdiction of ASTM Committee A04 on Iron Castings and is the direct responsibility of Subcommittee A04.01 on Gray and White Iron Castings.

Current edition approved Dec. 10, 1995. Published January 1996. Originally published as A 126 – 29T. Last previous edition A 126 – 93.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

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TABLE 2 Transverse Test Requirements

	Class A	Class B	Class C
Force at center, min, lb (kN)	2200 (9.75)	3300 (14.65)	4000 (17.75)
Deflection at center, min, in. (mm)	0.10 (2.5)	0.12 (3.0)	0.12 (3.0)

2 is intended simply to illustrate a method of designation. In the particular method shown[12] refers to December 8, B 1 is the cupola number, and the numeral 1 which follows shows the hour cast (1 p.m.).

10.2 Test bars that are intended to represent castings which are cooled in the mold to less than 900°F (480°C) before shakeout, shall be cooled in their molds to a temperature less than 900°F, and then may be cooled in still air to room temperature.

10.3 Test bars that are intended to represent castings which are hotter than 900°F when shaken out of their molds, shall be cooled as described in 9.2 or (by agreement between the manufacturer and the purchaser) may be shaken out of their molds at approximately the same temperature as the castings they represent.

11. Tension Test Apparatus

11.1 Ball and socket specimen holders or spherical-seated bearings or other device which will ensure that the specimen, when under load, will be as nearly as possible in pure axial tension without transverse stress shall be used in making the tension test.

NOTE 3—Suitable socket specimens holders and spherical-seated bearing device are shown in Fig. 4 and described in 5.2.3 of Test Methods E 8.

11.2 After reaching a stress of 15 000 psi (103 MPa), the speed of the crosshead of the testing machine shall not exceed ⅛ in. (3.2 mm)/min.

12. Sampling

12.1 A lot shall consist of one of the following:

12.1.1 All the metal poured from a single heating in a batch type melting furnace,

12.1.2 All the metal from two or more batch type melting furnaces poured into a single ladle or single casting, or

12.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry or 4 h, whichever is the shorter period.

12.1.3.1 The purchaser may agree to extend the 4-h time period to 8 h if the manufacturer can demonstrate sufficient process control to warrant such an extension.

13. Test Specimens

13.1 Tension test specimens shall have threaded ends and conform to the dimensions shown in Fig. 2. The cross-sectional area of the reduced section shall be 1 in.^{2}(645 mm^2) ±5 %. The actual cross-sectional area shall be used in calculating the tensile strength.

14. Alternate Test Bars

14.1 Alternate test bars poured in accordance with Specification A 48 to the equivalent classes shown in Table 5 may be substituted for the Specification A 126 test bars. When the alternate bars are used, they shall be machined and tested in accordance with Specification A 48 and shall meet the requirements of Specification A 48.

15. Inspection

15.1 All tests and inspections required by this specification shall be performed by the manufacturer or other reliable sources whose services have been contracted for by the manufacturer. Complete records of all tests and inspections shall be maintained by the manufacturer and shall be available for review by the purchaser.

16. Rejection and Rehearing

16.1 Castings which fail to conform to the requirements specified when inspected or tested by the purchaser or his agent may be rejected. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the test results, the manufacturer or supplier may make claim for a rehearing.

17. Certification

17.1 When requested by the purchaser, the manufacturer shall furnish the certification stating that the material was manufactured, sampled, tested, and inspected in accordance with Specification A 126, including the year date. The certification shall also include the results of all tests performed including chemical analysis.

17.2 A signature is not required on the certification. However, the document shall clearly identify the organization submitting the certification and the authorized agent of the manufacturer who certified the test results. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

18. Keywords

18.1 gray iron castings; pressure retaining parts

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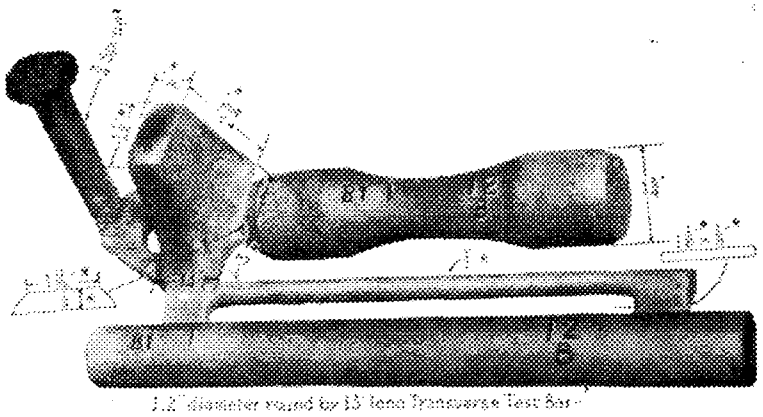
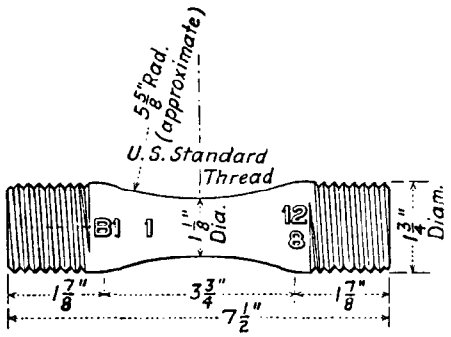


	Metric Equivalents											
in.	1/8	1/4	1/2	3/4	7/8	1 1/8	1.2	1 9/32	1 1/2	1 3/4	2 3/4	13
mm	3.2	6.4	12.7	19.0	22.2	28.6	30.5	32.5	38.1	44.4	69.8	1330

NOTE—These dimensions are suggested as satisfactory for average conditions, but may be varied to best suit individual pouring.

FIG. 1 Mold of Tension and Transverse Test Specimens



Metric Equivalents			
in.	mm	in.	mm
1 1/8	28.6	3 3/4	95.2
1 3/4	44.4	5 5/8	142.9
1 7/8	47.6	7 1/2	290.5

NOTE—Modification may be made to the grip-ends of the tension test specimen to allow alternative means of gripping as required by testing procedures and equipment. Should alternative grip-ends be disputed, the threaded grip-ends shall be used.

FIG. 2 Tension Test Specimen

TABLE 5 Equivalent Classes (Specification A 48)

Specification A 126 Class	Under 0.50 in. (12.7 mm)	0.51 to 1.00 in. (13.0 to 25.4 mm)	Over 1 in. (25.4 mm)
A	25 A	20 B	20 C
B	35 A	30 B	30 C
C	45 A	40 B	40 C

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Designation: A 135 – 01

An American National Standard

Standard Specification for Electric-Resistance-Welded Steel Pipe[1]

This standard is issued under the fixed designation A 135; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification[2] covers two grades of electric-resistance-welded steel pipe in NPS 2 to NPS 30 inclusive, with nominal (average) wall thickness up to 0.500 in. (12.70 mm), inclusive, and in nominal sizes NPS ¾ to NPS 5 inclusive with nominal (average) wall thickness 0.083 in. (2.11 mm) to 0.134 in. (3.40 mm), depending on size. Pipe having other dimensions (Note 1) may be furnished provided such pipe complies with all other requirements of this specification. The pipe is intended for conveying gas, vapor, water or other liquid; only Grade A is adapted for flanging and bending (Note 2). The suitability of pipe for various purposes is somewhat dependent upon its dimensions, properties, and conditions of service, so that the purpose for which the pipe is intended should be stated in the order. The pipe may be furnished either nonexpanded or cold expanded at the option of the manufacturer. When pipe is cold expanded, the amount of expansion shall not exceed 1.5 % of the outside diameter pipe size.

NOTE 1—A comprehensive listing of standardized pipe dimensions is contained in ASME B36.10.

NOTE 2—This provision is not intended to prohibit the cold bending of Grade B pipe.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI values, given in parentheses, are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3,4,5]

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment[4]

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[3,4,5]

A 865 Specification for Threaded Couplings, Steel, Black and Zinc-Coated (Galvanized) Welded or Seamless, for Use in Steel Pipe Joints[5]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys[5]

E 6 Terminology Relating to Methods of Mechanical Testing[6]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[7]

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[8]

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing[9]

E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing[9]

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation[9]

2.2 *ANSI Standard:*

B1.20.1 Pipe Threads, General Purpose[10]

2.3 *Federal Standards:*

Fed. STD No. 123 Marking for Shipments (Civil Agencies)[11]

Fed. STD No. 183 Continuous Identification Marking of Iron and Steel Products[11]

2.4 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[12]

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage[12]

2.5 *ASME Standard:*

B36.10 Welded and Seamless Wrought Steel Pipe[10,13]

3. Terminology

3.1 For definitions of terms relating to steel manufacturing and properties, refer to Terminology A 941.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.09 on Carbon Steel Tubular Products.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-135 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 01.05.

[5] *Annual Book of ASTM Standards*, Vol 01.01.

[6] *Annual Book of ASTM Standards*, Vol 03.01.

[7] *Annual Book of ASTM Standards*, Vol 14.02.

[8] Discontinued 1996; see *1995 Annual Book of ASTM Standards*, Vol 03.05.

[9] *Annual Book of ASTM Standards*, Vol 03.03.

[10] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

[11] Available from General Service Administration, Washington, DC 20405.

[12] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111–5094. Attn.: NOPD.

[13] Available from ASME International, Three Park Avenue, New York, NY 10016–5990.

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3.2 For definitions of terms relating to mechanical testing, refer to Terminology E 6.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *burr, n*—a rough or sharp edge left on pipe ends by cutting or sawing.

3.3.2 *lot, n*—all pipe of the same size, wall thickness and rolled length that is produced from the same heat of steel and subject to the same heat treatment.

3.3.3 *black thread, n*—a thread crease exhibiting the original pipe surface after machining.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet or number of lengths),

4.1.2 Name of material (electric-resistance-welded pipe),

4.1.3 Specification designation and year of issue,

4.1.4 Grade (see Table 1),

4.1.5 Size (nominal size, or outside diameter; and nominal wall thickness),

4.1.6 Length (specific or random, see 12.4),

4.1.7 End finish (plain or threaded, see 13.2),

4.1.7.1 Threaded and coupled, if specified,

4.1.7.2 Threads only, if specified,

4.1.7.3 Plain end, if specified,

4.1.8 Alternative electric test (see Section 11),

4.1.9 Tension test specimen (see Section 15),

4.1.10 Heat analysis, if required (see 6.1),

4.1.11 Certificate of compliance, if required (see Section 19), and

4.1.12 Special requirements.

5. Manufacture

5.1 The steel shall be made by either or both of the following processes: basic-oxygen or electric-furnace.

5.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

5.3 The pipe shall be manufactured from flat rolled steel in individual lengths or in continuous length by electric-resistance or electric-induction welding without the addition of extraneous material.

5.4 The weld seam of electric-resistance welded pipe to Grade B pipe shall be heat treated after welding to a minimum temperature of 1000 °F (540 °C) or processed in such a manner that no untempered martensite remains.

6. Chemical Composition

6.1 The steel shall conform to the requirements prescribed in Table 2, based on the heat analysis. When specified in the order, the heat analyses shall be reported to the purchaser or a representative of the purchaser.

7. Product Analysis

7.1 An analysis may be made by the purchaser on samples of pipe selected at random and shall conform to the requirements specified in Table 2. Methods and Practices relating to chemical analysis shall be in accordance with Test Method, Practices, and Terminology A 751.

8. Mechanical Properties Requirements

8.1 *Tensile Properties*:

8.1.1 The material shall conform to the requirements as to tensile properties prescribed in Table 1.

8.1.2 The yield strength shall be determined by the offset method utilizing 0.2 % of the gage length or by the total extension under load method using 0.5 % of the gage length.

8.1.3 Longitudinal test specimens shall be full-size longitudinal test specimens (see Figure A2.1 of Test Methods and Definitions A 370) or longitudinal strip test specimens (see Specimen No. 4 in Fig. A2.3 of Test Methods and Definitions A 370).

8.2 The test specimen taken across the weld shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe ordered. This test will not be

TABLE 1 Tensile Requirements

	Grade A	Grade B
Tensile strength, min, ksi (MPa)	48 (331)	60 (414)
Yield strength, min, ksi (MPa)	30 (207)	35 (241)
Elongation in 2 in. (50 mm), min, %:		
For pipe having a specified wall thickness of 5/16 in. (7.9 mm) or more, if tested using a longitudinal strip test specimen.	35	30
For pipe having a specified wall thickness of less than 5/16 in. (7.9 mm), if tested using a longitudinal strip test specimen.	[A]	[B]
For pipe of any size, if tested using a full-size longitudinal test specimen.	35	30

[A] The minimum elongation shall be determined by the following equation, with the calculated value rounded to the nearest percent:

$$E = 56t + 16.5$$

where:

E = elongation in 2 in. (50 mm), minimum, %, and

t = specified wall thickness, in.

[B] The minimum elongation shall be determined by the following equation, with the calculated value rounded to the nearest percent:

$$E = 48t + 14$$

where:

E = elongation in 2 in. (50 mm), minimum, %, and

t = specified wall thickness, in.

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TABLE 2 Chemical Requirements

Element	Composition, max, %	
	Grade A	Grade B
Carbon	0.25	0.30
Manganese	0.95	1.20
Phosphorus	0.035	0.035
Sulfur	0.035	0.035

required for pipe under NPS 8.

9. Flattening Test

9.1 A specimen at least 4 in. (102 mm) in length shall be flattened cold between parallel plates in three steps with the weld located either 0° or 90° from the line of direction of force as required in 9.2. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than two thirds of the original outside diameter of the pipe. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than one third of the original outside diameter of the pipe but is not less than five times the wall thickness of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

9.2 For pipe produced in single lengths, the flattening test specified in 9.1 shall be made on both crop ends cut from each length of pipe. The tests from each end shall be made alternately with the weld at 0° and at 90° from the line of direction of force. For pipe produced in multiple lengths, the flattening test shall be made on crop ends representing the front and back of each coil with the weld at 90° from the line of direction of force, and on two intermediate rings representing each coil with the weld 0° from the line of direction of force.

9.3 Surface imperfections in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements in Section 13.

9.4 Superficial cracks as a result of surface imperfections shall not be cause for rejection.

10. Hydrostatic Test

10.1 Except as provided for in 10.3, each length of pipe shall be hydrostatically tested at the mill, without leakage through the wall, to a pressure calculated from the following Eq 1:

$$P = 2St/D \quad (1)$$

where:

P = minimum hydrostatic test pressure, psi, (MPa). The test pressure need not exceed 2500 psi (17.24 MPa),

S = allowable fiber stress 18 000 psi (124 MPa) for Grade A and 21 000 psi (144 MPa) for Grade B. This does not prohibit testing at higher pressure at the manufacturer's option,

t = specified wall thickness, in., and

D = specified outside diameter, in.

Plain end pipe may be tested at the discretion of the manufacturer in single lengths or in multiple lengths.

10.2 The hydrostatic pressure shall be maintained for not less than 5 s.

10.3 When specified in the order, pipe may be furnished without hydrostatic testing, and each length so furnished shall include with the mandatory marking the letters "NH."

NOTE 3—This provision is not intended to apply to light wall (Schedule 10) pipe listed in Table X1.1.

10.4 When certification is required by the purchaser and the hydrostatic test has been omitted, the certification shall clearly state "Not Hydrostatically Tested." The specification number and material grade, as shown on the certification, shall be followed by the letters "NH."

11. Nondestructive Examination Requirements

11.1 As an alternate to the hydrostatic test for Schedule 10 pipe in sizes NPS ¾ to NPS 5 inclusive, and when accepted by the purchaser, each pipe shall be tested with a nondestructive electric test in accordance with Practice E 213, Practice E 273, or Practice E 309. It is the intent of this test to reject pipe containing defects.

11.2 Recognized methods for meeting this test are electromagnetic (eddy current) or ultrasonic.

11.3 The following information is for the benefit of the user of this specification:

11.3.1 The ultrasonic examination referred to in this specification is intended to detect longitudinal imperfections having a reflective area similar to or larger than the reference notch. The examination may not detect circumferentially oriented imperfections of short, deep imperfections.

11.3.2 The eddy-current examination referenced in this specification has the capability of detecting significant imperfections, especially of the short, abrupt type.

11.3.3 The hydrostatic test referred to in Section 10 is a test method provided for in many product specifications. This test has the capability of finding imperfections of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall imperfections or imperfections that extend an appreciable distance into the wall without complete penetration.

11.3.4 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of imperfections that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

11.4 In order to accommodate the various types of nondestructive electric testing equipment and techniques in use, the calibration pipe shall contain, at the option of the producer, any one or more of the following discontinuities to establish a

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minimum sensitivity level for rejection:

11.4.1 *Drilled Hole*—A hole not larger than 0.031-in. (0.8-mm) diameter shall be drilled radially and completely through pipe wall, preferably in the weld area, care being taken to avoid distortion of the pipe while drilling.

11.4.2 *Transverse Tangential Notch*—A notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe preferably in the weld area. Said notch shall have a depth not exceeding 12.5 % of the nominal wall thickness of the pipe or 0.004 in., (0.10 mm), whichever is greater.

11.4.3 *Longitudinal Notch*—A notch 0.031 in. (0.8 mm) or less in width shall be machined in a radial plane parallel to the pipe axis on the outside surface of the pipe preferably in the weld area, to have a depth not exceeding 12.5 % of the nominal wall thickness of the pipe or 0.004 in. (0.10 mm), whichever is greater.

11.5 Pipe producing a signal equal to or greater than the calibration imperfection shall be rejected.

12. Dimensions, Weight, and Permissible Variations

12.1 *Weight*—The weight of any length of pipe other than Schedule 10 shall not vary more than 3.5 % under or 10 % over that specified, but the carload weight shall be not more than 1.75 % under the nominal weight. The weight of pipe furnished to Schedule 10 shall not vary more than ±10 % from that calculated using the weight (mass) per unit length prescribed in Appendix Table X1.1. The weight of the pipe shall be calculated from the relevant equation in ASME B36.10 and with a constant of 10.69 rather than 10.68.

NOTE 4—A system of standard pipe sizes has been approved by the American National Standards Institute as American National Standard for Welded and Seamless Wrought Steel Pipe (ASME B36.10).

12.2 *Diameter*—The outside diameter shall not vary more than ±1 % from the nominal size specified.

12.3 *Minimum Wall Thickness*—The minimum wall thickness at any point shall be not more than 12.5 % under the specified wall thickness.

NOTE 5—The minimum wall thickness on inspection is shown in Table X1.2 of the Appendix.

12.4 *Lengths*:

12.4.1 Except as allowed in 12.4.2, pipe shall be furnished in lengths averaging 38 ft (11.6 m) or over, with a minimum length of 20 ft (6.1 m), but no more than 5 % may be under 32 ft (9.8 m). Jointers made by welding are permissible. When threaded pipe is ordered, jointers shall be made by threaded connections and shall not exceed 5 % of the order.

12.4.2 Unless otherwise specified, Schedule 10 pipe shall be between 16 and 22 ft (4.9 and 6.7 m) for a minimum of 90 % of the footage furnished, with any balance being shorter lengths at least 8 ft (2.4 m) long.

13. Workmanship, Finish, and Appearance

13.1 The finished pipe shall be reasonably straight and free of defects. Surface inperfections in excess of 12.5 % of the nominal wall thickness shall be considered defects.

13.2 *End Finish*:

13.2.1 *Schedule 10 Pipe*—Pipe furnished to Schedule 10 shall be plain end only. All inside and outside cutting burrs shall be removed. This generally involves breaking the corners.

13.2.2 *Ends, Plain End Pipe*—Unless otherwise specified, plain end pipe for use with the Dresser or Dayton type coupling shall be reamed both outside and inside sufficiently to remove all burrs. Plain end pipe for welding shall be beveled on the outside to an angle of 30° with a tolerance of + 5° and – 0° and with a width of flat at the end of the pipe of 1/16 +/– 1/32 in. (1.6 +/– 0.8 mm). When material is ordered beveled to any other than a 30° angle, it should be understood that the angle is to be measured from a line drawn perpendicular to the axis of the pipe. This means that a greater amount of material is removed with a 60° angle than with a 30° angle. Pipe shall be sufficiently free from indentations, projections, or roll marks for a distance of 8 in. (203 mm) from the end of the pipe to make a tight joint with the rubber gasket type of coupling. All plain end pipe intended for Dresser or Dayton type joints or for welding, sizes NPS 10 and smaller in outside diameter specified, shall be not more than 1/32 in. (0.8 mm) smaller than the outside diameter specified for a distance of 8 in. (203 mm) from the ends of the pipe and shall permit the passing for a distance of 8 in. (203 mm) of a ring gage that has a bore 1/16 in. (1.6 mm) larger than the outside diameter specified of the pipe. Sizes larger than NPS 10 shall be not more than 1/32 in. (0.8 mm) smaller than the nominal outside diameter for a distance of 8 in. (203 mm) from the end of the pipe and shall permit the passing for a distance of 8 in. (203 mm) of a ring gage which has a bore 3/32 in. (2.4 mm) larger than the nominal outside diameter of the pipe.

13.2.3 *Ends, Threaded Pipe*—Each end of threaded pipe shall be reamed to remove all burrs. All threads shall be in accordance with the American National Standard Pipe Threads (Note 6) and cut so as to make a tight joint when the pipe is tested at the mill to the specified internal hydrostatic pressure. The variation from the standard, when tested with the standard working gage, shall not exceed one and one-half turns either way. Pipe shall not be rounded by hammering in order to get a full thread. There shall be not more than two black threads for 3/4-in. (19.0-mm) taper among the perfect threads. Black threads should not be confused with imperfect threads, such as those torn, shaven, or broken.

NOTE 6—A complete description of the American National Standard Pipe Threads applicable to pipe, valves, and fittings is contained in the American National Standard for Pipe Threads (ANSI B1.20.1); also" Screw-Thread Standards for Federal Services, 1942," National Bureau of Standards *Handbook H 28*, January, 1942, the pertinent data in both sources being identical.

13.3 *Couplings*—Each length of threaded pipe shall be provided with one coupling manufactured in accordance with Specification A 865 except that the coupling may be wrought iron (Note 7). Threads shall be cut so as to make a tight joint. Taper-tapped couplings shall be furnished on all weights of threaded pipe NPS 2½ and larger.

NOTE 7—For sizes NPS 2 and smaller, it is commercial practice to furnish straight-tapped couplings for standard-weight (Schedule 40) pipe and taper-tapped couplings for extra-strong (Schedule 80) and double-extra-strong pipe. If taper-tapped couplings are required for sizes NPS 2 and smaller on standard weight (Schedule 40) pipe, line pipe in accordance with Specification 5L of the American Petroleum Institute should be

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ordered, thread lengths to be in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1). Taper-tapped couplings for sizes NPS 2 and smaller in standard weight may be used on mill-threaded standard weight type of the same size.

13.4 *Protective Coating*:

13.4.1 After the pipe has been subjected to the hydrostatic test, and if required by the purchaser, it shall be thoroughly cleaned of all dirt, oil, grease, loose scale, and rust; then dried, and given a protective coating of the kind and in the manner specified by the purchaser. Pipe furnished to Schedule 10 shall be normally shipped with a light coating of processing oil. If so specified, the pipe can be given a mill coating or a special coating.

14. Weld Repair

14.1 *Welding Repair*—

14.2 Defects in the pipe wall, provided their depth does not exceed one third the specified wall thickness, shall be repaired by electric welding. Defects in the welds such as sweats or leaks, unless otherwise specified, shall be repaired or the piece rejected at the option of the manufacturer. Repairs of this nature shall be made by completely removing the defect, cleaning the cavity, and then electric welding.

14.3 All repaired pipe shall be retested hydrostatically in accordance with Section 10.

15. Sampling

15.1 *Chemical Analysis*:

15.1.1 Samples for chemical analysis, except for spectrochemical analysis, shall be taken in accordance with Practice E 59. The number of samples shall be determined as follows:

NPS	Numbers of Samples Selected
Under 6	2 from each lot of 400 pipes or fraction thereof
6 to 20, incl	2 from each lot of 200 pipes or fraction thereof
Over 20 to 30, incl	2 from each lot of 100 pipes or fraction thereof

15.2 *Tension Test*:

15.2.1 One longitudinal tension test shall be made on length (Note 8) from each lot of 400 lengths or fraction thereof of each size under NPS 8 and one transverse body and one transverse weld tension test on one length from each lot of 200 lengths or fraction thereof of each size NPS 8 to NPS 20 and on one length from each lot of 100 lengths or fraction thereof of each size over NPS 20 to NPS 30. When taken from the skelp, the number of tests shall be determined in the same manner as when taken from the finished pipe.

NOTE 8—Length is defined as the length as ordered, except that in the case of orders for cut lengths shorter than double random, which is defined as the length as rolled, prior to cutting to the required short lengths.

15.3 *Flattening Test*:

15.3.1 The flattening test specified in 9.1 shall be made on both crop ends cut from each length of pipe. When pipe is produced in multiple lengths, flattening tests are required on the crop ends from the front and back ends of each coil and on two intermediate rings representing each coil.

15.4 *Hydrostatic Test*:

15.4.1 Each length of pipe shall be subjected to the hydrostatic test specified in Section 10.

16. Test, Retest, and Resampling

16.1 *Chemical Analysis*:

16.1.1 If the results of the analysis of either length of pipe does not conform to the requirements specified in Section 7, analyses of two additional lengths from the same lot shall be made, each of which shall conform to the requirements specified.

16.2 *Tension Test*:

16.2.1 The test specimens and the tests required by this specification shall conform to those described in Test Methods and Definitions A 370, except that all specimens shall be tested at room temperature.

16.2.2 The longitudinal tension test specimen shall be taken from the end of the pipe, or by agreement between the manufacturer and the purchaser may be taken from the skelp, at a point approximately 90° from the weld, and shall not be flattened between gage marks. The sides of each specimen shall be parallel between gage marks. At the manufacturer option, the tension test may be made on full section of pipe.

16.2.3 Transverse weld test specimens shall be taken with the weld at the center of the specimen. Transverse body test specimens shall be taken opposite to the weld. All transverse test specimens shall be approximately 1½ in. (38.1 mm) wide in the gage length and shall represent the full wall thickness of the pipe from which the specimen was cut.

16.2.4 If any test specimen shows defective machining or develops flaws not associated with the quality of the steel or the welding, it may be discarded and another specimen substituted.

16.2.5 If the results of the tension tests of any lot do not conform to the requirements specified in 9.1, retests of two additional lengths from the same lot shall be made, each of which shall conform to the requirements specified.

16.2.6 If the percentage of elongation of any tension test specimen is less than that specified in 8.1, and any part of the fracture is more than ¾-in. (19.0-mm) from the center of the gage length as indicated by scribe scratches marked on the specimen before testing, the specimen may be discarded and another substituted.

16.3 *Flattening Test*:

16.3.1 Specimens for flattening tests shall be smooth at the ends and free from burrs.

16.3.2 If any section of the pipe fails to comply with the requirements of 9.1, for pipe produced in single lengths, other sections may be cut from the same end of the same length until satisfactory tests are obtained, except that the finished pipe shall not be shorter than 80 % of its length after the initial cropping; otherwise, the length shall be rejected. For pipe produced in multiple lengths, retests may be cut from each end of each individual length in the multiple; such tests shall be made with the weld alternately 0° and 90° from the line of direction of force.

16.4 All specimens shall be tested at room temperature.

17. Inspection

17.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered.

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The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except check analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the manufacturer's operation.

18. Rejection

18.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

18.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

19. Certificate of Compliance

19.1 When specified in the purchase order, the producer or supplier shall furnish to the purchaser a certificate of compliance stating that the pipe has been manufactured, sampled, tested and inspected in accordance with this specification (including the year of issue) and has been found to meet the requirements.

20. Identification of Material

20.1 Each length of pipe shall be legibly marked with appropriate symbols by stenciling, stamping, or rolling to show the manufacturer's name, the size, the specification designation, the grade, and the hydrostatic test pressure when tested, or the letters "NH" when not tested.

20.2 In addition to the requirements in 20.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

21. Packaging, Marking, and Loading for Shipment

21.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

21.2 When specified in the contract or purchase order, the material shall be preserved, packaged, and packed in accordance with MIL-STD 163. The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD 129 or Fed. Std. No. 183 if continuous marking is required for military agencies.

22. Keywords

22.1 eddy current testing; electric resistance welded pipe; hydrostatic testing; plain end pipe; Schedule 10 pipe; threaded pipe

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APPENDIX

(Nonmandatory Information)

X1. ADDITIONAL DATA

X1.1 Additional data on dimensions nominal weights and test pressures is provided in Table X1.1.

X1.2 Additional data on wall thicknesses are provided in Table X1.2.

TABLE X1.1 Dimensions, Nominal Weights, and Test Pressures for Light Wall Steel Pipe

NPS	Outside Diameter, in. (mm)	Schedule 10		Test Pressure, psi (MPa)[A]	
		Specified Wall Thickness[A] in. (mm)	Weight (Mass) Per Unit Length lb/ft (kg/m)	Grade A	Grade B
¾	1.050 (26.7)	0.083 (2.11)	0.86 (1.28)	2500 (17.24)	2500 (17.24)
1	1.315 (33.4)	0.109 (2.77)	1.41 (2.09)	2500 (17.24)	2500 (17.24)
1¼	1.660 (42.2)	0.109 (2.77)	1.81 (2.69)	2400 (16.55)	2500 (17.24)
1½	1.900 (48.3)	0.109 (2.77)	2.09 (3.11)	2100 (14.48)	2400 (16.55)
2	2.375 (60.3)	0.109 (2.77)	2.64 (3.93)	1700 (11.72)	1900 (13.10)
2½	2.875 (73.0)	0.120 (3.05)	3.53 (5.26)	1500 (10.34)	1700 (11.72)
3	3.500 (88.9)	0.120 (3.05)	4.34 (6.46)	1200 (8.27)	1400 (9.65)
3½	4.000 (101.6)	0.120 (3.05)	4.98 (7.41)	1000 (6.89)	1200 (8.27)
4	4.500 (114.3)	0.120 (3.05)	5.62 (8.37)	900 (6.21)	1100 (7.58)
5	5.563 (141.3)	0.134 (3.40)	7.78 (11.58)	850 (5.86)	1000 (6.89)

[A] The test pressures are calculated by the following equation (but need not exceed 2500 psi or 17.24 MPa):

$$P = 2St/D$$

where:

P = pressure, psi (MPa),
S = fiber stress 60 % of the specified minimum yield strength, psi (MPa),
t = specified wall thickness, in. (mm), and
D = specified outside diameter, in. (mm).

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TABLE X1.2 Minimum Permissible Wall Thickness on Inspection

NOTE 1—The following equation, upon which this table is based, is used to derive the minimum permissible wall thickness values from the specified wall thickness values, with the calculated values rounded to three decimal places in accordance with the rounding method of Practice E 29:

$$t_m \times 0.875 = t$$

where:

t_m = minimum permissible wall thickness, in., and
t = specified wall thickness, in.

NOTE 2—This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

Specified Wall Thickness (t), in. (mm)	Minimum Permissible Wall Thickness (t_m), in. (mm)	Specified Wall Thickness (t), in. (mm)	Minimum Permissible Wall Thickness (t_m), in. (mm)	Specified Wall Thickness (t), in. (mm)	Minimum Permissible Wall Thickness (t_m), in. (mm)
0.068 (1.73)	0.060 (1.52)	0.294 (7.47)	0.257 (6.53)	0.750 (19.05)	0.656 (16.66)
0.088 (2.24)	0.077 (1.96)	0.300 (7.62)	0.262 (6.65)	0.812 (20.62)	0.710 (18.03)
0.091 (2.31)	0.080 (2.03)	0.307 (7.80)	0.269 (6.83)	0.843 (21.41)	0.738 (18.75)
0.095 (2.41)	0.083 (2.11)	0.308 (7.82)	0.270 (6.86)	0.864 (21.95)	0.756 (19.20)
0.113 (2.87)	0.099 (2.51)	0.312 (7.92)	0.273 (6.93)	0.875 (22.23)	0.766 (19.46)
0.119 (3.02)	0.104 (2.64)	0.318 (8.08)	0.278 (7.06)	0.906 (23.01)	0.793 (20.14)
0.125 (3.18)	0.109 (2.77)	0.322 (8.18)	0.282 (7.16)	0.937 (23.80)	0.820 (20.83)
0.126 (3.20)	0.110 (2.79)	0.330 (8.38)	0.289 (7.34)	0.968 (24.59)	0.847 (21.51)
0.133 (3.38)	0.116 (2.95)	0.337 (8.56)	0.295 (7.49)	1.000 (25.40)	0.875 (22.23)
0.140 (3.56)	0.122 (3.10)	0.343 (8.71)	0.300 (7.62)	1.031 (26.19)	0.902 (22.91)
0.145 (3.68)	0.127 (3.23)	0.344 (8.74)	0.301 (7.65)	1.062 (26.97)	0.929 (23.60)
0.147 (3.73)	0.129 (3.28)	0.358 (9.09)	0.313 (7.95)	1.093 (27.76)	0.956 (24.28)
0.154 (3.91)	0.135 (3.43)	0.365 (9.27)	0.319 (8.10)	1.125 (28.58)	0.984 (24.99)
0.156 (3.96)	0.136 (3.45)	0.375 (9.53)	0.328 (8.33)	1.156 (29.36)	1.012 (25.70)
0.179 (4.55)	0.157 (3.99)	0.382 (9.70)	0.334 (8.48)	1.218 (30.94)	1.066 (27.08)
0.187 (4.75)	0.164 (4.17)	0.400 (10.16)	0.350 (8.89)	1.250 (31.75)	1.094 (27.79)
0.188 (4.78)	0.164 (4.17)	0.406 (10.31)	0.355 (9.02)	1.281 (32.54)	1.121 (28.47)
0.191 (4.85)	0.167 (4.24)	0.432 (10.97)	0.378 (9.60)	1.312 (33.33)	1.148 (29.16)
0.200 (5.08)	0.175 (4.45)	0.436 (11.07)	0.382 (9.70)	1.343 (34.11)	1.175 (29.85)
0.203 (5.16)	0.178 (4.52)	0.437 (11.10)	0.382 (9.70)	1.375 (34.93)	1.203 (30.56)
0.216 (5.49)	0.189 (4.80)	0.438 (11.13)	0.383 (9.73)	1.406 (35.71)	1.230 (31.24)
0.218 (5.54)	0.191 (4.85)	0.500 (12.70)	0.438 (11.13)	1.437 (36.53)	1.258 (31.95)
0.219 (5.56)	0.192 (4.88)	0.531 (13.49)	0.465 (11.81)	1.500 (38.10)	1.312 (33.33)
0.226 (5.74)	0.198 (5.03)	0.552 (14.02)	0.483 (12.27)	1.531 (38.89)	1.340 (34.04)
0.237 (6.02)	0.207 (5.26)	0.562 (14.27)	0.492 (12.50)	1.562 (39.68)	1.367 (34.72)
0.250 (6.35)	0.219 (5.56)	0.593 (15.06)	0.519 (13.18)	1.593 (40.46)	1.394 (35.41)
0.258 (6.55)	0.226 (5.74)	0.600 (15.24)	0.525 (13.34)	1.750 (44.45)	1.531 (38.89)
0.276 (7.01)	0.242 (6.15)	0.625 (15.88)	0.547 (13.89)	1.781 (45.24)	1.558 (39.57)
0.277 (7.04)	0.242 (6.15)	0.656 (16.66)	0.574 (14.58)	1.812 (46.03)	1.586 (40.28)
0.279 (7.09)	0.244 (6.20)	0.674 (17.12)	0.590 (14.99)	1.968 (49.99)	1.722 (43.74)
0.280 (7.11)	0.245 (6.22)	0.687 (17.45)	0.601 (15.27)	2.062 (52.38)	1.804 (45.82)
0.281 (7.14)	0.246 (6.25)	0.719 (18.24)	0.629 (15.98)	2.343 (59.51)	2.050 (52.07)

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An American National Standard
Endorsed by Manufacturers Standardization
Society of the Valve and Fittings Industry
Used in USDOE-NE Standards

Standard Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service[1]

This standard is issued under the fixed designation A 182/A 182M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification[2] covers forged low alloy and stainless steel piping components for use in pressure systems. Included are flanges, fittings, valves, and similar parts to specified dimensions or to dimensional standards such as the ASME specifications that are referenced in Section 2.

1.2 For bars and products machined directly from bar, refer to Specifications A 479/A 479M and A 739, for the similar grades available in those specifications. Products made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. For larger products and products for other applications, refer to Specification A 336 for the similar grades available in that specification.

1.3 Several grades of low alloy steels and ferritic, martensitic, austenitic, and ferritic-austenitic stainless steels are included in this specification. Selection will depend upon design and service requirements.

1.4 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable" M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 In addition to the referenced documents listed in Specification A 961, the following list of standards apply to this specification.

2.2 *ASTM Standards:*

A 234/A 234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures[3]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels[4]

A 336/A 336M Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts[5]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[4]

A 403/A 403M Specification for Wrought Austenitic Stainless Steel Piping Fittings[3]

A 479/A 479M Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels[4]

A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings[4]

A 739 Specification for Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both[5]

A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels[4]

A 788 Specification for Steel Forgings, General Requirements[5]

A 961 Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications[3]

E 112 Test Methods for Determining the Average Grain Size[6]

E 340 Test Method for Macroetching Metals and Alloys[6]

2.3 *ASME Boiler and Pressure Vessel Codes:*[7]

Section IX Welding Qualifications

SFA-5.4 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-182 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

[4] *Annual Book of ASTM Standards*, Vol 01.03.

[5] *Annual Book of ASTM Standards*, Vol 01.05.

[6] *Annual Book of ASTM Standards*, Vol 03.01.

[7] Available from American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

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SFA-5.5 Specification for Low-Alloy Steel Covered Arc-Welding Electrodes
SFA-5.9 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes
SFA-5.11 Specification for Nickel and Nickel-Alloy Covered Welding Electrodes
B 16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings
B 16.9 Steel Butt-Welding Fittings
B 16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves
B 16.11 Forged Steel Fittings, Socket Weld, and Threaded
B 16.34 Valves—Flanged, Threaded and Welding End

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order, information necessary to purchase the needed material. In addition to the ordering information guidelines in Specification A 961, orders should include the following information:

3.1.1 Additional requirements (See 6.2.2, Table number 2 footnotes, 8.3, and 17.2), and

3.1.2 Requirement, if any, that manufacturer shall submit drawings for approval showing the shape of the rough forging before machining and the exact location of test specimen material (see 8.3.1).

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 961, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 961 constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 961, this specification shall prevail.

5. Manufacture

5.1 The low-alloy ferritic steels may be made by the open-hearth, electric-furnace, or basic-oxygen process with separate degassing and refining optional. Unless followed by separate refining, the basic oxygen process shall be limited to steels containing not over 6 % chromium.

5.2 The stainless steels shall be melted by one of the following processes: (*a*) electric-furnace (with separate degassing and refining optional); (*b*) vacuum-furnace; or (*c*) one of the former followed by vacuum or electroslag-consumable remelting. Grade F XM-27Cb may be produced by electron-beam melting. Because of difficulties that may be met in retaining nitrogen, vacuum melting or remelting processes should not be specified for Grades F XM-11, F 304LN, F 316LN, F 304N, F 316N, F XM-19, F 44, F 45, F 48, F 49, F 50, F 51, F 52, F 53, F 54, F 55, F 58, F 59, F 60, or F 62.

5.3 A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

5.4 The material shall be forged as close as practicable to the specified shape and size. Except for flanges of any type, forged or rolled bar may be used without additional hot working for small cylindrically shaped parts within the limits defined by Specification A 234/A 234M for low alloy steels and martensitic stainless steels and Specification A 403/A 403M for austenitic and ferritic-austenitic stainless steels. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

5.5 Except as provided for in 5.4, the finished product shall be a forging as defined in the Terminology section of Specification A 788.

6. Heat Treatment[8]

6.1 After hot working, forgings shall be cooled to a temperature below 1000°F [538°C] prior to heat treating in accordance with the requirements of Table 1.

6.2 *Low Alloy Steels and Ferritic and Martensitic Stainless Steels*—The low alloy steels and ferritic and martensitic stainless steels shall be heat treated in accordance with the requirements of 6.1 and Table 1.

6.2.1 Grade F 22V shall be furnished in the normalized and tempered, or liquid quenched and tempered condition. The minimum austenitizing temperature shall be 1650°F [900°C], and the minimum tempering temperature shall be 1250°F [677 C].

6.2.2 *Liquid Quenching*—When agreed to by the purchaser, liquid quenching followed by tempering shall be permitted provided the temperatures in Table 1 for each grade are utilized.

6.2.2.1 *Marking*—Parts that are liquid quenched and tempered shall be marked "QT."

6.2.3 Alternatively, Grade F 1, F 2, and F 12, Classes one and two may be given a heat treatment of 1200°F (650°C) minimum after final hot or cold forming.

6.3 *Austenitic and Ferritic-Austenitic Stainless Steels*—The austenitic and ferritic-austenitic stainless steels shall be heat treated in accordance with the requirements of 6.1 and Table 1.

6.3.1 Alternatively, immediately following hot working, while the temperature of the forging is not less than the minimum solutioning temperature specified in Table 1, forgings made from austenitic grades (except grades F 304H, F 316H, F 321, F 321H, F 347, F 347H, F 348, and F 348H) may be individually rapidly quenched in accordance with the requirements of Table 1.

[8] A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in F 321, F 321H, F 347, F 347H, F 348, F 348H. When specified by the purchaser, a lower temperature stabilization or resolution annealing shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S16).

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6.3.2 See Supplementary Requirement S8 if a particular heat treatment method is to be employed.

6.4 *Time of Heat Treatment*—Heat treatment of forgings may be performed before machining.

6.5 *Forged or Rolled Bar*—Forged or rolled austenitic stainless bar from which small cylindrically shaped parts are to be machined, as permitted by 5.4, and the parts machined from such bar, without heat treatment after machining, shall be furnished to the annealing requirements of Specification A 479 or this specification, with subsequent light cold drawing and straightening permitted (see Supplementary Requirement S3 if annealing must be the final operation).

TABLE 1 Heat Treating Requirements

Grade	Heat Treat Type	Austenitizing/Solutioning Temperature, min, °F (°C)[A]	Cooling Media	Quenching Cool Below °F (°C)	Tempering Temperature, min, °F (°C)
		Low Alloy Steels			
F 1	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1150 [620]
F 2	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1150 [620]
F5, F 5a	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	[B]	1250 [675]
F 9	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	[B]	1250 [675]
F 91	normalize and temper	1900-2000 [1040-1095]	air cool	[B]	1350 [730]
F 92	normalize and temper	1900 [1040]	air cool	[B]	1350 [730]
F911	normalize and temper	1900-2000 [1040-1095]	air cool or liquid	[B]	1350 [730]
F 11, Class 1, 2, 3	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1150 [620]
F 12, Class 1, 2	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1150 [620]
F 21, F 3V, nd F 3VCb	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	[B]	1250 [675]
F 22, Class 1, 3	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1250 [675]
F 23	normalize and temper	1900 [1040]	air cool	[B]	1350 [730]
F 24	normalize and temper	1800 [980]	accelerated cool air cool or liquid	[B]	1350 [730]
FR	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize	1750 [955]	air cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	[B]	1250 [675]
		Martensitic Stainless Steels			
F 122	normalize and temper	1900 [1040]	air cool	[B]	1350 [730]
F 6a Class 1	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1325 [725]
	temper	not required	[B]	[B]	1325 [725]
F 6a Class 2	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1250 [675]
	temper	not required	[B]	[B]	1250 [675]
F 6a Class 3	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1100 [595]
F 6a Class 4	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1000 [540]
F 6b	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	400 [205]	1150 [620]
F 6NM	normalize and temper	1850 [1010]	air cool	200 [95]	1040-1120 [560-600]
		Ferritic Stainless Steels			
F XM-27 Cb	anneal	1850 [1010]	furnace cool	[B]	[B]
F 429	anneal	1850 [1010]	furnace cool	[B]	[B]
F 430	anneal	not specified	furnace cool	[B]	[B]

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TABLE 1 *Continued*

Grade	Heat Treat Type	Austenitizing/Solutioning Temperature, min, °F (°C)[A]	Cooling Media	Quenching Cool Below °F (°C)	Tempering Temperature, min, °F (°C)
		Austenitic Stainless Steels			
F 304	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 304H	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 304L	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 304N	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 304LN	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 309H	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 310	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 310H	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 310MoLn	solution treat and quench	1900–2010 [1050–1100]	liquid	500 [260]	[B]
F 316	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 316H	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 316L	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 316N	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 316LN	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 317	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 317L	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 347	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 347H	solution treat and quench	2000 [1095]	liquid	500 [260]	[B]
F 348	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 348H	solution treat and quench	2000 [1095]	liquid	500 [260]	[B]
F 321	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 321H	solution treat and quench	2000 [1095]	liquid	500 [260]	[B]
F XM-11	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F XM-19	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 10	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 20	solution treat and quench	1700-1850 [925-1010]	liquid	500 [260]	[B]
F 44	solution treat and quench	2100 [1150]	liquid	500 [260]	[B]
F 45	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 46	solution treat and quench	2010-2140 [1100-1140]	liquid	500 [260]	[B]
F 47	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 48	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 49	solution treat and quench	2050 [1120]	liquid	500 [260]	[B]
F 56	solution treat and quench	2050-2160 [1120-1180]	liquid	500 [260]	[B]
F 58	solution treat and quench	2085 [1140]	liquid	500 [260]	[B]
F 62	solution treat and quench	2025 [1105]	liquid	500 [260]	[B]
		Ferritic-Austenitic Stainless Steels			
F 50	solution treat and quench	1925 [1050]	liquid	500 [260]	[B]
F 51	solution treat and quench	1870 [1020]	liquid	500 [260]	[B]
F 52[C]			liquid	500 [260]	[B]
F 53	solution treat and quench	1880 [1025]	liquid	500 [260]	[B]
F 54	solution treat and quench	1920-2060 [1050-1125]	liquid	500 [260]	[B]
F 55	solution treat and quench	2010-2085 [1100-1140]	liquid	500 [260]	[B]
F 57	solution treat and quench	1940 [1060]	liquid	175 [80]	[B]
F 59	solution treat and quench	1975-2050 [1080-1120]	liquid	500 [260]	[B]
F 60	solution treat and quench	1870 [1020]	liquid	500 [260]	[B]
F 61	solution treat and quench	1920-2060 [1050-1125]	liquid	500 [260]	[B]

[A] Minimum unless temperature range is listed.
[B] Not applicable.
[C] Grade F 52 shall be solution treated at 1825 to 1875°F [995 to 1025 C] 30 min in of thickness and water quenched.

7. Chemical Composition

7.1 A chemical heat analysis in accordance with Specification A 961 shall be made and conform to the chemical composition prescribed in Table 2.

7.2 Grades to which lead, selenium, or other elements are added for the purpose of rendering the material free-machining shall not be used.

7.3 Starting material produced to a specification that specifically requires the addition of any element beyond those listed in Table 2 for the applicable grade of material, is not permitted.

7.4 *Product Analysis*—The purchaser may make a product analysis on products supplied to this specification in accordance with Specification A 961.

8. Mechanical Properties

8.1 The material shall conform to the requirements as to mechanical properties for the grade ordered as listed in Table 3.

8.2 Mechanical test specimens shall be obtained from production forgings, or from separately forged test blanks prepared from the stock used to make the finished product. In either case, mechanical test specimens shall not be removed until after all heat treatment is complete. If repair welding is required, test specimens shall not be removed until after post-weld heat treatment is complete, except for ferritic grades when the post-weld heat treatment is conducted at least 50°F [30°C] below the actual tempering temperature. When test blanks are used, they shall receive approximately the same working as the finished product. The test blanks shall be heat treated with the finished product and shall approximate the

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maximum cross section of the forgings they represent.

8.3 For normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall correspond to the ¼ *T* plane or deeper position where *T* is the maximum heat treated thickness of the represented forging. In addition, for quenched and tempered forgings, the midlength of the test specimen shall be at least *T* from any second heat treated surface. When the section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location, as agreed to by the purchaser and the supplier.

8.3.1 With prior purchase approval, the test specimen for ferritic steel forgings may be taken at a depth (*t*) corresponding to the distance from the area of significant stress to the nearest heat treated surface and at least twice this distance (2 *t*) from any second surface. However, the test depth shall not be nearer to one treated surface than ¾ in. [19 mm] and to the second treated surface than 1½ in. [38 mm]. This method of test specimen location would normally apply to contour-forged parts, or parts with thick cross-sectional areas where ¼ *T* × *T* testing (8.3) is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

8.3.2 *Metal Buffers*—The required distances from heat-treated surfaces may be obtained with metal buffers instead of integral extensions. Buffer material may be carbon or low-alloy steel, and shall be joined to the forging with a partial penetration weld that seals the buffered surface. Specimens shall be located at ½-in. [13-mm] minimum from the buffered surface of the forging. Buffers shall be removed and the welded areas subjected to magnetic particle test to ensure freedom from cracks unless the welded areas are completely removed by subsequent machining.

8.4 For annealed low alloy steels, ferritic stainless steels, and martensitic stainless steels and also for austenitic and ferritic-austenitic stainless steels, the test specimen may be taken from any convenient location.

8.5 *Tension Tests*:

8.5.1 *Low Alloy Steels and Ferritic and Martensitic Stainless Steels*—One tension test shall be made for each heat in each heat treatment charge.

8.5.1.1 When the heat-treating cycles are the same and the furnaces (either batch or continuous type) are controlled within ±25°F [±14°C] and equipped with recording pyrometers so that complete records of heat treatment are available, then only one tension test from each heat of each forging type (Note 1) and section size is required instead of one test from each heat in each heat-treatment charge.

NOTE 1—"Type" in this case is used to describe the forging shape such as a flange, ell, tee, etc.

8.5.2 *Austenitic and Ferritic-Austenitic Stainless Steel Grades*—One tension test shall be made for each heat.

8.5.2.1 When heat treated in accordance with 6.1, the test blank or forging used to provide the test specimen shall be heat treated with a finished forged product.

8.5.2.2 When the alternative method in 6.3.1 is used, the test blank or forging used to provide the test specimen shall be forged and quenched under the same processing conditions as the forgings they represent.

8.5.3 Testing shall be performed in accordance with Test Methods and Definitions A 370 using the largest feasible of the round specimens. The gage length for measuring elongation shall be four times the diameter of the test section.

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TABLE 2 Chemical Requirements

Identification Symbol	UNS Designation	Grade	Composition, %									
			Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
			Low Alloy Steels										
F 1	K12822	carbon-molybdenum	0.28 max	0.60–0.90	0.045	0.045	0.15–0.35	...	...	0.44–0.65	...	...	
F 2[A]	K12122	0.5 % chromium, 0.5 % molybdenum	0.05–0.21	0.30–0.80	0.040	0.040	0.10–0.60	...	0.50–0.81	0.44–0.65	...	...	
F 5[B]	K41545	4 to 6 % chromium	0.15 max	0.30–0.60	0.030	0.030	0.50 max	0.50 max	4.0–6.0	0.44–0.65	...	...	
F 5a[B]	K42544	4 to 6 % chromium	0.25 max	0.60 max	0.040	0.030	0.50 max	0.50 max	4.0–6.0	0.44–0.65	...	...	
F 9	K90941	9 % chromium	0.15 max	0.30–0.60	0.030	0.030	0.50–1.00	...	8.0–10.0	0.90–1.10	...	...	
F 91	K90901	9 % chromium, 1 % molybdenum, 0.2 % vanadium plus columbium and nitrogen	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	0.40 max	8.0–9.5	0.85–1.05			Cb 0.06–0.10 N 0.03–0.07 Al 0.04 max V 0.18–0.25
F 92	...	9 % chromium, 1.8 % tungsten, 0.2 % vanadium plus columbium	0.07–0.13	0.30–0.60	0.020	0.010	0.50 max	0.40 max	8.50–9.50	0.30–0.60			Cb 0.04–0.09 V 0.15–0.25 N 0.030–0.070 Al 0.04 max W 1.50–2.00 B 0.001–0.006
F 911	...	9 % chromium, 1 % molybdenum, 0.2 % vanadium plus columbium and nitrogen	0.09–0.13	0.30–0.60	0.020	0.010	0.10–0.50	0.40 max	8.5–10.5	0.90–1.10		...	W 0.90–1.10 Cb 0.060–0.10 Al 0.04 max N 0.04–0.09 V 0.18–0.25 B 0.0003–0.006
F 11 Class 1	K11597	1.25 % chromium, 0.5 % molybdenum	0.05–0.15	0.30–0.60	0.030	0.030	0.50–1.00	...	1.00–1.50	0.44–0.65	...	...	
F 11 Class 2	K11572	1.25 % chromium, 0.5 % molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.50–1.00	...	1.00–1.50	0.44–0.65	...	...	
F 11 Class 3	K11572	1.25 % chromium, 0.5 % molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.50–1.00	...	1.00–1.50	0.44–0.65	...	...	
F 12 Class 1	K11562	1 % chromium, 0.5 % molybdenum	0.05–0.15	0.30–0.60	0.045	0.045	0.50 max	...	0.80–1.25	0.44–0.65	...	...	
F 12 Class 2	K11564	1 % chromium, 0.5 % molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.10–0.60	...	0.80–1.25	0.44–0.65	...	...	

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TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %									
			Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 21	K31545	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	...	2.7–3.3	0.80–1.06	...	...	
F 3V	K31830	3 % chromium, 1 % molybdenum, 0.25 % vanadium plus boron and titanium	0.05–0.18	0.30–0.60	0.020	0.020	0.10 max	...	2.8–3.2	0.90–1.10		0.015–0.035	V 0.20–0.30 B 0.001–0.003
F 3VCb	...	...	0.10–0.15	0.30–0.60	0.020	0.010	0.10 max	0.25 max	2.7–3.3	0.90–1.10		0.015 max	V 0.20–0.30 Cb 0.015–0.070 Cu 0.25 max Ca 0.0005–0.0150
F 22 Class 1	K21590	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	...	2.00–2.50	0.87–1.13	...	...	
F 22 Class 3	K21590	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	...	2.00–2.50	0.87–1.13	...	...	
F 22V	K31835	2.25 % chromium, 1 % molybdenum, 0.25 % vanadium	0.11–0.15	0.30–0.60	0.015	0.010	0.10 max	0.25 max	2.00–2.50	0.90–1.10		0.030 max	Cu 0.20 max V 0.25–0.35 Cb 0.07 max B 0.002 max Ca 0.015 max[C]
F 23	K41650	2.25 % chromium, 1.6 % tungsten, 0.25 % vanadium, plus molybdenum, columbium, and boron	0.04–0.10	0.10–0.60	0.030	0.010	0.50 max	...	1.90-2.60	0.05-0.30	0.02–0.08		V 0.20–0.30 B 0.0005–0.006 N 0.030 max Al 0.030 max W 1.45–1.75

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TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 24	...	2.25 % chromium, 1 % molybdenum, 0.25 % vanadium plus titanium and boron	0.05–0.10	0.30–0.70	0.020	0.010	0.15–0.45	...	2.20–2.60	0.90–1.10		0.06-0.10	V 0.20–0.30 N 0.12 max Al 0.020 max B 0.0015–0.0070
FR	K22035	2 % nickel, 1 % copper	0.20 max	0.40–1.06	0.045	0.050	...	1.60–2.24	...	...			Cu 0.75–1.25
			Martensitic Stainless Steels										
F 122	K92930	11 % chromium, 2 % tungsten, 0.2 % vanadium, plus molybdenum, columbium, copper, nickel, nitrogen, and boron	0.07–0.14	0.70 max	0.020	0.010	0.50 max	0.50 max	10.00–12.50	0.25–0.60	0.04–0.10		V 0.15–0.30 B 0.005 max N 0.040–0.100 Al 0.040 max Cu 0.30–1.70 W 1.50–2.50
F 6a	S41000	13 % chromium	0.15 max	1.00	0.040	0.030	1.00 max	0.50 max	11.5–13.5	...	...	...	
F 6b	S41026	13 % chromium, 0.5 % molybdenum	0.15 max	1.00	0.020	0.020	1.00 max	1.00–2.00	11.5–13.5	0.40–0.60			Cu 0.50 max
F 6NM	S41500	13 % chromium, 4 % nickel	0.05 max	0.50–1.00	0.030	0.030	0.60 max	3.5–5.5	11.5–14.0	0.50–1.00	...	...	
			Ferritic Stainless Steels										
F XM-27Cb[D]	S44627	27 chromium, 1 molybdenum	0.010 max	0.40 max	0.020	0.020	0.40 max	0.50 max	25.0–27.5	0.75–1.50			N 0.015 max Cu 0.20 max Cb 0.05–0.20
F 429	S42900	15 chromium	0.12 max	1.00 max	0.040	0.030	0.75 max	0.50 max	14.0–16.0	...	...	...	
F 430	S43000	17 chromium	0.12 max	1.00 max	0.040	0.030	0.75 max	0.50 max	16.0–18.0	...	...	...	
			Austenitic Stainless Steels										
F 304[E]	S30400	18 chromium, 8 nickel	0.08 max	2.00 max	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	...	...	...	

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TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 304H	S30409	18 chromium, 8 nickel	0.04–0.10	2.00 max	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	...	...	...	
F 304L[E]	S30403	18 chromium, 8 nickel, low carbon	0.030 max	2.00 max	0.045	0.030	1.00 max	8.0–13.0	18.0–20.0	...	...	...	
F 304N[F]	S30451	18 chromium, 8 nickel, modified with nitrogen	0.08 max	2.00 max	0.045	0.030	1.00 max	8.0–10.5	18.0–20.0	...	...	...	
F 304LN[F]	S30453	18 chromium, 8 nickel, modified with nitrogen	0.030 max	2.00 max	0.045	0.030	1.00 max	8.0–10.5	18.0–20.0	...	...	...	
F 309H	S30909	23 chromium, 13.5 nickel	0.04–0.10	2.00 max	0.045	0.030	1.00 max	12.0–15.0	22.0–24.0	...	...	...	
F 310	S31000	25 chromium, 20 nickel	0.25 max	2.00 max	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	...	...	...	
F 310H[F]	S31009	25 chromium, 20 nickel	0.04–0.10	2.00 max	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	...	...	...	
F 310MoLN[F]	S31050	25 chromium, 22 nickel, modified with molybdenum and nitrogen, low carbon	.020 max	2.00 max	0.030	0.010	0.050 max	20.5–23.5	24.0–26.0	1.60–2.60	...		N .09–.15
F 316[E]	S31600	18 chromium, 8 nickel, modified with molybdenum	0.08 max	2.00 max	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	
F 316H	S31609	18 chromium, 8 nickel, modified with molybdenum	0.04–0.10	2.00 max	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	
F 316L[E]	S31603	18 chromium, 8 nickel, modified with molybdenum, low carbon	0.030 max	2.00 max	0.045	0.030	1.00 max	10.0–15.0	16.0–18.0	2.00–3.00	...	...	
F 316N[F]	S31651	18 chromium, 8 nickel, modified with molybdenum and nitrogen	0.08 max	2.00 max	0.045	0.030	1.00 max	11.0–14.0	16.0–18.0	2.00–3.00	...	...	
F 316LN[F]	S31653	18 chromium, 8 nickel, modified with molybdenum and nitrogen	0.030 max	2.00 max	0.045	0.030	1.00 max	11.0–14.0	16.0–18.0	2.00–3.00	...	...	
F 317	S31700	19 chromium, 13 nickel, 3.5 molybdenum	0.08 max	2.00 max	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	...	...	
F 317L	S31703	19 chromium, 13 nickel, 3.5 molybdenum	0.030 max	2.00 max	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	...	...	
F 321	S32100	18 chromium, 8 nickel modified with titanium	0.08 max	2.00 max	0.045	0.030	1.00 max	9.0–12.0	17.0–19.0	...	...	[G]	
F 321H	S32109	18 chromium, 8 nickel, modified with titanium	0.04–0.10	2.00 max	0.045	0.030	1.00 max	9.0–12.0	17.0–19.0	...	...	[H]	
F 347	S34700	18 chromium, 8 nickel modified with columbium	0.08 max	2.00 max	0.045	0.030	1.00 max	9.0–13.0	17.0–20.0	...	[I]	...	
F 347H	S34709	18 chromium, 8 nickel, modified with columbium	0.04–0.10	2.00 max	0.045	0.030	1.00 max	9.0–13.0	17.0–20.0	...	[J]	...	
F 348	S34800	18 chromium, 8 nickel modified with columbium	0.08 max	2.00 max	0.045	0.030	1.00 max	9.0–13.0	17.0–20.0	...	[I]		Co 0.20 max Ta 0.10

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TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 348H	S34809	18 chromium, 8 nickel, modified with columbium	0.04–0.10	2.00 max	0.045	0.030	1.00 max	9.0–13.0	17.0–20.0	...			Co 0.20 max Ta 0.10
F XM-11	S21904	20 chromium, 6 nickel, 9 manganese	0.040 max	8.0–10.0	0.060	0.030	1.00 max	5.5–7.5	19.0–21.5	...	...		N 0.15–0.40
F XM-19	S20910	22 chromium, 13 nickel, 5 manganese	0.06 max	4.0–6.0	0.040	0.030	1.00 max	11.5–13.5	20.5–23.5	1.50–3.00	0.10–0.30		N 0.20–0.40 V 0.10–0.30
F 10	S33100	20 nickel, 8 chromium	0.10–0.20	0.50–0.80	0.040	0.030	1.00–1.40	19.0–22.0	7.0–9.0	...	...	...	
F 20	N08020	35 nickel, 20 chromium, 3.5 copper, 2.5 molybdenum	.07 max	2.00 max	0.045	0.035	1.00 max	32.0–38.0	19.0–21.0	2.00–3.00	8xCmin –1.00 max	...	Cu 3.0–4.0
F 44	S31254	20 chromium, 18 nickel, 6 molybdenum, low carbon	0.020 max	1.00 max	0.030	0.010	0.80 max	17.5–18.5	19.5–20.5	6.0–6.5	...		Cu 0.50–1.00 N 0.18–0.22
F 45	S30815	21 chromium, 11 nickel modified with nitrogen and cerium	0.05–0.10	0.80 max	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	...	...		N 0.14–0.20 Ce 0.03–0.08
F 46	S30600	18 chromium, 15 nickel, 4 silicon	0.018 max	2.00 max	0.020	0.020	3.7–4.3	14.0–15.5	17.0–18.5	0.20 max	...		Cu 0.50 max
F 47	S31725	19 chromium, 15 nickel, 4 molybdenum	0.030 max	2.00 max	0.045	0.030	0.75 max	13.0–17.5	18.0–20.0	4.0–5.0	...		N 0.10 max
F 48	S31726	19 chromium, 15 nickel, 4 molybdenum	0.030 max	2.00 max	0.045	0.030	0.75 max	13.5–17.5	17.0–20.0	4.0–5.0	...		N 0.10–0.20
F 49	S34565	24 chromium, 17 nickel, 6 manganese, 5 molybdenum	0.030 max	5.0–7.0	0.030	0.010	1.00 max	16.0–18.0	23.0–25.0	4.0–5.0	0.10		N 0.40–0.60
F 56	S33228	32 nickel, 27 chromium with columbium	0.04–0.08	1.00 max	0.020	0.015	0.30 max	31.0–33.0	26.0–28.0	...	0.6–1.0		Ce 0.05–0.10 Al 0.025
F 58	S31266	24 chromium, 20 nickel, 8 molybdenum, 2 tungsten with nitrogen	0.030 max	2.0–4.0	0.035	0.020	1.00 max	21.0–24.0	23.0–25.0	5.2–6.2			N 0.35–0.60 Cu 1.00–2.50 W 1.50–2.50
F 62	N08367	21 chromium, 25 nickel, 6.5 molybdenum	0.030 max	2.0 max	0.040	0.030	1.00 max	23.50–25.50	20.00–22.00	6.00–7.00	...		N 0.18–0.25 Cu 0.75 max
			Ferritic-Austenitic Stainless Steels										
F 50	S31200	25 chromium, 6 nickel, modified with nitrogen	0.030 max	2.00 max	0.045	0.030	1.00 max	5.5–6.5	24.0–26.0	1.20–2.00	...		N 0.14–0.20
F 51	S31803	22 chromium, 5.5 nickel, modified with nitrogen	0.030 max	2.00 max	0.030	0.020	1.00 max	4.5–6.5	21.0–23.0	2.5–3.5	...		N 0.08–0.20
F 52	S32950	26 chromium, 3.5 nickel, 1.0 molybdenum	0.030 max	2.00 max	0.035	0.010	0.60 max	3.5–5.2	26.0–29.0	1.00–2.50	...		N 0.15–0.35

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TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 53	S32750	25 chromium, 7 nickel, 4 molybdenum, modified with nitrogen	0.030 max	1.20 max	0.035	0.020	0.80 max	6.0–8.0	24.0–26.0	3.0–5.0	...		N 0.24–0.32 Cu 0.50 max
F 54	S39274	25 chromium, 7 nickel, modified with nitrogen and tungsten	0.030 max	1.00 max	0.030	0.020	0.80 max	6.0–8.0	24.0–26.0	2.5–3.5	...		N 0.24–0.32 Cu 0.20–0.80 W 1.50–2.50
F 55	S32760	25 chromium, 7 nickel, 3.5 molybdenum, modified with nitrogen and tungsten	0.030 max	1.00 max	0.030	0.010	1.00 max	6.0–8.0	24.0–26.0	3.0–4.0	...		N 0.20–0.30 Cu 0.50–1.00 W 0.50–1.00[K]
F 57	S39277	26 chromium, 7 nickel, 3.7 molybdenum	0.025 max	0.80 max	0.025	0.002	0.80 max	6.5–8.0	24.0–26.0	3.0–4.0	...		Cu 1.20–2.00 W 0.80–1.20 N 0.23–0.33
F 59	S32520	25 chromium, 6.5 nickel, 4 molybdenum with nitrogen	0.030 max	1.50 max	0.035	0.020	0.80 max	5.5–8.0	24.0–26.0	3.0–5.0	...		N 0.20–0.35 Cu 0.50–3.00
F 60	S32205	22 chromium, 5.5 nickel, 3 molybdenum, modified with nitrogen	0.030 max	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5	...		N 0.14–0.20
F 61	S32550	26 chromium, 6 nickel, 3.5 molybdenum with nitrogen and copper	0.04 max	1.50 max	0.040	0.030	1.00 max	4.5–6.5	24.0–27.0	2.9–3.9	...		Cu 1.50–2.50 N 0.10–0.25

[A] Grade F 2 was formerly assigned to the 1 % chromium, 0.5 % molybdenum grade which is now Grade F 12.

[B] The present grade F 5a (0.25 max carbon) previous to 1955 was assigned the identification symbol F 5. Identification symbol F 5 in 1955 was assigned to the 0.15 max carbon grade to be consistent with ASTM specifications for other products such as pipe, tubing, bolting, welding fittings, etc.

[C] For Grade F22V, rare earth metals (REM) may be added in place of calcium, subject to agreement between the producer and the purchaser. In that case the total amount of REM shall be determined and reported.

[D] Grade F XM-27Cb shall have a nickel plus copper content of 0.50 max %. Product analysis tolerance over the maximum specified limit for carbon and nitrogen shall be 0.002 %.

[E] Grades F 304, F 304L, F 316, and F 316L shall have a maximum nitrogen content of 0.10 %.

[F] Grades F 304N, F 316N, F 304LN, and F 316LN shall have a nitrogen content of 0.10 to 0.16 %.

[G] Grade F 321 shall have a titanium content of not less than five times the carbon content and not more than 0.70 %.

[H] Grade F 321H shall have a titanium content of not less than 4 times the carbon content and not more than 0.70 %.

[I] Grades F 347 and F 348 shall have a columbium content of not less than ten times the carbon content and not more than 1.10 %.

[J] Grades F 347H and F 348H shall have a columbium content of not less than 8 times the carbon content and not more than 1.10 %.

[K] % Cr + 3.3 × % Mo + 16 × % N = 40 min.

TABLE 3 Tensile and Hardness Requirements

Grade Symbol	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa][A]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Brinell Hardness Number
		Low Alloy Steels			
F 1	70 [485]	40 [275]	20.0	30.0	143–192
F 2	70 [485]	40 [275]	20.0	30.0	143–192
F 5	70 [485]	40 [275]	20.0	35.0	143–217
F 5a	90 [620]	65 [450]	22.0	50.0	187–248
F 9	85 [585]	55 [380]	20.0	40.0	179–217
F 91	85 [585]	60 [415]	20.0	40.0	248 max
F 92	90 [620]	64 [440]	20	45	269 max
F 911	90 [620]	64 [440]	18	40.0	187–248
F 11 Class 1	60 [415]	30 [205]	20	45	121–174
F 11 Class 2	70 [485]	40 [275]	20.0	30.0	143–207
F 11 Class 3	75 [515]	45 [310]	20	30	156–207
F 12 Class 1	60 [415]	32 [220]	20	45	121–174
F 12 Class 2	70 [485]	40 [275]	20.0	30.0	143–207
F 21	75 [515]	45 [310]	20.0	30.0	156–207
F 3V, and F 3VCb	85–110 [585–760]	60 [415]	18	45	174–237
F 22 Class 1	60 [415]	30 [205]	20.0	35.0	170 max
F 22 Class 3	75 [515]	45 [310]	20.0	30.0	156–207
F 22V	85–110 [585–780]	60 [415]	18.0	45.0	174–237
F 23	74 [510]	58 [400]	20.0	40.0	220 max
F 24	85 [585]	60 [415]	20.0	40.0	248 max
FR	63 [435]	46 [315]	25.0	38.0	197 max
		Martensitic Stainless Steels			
F 122	90 [620]	58 [400]	20	40	250 max
F 6a Class 1	70 [485]	40 [275]	18	35.0	143–207
F 6a Class 2	85 [585]	55 [380]	18	35.0	167–229
F 6a Class 3	110 [760]	85 [585]	15	35.0	235–302
F 6a Class 4	130 [895]	110 [760]	12	35.0	263–321
F 6b	110–135 [760–930]	90 [620]	16	45.0	235–285
F 6NM	115 [790]	90 [620]	15	45.0	295 max
		Ferritic Stainless Steels			
F XM-27Cb	60 [415]	35 [240]	20.0	45.0	190 max
F 429	60 [415]	35 [240]	20.0	45.0	190 max
F 430	60 [415]	35 [240]	20.0	45.0	190 max
		Austenitic Stainless Steels			
F 304	75 [515][B]	30 [205]	30	50	...
F 304H	75 [515][B]	30 [205]	30	50	...
F 304L	70 [485][C]	25 [170]	30	50	...
F 304N	80 [550]	35 [240]	30[D]	50[E]	...
F 304LN	75 [515][B]	30 [205]	30	50	...
F 309H	75 [515][B]	30 [205]	30	50	...
F 310	75 [515][B]	30 [205]	30	50	...
F 310 MoLn	78 [540]	37 [255]	25	40	...
F 310H	75 [515][B]	30 [205]	30	50	...
F 316	75 [515][B]	30 [205]	30	50	...
F 316H	75 [515][B]	30 [205]	30	50	...
F 316L	70 [485][C]	25 [170]	30	50	...
F 316N	80 [550]	35 [240]	30[D]	50[E]	...
F 316LN	75 [515][B]	30 [205]	30	50	...
F 317	75 [515][B]	30 [205]	30	50	...
F 317L	70 [485][C]	25 [170]	30	50	...
F 347	75 [515][B]	30 [205]	30	50	...
F 347H	75 [515][B]	30 [205]	30	50	...
F 348	75 [515][B]	30 [205]	30	50	...
F 348H	75 [515][B]	30 [205]	30	50	...
F 321	75 [515][B]	30 [205]	30	50	...
F 321H	75 [515][B]	30 [205]	30	50	...
F XM-11	90 [620]	50 [345]	45	60	...
F XM-19	100 [690]	55 [380]	35	55	...
F 10	80 [550]	30 [205]	30	50	...
F 20	80 [550]	35 [240]	30	50	...
F 44	94 [650]	44 [300]	35	50	...
F 45	87 [600]	45 [310]	40	50	...
F 46	78 [540]	35 [240]	40.0	50.0	...
F 47	75 [525]	30 [205]	40.0	50.0	...

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TABLE 3 *Continued*

Grade Symbol	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa][A]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Brinell Hardness Number
F 48	80 [550]	35 [240]	40.0	50.0	...
F 49	115 [795]	60 [415]	35	40	...
F 56	73 [500]	27 [185]	30	35	...
F 58	109 [750]	61 [420]	35	50	...
F 62	95 [655]	45 [310]	30	50	...
		Ferritic-Austenitic Stainless Steels			
F 50	100–130 [690–900]	65 [450]	25	50	...
F 51	90 [620]	65 [450]	25	45	...
F 52	100 [690]	70 [485]	15	...	...
F 53	116 [800][F]	80 [550][F]	15	...	310 max
F 54	116 [800]	80 [550]	15	30	310 max
F 55	109–130 [750–895]	80 [550]	25.0	45	...
F 57	118 [820]	85 [585]	25	50	...
F 59	112 [770]	80 [550]	25	40	...
F 60	95 [655]	70 [485]	25	45	...
F 61	109 [750]	80 [550]	25.0	50	...

[A] Determined by the 0.2 % offset method. For ferritic steels only, the 0.5 % extension-under-load method may also be used.
[B] For sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 70 ksi [485 MPa].
[C] For sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 65 ksi [450 MPa].
[D] Longitudinal. The transverse elongation shall be 25 % in 2 in. or 50 mm, min.
[E] Longitudinal. The transverse reduction of area shall be 45 % min.
[F] For sections over 2 in. [50 mm] in thickness, the minimum tensile strength shall be 106 ksi [730 MPa]; the minimum yield strength shall be 75 ksi [515 MPa].

8.6 *Hardness Tests*:

8.6.1 Except when only one forging is produced, a minimum of two pieces per batch or continuous run as defined in 8.6.2 shall be hardness tested in accordance with Test Methods and Definitions A 370 to ensure that the forgings are within the hardness limits given for each grade in Table 3. The purchaser may verify that the requirement has been met by testing at any location on the forging provided such testing does not render the forging useless.

8.6.2 When the reduced number of tension tests permitted by 8.5.1.1 is applied, additional hardness tests shall be made on forgings or samples as defined in 8.2 scattered throughout the load (Note 2). At least eight samples shall be checked from each batch load and at least one check per hour shall be made from a continuous run. When the furnace batch is less than eight forgings, each forging shall be checked. If any check falls outside the prescribed limits, the entire lot of forgings shall be reheat treated and the requirements of 8.5.1 shall apply.

NOTE 2—The tension test required in 8.5.1 is used to determine material capability and conformance in addition to verifying the adequacy of the heat-treatment cycle. Additional hardness tests in accordance with 8.6.2 are required when 8.5.1.1 is applied to ensure the prescribed heat-treating cycle and uniformity throughout the load.

8.7 *Notch Toughness Requirements*—Grades F 3V, F 3VCb, and F 22V.

8.7.1 Impact test specimens shall be Charpy V-notch Type, as shown in Fig. 11a of Test Methods and Definitions A 370. The usage of subsize specimens due to material limitations must have prior purchaser approval.

8.7.2 The Charpy V-notch test specimens shall be obtained as required for tension tests in 8.2, 8.3 and 8.5. One set of three Charpy V-notch specimens shall be taken from each tensile specimen location.

8.7.3 The longitudinal axis and mid-length of impact specimen shall be located similarly to the longitudinal axis of the tension test specimens. The axis of the notch shall be normal to the nearest heat treated surface of the forging.

8.7.4 The Charpy V-notch tests shall meet a minimum energy absorption value of 40 ft-lbf [54 J] average of three specimens. One specimen only in one set may be below 40 ft-lbf [54 J], and it shall meet a minimum value of 35 ft-lbf [48 J].

8.7.5 The impact test temperature shall be 0°F [−18°C].

9. Grain Size for Austenitic Grades

9.1 All H grades shall be tested for average grain size by Test Methods E 112.

9.1.1 Grades F 304H, F 309H, F 310H, and F 316H shall have a grain size of ASTM No. 6 or coarser.

9.1.2 Grades F 321H, F 347H, and F 348H shall have a grain size of ASTM No. 7 or coarser.

10. Corrosion Testing for Austenitic Grades

10.1 Corrosion testing is not required by this specification.

10.2 Austenitic Grades shall be capable of meeting the intergranular corrosion test requirements described in Supplementary Requirement S4.

11. Retreatment

11.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings and repeat the tests specified in Section 8.

12. Workmanship, Finish, and Appearance

12.1 Forgings shall conform to the requirements of Specification A 961.

12.2 The forgings shall be free of scale, machining burrs

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which might hinder fit-up, and other injurious imperfections as defined herein. The forgings shall have a workmanlike finish and machined surfaces (other than surfaces having special requirements) shall have a surface finish not to exceed 250 AA (arithmetic average) roughness height.

13. Repair by Welding

13.1 Weld repairs shall be permitted (see Supplementary Requirement S9 of Specification A 961) at the discretion of the manufacturer with the following limitations and requirements:

13.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

13.1.2 The weld metal shall be deposited using the electrodes specified in Table 4 except as otherwise provided in Supplementary Requirement S5. The electrodes shall be purchased in accordance with ASME Specifications SFA-5.4, SFA-5.5, SFA-5.9 or SFA-5.11. The submerged arc process with neutral flux, the gas metal-arc process, the gas tungsten-arc process, and gas shielded processes using flux-core consumables, may be used.

13.1.3 Defects shall be completely removed prior to welding by chipping or grinding to sound metal as verified by magnetic particle inspection in accordance with Test Method A 275/A 275M for the low alloy steels and ferritic, martensitic, or ferritic-austenitic stainless steels, or by liquid penetrant inspection in accordance with Test Method E 165 for all grades.

13.1.4 After repair welding, the welded area shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic-particle or liquid-penetrant inspection, as applicable.

13.1.5 The preheat, interpass temperature, and post-weld heat treatment requirements given in Table 4 shall be met. Austenitic stainless steel forgings may be repair-welded without the post-weld heat treatment of Table 4, provided purchaser approval is obtained prior to repair.

13.1.6 Repair by welding shall not exceed 10 % of the surface area of the forging nor 33⅓ % of the wall thickness of the finished forging or ⅜ in. [9.5 mm], whichever is less, without prior approval of the purchaser.

13.1.7 When approval of the purchaser is obtained, the limitations set forth in 13.1.6 may be exceeded, but all other requirements of Section 13 shall apply.

13.1.8 No weld repairs are permitted for F 6a Classes 3 and 4.

TABLE 4 Repair Welding Requirements

Grade Symbol	Electrodes[A]	Recommended Preheat and Interpass Temperature Range; °F [°C]	Minimum Post Weld Heat-Treatment Temperature °F [°C]
		Low Alloy Steels	
F 1	E 7018-A 1	200–400 [95–205]	1150 [620]
F 2	E 8018-B 1	300–600 [150–315]	1150 [620]
F 5	E 502-15 or 16	400–700 [205–370]	1250 [675]
F 5a	E 502-15 or 16	400–700 [205–370]	1250 [675]
F 9	E 505-15 or 16	400–700 [205–370]	1250 [675]
F 91	9 % Cr, 1 % Mo, VCbN	400–700 [205–370]	1300 [705]
F 92	9 % Cr, 0.5 % Mo, 1.5 % W, VCbNiN	400–700 [205–370]	1300 [1705]
F 911	9 % Cr, 1 % Mo, 1 % W, VCbN	400–700 [205–370]	1300 [705]
F 11, Class 1, 2, and 3	E 8018-B 2	300–600 [150–315]	1150 [620]
F 12, Class 1 and 2	E 8018-B 2	300–600 [150–315]	1150 [620]
F 21	E 9018-B 3	300–600 [150–315]	1250 [675]
F 3V, and F 3VCb	3 % Cr, 1 % Mo, ¼ % V-Ti	300–600 [150–315]	1250 [675]
F 22 Class 1	E 9018-B 3	300–600 [150–315]	1250 [675]
F 22 Class 3	E 9018-B 3	300–600 [150–315]	1250 [675]
F 22V	2.25 % Cr, 1 % Mo, 0.25 % V-Cb	300–600 [150–315]	1250 [675]
F 23	2.25 % Cr, 1.6 % W, 0.25 % V-Mo-Cb-B	300-600 [150–315]	1250 [675]
F 24	2.25 % Cr, 1 % Mo, 0.25 % V	200–400 [95–205][B]	1250 [675][B]
		Martensitic Stainless Steels	
F 122	11 % Cr, 2 % W, MoVCbCuN	400–700 [205–370]	1300 [705]
F 6a, Class 1	E 410-15 or 16	400–700 [205–370]	1250 [675]
F 6a, Class 2	E 410-15 or 16	400–700 [205–370]	1250 [675]
F 6b	13 % Cr, 1½ % Ni, ½ % Mo	400–700 [205–370]	1150 [620]
F 6NM	13 % Cr, 4 % Ni	300–700 [150–370]	1050 [565]
		Ferritic Stainless Steels	
F XM-27Cb	26 % Cr, 1 % Mo	NR[C]	NR
F 429	E 430-16	400–700 [205–370]	1400 [760]
F 430	E 430-16	NR	1400 [760]
FR	E 8018-C2	NR	NR
		Austenitic Stainless Steels	
F 304	E 308-15 or 16	NR	1900 [1040] + WQ[D]
F 304L	E 308L-15 or 16	NR	1900 [1040] + WQ

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TABLE 4 *Continued*

Grade Symbol	Electrodes[A]	Recommended Preheat and Interpass Temperature Range; °F [°C]	Minimum Post Weld Heat-Treatment Temperature °F [°C]
F 304H	E 308-15 or 16	NR	1900 [1040] + WQ
F 304N	E 308-15 or 16	NR	1900 [1040] + WQ
F 304LN	E 308L-15 or 16	NR	1900 [1040] + WQ
F 309H	E 309-15 or 16[E]	NR	1900 [1040] + WQ
F 310	E 310-15 or 16	NR	1900 [1040] + WQ
F 310H	E 310-15 or 16	NR	1900 [1040] + WQ
F 310MoLn	E 310Mo-15 or 16	NR	1920–2010 [1050–1100] + WQ
F 316	E 316-15 or 16	NR	1900 [1040] + WQ
F 316L	E 316L-15 or 16	NR	1900 [1040] + WQ
F 316H	E 316-15 or 16	NR	1900 [1040] + WQ
F 316N	E 316-15 or 16	NR	1900 [1040] + WQ
F 316LN	E 316L-15 or 16	NR	1900 [1040] + WQ
F 317	E 317-15 or 16	NR	1900 [1040] + WQ
F 317L	E 317L-15 or 16	NR	1900 [1040] + WQ
F 321[F]	E 347-15 or 16	NR	1900 [1040] + WQ
F 321H[F]	E 347-15 or 16	NR	1925 [1050] + WQ
F 347	E 347-15 or 16	NR	1900 [1040] + WQ
F 347H	E 347-15 or 16	NR	1925 [1050] + WQ
F 348	E 347-15 or 16	NR	1900 [1040] + WQ
F 348H	E 347-15 or 16	NR	1925 [1050] + WQ
F XM-11	XM-10W	NR	NR
F XM-19	XM-19W	NR	NR
F 10[F]	...	...	...
F 20	E/ER-320, 320LR	NR	1700–1850 [925–1010] + WQ
F 44	E NiCrMo-3	NR	2100 [1150] + WQ
F 45[F]	...	...	...
F 46	...	...	...
F 47	...[G]	...	2100 [1150] + WQ
F 48	...[G]	...	2100 [1150] + WQ
F 49	...[G]	...	2100 [1150] + WQ
F 58	E NiCrMo-10	...	2100 [1150] + WQ
F 62	E NiCrMo-3	NR	2025 [1105] + WQ
	Ferritic-Austenitic Stainless Steels		
F 50	25 % Cr, 6 % Ni, 1.7 % Mo	NR	NR
F 51	22 % Cr, 5.5 % Ni, 3 % Mo	NR	NR
F 52	26 % Cr, 8 % Ni, 2 % Mo	NR	NR
F 53	25 % Cr, 7 % Ni, 4 % Mo	NR	NR
F 54	25 % Cr, 7 % Ni, 3 % Mo, W	NR	NR
F 55	25 % Cr, 7 % Ni, 3.5 % Mo	NR	NR
F 57	25 % Cr, 7 % Ni, 3 % Mo, 1.5 % Cu, 1 % W	NR	NR
F 59	E Ni CrMo-10	NR	NR
F 60	22 % Cr, 5.5 % Ni, 3 % Mo	NR	NR
F 61	26 % Cr, 9 % Ni, 3.5 % Mo	NR	NR

[A] Electrodes shall comply with ASME SFA 5.4, SFA 5.5, and corresponding ER grades of SFA-5.9 or SFA-5.11.
[B] Not required for not below 0.500 in. [12.7 mm].
[C] NR = not required.
[D] WQ = water quench.
[E] Filler metal shall additionally have 0.04 % minimum carbon.
[F] Purchaser approval required.
[G] Match filler metal is available. Fabricators have also used AWS A 5.14, Class ER, NiCrMo-3 and AWS A 5.11, Class E, NiCrMo-3 filler metals.

14. Inspection

14.1 Inspection provisions of Specification A 961 apply.

15. Rejection and Rehearing

15.1 The purchaser shall comply with the provisions of Specification A 961.

16. Certification

16.1 In addition to the certification requirements of Specification A 961, the following certification requirements apply:

16.2 For forgings made to specified dimensions, when agreed upon by the purchaser, and for forgings made to dimensional standards, the application of identification marks as required in 17.1 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification.

16.3 Test reports, when required, shall include certification that all requirements of this specification have been met. The specification designation included on test reports shall include year of issue and revision letter, if any. The manufacturer shall provide the following where applicable:

16.3.1 Type heat treatment, Section 6,

16.3.2 Product analysis results, Section 8 of Specification A 961,

16.3.3 Tensile property results, Section 8 (Table 3), report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent,

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16.3.4 Chemical analysis results, Section 7 (Table 2),
16.3.5 Hardness results, Section 8 (Table 3),
16.3.6 Grain size results, Section 9, and
16.3.7 Any supplementary testing required by the purchase order.

17. Product Marking

17.1 In addition to the marking requirements of Specification A 961, the manufacturer's name (Note 3) or symbol shall be permanently marked on each forging.

NOTE 3—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

17.1.1 Quenched and tempered low alloy or martensitic stainless forgings shall be stamped with the letters QT following the specification designation.

17.1.2 Forgings repaired by welding shall be marked with the letter "W" following the Specification designation. When repair-welded austenitic stainless steel forgings have not been postweld heat treated in accordance with Table 4, the letters "WNS" shall be marked following the specification designation.

17.1.3 When test reports are required, the markings shall consist of the manufacturer's symbol or name, the grade symbol, and such other markings as necessary to identify the part with the test report (17.1.1 and 17.1.2 shall apply).

17.1.4 Parts meeting all requirements for more than one class or grade may be marked with more than one class or grade designation such as F 304/F 304H, F 304/F 304L, etc.

17.2 *Bar Coding*—In addition to the requirements in 17.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 austenitic stainless steel; chromium alloy steel; chromium-molybdenum steel; ferritic/austenitic stainless steel; ferritic stainless steel; martensitic stainless steel; nickel alloy steel; notch toughness requirements; pipe fittings; steel; piping applications; pressure containing parts; stainless steel fittings; stainless steel forgings; steel flanges; steel forgings, alloy; steel valves; temperature service applications, elevated; temperature service applications, high; wrought material

SUPPLEMENTARY REQUIREMENTS

In addition to any of the supplementary requirements of Specification A 961, the following supplementary requirements shall apply only when specified by the purchaser in the order.

S1. Macroetch Test

S1.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted according to Test Method E 340. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S2. Heat Treatment Details

S2.1 The manufacturer shall furnish a detailed test report containing the information required in 16.3 and shall include all pertinent details of the heat-treating cycle given the forgings.

S3. Material for Optimum Resistance to Stress-Corrosion Cracking

S3.1 Austenitic stainless steel shall be furnished in the solution-annealed condition as a final operation with no subsequent cold working permitted, except, unless specifically prohibited by the purchaser, straightening of bars from which parts are machined is permitted to meet the requirements of Specification A 484/A 484M.

S4. Corrosion Tests

S4.1 All austenitic stainless steels shall pass intergranular corrosion tests performed in accordance with Practice E of Practices A 262.

S4.2 Intergranular corrosion tests shall be performed on specimens of ferritic stainless steels as described in Practices A 763.

S4.3 For both the austenitic and ferritic stainless steels, details concerning the number of specimens and their source and location are to be a matter of agreement between the manufacturer and the purchaser.

S5. Special Filler Metal

S5.1 In repair welded F 316, F 316L, F 316H, and F 316N forgings, the deposited weld metal shall conform to E 308 composition wire. Forgings repair welded with E 308 weld metal shall be marked F __ W 308.

S6. Hardness Test

S6.1 Each forging shall be hardness tested and shall meet the requirements of Table 3.

S7. Alternate Heat Treatment (Grade F 91 and F 92)

S7.1 Grade F 91 shall be normalized in accordance with Section 6 and tempered at a temperature, to be specified by the purchaser, less than 1350°F [730°C]. It shall be the purchaser's responsibility to subsequently temper at 1350°F [730°C] minimum to conform to the requirements of the specification. All mechanical tests shall be made on material heat treated in accordance with Section 6. The certification shall reference this

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supplementary requirement indicating the tempering temperature applied. The notation "S7" shall be included with the required marking of the forging.

S8. Heat Treatment of Austenitic Forgings

S8.1 The purchaser shall specify the heat treatment method (in 6.1 or in 6.3.1) that shall be employed.

S8.2 The manufacturer shall provide a test report containing the information required in 16.3 and shall include a statement of the heat treatment method employed.

S9. Grain Size for Austenitic Grades

S9.1 Forgings made from austenitic grades other than H grades shall be tested for average grain size by Test Method E 112. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S10. Stabilization Treatment

S10.1 Subsequent to the solution anneal for Grades F 321, F 321H, F 347, F 347H, F 348, and F 348H, these grades shall be given a stabilization heat treatment at 1500 to 1600°F [815 to 870°C] for a minimum of 2 h/in. [4.7 min/mm] of thickness and then cooling in the furnace or in air. In addition to the marking required in Section 17, the grade designation symbol shall be followed by the symbol "S10."

S11. Grain Size Requirements for Non-H-Grade Austenitic Steels Used Above 1000°F [540°C]

S11.1 Non-H grades of austenitic stainless steels shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E 112. The grain size so determined shall be on a certified test report.

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Manufacturers Standardization Society
of the Valve and Fittings Industry
Used in USNRC-RDT Standards

Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both[1]

This standard is issued under the fixed designation A 194/A 194M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification[2] covers a variety of carbon, alloy, and martensitic stainless steel nuts in the size range ¼ through 4 in. and metric M6 through M100 nominal. It also covers austenitic stainless steel nuts in the size range ¼ in. and M6 nominal and above. These nuts are intended for high-pressure or high-temperature service or both. Grade substitutions without the purchaser's permission are not allowed.

1.2 Bars from which the nuts are made shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be solution annealed or annealed and strain-hardened. When annealed and strain hardened austenitic stainless steel is ordered in accordance with Supplementary Requirement S1, the purchaser should take special care to ensure that 7.2.2, Supplementary Requirement S1, and Appendix X1 are thoroughly understood.

1.3 Supplementary requirements (S1 through S6) of an optional nature are provided. These shall apply only when specified in the inquiry, contract, and order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable" M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in noncomformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware[3]

A 276 Specification for Stainless Steel Bars and Shapes[4]

A 320/A 320M Specification for Alloy-Steel Bolting Materials for Low-Temperature Service[5]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[4]

A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range[5]

B 633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel[6]

B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel[6]

B 696 Specification for Coatings of Cadmium Mechanically Deposited[6]

B 766 Specification for Electrodeposited Coatings of Cadmium[6]

E 112 Test Methods for Determining Average Grain Size[7]

2.2 *American National Standards:*[8]

B 1.1 Unified Screw Threads

B 1.13M Metric Screw Threads

B 18.2.2 Square and Hex Nuts

B 18.2.4.6M Metric Heavy Hex Nuts

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *Austenitic Grades*—All grades with a prefix of "8" or "9".

3.1.2 *Ferritic Grades*—Grades 1, 2, 2H, 2HM, 3, 4, 6, 6F, 7, 7M, and 16.

3.1.3 *Lot*:

3.1.3.1 Unless otherwise specified (see 3.1.3.2), a lot is the

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-194 in Section II of that code.

[3] *Annual Book of ASTM Standards*, Vol 01.06.

[4] *Annual Book of ASTM Standards*, Vol 01.03.

[5] *Annual Book of ASTM Standards*, Vol 01.01.

[6] *Annual Book of ASTM Standards*, Vol 02.05.

[7] *Annual Book of ASTM Standards*, Vol 03.01.

[8] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

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quantity of nuts of a single nominal size and grade produced by the same manufacturing process.

3.1.3.2 When Supplementary Requirement S5 is invoked on the purchase order, the following definitions of a lot shall apply:

For Grade 8 Nuts—The quantity of all the nuts of a single nominal diameter and grade made from the same heat of steel and made by the same manufacturing process.

For All Other Grade Nuts (see 7.2 and 7.1.2.1)—All the nuts of a single nominal diameter and grade made from the same heat number and heat treated in the same batch if batch-type heat treating equipment is used or heat treated in the same continuous run of not more than 8 h under the same conditions if continuous-type heat treating equipment is used.

3.1.4 *For Grade 8 Nuts*—Variations within the grade designated by a letter and differentiated by chemistry and by manufacturing process.

3.1.5 *For Grade 6 Nuts*—Variations within the grade designated by the letter F as differentiated by chemical additions made for machineability.

3.1.6 *Series*—The dimensional relationship and geometry of the nuts as described in ANSI B 18.2.2 or B 18.2.4.6M.

4. Ordering Information

4.1 The inquiry and order for material under this specification shall include the following as required to describe the material adequately:

4.1.1 Specification designation, year date, and grade, issue date and revision letter,

4.1.2 Quantity, number of pieces,

4.1.3 Dimensions (see Section 8),

4.1.4 Options in accordance with 7.2.2.1, 8.1, 8.2, 9.3, and 11, and

4.1.5 Supplementary Requirements, if any.

4.2 *Coatings*—Coatings are prohibited unless specified by the purchaser. Nuts plated with cadmium or zinc shall be marked as stated in 12.2. When coated nuts are ordered, the purchaser should take special care to ensure that Appendix X2 is thoroughly understood. It is the purchaser's responsibility to specify in the purchase order all information required by the coating facility. Examples of such information may include, but are not limited to, the following:

4.2.1 Reference to the appropriate coating specification: Specifications B 766, B 696, A 153/A 153M, B 695, B 633, or other specifications as agreed upon by the purchaser and manufacturer.

4.2.2 Requirements for coating thickness and local or batch average thickness measurement, or both.

4.2.3 Requirements for selective plating or coating or modification of dimensions to accommodate coating.

4.2.4 Requirements for hydrogen embrittlement relief.

5. Common Requirements

5.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 962/A 962M, this specification shall prevail.

6. Manufacture (Process)

6.1 Stainless steels for all types of Grade 6 and 8 nuts shall be made by one of the following processes:

6.1.1 Electric-furnace (with separate degassing and refining optional),

6.1.2 Vacuum induction furnace, or

6.1.3 Either of the above followed by electroslag remelting, or consumable-arc remelting.

6.2 The steel producer shall exercise adequate control to eliminate excessive unhomogeneity, nonmetallics, pipe, porosity, and other defects.

6.3 Grades 1 and 2 nuts shall be hot or cold forged, or shall be machined from hot-forged, hot-rolled, or cold-drawn bars.

6.3.1 All Grade 1 and 2 nuts made by cold forging or by machining from cold-drawn bars shall be stress-relief annealed at a temperature of at least 1000°F [538°C].

6.3.2 Grade 1 and 2 nuts made by hot forging or by machining from hot-forged or hot-rolled bars need not be given any stress relief annealing treatment.

6.4 Grades 2HM, 2H, 3, 4, 6, 6F, 7, 7M, and 16 nuts shall be hot or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and shall be heat treated to meet the required mechanical properties. However, nuts machined from heat-treated bars need not be reheat treated. See Supplementary Requirement S3 for nuts to be used in low-temperature applications (Specification A 320/A 320M). These grades of nuts shall be reheated above the critical range of the steel, quenched in a suitable medium, and then tempered at a temperature not less than the following:

Grade and Type	Minimum Tempering Temperature,°F [°C]
2H	850 [455]
2HM	1150 [620]
3	1050 [565]
4	1100 [595]
6 and 6F	1100 [595]
7 and 7M	1100 [595]
16	1200 [650]

6.4.1 Grade 6 and 6F nuts shall be tempered for a minimum of 1 h at the temperature.

6.5 Grades 8, 8C, 8M, 8T, 8F, 8P, 8N, 8MN, 8R, 8S, 8LN, 8MLN, 8MLCuN, and 9C nuts shall be hot or cold forged, or shall be machined from hot-forged, hot-rolled or cold-drawn bars.

6.6 Grades 8A, 8CA, 8MA, 8TA, 8FA, 8PA, 8NA, 8MNA, 8RA, 8SA, 8LNA, 8MLNA, 8MLCuNA, and 9CA nuts shall be hot or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and the nuts shall subsequently be carbide-solution treated by heating them for a sufficient time at a temperature to dissolve chromium carbides followed by cooling at a rate sufficient to prevent reprecipitation of the carbides.

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TABLE 1 Chemical Requirements[A,B,C]

Grade Symbol	Material	UNS Number	Carbon, %	Manganese, %	Phosphorus, %	Sulfur,[D] %	Silicon, %	Chromium, %	Nickel, %	Molybdenum, %	Titanium, %	Columbium and Tantalum, %	Nitrogen, %	Other Elements, %
1	carbon		0.15 min	1.00	0.040	0.050	0.40	...	...	...	...	...	...	...
2, 2HM, and 2H	carbon		0.40 min	1.00	0.040	0.050	0.40	...	...	...	...	...	...	...
4	carbon, molybdenum		0.40–0.50	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30	...	...	...	...
3	AISI 501		0.10 min	1.00	0.040	0.030	1.00	4.0–6.0	...	0.40–0.65	...	...	...	...
6	AISI 410	S41000	0.15	1.00	0.040	0.030	1.00	11.5–13.5	...	...	...	...	...	...
6F	AISI 416	S41600	0.15	1.25	0.060	0.15 min	1.00	12.0–14.0	...	...	...	...	...	...
6F	AISI 416Se	S41623	0.15	1.25	0.060	0.060	1.00	12.0–14.0	...	...	...	...		Selenium, 0.15 min
7, 7M	AISI 4140/ 4142/ 4145, 4140H, 4142H, 4145H		0.37–0.49	0.65–1.10	0.04	0.04	0.15–0.35	0.75–1.20	...	0.15–0.25	...	...	...	...
8, 8A	AISI 304	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...	...
8C, 8CA	AISI 347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	10 x carbon content, min	...	...
8M, 8MA	AISI 316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	...
8T, 8TA	AISI 321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	5 x (C+N) min - 0.70 max	...	...	...
8F, 8FA	AISI 303	S30300	0.15	2.00	0.20	0.15 min	1.00	17.0–19.0	8.0–10.0	...	...	...	...	...
8F, 8FA	AISI 303Se	S30323	0.15	2.00	0.20	0.06	1.00	17.0–19.0	8.0–10.0	...	...	...		Selenium, 0.15 min
8P, 8PA	AISI 305 with restricted carbon	S30500	0.08	2.00	0.045	0.030	1.00	17.0–19.0	11.0–13.0	...	...	...	...	...
8N, 8NA	AISI 304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	0.10–0.16	
8LN, 8LNA	AISI 304LN	S30453	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	0.10–0.16	
8MN, 8MNA	AISI 316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	...	...	0.10–0.16	
8MLN, 8MLNA	AISI 316LN	S31653	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	...	...	0.10 0.16	
8R, 8RA[E]	XM19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	...	0.10–0.30	0.20–0.40	Vanadium, 0.10–0.30
8S, 8SA		S21800	0.10	7.0–9.0	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	...	...	...	0.08–0.18	
8MLCuN, 8MLCuNA	S31254	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	...	...	0.18–0.22	Copper, 0.50–1.00
9C, 9CA	N08367	N08367	0.030	2.00	0.040	0.030	1.00	20.0-22.0	23.5- 25.5	6.0-7.0			0.18-0.25	Copper 0.75
16	Chromium Molybdenum Vanadium		0.36–0.47	0.45–0.70	0.035	0.040	0.15–0.35	0.80–1.15	...	0.50–0.65	...	...	...	Vanadium, 0.25–0.35 Aluminum[B] 0.015

[A] The intentional addition of Bl, Se, Te, and Pb is not permitted except for Grades 6F, 8F, and 8FA, in which Se is specified and required.
[B] Total aluminum, soluble and insoluble.
[C] Maximum, unless minimum or range is indicated.
[D] Because of the degree to which sulfur segregates, product analysis for sulfur over 0.060 % max is not technologically appropriate.
[E] As described in Specification A 276.

7. Mechanical Requirements

7.1 *Hardness Test*:

7.1.1 *Requirements*:

7.1.1.1 All nuts shall be capable of meeting the hardness requirements specified in Table 2.

7.1.1.2 Sample nuts of Grades 1, 2, 2H, 2HM, 3, 4, 7, 7M,

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TABLE 2 Hardness Requirements

Grade and Type	Completed Nuts			Sample Nut after Treatment as in 7.1.5	
	Brinell Hardness	Rockwell Hardness		Brinell Hardness, min	Rockwell Hardness B Scale, min
		C Scale	B Scale		
1	121 min	...	70 min	121	70
2	159 to 352	...	84 min	159	84
2H	248 to 352	24 to 38	...	179	89
To 1½ in. or M36, incl	248 to 352	24 to 38	...	179	89
Over 1½ in. or M36	212 to 352	38 max	95 min	147	79
2HM and 7M	159 to 237	22 max	...	159	84
3, 4, 7, and 16	248 to 352	24 to 38	...	201	94
6 and 6F	228 to 271	20 to 28	...	...	...
8, 8C, 8M, 8T, 8F, 8P, 8N,	126 to 300	...	60 to 105	...	...
8MN, 8LN, 8MLN, 8MLCuN, and 9C	126 to 300	...	60 to 105	...	...
8A, 8CA, 8MA, 8TA,	126 to 192	...	60 to 90	...	...
8FA, 8PA, 8NA, 8MNA,	126 to 192	...	60 to 90	...	...
8LNA, 8MLNA, and 8MLCuNA	126 to 192	...	60 to 90	...	...
8R, 8RA, 8S, and 8SA	183 to 271	B 88 to C 25	...	...	...
9C, 9CA	126 to 192	...	60 to 90	...	...

and 16 which have been given the treatment described in 7.1.5 shall meet the minimum hardness specified in Table 2.

7.1.2 *Number of Tests*— (Grades 1, 2, 2H, 3, 4, 7, and 16 and all types of Grade 6):

7.1.2.1 Tests on the number of sample nuts in accordance with the following table shall be performed by the manufacturer following all production heat treatments:

Lot Size	Samples
Up to 800	1
801 to 8000	2
8001 to 22 000	3
Over 22 000	5

7.1.2.2 In addition, a hardness test shall be performed by the manufacturer in accordance with 7.1.5 on one sample nut selected from each nominal diameter and series from each grade and heat number following completion of all production heat treatments.

7.1.3 *Number of Tests, Grades 2HM and 7M*:

7.1.3.1 The maximum hardness of Grade 2HM and 7M shall be 235 HB or 99 HRB. Product which has been 100 % tested and found acceptable shall have a line under the "M."

7.1.3.2 In addition, 7.1.2.2 shall be met.

7.1.4 *Number of Tests, All Types of Grade 8*—Tests on the number of sample nuts in accordance with 7.1.2.1 shall be performed by the manufacturer.

7.1.5 *Test 2*—In addition to the testing required by 7.1.2.1 the manufacturer shall also perform hardness tests on sample nuts after the following test heat treatment. After completion of all production heat treatments heat the specimen nuts to the temperatures indicated below for 24 h, then slow cool. Test at room temperature.

Grade	Temperature, °F [°C]
1	850 [455]
2, 2H, 2HM	1000 [540]
3, 4, 7, 7M	1100 [590]
16	1200 [650]

7.1.5.1 *Special Requirement, Grades 2HM and 7M*—Preparation of Grades 2HM and 7M nuts for hardness test and the hardness test itself shall be performed with consideration to (*1*) protect legibility of markings; (*2*) minimize exterior dimensional changes; and (*3*) maintain thread fit.

7.2 *Proof Load Test*:

7.2.1 *Requirements*—All nuts shall be capable of withstanding the proof loads specified in Table 3 and Table 4. However, nuts manufactured to dimensions and configurations other than those covered by ANSI B 1.1, ANSI B 1.13M, ANSI B 18.2.2, and B 18.2.4.6M are not subject to the proof load test.

7.2.2 *Number of Tests*:

7.2.2.1 Tests on the number of sample nuts in accordance with 7.1.2.1 shall be performed by the manufacturer following all production heat treatments except that, unless proof load testing or Supplementary Requirement S1 is specified in the order, nuts which would require a proof load in excess of 120 000 lbf or 530 kN may be furnished on the basis of minimum hardness requirements. Proof load testing of nuts requiring a proof load of over 120 000 lbf or 530 kN is covered in Supplementary Requirement S4.

7.2.3 *Test Method*—The test shall be in accordance with Annex A3, Paragraph A3.5.1, of Test Methods and Definitions A 370.

7.3 *Cone Proof Load Test:*

7.3.1 *Requirements*—This test shall be performed only when visible surface discontinuities become a matter of issue between the manufacturer and the purchaser. The requirements specified in Table 5 and Table 6 shall be met for the size range ¼ to 1½ in. and M6 to M36. Nuts not in this size range and all types of Grade 8 nuts are not subject to this test. Also, nuts manufactured to dimensions and configurations other than those covered by ANSI B 1.1, ANSI B 1.13M, ANSI B 18.2.2, and ANSI B 18.2.4.6M are not subject to the cone proof load test.

7.3.2 *Number of Tests*—Sample nuts in accordance with 7.1.2.1 shall be tested by the manufacturer.

7.3.3 *Test Method*—The test shall consist of assembling a hardened cone (see Fig. 1) and the nut to be tested on a hardened steel mandrel, and applying the proof load specified

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TABLE 3 Proof Load Using Threaded Mandrel — Inch Series

NOTE 1—Proof loads are not design loads.

Nominal Size, in.	Threads per Inch	Stress Area in.^{2}	Proof Load, lbf[A]					
			Grade 1		Grades 2, 2HM, 6, 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[E]	Heavy Hex[F]	Hex[G]
¼	20	0.0316	4 130	3 820	4 770	4 300	5 570	4 770
5/16	18	0.0524	6 810	6 290	7 860	7 070	9 170	7 860
⅜	16	0.0774	10 080	9 300	11 620	10 460	13 560	11 620
7/16	14	0.1063	13 820	12 760	15 940	14 350	18 600	15 940
½	13	0.1419	18 450	17 030	21 280	19 160	24 830	21 280
9/16	12	0.182	23 660	21 840	27 300	24 570	31 850	27 300
⅝	11	0.226	29 380	27 120	33 900	30 510	39 550	33 900
¾	10	0.334	43 420	40 080	50 100	45 090	58 450	50 100
⅞	9	0.462	60 060	55 440	69 300	62 370	80 850	69 300
1	8	0.606	78 780	72 720	90 900	81 810	106 000	90 900
1⅛	8	0.790	102 700	94 800	118 500	106 700	138 200	118 500
1¼	8	1.000	130 000	120 000	150 000	135 000	175 000	150 000
1⅜	8	1.233	160 200	148 000	185 000	166 500	215 800	185 000
1½	8	1.492	194 000	170 040	223 800	201 400	261 100	223 800

			All Types of Grade 8, Grades 9C and 9CA	
			Heavy Hex[H]	Hex[I]
¼	20	0.0316	2 540	2 380
5/16	18	0.0524	4 190	3 930
⅜	16	0.0774	6 200	5 810
7/16	14	0.1063	8 500	7 970
½	13	0.1419	11 350	10 640
9/16	12	0.182	14 560	13 650
⅝	11	0.226	18 080	16 950
¾	10	0.334	26 720	25 050
⅞	9	0.462	36 960	34 650
1	8	0.606	48 480	45 450
1⅛	8	0.790	63 200	59 250
1¼	8	1.000	80 000	75 000
1⅜	8	1.233	98 640	92 450
1½	8	1.492	119 360	111 900

[A] See limit for proof load test in 7.2.2.1. The proof load for jam nuts shall be 46 % of the tabulated load.
[B] Based on proof stress of 130 000 psi.
[C] Based on proof stress of 120 000 psi.
[D] Based on proof stress of 150 000 psi.
[E] Based on proof stress of 135 000 psi.
[F] Based on proof stress of 175 000 psi.
[G] Based on proof stress of 150 000 psi.
[H] Based on proof stress of 80 000 psi.
[I] Based on proof stress of 75 000 psi.

in Table 5 and Table 6. The mandrel shall conform to the requirements of Annex A3, Paragraph A3.5.1 of Test Methods and Definitions A 370 except that the threads shall be in accordance with ANSI B 1.1 of the appropriate thread series, Class 3A fit or ANSI B 1.13M of the appropriate thread pitch, tolerance 4H. The hardened cone shall be as described in Fig. 2. The lot shall be considered acceptable if the sample nut withstands application of the proof load without failure.

8. Dimensions

8.1 Nuts shall be hexagonal in shape, and in accordance with the dimensions for the hex or heavy hex series, as required, by ANSI B 18.2.2 and ANSI B 18.2.4.6M. Unless otherwise specified, the American National Standard Heavy Hex Series shall be used and nuts shall be either double chamfered or have a machined or forged washer face, at the option of the manufacturer, and, conform to the angularity requirements of ANSI B 18.2.2 and ANSI B 18.2.4.6M.

8.2 Unless otherwise specified, threads shall be in accordance with ANSI B 1.1 or ANSI B 1.13M, and shall be gaged in accordance with ANSI B 1.2 and ANSI B 1.13M as described in 8.2.1 and 8.2.2.

8.2.1 Nuts up to and including 1 in. nominal size shall be UNC Series Class 2B fit. Metric nuts up to and including M24 nominal size shall be coarse thread series tolerance 6H.

8.2.2 Nuts over 1 in. nominal size shall be either UNC Series Class 2B fit or 8 UN Series Class 2B fit. Unless otherwise specified, the 8 UN series shall be furnished. Metric nuts over M24 nominal size shall be coarse thread series tolerance 6H.

9. Workmanship, Finish, and Appearance

9.1 Nuts shall be free of defects and shall be good commercial finish.

9.2 If visible surface imperfections in size ¼ through 1½ in. and M6 through M36 and in any grade other than Grade 8

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TABLE 4 Proof Load Using Threaded Mandrel — Metric

NOTE 1—Proof loads are not design loads.

Nominal Size, mm	Threads Pitch	Stress Area mm²	Proof Load, kN[A]					
			Grade 1		Grades 2, 2HM, 6, 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[E]	Heavy Hex[F]	Hex[G]
M6	1.0	20.1	18.0	16.6	20.8	18.7	29.2	20.8
M8	1.25	36.6	32.8	30.2	37.9	34.0	44.1	37.9
M10	1.50	58.0	51.9	47.9	60.0	53.9	69.9	60.0
M12	1.75	84.3	75.5	69.5	87.3	78.4	101.6	87.3
M14	2.0	115.0	102.9	94.9	119.0	107.0	138.6	119.0
M16	2.0	157.0	140.5	129.5	162.5	146.0	189.2	162.5
M20	2.5	245.0	219.3	202.1	253.6	227.8	295.2	253.6
M22	2.5	303.0	271.2	249.9	313.6	281.8	365.1	313.6
M24	3.0	353.0	315.9	291.2	365.4	328.3	425.4	365.4
M27	3.0	459.0	411.0	378.7	475.1	426.9	553.4	475.1
M30	3.5	561.0	502.1	462.8	580.6	521.7	676.0	580.6
M36	4.0	817.0	731.2	674.0	845.6	759.8	984.5	845.6

Nominal Size, mm	Thread Pitch	All Types of Grade 8, and Grades 9C and 9CA		
		Stress Area, mm²	Heavy Hex[H]	Hex[I]
M6	1.0	20.1	11.1	10.4
M8	1.25	36.6	20.1	18.8
M10	1.50	58.0	31.9	29.9
M12	1.75	84.3	46.4	43.4
M14	2.0	115.0	63.3	59.2
M16	2.0	157.0	86.4	80.9
M20	2.5	245.0	134.8	126.2
M22	2.5	303.0	166.7	156.0
M24	3.0	353.0	194.2	181.8
M27	3.0	459.0	252.5	236.4
M30	3.5	561.0	308.6	288.9
M36	4.0	817.0	449.4	420.8

[A] See limit for proof load test in 7.2.2.1. The proof load for jam nuts shall be 46 % of the tabulated load.
[B] Based on proof stress of 895 MPa.
[C] Based on proof stress of 825 MPa.
[D] Based on proof stress of 1035 MPa.
[E] Based on proof stress of 930 MPa.
[F] Based on proof stress of 1205 MPa.
[G] Based on proof stress of 1035 MPa.
[H] Based on proof stress of 550 MPa.
[I] Based on proof stress of 515 MPa.

become a matter of issue between the manufacturer and the purchaser, the cone proof load test described in 7.3 shall be employed.

9.3 If a scale-free bright finish is required, this shall be specified on the purchase order.

10. Retests

10.1 Provisions for retests by the purchaser and his representative are specified in Supplementary Requirement S2.

11. Certification

11.1 The producer of nuts shall furnish a certification to the purchaser or his representative showing the results of the chemical analysis, macroetch examination (Carbon and Alloy Steels Only), mechanical tests, and the minimum tempering temperature for nuts of Grades 2H, 2HM, 3, 4, 6, 6F, 7, and 7M.

11.2 Certification shall also include at least the following:

11.2.1 A statement that the fasteners were manufactured, sampled, tested and inspected in accordance with the specification and any supplementary requirements or other requirements designated in the purchase order or contract and was found to meet those requirements.

11.2.2 The specification number, year date, and identification symbol.

12. Product Marking

12.1 All nuts shall bear the manufacturer's identification mark.

12.2 Nuts shall be legibly marked on one face to indicate the grade and process of the manufacturer, as presented in Table 7. Marking of wrench flats or bearing surfaces is not permitted unless agreed upon between manufacturer and purchaser. Nuts coated with zinc shall have an asterisk (*) marked after the grade symbol. Nuts coated with cadmium shall have a plus sign (+) marked after the grade symbol.

12.3 For purposes of identification marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

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TABLE 5 Proof Load Using 120° Hardened Steel Cone — Inch[A]

Nominal Size, in.	Threads per Inch	Stress Area in.^{2}	Proof Load, lbf					
			Grade 1		Grades 2, 2HM, 6, 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[E]	Heavy Hex[F]	Hex[D]
1/4	20	0.0318	3 800	3 550	4 400	4 000	5 150	4 400
5/16	18	0.0524	6 150	5 700	7 100	6 400	8 300	7 100
3/8	16	0.0774	8 950	8 250	10 300	9 300	12 000	10 300
7/16	14	0.1063	12 000	11 100	13 850	12 450	16 150	13 850
1/2	13	0.1419	15 700	14 500	18 100	16 300	21 100	18 100
9/16	12	0.182	19 650	18 150	22 700	20 400	26 500	22 700
5/8	11	0.226	23 900	22 050	27 550	24 800	32 150	27 550
3/4	10	0.334	33 650	31 050	38 850	34 950	45 300	38 850
7/8	9	0.462	44 300	40 900	51 100	46 600	59 650	51 100
1	8	0.606	55 150	50 900	63 650	57 300	74 250	63 650
1 1/8	8	0.790	68 000	62 800	78 500	70 650	91 600	78 500
1 1/4	8	1.000	81 250	75 000	93 750	84 400	109 350	93 750
1 3/8	8	1.233	94 250	86 950	108 750	97 800	126 850	108 750
1 1/2	8	1.492	106 700	98 500	123 100	110 800	143 600	123 100

[A] Based upon the following equation (this equation cannot be used for extrapolating values beyond the size ranges listed in this table):

$$CPL = (1 - 0.30D) \times f \times As$$

where:

CPL = *cone stripping proof load lbf*,
D = nominal diameter of nut, in.,
f = minimum proof stress of nut, psi; see footnote *b*, *c*, *d*, *e*, and *f*,
As = tensile stress area of nut, in.^{2} = 0.7854 [D - 0.9743/n]^2, and
n = threads per inch.

[B] Based on proof stress of 130 000 psi.
[C] Based on proof stress of 120 000 psi.
[D] Based on proof stress of 150 000 psi.
[E] Based on proof stress of 135 000 psi.
[F] Based on proof stress of 175 000 psi.

TABLE 6 Proof Load Using 120° Hardened Steel Cone — Metric[A]

Nominal Size, mm	Thread Pitch	Stress Area mm^2	Proof Load, kN					
			Grade 1		Grades 2, 2HM, 6 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[E]	Heavy Hex[F]	Hex[D]
M6	1.0	20.1	16.9	15.4	19.3	17.3	22.5	19.3
M8	1.25	36.6	29.6	27.3	34.2	30.8	39.9	34.2
M10	1.50	58.0	45.7	42.1	52.8	47.5	61.5	52.8
M12	1.75	84.3	64.6	59.5	74.7	67.1	86.9	74.7
M14	2.0	115.0	85.6	78.9	99.0	88.9	115.3	99.0
M16	2.0	157.0	113.5	104.7	131.2	118.0	152.9	131.2
M20	2.5	245.0	166.6	153.6	192.7	173.2	224.4	192.7
M22	2.5	303.0	199.6	183.9	230.8	207.4	268.7	230.8
M24	3.0	353.0	224.9	207.4	260.1	233.7	302.9	260.1
M27	3.0	459.0	277.7	256.0	321.1	288.6	373.9	321.1
M30	3.5	561.0	321.3	296.2	371.6	334.0	432.6	371.6
M36	4.0	817.0	415.3	382.8	480.3	431.6	559.2	480.3

[A] Based upon the following equation (this equation cannot be used for extrapolating values beyond the size ranges listed in this table):

$$CPL = (1 - 0.012D) \times f \times As \times 0.001$$

where:

CPL = cone stripping proof load lbf [kN],
D = nominal diameter of nut, in. [mm],
f = minimum proof stress of nut, psi [MPa]; see footnote *b*, *c*, *d*, *e*, and *f*,
As = tensile stress area of nut, mm^2 = 0.7854 [D - 0.9382P]^2, and
n = thread pitch, mm.

[B] Based on proof stress of 895 MPa.
[C] Based on proof stress of 825 MPa.
[D] Based on proof stress of 1035 MPa.
[E] Based on proof stress of 930 MPa.
[F] Based on proof stress of 1205 MPa.

13. Keywords

13.1 bolting; chemical analysis; coated; marking on fasteners; plated

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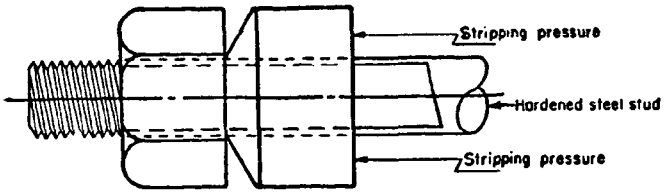
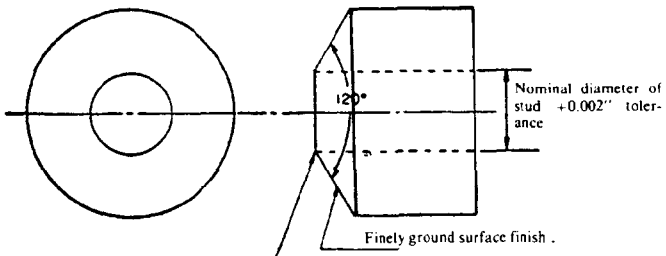


FIG. 1 Application of Hardened Steel Cone to Testing of Nuts



Contact point of cone to be sharp for nut sizes ½" and less. For sizes over ½" this point shall be flat and 0.015" ±0.001" in width Hardness 57 Rockwell C minimum. Specified tolerance for dimensions must be met for consistent results.

FIG. 2 Hardened Steel Cone

TABLE 7 Marking of Nuts

Grade and Type	Nuts Hot-Forged or Cold-Punched	Nuts Machined from Bar Stock	Nuts Manufactured in Accordance with 6.6
1	1	1B	...
2	2	2B	...
2H[A]	2H	2HB	...
2HM[A]	2HM	2HMB	...
3	3	3B	...
4	4	4B	...
4L[B]	4L	4BL	. . .
6	6	6B	. . .
6F	6F	6FB	...
7	7	7B	...
7L[B]	7L	7BL	...
7M[A]	7M	7MB	...
8	8	8B	8A
8C	8C	8CB	8CA
8M	8M	8MB	8MA
8T	8T	8TB	8TA
8F	8F	8FB	8FA
8P	8P	8PB	8PA
8N	8N	8NB	8NA
8MN	8MN	8MNB	8MNA
8R	8R	8RB	8RA
8S	8S	8SB	8SA
8LN	8LN	8LNB	8LNA
8MLN	8MLN	8MLNB	8MLNA
8MLCuN	8MLCuN	8MLCuNB	8MLCuNA
9C	9C	9CB	9CA
16	16	16B	

[A] The letters H and M indicate heat-treated nuts (see Section 6).
[B] See Supplementary Requirement S3.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

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S1. Strain-Hardened Austenitic Steel Nuts

S1.1 Strain hardened Grades 8, 8C, 8T, 8M, 8F, 8P, 8N, or 8MN nuts may be specified. When Supplementary Requirement S1 is invoked in the order, nuts shall be machined from cold drawn bars or shall be cold forged to shape. No subsequent heat treatment shall be performed on the nuts. Nuts made in accordance with this requirement shall be proof load tested in accordance with 7.2.2.1 and shall withstand the proof load specified in Table S1.1 and Table S1.2. For nuts requiring proof loads over 120 000 lbf or 530 kN, Supplementary Requirement S4 is invoked. The hardness limits of Table 2 do not apply to strain hardened nuts. Nuts made in accordance with this requirement shall be marked with the Grade symbol underlined.

S2. Retests by Purchaser's Representative

S2.1 The purchaser's representative may select two nuts per keg (200-lb unit [90-kg]) for sizes 5/8 in.and M16 and smaller, one nut per keg for sizes over 5/8 in. and M16 up to and including 1½ in. and M36, and one nut per every two kegs for sizes larger than 1½ in. and M36, which shall be subjected to the tests specified in Section 7.

S3. Low-Temperature Requirements for Grade 4 or Grade 7 Nuts

S3.1 When low-temperature requirements are specified for Grade 4 or Grade 7 nuts, the Charpy test procedures and requirements as defined in Specification A 320/A 320M for Grade L7 shall apply. Depending on the size of nuts, separate test samples of the same heat may be required and shall be processed through heat treatment with the nuts for which the test is to apply. Full-size impact specimens cannot be obtained if the bar stock is smaller than 5/8 in. in diameter or 16M in diameter.

S3.2 An" L" shall be added to the marking, as shown in Table 7, for nuts so tested.

S4. Proof Load Tests of Large Nuts

S4.1 Proof load testing of nuts requiring proof loads of over 120 000 lbf or 530 kN may be required. When specified, the test is to be performed in accordance with 7.2 to the loads required by Table S4.1 and Table S4.2. The maximum load will be based entirely on the equipment available.

S5. Control of Product by Heat Number

S5.1 When control of nuts by actual heat analysis is required and this supplementary requirement is specified, the manufacturer shall identify the completed nuts in each shipment by the actual heat number. When this supplementary requirement is specified, a certificate including the results of the actual production tests of each test lot together with the heat chemical analysis shall be furnished by the manufacturer.

S6. Grain Size Requirements for Non H Grade Austenitic Steels Used Above 1000°F

S6.1 For design metal temperatures above 1000°F [540°C], the material shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E 112. The grain size so determined shall be reported on the Certificate of Test.

TABLE S1.1 Proof Load Testing of Strain Hardened Nuts Using Threaded Mandrel — Inch Series

NOTE 1—Proof loads are not design loads.

Nominal Size, in.	Threads per in.	Stress Area, in.[2]	Proof Load, lbf[A]			
			Grade 8M (strain hardened)	Grade 8M (strain hardened)	All Other Types of Grade 8 (strain hardened)	All Other Types of Grade 8 (strain hardened)
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[B]
¼	20	0.0316	3 480	3 160	3 950	3 480
5/16	18	0.0523	5 760	5 240	6 550	5 760
3/8	16	0.0774	8 510	7 740	9 675	8 510
7/16	14	0.1063	11 690	10 630	13 290	11 690
½	13	0.1419	15 610	14 190	17 740	15 610
9/16	12	0.182	20 020	18 200	22 750	20 020
5/8	11	0.226	24 860	22 600	28 250	24 860
¾	10	0.334	36 740	33 400	41 750	36 740
7/8	9	0.462	46 200	41 580	53 130	46 200
1	8	0.606	60 600	54 540	69 690	60 600
1⅛	8	0.790	75 050	67 150	82 950	75 050
1¼	8	1.000	95 000	85 000	105 000	95 000
1⅜	8	1.233	110 970	98 640	123 300	110 970
1½	8	1.492	134 280	119 360	149 200	134 280

[A] The proof load for jam nuts shall be 46 % of the tabulated value.
[B] Based on proof stress of 110 000 psi up to ¾ in.; 100 000 psi 7/8 to 1 in.; 95 000 psi 1⅛ to 1¼ in.; 90 000 psi 1⅜ to 1½ in.
[C] Based on proof stress of 100 000 psi up to ¾ in.; 90 000 psi 7/8 to 1 in.; 85 000 psi 1⅛ to 1¼ in.; 80 000 psi 1⅜ to 1½ in.
[D] Based on proof stress of 125 000 psi up to ¾ in.; 115 000 psi 7/8 to 1 in.; 105 000 psi 1⅛ to 1¼ in.; 100 000 psi 1⅜ to 1½ in.

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TABLE S1.2 Proof Load Testing of Strain Hardened Nuts Using Threaded Mandrel — Metric

NOTE 1—Proof loads are not design loads.

Nominal Size, mm	Thread Pitch	Stress Area, mm^2	Proof Load, kN[A] Grade 8M (strain hardened)	Grade 8M (strain hardened)	All Other Types of Grade 8 (strain hardened)	All Other Types of Grade 8 (strain hardened)
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[B]
M6	1.0	20.1	15.3	13.9	17.3	15.3
M8	1.25	36.6	27.8	25.3	31.3	27.8
M10	1.50	58.0	44.1	40.0	49.9	44.1
M12	1.75	84.3	64.1	58.2	72.5	64.1
M14	2.0	115.0	87.4	79.4	98.9	87.4
M16	2.0	157.0	119.3	108.3	135.0	119.3
M20	2.5	245.0	186.2	169.0	210.9	186.2
M22	2.5	303.0	209.0	187.9	240.9	209.0
M24	3.0	353.0	243.5	218.9	280.6	243.5
M27	3.0	459.0	300.6	268.5	332.7	300.6
M30	3.5	561.0	367.5	328.2	406.7	367.5
M36	4.0	817.0	506.5	449.4	563.7	506.5

[A] The proof load for jam nuts shall be 46 % of the tabulated value.
[B] Based on proof stress of 760 MPa up to M20 mm; 690 MPa M22 to M24 mm; 655 MPa M27 to M30; and 620 MPa for M36.
[C] Based on proof stress of 690 MPa up to M20 mm; 620 MPa M22 to M24 mm; 585 MPa M27 to M30; and 550 MPa for M36.
[D] Based on proof stress of 860 MPa up to M20 mm; 795 MPa M22 to M24 mm; 725 MPa M27 to M30 mm; and 690 MPa for M36.

TABLE S4.1 Proof Load for Large Heavy Hex Nuts — Inch[A]

Nominal Size, in.	Threads per in.	Stress Area, $in.^2$	Proof Load, lbf[B] Grade 1 Heavy Hex	Grades 2, 6, 6F Heavy Hex	Grades 2H, 3, 4, 7, 16 Heavy Hex
1⅝	8	1.78	231 400	267 000	311 500
1¾	8	2.08	270 400	312 000	364 000
1⅞	8	2.41	313 300	361 500	421 800
2	8	2.77	360 100	415 500	484 800
2¼	8	3.56	462 800	534 000	623 000
2½	8	4.44	577 200	666 000	777 000
2¾	8	5.43	705 900	814 500	950 250

[A] ANSI B18.2.2 in the size range over 1½ in. provides dimensions only for heavy hex nuts. Refer to 7.3.1.
[B] Proof loads for nuts of larger dimensions or other thread series may be calculated by multiplying the thread stress area times the proof stress in the notes to Table 3 or Table S1.1. The proof load for jam nuts shall be 46 % of the tabulated load.

TABLE S4.2 Proof Load for Large Heavy Hex Nuts — Metric[A]

Nominal Size, mm	Thread Pitch	Stress Area, mm^2	Proof Load, kN[B] Grade 1 Heavy Hex	Grades 2, 6, 6F Heavy Hex	Grades 2H, 3, 4, 7, 16 Heavy Hex
M42	4.5	1120	1002.4	1159.2	1771.4
M48	5	1470	1315.7	1521.4	1771.4
M56	5.5	2030	1816.9	2101.0	2446.2
M64	6	2680	2398.6	2773.8	3229.4
M72	6	3460	3096.7	3581.1	4169.3

[A] ANSI B 18.2.4.6M in the size range over M36 provides dimensions only for heavy hex nuts. Refer to 7.3.1.
[B] Proof loads for nuts of larger dimensions or other thread series may be calculated by multiplying the thread stress area times the proof stress in the notes to Table 3 or Table S1.1. The proof load for jam nuts shall be 46 % of the tabulated load.

APPENDIXES

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle and bar size. In large diameter bars,

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for example, plastic deformation will occur principally in the outer regions of the bar, so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening. Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined.

X2. COATINGS AND APPLICATION LIMITS

X2.1 Use of coated fasteners at temperatures above approximately one-half the melting point (Fahrenheit or Celsius) of the coating is not recommended unless consideration is given to the potential for liquid and solid metal embrittlement, or both. The melting point of elemental zinc is approximately 780°F [415°C]. Therefore, application of zinc coated fasteners should be limited to temperatures less than 390°F [210°C]. The melting point of cadmium is approximately 600°F [320°C]. Therefore, application of cadmium coated fasteners should be limited to temperatures less than 300°F [160°C].

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Endorsed by Manufacturers Standardization Society of the Valve and Fittings Industry
Endorsed by American Foundrymen's Society
Used in USDOE-NE Standards
An American National Standard

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Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service[1]

This standard is issued under the fixed designation A 216/A216M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification[2] covers carbon steel castings for valves, flanges, fittings, or other pressure-containing parts for high-temperature service and of quality suitable for assembly with other castings or wrought-steel parts by fusion welding.

1.2 Three grades, WCA, WCB, and WCC, are covered in this specification. Selection will depend upon design and service conditions, mechanical properties, and the high temperature characteristics.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[3]

A 703/A703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts[3]

E 165 Test Method for Liquid Penetrant Examination[4]

E 709 Guide for Magnetic Particle Examination[4]

2.2 *Manufacturers' Standardization Society of the Valve and Fittings Industry Standard:*

SP 55 Steel Castings for Valve, Flanges, and Fittings, and Other Components (Visual Method)[5]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition.

5.2 Castings shall be furnished in the annealed, or normalized, or normalized and tempered condition unless Supplementary Requirement S15 is specified.

5.3 Heat treatment shall be performed after castings have been allowed to cool below the transformation range.

6. Temperature Control

6.1 Furnace temperatures for heat treating shall be effectively controlled by pyrometer.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-216/SA-216M in Section II of that code.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] Available from Manufacturers' Standardization Society of the Valve and Fittings Industry, 127 Park St., N.E. Vienna, VA 22180.

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TABLE 1 Chemical Requirements

Element	Composition, %		
	Grade WCA	Grade WCB	Grade WCC
Carbon, max	0.25[A]	0.30[B]	0.25[C]
Manganese, max	0.70[A]	1.00[B]	1.20[C]
Phosphorus, max	0.04	0.04	0.04
Sulfur, max	0.045	0.045	0.045
Silicon, max	0.60	0.60	0.60
Specified residual elements:			
Copper, max	0.30	0.30	0.30
Nickel, max	0.50	0.50	0.50
Chromium, max	0.50	0.50	0.50
Molybdenum, max	0.20	0.20	0.20
Vanadium, max	0.03	0.03	0.03
Total of these specified residual elements, max[D]	1.00	1.00	1.00

[A]For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % manganese above the specified maximum will be permitted up to a maximum of 1.10 %.

[B]For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % Mn above the specified maximum will be permitted up to a maximum of 1.28 %.

[C]For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % manganese above the specified maximum will be permitted to a maximum of 1.40 %.

[D]Not applicable when Supplementary Requirement S11 is specified.

8. Tensile Requirements

8.1 Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Table 2.

9. Quality

9.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

9.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10 may be ordered.

9.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

TABLE 2 Tensile Requirements

	Grade WCA	Grade WCB	Grade WCC
Tensile strength, ksi [MPa]	60 to 85 [415 to 585]	70 to 95 [485 to 655]	70 to 95 [485 to 655]
Yield strength,[A] min, ksi [MPa]	30 [205]	36 [250]	40 [275]
Elongation in 2 in. [50 mm], min, %[B]	24	22	22
Reduction of area, min, %	35	35	35

[A]Determine by either 0.2 % offset method or 0.5 % extension-under-load method.

[B]When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

10. Repair by Welding

10.1 Repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

10.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2}[65 cm^2], shall be radiographed to the same standards that are used to inspect the castings.

10.3 Castings containing any repair weld that exceeds 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or that exceeds approximately 10 in.^{2}[65 cm^2] in area, or that was made to correct hydrostatic test defects, shall be stress relieved or heat-treated after welding. This mandatory stress relief or heat-treatment shall be in accordance with the procedure qualification used.

11. Keywords

11.1 carbon steel; high temperature; pressure containing parts; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

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S1. Unspecified Elements

S2. Destruction Tests

S3. Bend Test

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 709 or Practice E 165.

S11. Carbon Equivalent

S11.1 When specified on the order, the maximum carbon equivalent shall be:

Grade	Carbon Equivalent, max
WCA	0.50
WCB	0.50
WCC	0.55

S11.2 Carbon equivalent (CE) shall be determined as follows:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

S15. Quench and Temper Heat-Treatment

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Endorsed by Manufacturers Standardization Society of the Valve and Fittings Industry

Endorsed by American Foundrymen's Society
Used in USDOE-NE Standards
An American National Standard

Standard Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service[1]

This standard is issued under the fixed designation A 217/A 217M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification[2] covers martensitic stainless steel and alloy steel castings for valves, flanges, fittings, and other pressure-containing parts (Note 1) intended primarily for high-temperature and corrosive service (Note 2).

1.2 One grade of martensitic stainless steel and nine grades of ferritic alloy steel are covered. Selection will depend on design and service conditions, mechanical properties, and the high-temperature and corrosion-resistant characteristics (Note 3).

NOTE 1—Carbon steel castings for pressure-containing parts are covered by Specification A 216/A 216M. Low alloy quench-and-tempered grades equivalent to Specification A 217/A 217M grades may be found in both Specifications A 352/A 352M and A 487/A 487M.

NOTE 2—The grades covered by this specification represent materials that are generally suitable for assembly with other castings or wrought steel parts by fusion welding. It is not intended to imply that these grades possess equal degrees of weldability; therefore, it is the responsibility of the purchaser to establish for himself a suitable welding technique. Since these grades possess varying degrees of suitability for high-temperature and corrosion-resistant service, it is also the responsibility of the purchaser to determine which grade shall be furnished, due consideration being given to the requirements of the applicable construction codes.

NOTE 3—The committee formulating this specification has included nine grades of materials that are considered to represent basic types of ferritic alloy steels suitable for valves, flanges, fittings, and other pressure-containing parts. Additional alloy steels that may better fulfill certain types of service will be considered for inclusion in this specification by the committee as the need becomes apparent.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 217 and SI units for materials ordered to Specification A 217M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service[3]

A 352/A 352M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service[3]

A 487/A 487M Specification for Steel Castings Suitable for Pressure Service[3]

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel[3]

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts[3]

A 802/A 802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination[3]

E 165 Test Method for Liquid Penetrant Examination[4]

E 709 Guide for Magnetic Particle Examination[4]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved Mar. 10, 2001. Published May 2001. Originally published as A 217 – 39 T. Last previous edition A 217/A 217M – 99.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-217/SA 217M in Section II of that code.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

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4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition.

5.2 Castings shall be furnished in the normalized and tempered conditions; Grades WC1, WC4, WC5, WC6, and CA15 shall be tempered at 1100°F [595°C] min; Grades WC9, C5, C12, and WC11 shall be tempered at 1250°F [675°C] min. Grade C12A shall be tempered at 1350°F (730°C) min.

5.3 Heat treatment shall be performed after castings have been allowed to cool below the transformation range.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Tensile Requirements

7.1 Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Table 2.

8. Quality

8.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A 802/A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperature are used in the removal of discontinuities, castings shall be preheated to at least the minimum temperatures in Table 3.

8.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10 may be ordered.

TABLE 2 Tensile Requirements

Grade	Tensile Strength, ksi [MPa]	Yield Strength,[A] min, ksi [MPa]	Elongation in 2 in. [50 mm] min, %[B]	Reduction of Area, min, %
WC1	65 [450] to 90 [620]	35 [240]	24	35
WC4, WC5, WC6, WC9	70 [485] to 95 [655]	40 [275]	20	35
WC11	80 [550] to 105 [725]	50 [345]	18	45
C5, C12	90 [620] to 115 [795]	60 [415]	18	35
C12A (J84090)	85 [585] to 110 [760]	60 [415]	18	45
CA15	90 [620] to 115 [795]	65 [450]	18	30

[A] Determine by either 0.2 % offset method or 0.5 % extension-under-load method.

[B] When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

TABLE 1 Chemical Requirements

NOTE—All values are maximum unless otherwise indicated.

	Composition, %									
	Carbon Molybdenum	Nickel Chromium Molybdenum	Nickel Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum Vanadium	Chromium
Grade Identification Symbol	WC1	WC4	WC5	WC6	WC9	WC11	C5	C12	C12A (J84090)	CA15
Carbon	0.25	0.05–0.20	0.05–0.20	0.05–0.20	0.05–0.18	0.15–0.21	0.20	0.20	0.08-0.12	0.15
Manganese	0.50–0.80	0.50–0.80	0.40–0.70	0.50–0.80	0.40–0.70	0.50–0.80	0.40–0.70	0.35–0.65	0.30–0.60	1.00
Phosphorus	0.04	0.04	0.04	0.04	0.04	0.020	0.04	0.04	0.030	0.040
Sulfur	0.045	0.045	0.045	0.045	0.045	0.015	0.045	0.045	0.010	0.040
Silicon	0.60	0.60	0.60	0.60	0.60	0.30–0.60	0.75	1.00	0.20–0.50	1.50
Nickel	...	0.70–1.10	0.60–1.00	...	...	...	...	...	0.40	1.00
Chromium	...	0.50–0.80	0.50–0.90	1.00–1.50	2.00–2.75	1.00–1.50	4.00–6.50	8.00–10.00	8.0–9.5	11.5–14.0
Molybdenum	0.45–0.65	0.45–0.65	0.90–1.20	0.45–0.65	0.90–1.20	0.45–0.65	0.45–0.65	0.90–1.20	0.85–1.05	0.50
Columbium	...	...	...	...	...	...	...	...	0.060–0.10	...
Nitrogen	...	...	...	...	...	...	...	...	0.030–0.070	...
	Specified Residual Elements									
Aluminum	...	...	...	...	...	0.01	...	...	0.040	...
Copper	0.50	0.50	0.50	0.50	0.50	0.35	0.50	0.50	...	...
Nickel	0.50	...	...	0.50	0.50	0.50	0.50	0.50	...	...
Chromium	0.35	...	...	...	...	...	...	...	...	...
Tungsten	0.10	0.10	0.10	0.10	0.10	...	0.10	0.10	...	...
Vanadium	...	...	...	...	...	0.03	...	...	0.18–0.25	...
Total content of these residual elements	1.00	0.60	0.60	1.00	1.00	1.00	1.00	1.00		

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TABLE 3 Minimum Preheat Temperatures

Grade	Thickness, in. [mm]	Minimum Preheat Temperature, °F [°C]
WC1	5/8 and under	50 [10]
	Over 5/8 [15.9]	250 [120]
WC4	All	300 [150]
WC5	All	300 [150]
WC6	All	300 [150]
WC9	All	400 [200]
WC11	All	300 [150]
C5	All	400 [200]
C12	All	400 [200]
C12A (J84090)	All	400 [200]
CA15	All	400 [200]

8.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

9. Repair by Welding

9.1 Repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

9.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2} [65 cm^2], shall be radiographed to the same standards that are used to inspect the castings.

9.3 Weld repairs shall be considered major in the case of a casting that has leaked on hydrostatic test, or when the depth of the cavity prepared for welding exceeds 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2} [65 cm^2]. All castings with major repair welds shall be thermally stress relieved or completely reheat-treated. This mandatory stress relief or reheat-treatment shall be in accordance with the qualified procedure used. Major repairs shall be inspected to the same quality standards that are used to inspect the castings.

10. Keywords

10.1 alloy steel; high-temperature; martensitic stainless steel; pressure-containing; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements
S2. Destruction Tests
S3. Bend Tests
S4. Magnetic Particle Inspection
S5. Radiographic Inspection

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Test Method E 165 or Guide E 709.

S13. Hardness Test
S21. Heat Treatment Furnace Record
S22. Heat Treatment

S51. Mandatory Postweld Heat Treatment

S51.1 All castings with repair welds shall receive a mandatory thermal stress relief or complete reheat treatment in accordance with the qualified procedure after all weld repairs.

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Designation: A 307 – 00

Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength[1]

This standard is issued under the fixed designation A 307; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification[2] covers the chemical and mechanical requirements of three grades of carbon steel bolts and studs in sizes ¼in. (6.35 mm) through 4 in. (104 mm). The fasteners are designated by "Grade" denoting tensile strength and intended use, as follows:

Grade	Description
Grade A	Bolts and studs having a minimum tensile strength of 60 ksi (414 MPa) and intended for general applications,
Grade B	Bolts and studs having a tensile strength of 60 to 100 ksi (414 to 690 MPa) and intended for flanged joints in piping systems with cast iron flanges, and
Grade C	Nonheaded anchor bolts, either bent or straight, having properties conforming to Specification A 36 (tensile strength of 58 to 80 ksi (400 to 550 MPa)) and intended for structural anchorage purposes.

1.1.1 The term *studs* includes stud stock, sometimes referred to as *threaded rod.*

1.2 This specification does not cover requirements for machine screws, thread cutting/forming screws, mechanical expansion anchors or similar externally threaded fasteners.

1.3 Suitable nuts are covered in Specification A 563. Unless otherwise specified, the grade and style of nut for each grade of fastener, of all surface finishes, shall be as follows:

Fastener Grade and Size	Nut Grade and Style[A]
A, C, ¼ to 1½in.	A, hex
A, C, over 1½ to 4 in.	A, heavy hex
B, ¼ to 4 in.	A, heavy hex

[A] Nuts of other grades and styles having specified proof load stresses (Specification A 563, Table 3) greater than the specified grade and style of nut are also suitable.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 Supplementary Requirement S1 of an optional nature is provided, which describes additional restrictions to be applied when bolts are to be welded. It shall apply only when specified in the inquiry, order, and contract.

2. Referenced Documents

2.1 *ASTM Standards:*

A 36/A 36M Specification for Carbon Structural Steel[3]

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware[4]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[5]

A 563 Specification for Carbon and Alloy Steel Nuts[6]

A 706/A706M Specification for Low-Alloy Steel Deformed Bars for Concrete Reinforcement[3]

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[5]

B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel[7]

D 3951 Practice for Commercial Packaging[8]

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets[6]

F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection[6]

2.2 *ANSI/ASME Standards:*

B 1.1 Unified Screw Threads[9]

B 18.2.1 Square and Hex Bolts and Screws[9]

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[1] This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets, and Washers.

Current edition approved May 10, 2000. Published July 2000. Originally published as A 307 – 47 T. Last previous edition A 307 – 97.

[2] For *ASME Boiler and Pressure Vessel Code* applications see related Specification SA-307 in Section II of that Code.

[3] *Annual Book of ASTM Standards,* Vol 01.04.

[4] *Annual Book of ASTM Standards,* Vol 01.06.

[5] *Annual Book of ASTM Standards,* Vol 01.03.

[6] *Annual Book of ASTM Standards,* Vol 01.08.

[7] *Annual Book of ASTM Standards,* Vol 02.05.

[8] *Annual Book of ASTM Standards,* Vol 15.09.

[9] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

***A Summary of Changes section appears at the end of this standard.**

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B 18.24.1 Part Identifying Number (PIN) Code System[10]

2.3 *Military Standard:*

MIL-STD 105 Single Sampling Plan for Normal Inspection[11]

3. Ordering Information

3.1 Orders for externally threaded fasteners (including nuts and accessories) under this specification shall include the following:

3.1.1 ASTM designation and year of issue,

3.1.2 Name of product, bolts or studs; and bolt head style, that is, hex or heavy hex,

3.1.3 Grade, that is, A, or B, or C. If no grade is specified, Grade A is furnished.

3.1.4 Quantities (number of pieces by size including nuts),

3.1.5 Fastener size and length,

3.1.6 *Washers*—Quantity and size (separate from bolts),

3.1.7 *Zinc Coating*—Specify the zinc-coating process required for example, hot-dip, mechanically deposited or no preference (see 4.5).

3.1.8 *Other Finishes*—Specify other protective finish, if required.

3.1.9 Specify if inspection at point of manufacture is required,

3.1.10 Specify if certified test report is required (see 8.2), and

3.1.11 Specify additional testing (8.3) or special requirements.

3.1.12 For establishment of a part identifying system, see ASME B18.24.1.

4. Materials and Manufacture

4.1 Steel for bolts and studs shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

4.2 Bolts shall be produced by hot or cold forging of the heads or machining from bar stock.

4.3 *Heat Treatment:*

4.3.1 Cold headed fasteners with head configurations other than hex shall be stress relief annealed.

4.3.2 Stress relieving of hex head fasteners shall be at the manufacturer's option.

4.4 Bolt and stud threads shall be rolled or cut.

4.5 *Zinc Coatings, Hot-Dip and Mechanically Deposited:*

4.5.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc-coating process, for example hot dip, mechanically deposited, or no preference.

4.5.2 When hot-dip is specified, the fasteners shall be zinc-coated by the hot-dip process in accordance with the requirements of Class C of Specification A 153.

4.5.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical-deposition process in accordance with the requirements of Class 50 of Specification B 695.

4.5.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153, Class C or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier's option is limited to one process per item with no mixed processes in a lot.

5. Chemical Composition

5.1 Grade A and B bolts and studs shall have a heat analysis conforming to the requirements specified in Table 1 based on the steel producer's heat analysis.

5.2 The purchaser shall have the option of conducting product analyses on finished bolts in each lot, which shall conform to the product analysis specified in Table 1.

5.3 In case of conflict or for referee purposes, the product analysis shall take precedence.

5.4 Bolts and studs are customarily furnished from stock, in which case individual heats of steel cannot be identified.

5.5 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for Grade B bolts and studs.

5.6 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Grades A and B bolts and studs shall conform to the hardness specified in Table 2.

6.2 Grade A and B bolts and studs 1½ in. in diameter or less, other than those excepted in 6.4, shall be tested full size and shall conform to the requirements for tensile strength specified in Table 3.

6.3 Grade A and B bolts and studs larger than 1½ in. in diameter, other than those excepted in 6.4, shall preferably be tested full size and when equipment of sufficient capacity is available and shall conform to the requirements for tensile strength specified in Table 3. When equipment of sufficient capacity for full-size bolt testing is not available, or when the length of the bolt makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements specified in Table 4.

6.4 Grades A and B bolts and studs less than three diameters in length or bolts with drilled or undersize heads are not subject to tensile tests.

6.5 Grade C nonheaded anchor bolts shall be tested using machined specimens and shall conform to the tensile properties specified for bars in Specification A 36. Properties are shown in Table 4 for information. In the event of conflict Specification A 36 shall control.

TABLE 1 Chemical Requirements for Grades A and B Bolts and Studs

	Heat Analysis	Product Analysis
Carbon, max	0.29	0.33
Manganese, max	0.90	0.93
Phosphorus, max	0.04	0.041
Sulfur, max		
Grade A	0.15	[A]
Grade B	0.05	0.051

[A] Resulfurized steel is not subject to rejection based on product analysis for sulfur.

[10] Available from American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016–5990.

[11] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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TABLE 2 Hardness Requirements for Bolts and Studs

Grade	Length, in. 0	Hardness[A]			
		Brinell		Rockwell B	
		min	max	min	max
A	Less than 3 × dia[B]	121	241	69	100
	3 × dia and longer	...	241	...	100
B	Less than 3 × dia[B]	121	212	69	95
	3 × dia and longer	...	212	...	95
C	All	No hardness required			

[A] As measured anywhere on the surface or through the cross section.
[B] Also bolts with drilled or undersize heads. These sizes and bolts with modified heads shall meet the minimum and maximum hardness as hardness is the only requirement.

TABLE 3 Tensile Requirements for Full-Size Bolts and Studs

Bolt Size, in.	Threads per inch	Stress Area,[A] in.[2]	Tensile Strength, lbf[B]		
			Grade A, min[C]	Grade B	
				min[D]	max[D]
¼	20	0.0318	1 900	1 900	3 180
5/16	18	0.0524	3 100	3 100	5 240
⅜	16	0.0775	4 650	4 650	7 750
7/16	14	0.1063	6 350	6 350	10 630
½	13	0.1419	8 500	8 500	14 190
9/16	12	0.182	11 000	11 000	18 200
⅝	11	0.226	13 550	13 550	22 600
¾	10	0.334	20 050	20 050	33 400
⅞	9	0.462	27 700	27 700	46 200
1	8	0.606	36 350	36 350	60 600
1⅛	7	0.763	45 800	45 800	76 300
1¼	7	0.969	58 150	58 150	96 900
1⅜	6	1.155	69 300	69 300	115 500
1½	6	1.405	84 300	84 300	140 500
1¾	5	1.90	114 000	114 000	190 000
2	4½	2.50	150 000	150 000	250 000
2¼	4½	3.25	195 000	195 000	325 000
2½	4	4.00	240 000	240 000	400 000
2¾	4	4.93	295 800	295 800	493 000
3	4	5.97	358 200	358 200	597 000
3¼	4	7.10	426 000	426 000	710 000
3½	4	8.33	499 800	499 800	833 000
3¾	4	9.66	579 600	579 600	966 000
4	4	11.08	664 800	664 800	1 108 000

[A] Area calculated from the equation:

$$A_s = 0.7854\,[D - (0.9743/n)]^2$$

where:

A_s = stress area,
D = nominal diameter of bolt, and
n = threads per inch.

[B] 1 lbf = 4.448 N.
[C] Based on 60 ksi (414 MPa).
[D] Based on 60–100 ksi (414–690 MPa).

6.6 In the event that bolts are tested by both full size and by machine test specimen methods, the full-size test shall govern if a controversy between the two methods exists.

6.7 For bolts and studs on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event that there is controversy over low readings of hardness tests.

7. Dimensions

7.1 Unless otherwise specified, threads shall be the Coarse Thread Series as specified in the latest issue of ANSI/ASME B1.1, and shall have a Class 2A tolerance.

TABLE 4 Tensile Requirements for Machined Specimens

	Grade A	Grade B	Grade C
Tensile strength, ksi (MPa)	60 (415) min	60–100 (415–690)	58–80 (400–550)
Yield point, min ksi (MPa)	...	...	36 (50)
Elongation in 2 in. (50 mm), min, %	18	18	23

7.2 Unless otherwise specified, Grade A bolts shall be hex bolts with dimensions as given in the latest issue of ANSI/ASME B18.2.1. Unless otherwise specified, Grade B bolts shall be heavy hex bolts with dimensions as given in the latest issue of ANSI/ASME B18.2.1.

7.3 Unless otherwise specified, bolts and studs to be used with nuts or tapped holes which have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot-dip or mechanically deposited zinc coating. After zinc coating the maximum limit of pitch and major diameter shall not exceed the Class 2A maximum limit by more than the following amounts:

Diameter, in.	Oversize Limit, in. (mm)[A]
¼	0.016
5/16, ⅜	0.017
7/16, ½	0.018
9/16 to ¾ incl	0.020
⅞	0.022
1.0 to 1¼ incl	0.024
1⅜, 1½	0.027
1¾ to 4.0 incl	0.050

[A] These values are the same as the overtapping required for zinc-coated nuts in Specification A 563.

7.4 The gaging limit for bolts and studs shall be verified during manufacture or use by assembly of a nut tapped as nearly as practical to the amount oversize shown above. In case of dispute, a calibrated thread ring gage of that same size (Class X tolerance, gage tolerance plus) shall be used. Assembly of the gage, or the nut described above, must be possible with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve disputes, shall be performed at the frequency and quality described in Table 5.

8. Number of Tests and Retests

8.1 The requirements of this specification shall be met in

TABLE 5 Sample Sizes and Acceptance Numbers for Inspection of Hot-Dip or Mechanically Deposited Zinc-Coated Threads

Lot Size	Sample Size[A,B]	Acceptance Number[A]
2 to 90	13	1
91 to 150	20	2
151 to 280	32	3
281 to 500	50	5
501 to 1 200	80	7
1 201 to 3 200	125	10
3 201 to 10 000	200	14
10 001 and over	315	21

[A] Sample sizes of acceptance numbers are extracted from "Single Sampling Plan for Normal Inspection," Table IIA, MIL-STD-105.
[B] Inspect all bolts in the lot if the lot size is less than the sample size.

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continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. Individual heats of steel are not identified in the finished product.

8.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

8.3 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all material offered for inspection at one time that has the following common characteristics:

8.3.1 One type of item,

8.3.2 One nominal size, and

8.3.3 One nominal length of bolts and studs.

8.4 From each lot, the number of tests for each requirement shall be as follows:

Number of Pieces in Lot	Number of Samples
800 and under	1
801 to 8 000	2
8 001 to 22 000	3
Over 22 000	5

8.5 If any machined test specimen shows defective machining it shall be discarded and another specimen substituted.

8.6 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be tested, in which case all of the additional samples shall meet the specification.

9. Test Methods

9.1 Grades A and B bolts and studs shall be tested in accordance with Test Methods F 606.

9.2 Grade C nonheaded anchor bolts shall have machined specimen tension tests made on the bolt body or on the bar stock used for making the anchor bolts. Tests on finished anchor bolts shall be made in accordance with Test Methods F 606 and tests on bar stock in accordance with Specification A 36 and Test Methods A 370.

9.3 Standard square and hex head bolts only shall be tested by the wedge tension method except as noted in 6.4. Fracture shall be in the body or threads of the bolt without any fracture at the junction of the head and body. Other headed bolts shall be tested by the axial tension method.

9.4 Speed of testing as determined with a free running crosshead shall be a maximum of 1 in. (25.4 mm)/min for the tensile strength tests of bolts.

10. Inspection

10.1 If the inspection described in 10.2 is required by the purchaser it shall be specified in the inquiry, order, or contract.

10.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

11. Responsibility

11.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

12. Rejection and Rehearing

12.1 Disposition of nonconforming lots shall be in accordance with Guide F 1470, specifically sections on disposition of nonconforming lots, suppliers option, and purchasers option.

13. Product Marking

13.1 *Grades A and B Bolts and Studs*:

13.1.1 Bolt heads and one end of studs shall be marked with a unique identifier by the manufacturer to identify the manufacturer or private label distributor, as appropriate. Additional marking required by the manufacturer for his own use shall be at the option of the manufacturer.

13.1.2 In addition to the requirements of 13.1, all bolt heads, one end of studs ⅜ in. and larger, and whenever feasible studs less than ⅜ in. shall be marked with a grade marking as follows:

Grade	Marking
A	307A
B	307B

13.1.3 All markings shall be located on the top of the bolt head or stud end and shall be raised or depressed at the option of the manufacturer.

13.2 *Grade C Anchor Bolts*:

13.2.1 The end of Grade C anchor bolts intended to project from the concrete shall be color coded green.

13.2.2 When permanent marking of manufacturer's identification and grade identification is required, Supplementary Requirements S2 and S3 shall be specified.

13.3 Grade and manufacturer's or private label distributor's identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

14. Packaging and Package Marking

14.1 *Packaging*:

14.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

14.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

14.2 *Package Marking*:

14.2.1 Each shipping unit shall include or be plainly marked with the following information:

14.2.1.1 ASTM designation and grade,

14.2.1.2 Size,

14.2.1.3 Name and brand or trademark of the manufacturer,

14.2.1.4 Number of pieces,

14.2.1.5 Purchase order number,

14.2.1.6 Country of origin.

15. Keywords

15.1 bolts; carbon steel; steel; studs

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SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified in the purchase order or contract:

S1. Bolts Suitable for Welding

S1.1 The material described in this section is intended for welding. This supplemental section, by additional chemical composition restrictions and by a carbon equivalent formula, provides assurance of weldability by chemical composition control.

S1.2 Welding technique is of fundamental importance when bolts produced to this supplementary section are welded. It is presupposed that suitable welding procedures for the steel being welded and the intended service will be selected.

S1.3 All of the requirements of this supplemental section apply in addition to all of the chemical, mechanical, and other requirements of the base specification, Specification A 307 for Grade B.

S1.4 Because of the embrittling effects of welding temperatures on cold-forged steel, this supplemental section is limited to hot-forged bolts, or, if not forged, then to bolts produced from hot-rolled bars without forging or threaded bars, bars studs, or stud bolts produced from hot-rolled bars without forging. Cold-forged bolts, or cold-drawn threaded bars, if they are given a thermal treatment by heating to a temperature of not less than 1500°F (815°C) and air-cooled are also suitable.

S1.5 *Chemical Requirements:*

S1.5.1 *Heat Chemical Analysis*—Material conforming to the following additional analysis limitations shall be used to manufacture the product described in this supplementary requirement.

Carbon	0.30 %, max
Manganese	1.00 %, max
Phosphorus	0.04 %, max
Sulfur	0.05 %, max
Silicon	0.50 %, max

S1.5.2 *Carbon Equivalent (Source—Specification A 706/A 706M)*—In addition to the heat chemical analysis requirements in S1.5.1, the heat analysis shall be such as to provide a carbon equivalent (CE) not exceeding 0.55 when calculated as follows:

$$CE = \%\,C + \frac{\%\,Mn}{6} + \frac{\%\,Cu}{40} + \frac{\%\,N\,1}{20} + \frac{\%\,Cr}{10} - \frac{\%\,Mo}{50} - \frac{\%\,V}{10}$$

S1.6 *Analysis Reports*—If requested on the order or contract, the chemical composition of each heat of steel used and the calculated carbon equivalent for each heat shall be reported to the purchaser.

S1.7 *Product (Check) Verification Analysis*—Chemical analyses when made by the purchaser or a representative on bolts from each heat of steel, shall not exceed the values specified in S1.5.2 by more than the following amounts:

	%
Carbon	+0.03
Manganese	+0.06
Phosphorus	+0.008
Sulfur	+0.008
Silicon	+0.05

S2. Permanent Manufacturer's Identification

S2.1 The end of the anchor bolt intended to project from the concrete shall be steel die stamped with the manufacturer's identification.

NOTE —For marking small sizes, customarily less than ⅜ in., consult the anchor bolt manufacturer for the minimum size capable of being marked.

S3. Permanent Grade Identification

S3.1 The end of the anchor bolt intended to project from the concrete shall be steel die stamped with the Grade identification "307C".

S3.2 The requirements in S2.1 for marking small sizes shall also apply to Supplementary Requirement S3.

SUMMARY OF CHANGES

This section identifies the location of selected changes to this standard that have been incorporated since the –97 issue. For the convenience of the user, Committee F16 has highlighted those changes that impact the use of this standard. This section may also include descriptions of the changes or reasons for the changes, or both.

(1) Added 3.1.12, providing for optional use of ASME B18.24.1, Part Identifying Number (PIN) Code System.

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Designation: A 312/A 312M – 01

An American National Standard
Used in USDOE-NE standards

Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipes[1]

This standard is issued under the fixed designation A 312/A 312M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification[2] covers seamless, straight-seam welded, and heavily cold worked welded austenitic stainless steel pipe intended for high-temperature and general corrosive service.

NOTE 1—When the impact test criterion for a low-temperature service would be 15 ft·lbf [20 J] energy absorption or 15 mils [0.38 mm] lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades TP304, TP304L, and TP347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by the Chemical Plant and Refinery Piping Code, ANSI B31.3, for service at temperatures as low as −425°F [−250°C] without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as −325°F [−200°C] without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10 %, are required to be impact tested under the rules of ASME Section VIII Division 1 when service temperatures are lower than −50°F [−45°C].

1.2 Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP309Cb, TP309S, TP310Cb, TP310S, TP316, TP321, TP347, and TP348, and are intended for high-temperature service.

1.3 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.4 Table X1.1 lists the standardized dimensions of welded and seamless stainless steel pipe as shown in ANSI B36.19. These dimensions are also applicable to heavily cold worked pipe. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.5 Grades TP321 and TP321H have lower strength requirements for pipe manufactured by the seamless process in nominal wall thicknesses greater than ⅜ in. [9.5 mm].

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 2—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels[3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes[4]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys[4]

A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe[4]

E 112 Test Methods for Determining the Average Grain Size[5]

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings[5]

E 527 Practice for Numbering Metals and Alloys (UNS)[4]

2.2 *ANSI Standards:*[6]

B1.20.1 Pipe Threads, General Purpose

B36.10 Welded and Seamless Wrought Steel Pipe

B36.19 Stainless Steel Pipe

2.3 *ASME Standard:*

ASME Boiler and Pressure Vessel Code: Section VIII[7]

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.10 on Stainless and Alloy Steel Tubular Products.

Current edition approved Apr. 10, 2001. Published September 2001. Originally published as A 312 – 48 T. Last previous edition A 312/A 312M – 00c.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-312 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

[6] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

[7] Available from American Society for Mechanical Engineers, Three Park Avenue, New York, NY 10016–5990.

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2.4 *AWS Standard:*

A5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Electrodes[8]

2.5 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[9]

2.6 *Other Standard:*

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing[10]

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Specification A 999/A 999M and Terminology A 941 are applicable to this specification.

4. Ordering Information

4.1 Orders for material to this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, centimetres, or number of lengths),

4.1.2 Name of material (austenitic steel pipe),

4.1.3 Process (seamless (SML) or welded (WLD) or heavily cold worked (HCW)),

4.1.4 Grade (Table 1),

4.1.5 Size (NPS or outside diameter and schedule number or average wall thickness),

4.1.6 Length (specific or random) (Section 13),

4.1.7 End finish (Section on Ends of Specification A 999/A 999M),

4.1.8 Optional requirements (product analysis, see Section 8; hydrostatic or nondestructive electric test, see Section 12),

4.1.9 Test report required (Certification Section of Specification A 999/A 999M),

4.1.10 Specification number, and

4.1.11 Special requirements or any supplementary requirements selected, or both.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

5.2 *Heat Treatment*:

5.2.1 All pipe shall be furnished in the heat—treated condition in accordance with the requirements of Table 2. The heat—treatment procedure, except for "H" grades, S30815, S31272, S31254, S32654, N08367, N08904, and N08926 shall consist of heating the pipe to a minimum temperature of 1900°F [1040°C] and quenching in water or rapidly cooling by other means.

6. Materials and Manufacture

6.1 *Manufacture*:

6.1.1 The pipe shall be manufactured by one of the following processes:

6.1.2 *Seamless (SML) pipe* shall be made by a process that does not involve welding at any stage of production.

6.1.3 *Welded (WLD) pipe* shall be made using an automatic welding process with no addition of filler metal during the welding process.

6.1.4 *Heavily cold-worked (HCW) pipe* shall be made by applying cold working of not less than 35 % reduction in thickness of both wall and weld to a welded pipe prior to the final anneal. No filler shall be used in making the weld. Prior to cold working, the weld shall be 100 % radiographically inspected in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest revision, Paragraph UW-51.

6.1.5 Welded pipe and HCW pipe of NPS 14 and smaller shall have a single longitudinal weld. Welded pipe and HCW pipe of a size larger than NPS 14 shall have a single longitudinal weld or shall be produced by forming and welding two longitudinal sections of flat stock when approved by the purchaser. All weld tests, examinations, inspections, or treatments shall be performed on each weld seam.

6.1.6 At the option of the manufacturer, pipe shall be either hot finished or cold finished.

6.1.7 The pipe shall be free of scale and contaminating exogenous iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser is permitted to require that a passivating treatment be applied to the finished pipe.

[8] Available from the American Welding Society, 550 N.W. LeJeune Rd., Miami, FL 33135.

[9] Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

[10] Society for Nondestructive Testing, 1711 Arlingate Plaza, PO Box 28518, Columbus, OH, 43228-0518.

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TABLE 1 Chemical Requirements

Grade	UNS Designation[A]	Composition, %[B]									
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen[C]	Other Elements
...	S20400	0.030	7.0-9.0	0.045	0.030	1.00	15.0-17.0	1.50-3.00	...	0.15-0.30	...
TPXM-19	S20910	0.06	4.0-6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	0.20–0.40	Cb 0.10-0.30 V 0.10-0.30
TPXM-10	S21900	0.08	8.0–10.0	0.045	0.030	1.00	19.0–21.5	5.5–7.5	...	0.15–0.40	...
TPXM-11	S21904	0.04	8.0–10.0	0.045	0.030	1.00	19.0–21.5	5.5–7.5	...	0.15–0.40	...
TPXM-29	S24000	0.08	11.5–14.5	0.060	0.030	1.00	17.0–19.0	2.3–3.7	...	0.20–0.40	
TP304	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...
TP304L	S30403	0.035[D]	2.00	0.045	0.030	1.00	18.0–20.0	8.0–13.0	...	...	...
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...
...	S30415	0.04-0.06	0.80	0.045	0.030	1.00–2.00	18.0–19.0	9.0–10.0	...	0.12–0.18	Ce 0.03-0.08
TP304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–18.0	...	0.10–0.16	
TP304LN	S30453	0.035	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	...	0.10–0.16	...
...	S30600	0.018	2.00	0.02	0.02	3.7–4.3	17.0–18.5	14.0–15.5	0.20	...	Cu 0.50
...	S30615	0.16–0.24	2.00	0.030	0.03	3.2-4.0	17.0–19.5	13.5–16.0	...	...	Al 0.80-1.50
...	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	...	0.14–0.20	Ce 0.03-0.08
TP309S	S30908	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	0.75	...	...
TP309H	S30909	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	...	...	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	0.75	...	Cb (10 × C)-1.10
TP309HCb	S30941	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	0.75	...	Cb (10 × C)-1.10
...	S31002	0.015	2.00	0.020	0.015	0.15	19.0–22.0	24.0–26.0	0.10	0.10	...
TP310S	S31008	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	0.75	...	...
TP310H	S31009	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	0.75	...	Cb (10 × C)-1.10
TP310HCb	S31041	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	0.75	...	Cb (10 × C)-1.10
...	S31050	0.025	2.00	0.020	0.015	0.4	24.0–26.0	20.5–23.5	1.6–2.6	0.09–0.15	...
...	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	0.18–0.22	Cu 0.50-1.00
...	S31272	0.08–012	1.5–2.00	0.030	0.015	0.25–0.75	14.0–16.0	14.0–16.0	1.00–1.40		Ti 0.30-0.60 B 0.004-0.008
TP316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	11.0–14.0[E]	2.00–3.00	...	...
TP316L	S31603	0.035[D]	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	16.0–18.0	11.0–14.0[E]	2.00–3.00	...	...
...	S31635	0.08	2.00	0.045	0.030	0.75	16.0-18.0	10.0-12.0	2.00-3.00	0.10	T (5 × C)-0.70
TP316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	11.0–14.0[E]	2.00–3.00	0.10–0.16	...
TP316LN	S31653	0.035	2.00	0.045	0.030	1.00	16.0–18.0	11.0–14.0[E]	2.00–3.00	0.10–0.16	
TP317	S31700	0.08	2.00	0.045	0.030	1.00	18.0–20.0	11.0–14.0	3.0–4.0	...	...
TP317L	S31703	0.035	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...
...	S31725	0.030	2.00	0.040[F]	0.030	1.00	18.0–20.0	13.5–17.5	4.0–5.0	0.10	Cu 0.75
...	S31726	0.030	2.00	0.040[F]	0.030	1.00	17.0–20.0	14.5–17.5	4.0–5.0	0.10–0.20	Cu 0.75
TP321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	0.10	Ti (5 × C)-0.70
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	Ti (4 × C)-0.60
...	S32615	0.07	2.00	0.045	0.030	4.8–6.0	16.5–19.5	19.0–22.0	0.30–1.50	...	Cu 1.50-2.50
...	S32654	0.020	2.0–4.0	0.030	0.005	0.50	24.0–25.0	21.0–23.0	7.0–8.0	0.45–0.55	Cu 0.30-0.60
...	S33228	0.04–0.08	1.0	0.020	0.015	0.30	26.0–28.0	31.0–33.0	...	...	Cb 0.60-1.00 Ce 0.05-0.10 Al 0.025
...	S34565	0.030	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	0.40–0.60	Cb 0.10
TP347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	Cb (10 × C)-1.00
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	Cb (8 × C)-1.10
TP347LN	S34751	0.005–0.020	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	0.06–0.10	Cb 0.20-0.50 Cb (15 × C) min
TP348	S34800	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	Cb (10 × C)-1.00 Ta 0.10
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	Cb (8 × C)-1.10 Ta 0.10

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TABLE 1 *Continued*

Grade	UNS Designation[A]	Composition, %[B]									
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen[C]	Other Elements
...	S35045	0.06-0.10	1.50	...	0.015	1.00	25.0-29.0	32.0-37.0	...	...	Ti 0.15-1.10 Cu 0.75 Al 0.15-0.60
...	S35315	0.04–0.08	2.00	0.040	0.030	1.20–2.00	24.0–26.0	34.0–36.0	...	0.12–0.18	Ce 0.03-0.08
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.0–19.0	17.5–18.5	...	...	...
...	N08367	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.50	6.0–7.0	0.18–0.25	Cu 0.75
...	N08904	0.020	2.00	0.040	0.030	1.00	19.0–23.0	23.0–28.0	4.0–5.0	0.10	Cu 1.00-2.00
...	N08926	0.020	2.00	0.030	0.010	0.50	24.0–26.0	19.0–21.0	6.0–7.0	0.15–0.25	Cu 0.50-1.50

[A] Maximum, unless otherwise indicated.

[B] New designation established in accordance with Practice E 527 and SAE J1086.

[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

[D] For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.20 mm] in average wall thickness (0.044 in. [1.10 mm] in minimum wall thickness).

[E] For welded TP316, TP316N, TP316LN, and TP316H pipe, the nickel range shall be 10.0–14.0 %.

[F] For welded pipe, the phosphorus maximum shall be 0.045 %.

6.2 *Heat Treatment*—All pipe shall be furnished in the heat-treated condition in accordance with the requirements of Table 2. Alternatively, for seamless pipe, immediately following hot forming while the temperature of the pipes is not less than the specified minimum solution treatment temperature, pipes may be individually quenched in water or rapidly cooled by other means.

6.3 *Grain Size:*

6.3.1 The grain size of Grade UNS S32615, as determined in accordance with Test Methods E 112, shall be No. 3 or finer.

6.3.2 The grain size of grades TP309H, TP309HCb, TP310H and TP310HCb, as determined in accordance with Test Methods E 112, shall be No. 6 or coarser.

6.3.3 The grain size of grades 304H, 316H, 321H, 347H, and 348H, as determined in accordance with Test Methods E 112, shall be No. 7 or coarser.

TABLE 2 Annealing Requirements

Grade or UNS Designation[A]	Heat Treating Temperature[B]	Cooling/Testing Requirements
All grades not individually listed below:	1900°F [1040°C]	[C]
TP321H, TP347H, TP348H		
Cold finished	2000°F [1100°C]	[D]
Hot finished	1925°F [1050°C]	[D]
TP304H, TP316H		
Cold finished	1900°F [1040°C]	[D]
Hot finished	1900°F [1040°C]	[D]
TP309H, TP309HCb, TP310H, TP310HCb	1900°F [1040°C]	[D]
S30600	2010–2140°F [1100–1170°C]	[D]
S30815, S31272	1920°F [1050°C]	[D]
S31254, S32654	2100°F [1150°C]	[D]
S33228	2050–2160°F [1120–1180°C]	[D]
S34565	2050–2140°F [1120–1170°C]	[D]
S35315	2010°F [1100°C]	[D]
N08367	2025°F [1110°C]	[D]
N08904	2000°F [1100°C]	[D]
N08926	2010°F [1100°C]	[D]

[A] New designation established in accordance with Practice E 527 and SAE J1086.

[B] Minimum, unless otherwise stated.

[C] Quenched in water or rapidly cooled by other means, at a rate sufficient to prevent reprecipitation of carbides, as demonstrable by the capability of passing Practices A 262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (see Supplementary Requirement S7). Note that Practices A 262 requires the test to be performed on sensitized specimens in the low-carbon and stabilized types and on specimens representative of the as-shipped condition for other types. In the case of low-carbon types containing 3 % or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and the purchaser.

[D] Quenched in water or rapidly cooled by other means.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

8. Product Analysis

8.1 At the request of the purchaser, an analysis of one billet or one length of flat-rolled stock from each heat, or two pipes from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel:

NPS Designator	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5	200 or fraction thereof
6 and over	100 or fraction thereof

8.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 7.

8.3 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in Section 7, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

9. Permitted Variations in Wall Thickness

9.1 In addition to the implicit limitation of wall thickness for seamless pipe imposed by the limitation on weight in Specification A 999/A 999M, the wall thickness for seamless and welded pipe at any point shall be within the tolerances specified in Table 3, except that for welded pipe the weld area shall not be limited by the "Over" tolerance. The wall thickness and outside diameter for inspection for compliance with this requirement for pipe ordered by NPS and schedule number is shown in Table X1.1.

10. Tensile Requirements

10.1 The tensile properties of the material shall conform to the requirements prescribed in Table 4.

11. Mechanical Tests, Grain Size Determinations, and Weld Decay Tests Required

11.1 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes.

NOTE 3—The term "lot," for mechanical tests, applies to all pipe of the same diameter and wall thickness (or schedule) which are produced from the same heat of steel and subjected to the same finishing treatment: (*1*) in a continuous heat-treatment furnace, (*2*) in a batch-type heat-treatment furnace, equipped with recording pyrometers and automatically controlled within a 50°F [30°C] range, or (*3*) by direct quenching after hot forming, the larger of: (*a*) Each 200 ft [60 m] or fraction thereof or, (*b*) That pipe heat treated in the same batch furnace charge.

11.2 *Flattening Test*—For material heat treated in a batch-type furnace, flattening tests shall be made on 5 % of the pipe

TABLE 3 Permitted Variations in Wall Thickness

	Tolerance, % from Nominal	
NPS Designator	Over	Under
⅛ to 2½ incl., all t/D ratios	20.0	12.5
3 to 18 incl., t/D up to 5 % incl.	22.5	12.5
3 to 18 incl., t/D > 5 %	15.0	12.5
20 and larger, welded, all t/D ratios	17.5	12.5
20 and larger, seamless, t/D up to 5 % incl.	22.5	12.5
20 and larger, seamless, t/D > 5 %	15.0	12.5

where:

t = Nominal Wall Thickness
D = Ordered Outside Diameter

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TABLE 4 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
...	S20400	95 [635]	48 [330]
TPXM-19	S20910	100 [690]	55 [380]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21904	90 [620]	50 [345]
TPXM-29	S24000	100 [690]	55 [380]
TP304	S30400	75 [515]	30 [205]
TP304L	S30403	70 [485]	25 [170]
TP304H	S30409	75 [515]	30 [205]
...	S30415	87 [600]	42 [290]
TP304N	S30451	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
...	S30600	78 [540]	35 [240]
...	S30615	90 [620]	40 [275]
...	S30815	87 [600]	45 [310]
TP309S	S30908	75 [515]	30 [205]
TP309H	S30909	75 [515]	30 [205]
TP309Cb	S30940	75 [515]	30 [205]
TP309HCb	S30941	75 [515]	30 [205]
	S31002	73 [500]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP310H	S31009	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310HCb	S31041	75 [515]	30 [205]
...	S31050:		
$t \le 0.25$ in.		84 [580]	39 [270]
$t > 0.25$ in.		78 [540]	37 [255]
...	S31254:		
$t \le 0.187$ in. [5.00 mm]		98 [675]	45 [310]
$t > 0.187$ in. [5.00 mm]		95 [655]	45 [310]
	S31272	65 [450]	29 [200]
TP316	S31600	75 [515]	30 [205]
TP316L	S31603	70 [485]	25 [170]
TP316H	S31609	75 [515]	30 [205]
...	S31635	75 [515]	30 [205]
TP316N	S31651	80 [550]	35 [240]
TP316LN	S31653	75 [515]	30 [205]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
...	S31725	75 [515]	30 [205]
...	S31726	80 [550]	35 [240]
TP321	S32100:		
Welded		75 [515]	30 [205]
Seamless:			
$\le 3/8$ in.		75 [515]	30 [205]
$> 3/8$ in.		70 [485]	25 [170]
TP321H	S32109:		
Welded		75 [515]	30 [205]
Seamless:			
$\le 3/16$ in.		75 [515]	30 [205]
$> 3/16$ in.		70 [480]	25 [170]
...	S32615	80 [550]	32 [220]
...	S32654	109 [750]	62 [430]
...	S33228	73 [500]	27 [185]
...	S34565	115 [795]	60 [415]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP347LN	S34751	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
...	S35045	70 [485]	25 [170]
...	S35315	94 [650]	39 [270]
TPXM-15	S38100	75 [515]	30 [205]
...	N08367:		
$t \le 0.187$		100 [690]	45 [310]
$t > 0.187$		95 [655]	45 [310]
...	N08904	71 [490]	31 [215]
...	N08926	94 [650]	43 [295]
Elongation in 2 in. or 50 mm (or 4*D*), min, %:		Longi-tudinal	Trans-verse
All Grades except S31050 and S32615		35	25
S32615, S31050		25	...
N08367		30	...

from each heat-treated lot. For material heat treated by the continuous process, or by direct quenching after hot forming this test shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than two lengths of pipe.

11.2.1 For welded pipe a transverse-guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A 370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5 % of the lot shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

11.3 *Grain Size*—Grain size determinations on Grades TP309H, TP309HCb, TP310H, TP310HCb, and UNS S32615 shall be made on the same number of tubes as prescribed for the flattening test.

11.4 HCW pipe shall be capable of passing the weld decay tests listed in Supplementary S9 with a weld metal to base metal loss ratio of 0.90 to 1.1. The test is not required to be performed unless S9 is specified in the purchase order.

12. Hydrostatic or Nondestructive Electric Test

12.1 Each pipe shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

12.2 The hydrostatic test shall be in accordance with Specification A 999/A 999M, unless specifically exempted under the provisions of 12.3.

12.3 For pipe whose dimensions equal or exceed NPS 10, the purchaser, with the agreement of the manufacturer, may waive the hydrostatic test requirement when in lieu of such test the purchaser performs a system test. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory markings the letters "NH."

12.4 *Nondestructive Electric Test*:

Nondestructive electric tests shall be in accordance with Specification A 999/A 999M.

13. Lengths

13.1 Pipe lengths shall be in accordance with the following regular practice:

13.1.1 Unless otherwise agreed upon, all sizes from NPS ⅛ to and including NPS 8 are available in a length up to 24 ft (Note 4) with the permissible range of 15 to 24 ft (Note 4). Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

NOTE 4—This value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and the purchaser.

13.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the

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specified length and not more than ¼ in. [6 mm] over that specified.

13.1.3 No jointers are permitted unless otherwise specified.

14. Workmanship, Finish, and Appearance

14.1 The finished pipes shall be reasonably straight and shall have a workmanlike finish. Imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted in Section 9 of Specification A 999/A 999M.

15. Repair by Welding

15.1 For welded pipe whose diameter equals or exceeds NPS 6, and whose nominal wall thickness equals or exceeds 0.200, weld repairs made with the addition of compatible filler metal may be made to the weld seam with the same procedures specified for plate defects in the section on Repair by Welding of Specification A 999/A 999M.

15.2 Weld repairs of the weld seam shall not exceed 20 % of the seam length.

15.3 Weld repairs shall be made only with the gas tungsten-arc welding process using the same classification of bare filler rod qualified to the most current AWS Specification A5.9 as the grade of stainless steel pipe being repaired and as shown in Table 5. Alternatively, subject to approval by the purchaser, weld repairs shall be made only with the gas tungsten-arc welding process using a filler metal more highly alloyed than the base metal when needed for corrosion resistance or other properties.

15.4 Pipes that have had weld seam repairs with filler metal shall be uniquely identified and shall be so stated and identified on the certificate of tests. When filler metal other than that listed in Table 5 is used, the filler metal shall be identified on the certificate of tests.

TABLE 5 Pipe and Filler Metal Specification

Pipe		Filler Metal	
Grade	UNS Designation	AWS A5.9 Class	UNS Designation
TP304	S30400	ER308	S30800, W30840
TP304L	S30403	ER308L	S30883, W30843
TP304N	S30451	ER308	S30880, W30840
TP304LN	S30453	ER308L	S30883, W30843
TP304H	S30409	ER308	S30880, W30840
TP309Cb	S30940	...	... ...
TP309S	S30908	...	... ...
TP310Cb	S31040	...	... ...
TP310S	S31008	...	... ...
	S31272	...	... ...
TP316	S31600	ER316	S31680, W31640
TP316L	S31603	ER316L	S31683, W31643
TP316N	S31651	ER316	S31680, W31640
TP316LN	S31653	ER316L	S31683, W31643
TP316H	S31609	ER316H	S31680, W31640
TP321	S32100	ER321	S32180, W32140
		ER347	S34780, W34740
TP347	S34700	ER347	S34780, W34740
TP348	S34800	ER347	S34780, W34740
TPXM-19	S22100	ER209	S20980, W32240
TPXM-29	S28300	ER240	S23980, W32440
...	N08367	...	N06625
...	S20400	ER209	S20980, W32240
...	N08926	...	N06625

16. Certification

16.1 In addition to the information required by Specification A 999/A 999M, the certification shall state whether or not the material was hydrostatically tested. If the material was nondestructively tested, the certification shall so state and shall show which standard practice was followed and what reference discontinuities were used.

17. Marking

17.1 In addition to the marking specified in Specification A 999/A 999M, the marking shall include the NPS (nominal pipe size) or outside diameter and schedule number or average wall thickness, heat number, and NH when hydrotesting is not performed and ET when eddy-current testing is performed or UT when ultrasonic testing is performed. The marking shall also include the manufacturer's private identifying mark, the marking requirement of 12.3, if applicable, and whether seamless (SML), welded (WLD), or heavily cold-worked (HCW). For Grades TP304H, TP316H, TP321H, TP347H, TP348H, and S30815, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

18. Government Procurement

18.1 *Scale Free Pipe for Government Procurement*:

18.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry, contract or order, for agencies of the U.S. Government where scale free pipe or tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specifications.

18.1.2 The requirements of Specification A 999/A 999M for pipe and Specification A 450/A 450M for tubes shall be applicable when pipe or tube is ordered to this specification.

18.1.3 Pipe and tube shall be one of the following grades as specified herein:

Grade	UNS Designation
TP304	S30400
TP304L	S30403
TP304N	S30451
TP316	S31600
TP316L	S31603
TP316N	S31651
TP317	S31700
TP317L	S31703
TP321	S32100
TP347	S34700

18.1.4 *Part Number*:

Example: ASTM A 312/A 312M Pipe 304 NPS 12 SCH 40S SMLS

Specification Number	ASTM A 312
Pipe	P
Grade	304
NPS	12
Wall	0.375
SMLS OR WELDED	SML

18.1.4.1

Specification Number	ASTM A 312

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Tube	T
Grade	304
Outside Diameter	0.250
Wall	0.035
SMLS OR WELDED	WLD

18.1.5 *Ordering Information*—Orders for material under this specification shall include the following in addition to the requirements of Section 4:

18.1.5.1 Pipe or tube,

18.1.5.2 Part number,

18.1.5.3 Ultrasonic inspection, if required,

18.1.5.4 If shear wave test is to be conducted in two opposite circumferential directions,

18.1.5.5 Intergranular corrosion test, and

18.1.5.6 Level of preservation and packing required.

19. Keywords

19.1 austenitic stainless steel; seamless steel pipe; stainless steel pipe; steel pipe; welded steel pipe

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe NPS 5 and larger in nominal size there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 7 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This applies only to pipe NPS 8 and larger.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Radiographic Examination

S5.1 The entire length of weld in each double welded pipe shall be radiographically examined, using X-radiation, in accordance with Paragraph UW-51 of Section VIII Division 1 of the ASME Boiler and Pressure Vessel Code. In addition to the marking required by Section 13 each pipe shall be marked "RT" after the specification and grade. Requirements of S5 shall be required in the certification.

S6. Stabilizing Heat Treatment

S6.1 Subsequent to the solution anneal required in 5.3, Grades TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S7. Intergranular Corrosion Test

S7.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S7.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S7.2 A stabilization heat treatment in accordance with Supplementary Requirement S6 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

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S8. Minimum Wall Pipe

S8.1 When specified by the purchaser, pipe shall be furnished on a minimum wall basis. The wall of such pipe shall not fall below the thickness specified. In addition to the marking required by Section 17, the pipe shall be marked S8.

S9. Weld Decay Test

S9.1 When specified in the purchase order, one sample from each lot of pipe shall be subject to testing in a boiling solution of 50 % reagent grade hydrochloric acid and 50 % water.

S9.2 The sample, of approximately 2–in. [50–mm] length, shall be prepared from a production length of pipe. Depending on the size of the pipe, it is permitted to section the sample longitudinally to allow it to fit in the Erlenmeyer flask. As a minimum, the tested sample shall include the entire weld and adjacent area and the full length of base metal 180° across from the weld. All burrs and sharp edges shall be removed by light grinding. Dust and grease shall be removed by cleaning with soap and water or other suitable solvents.

S9.3 The hydrochloric acid solution shall be prepared by slowly adding reagent grade (approximately 37 %) hydrochloric acid to an equal volume of distilled water.

Warning—Protect eyes and use rubber gloves when handling acid. Mixing and testing shall be performed in a protective enclosure.

S9.4 The test container shall be a 1–L Erlenmeyer flask equipped with ground-glass joints and an Ahline condenser. The volume of the solution shall be approximately 700 mL.

S9.5 The thickness of the weld and the base metal 180° from the weld shall be measured near both ends of the sample. These measurements shall be made with a micrometer with an anvil shape suitable for measuring the thickness with an accuracy to at least 0.001 in. [0.025 mm].

S9.6 The sample sections, both weld and base metal, shall be immersed in the flask containing the solution. Boiling chips shall be added and the solution brought to a boil. Boiling shall be maintained through the duration of the test. The time of testing shall be that which is required to remove 40 to 60 % of the original base metal thickness (usually 2 h or less) If more than 60 % of the base metal thickness remains, it is permitted to terminate the test after 24 h.

S9.7 At the end of the test period, the samples shall be removed from the solution, rinsed with distilled water, and dried.

S9.8 The thickness measurements as in S9.5 shall be repeated. The anvil shape of the micrometer used shall be suitable for measuring the minimum remaining thickness with an accuracy to at least 0.001 in. [0.025 mm].

S9.9 The corrosion ratio, R, shall be calculated as follows:

$$R = (W_0 - W) / (B_0 - B)$$

where:

W_0 = average weld-metal thickness before the test,
W = average weld-metal thickness after the test,
B_0 = average base-metal thickness before the test,and
B = average base-metal thickness after the test,

S9.9.1 The corrosion ratio for HCW pipe shall be as specified in 11.4.

S9.9.2 The corrosion ratio shall be 1.25 or less, or as further restricted in the purchase order, when the weld decay test is specified for welded (WLD) pipe.

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APPENDIX

(Nonmandatory Information)

X1. DIMENSIONS OF WELDED AND SEAMLESS STAINLESS STEEL PIPE

X1.1 Table X1.1 is based on Table number 1 of the American National Standard for stainless steel pipe (ANSI B36.19).

TABLE X1.1 Dimensions of Welded and Seamless Stainless Steel Pipe

NOTE 1—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[A]		Schedule 10S[A]		Schedule 40S		Schedule 80S	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
⅛	0.405	10.29	...	...	0.049	1.24	0.068	1.73	0.095	2.41
¼	0.540	13.72	...	...	0.065	1.65	0.088	2.24	0.119	3.02
⅜	0.675	17.15	...	...	0.065	1.65	0.091	2.31	0.126	3.20
½	0.840	21.34	0.065	1.65	0.083	2.11	0.109	2.77	0.147	3.73
¾	1.050	26.67	0.065	1.65	0.083	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065	1.65	0.109	2.77	0.133	3.38	0.179	4.55
1¼	1.660	42.16	0.065	1.65	0.109	2.77	0.140	3.56	0.191	4.85
1½	1.900	48.26	0.065	1.65	0.109	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065	1.65	0.109	2.77	0.154	3.91	0.218	5.54
2½	2.875	73.03	0.083	2.11	0.120	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120	3.05	0.216	5.49	0.300	7.62
3½	4.000	101.60	0.083	2.11	0.120	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109	2.77	0.134	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109	2.77	0.148	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134	3.40	0.165	4.19	0.365	9.27	0.500[B]	12.70[B]
12	12.750	323.85	0.156	3.96	0.180	4.57	0.375[B]	9.52[B]	0.500[B]	12.70[B]
14	14.000	355.60	0.156	3.96	0.188[B]	4.78[B]	...	...	...	...
16	16.000	406.40	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
18	18.000	457.20	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
20	20.000	508.00	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
22	22.000	558.80	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
24	24.000	609.60	0.218	5.54	0.250	6.35	...	...	...	...
30	30.000	762.00	0.250	6.35	0.312	7.92	...	...	...	...

[A] Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).
[B] These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10–1979).

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Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service[1]

This standard is issued under the fixed designation A 333/A 333M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification[2] covers nominal (average) wall seamless and welded carbon and alloy steel pipe intended for use at low temperatures. Several grades of ferritic steel are included as listed in Table 1. Some product sizes may not be available under this specification because heavier wall thicknesses have an adverse affect on low-temperature impact properties.

1.2 Supplementary Requirement S1 of an optional nature is provided. This shall apply only when specified by the purchaser.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe[4]

A 671 Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures[4]

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials[5]

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing[6]

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation[6]

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the material adequately:

3.1.1 Quantity (feet, centimetres, or number of lengths),

3.1.2 Name of material (seamless or welded pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (NPS or outside diameter and schedule number of average wall thickness),

3.1.5 Length (specific or random), (Section 12) (Permissible Variations in Length Section of Specification A 530/A 530M),

3.1.6 End finish (Ends Section of Specification A 530/A 530M),

3.1.7 Optional requirements, (Heat analysis requirement in the Chemical composition Section of A 530/A530M; 4.2.5 stress relieving; 10 repair by welding, 14.1.1 other temperatures for impact test; 15 hydrostatic test or nondestructive electric test),

3.1.8 Test report required, (Certification Section of Specification A 530/A 530M),

3.1.9 Specification designation, and

3.1.10 Special requirements or exceptions to this specification.

4. Materials and Manufacture

4.1 *Manufacture*—The pipe shall be made by the seamless or welding process with the addition of no filler metal in the welding operation. Grade 4 shall be made by the seamless process.

NOTE 2—For electric-fusion-welded pipe, with filler metal added, see Specification A 671.

4.2 *Heat Treatment*:

4.2.1 All seamless and welded pipe, other than Grades 8 and 11, shall be treated to control their microstructure in accordance with one of the following methods:

4.2.1.1 Normalize by heating to a uniform temperature of not less than 1500°F [815°C] and cool in air or in the cooling chamber of an atmosphere controlled furnace.

4.2.1.2 Normalize as in 4.2.1.1, and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

4.2.1.3 For the seamless process only, reheat and control hot

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.10 on Tubing.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-333 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

[6] *Annual Book of ASTM Standards*, Vol 03.03.

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TABLE 1 Chemical Requirements

Element	Composition, %								
	Grade 1[A]	Grade 3	Grade 4	Grade 6[A]	Grade 7	Grade 8	Grade 9	Grade 10	Grade 11
Carbon, max	0.30	0.19	0.12	0.30	0.19	0.13	0.20	0.20	0.10
Manganese	0.40–1.06	0.31–0.64	0.50–1.05	0.29–1.06	0.90 max	0.90 max	0.40–1.06	1.15–1.50	0.60 max
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.035	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.015	0.025
Silicon	...	0.18–0.37	0.08–0.37	0.10 min	0.13–0.32	0.13–0.32	...	0.10–0.35	0.35 max
Nickel	...	3.18–3.82	0.47–0.98	...	2.03–2.57	8.40–9.60	1.60–2.24	0.25 max	35.0–37.0
Chromium	...	...	0.44–1.01	...	...	...	...	0.15 max	0.50 max
Copper	...	...	0.40–0.75	...	...	...	0.75–1.25	0.15 max	...
Aluminum	...	...	0.04–0.30	...	...	...	...	0.06 max	...
Vanadium, max	...	...	...	...	...	...	...	0.12	...
Columbium, max	...	...	...	...	...	...	...	0.05	...
Molybdenum, max	...	...	...	...	...	...	...	0.05	0.50 max
Cobalt	...	...	...	...	...	...	...	...	0.50 max

[A] For each reduction of 0.01 % carbon below 0.30 %, an increase of 0.05 % manganese above 1.06 % would be permitted to a maximum of 1.35 % manganese.

working and the temperature of the hot-finishing operation to a finishing temperature range from 1550 to 1750°F [845 to 945°C] and cool in air or in a controlled atmosphere furnace from an initial temperature of not less than 1550°F [845°C].

4.2.1.4 Treat as in 4.2.1.3 and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

4.2.1.5 Seamless pipe of Grades 1, 6, and 10 may be heat treated by heating to a uniform temperature of not less than 1500°F [815°C], followed by quenching in liquid and reheating to a suitable tempering temperature, in place of any of the other heat treatments provided for in 4.2.1.

4.2.2 Grade 8 pipe shall be heat treated by the manufacturer by either of the following methods:

4.2.2.1 *Quenched and Tempered*—Heat to a uniform temperature of 1475 ± 25°F [800 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; quench by immersion in circulating water. Reheat until the pipe attains a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air or water quench at a rate no less than 300°F [165°C]/h.

4.2.2.2 *Double Normalized and Tempered*— Heat to a uniform temperature of 1650 ± 25°F [900 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat until the pipe attains a uniform temperature of 1450 ± 25°F [790 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat to a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. [2 min/mm] of thickness but in no case less than 15 min; cool in air or water quench at a rate not less than 300°F [165°C]/h.

4.2.3 Whether to anneal Grade 11 pipe is per agreement between purchaser and supplier. When Grade 11 pipe is annealed, it shall be normalized in the range of 1400 to 1600°F [760 to 870°C].

4.2.4 Material from which test specimens are obtained shall be in the same condition of heat treatment as the pipe furnished. Material from which specimens are to be taken shall be heat treated prior to preparation of the specimens.

4.2.5 When specified in the order the test specimens shall be taken from full thickness test pieces which have been stress relieved after having been removed from the heat-treated pipe. The test pieces shall be gradually and uniformly heated to the prescribed temperature, held at that temperature for a period of time in accordance with Table 2, and then furnace cooled at a temperature not exceeding 600°F [315°C]. Grade 8 shall be cooled at a minimum rate of 300°F [165°C]/h in air or water to a temperature not exceeding 600°F [315°C].

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

5.2 When Grades 1, 6, or 10 are ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 is not permitted. However, the addition of elements required for the deoxidation of the steel is permitted.

6. Product Analysis

6.1 At the request of the purchaser, an analysis of one billet or two samples of flat-rolled stock from each heat or of two pipes from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following:

TABLE 2 Stress Relieving of Test Pieces

Metal Temperature[A,B]				Minimum Holding Time, h/in. [min/mm] of Thickness
Grades 1, 3, 6, 7, and 10		Grade 4[C]		
°F	°C	°F	°C	
1100	600	1150	620	1 [2.4]
1050	565	1100	600	2 [4.7]
1000	540	1050	565	3 [7.1]

[A] For intermediate temperatures, the holding time shall be determined by straight-line interpolation.

[B] Grade 8 shall be stress relieved at 1025 to 1085°F, [550 to 585°C], held for a minimum time of 2 h for thickness up to 1.0 in. [25.4 mm], plus a minimum of 1 h for each additional inch [25.4 mm] of thickness and cooled at a minimum rate of 300°F [165°C]/h in air or water to a temperature not exceeding 600°F [315°C].

[C] Unless otherwise specified, Grade 4 shall be stress relieved at 1150°F [620°C].

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NPS Designator	Length of Pipe in Lot
Under 2	400 or fraction thereof
2 to 6	200 or fraction thereof
Over 6	100 or fraction thereof

6.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified.

6.3 If the analysis of one of the tests specified in 6.1 does not conform to the requirements specified, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

7. Tensile Requirements

7.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

8. Impact Requirements

8.1 For Grades 1, 3, 4, 6, 7, 9, and 10, the notched-bar impact properties of each set of three impact specimens, including specimens for the welded joint in welded pipe with wall thicknesses of 0.120 in. [3 mm] and larger, when tested at temperatures in conformance with 14.1 shall be not less than the values prescribed in Table 4. The impact test is not required for Grade 11.

8.1.1 If the impact value of one specimen is below the minimum value, or the impact values of two specimens are less than the minimum average value but not below the minimum value permitted on a single specimen, a retest shall be allowed. The retest shall consist of breaking three additional specimens and each specimen must equal or exceed the required average value. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedures, a retest will be allowed.

8.2 For Grade 8 each of the notched bar impact specimens shall display a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm].

8.2.1 When the average lateral expansion value for the three impact specimens equals or exceeds 0.015 in. [0.38 mm] and the value for one specimen is below 0.015 in. [0.38 mm] but not below 0.010 in. [0.25 mm], a retest of three additional specimens may be made. The lateral expansion of each of the retest specimens must equal or exceed 0.015 in. [0.38 mm].

8.2.2 Lateral expansion values shall be determined by the procedure in Test Methods and Definitions A 370.

8.2.3 The values of absorbed energy in foot-pounds and the fracture appearance in percentage shear shall be recorded for information. A record of these values shall be retained for a period of at least 2 years.

9. Lengths

9.1 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft (Note 3) with 5 % 12 to 16 ft (Note 4), or in double random lengths with a minimum average of 35 ft (Note 4) and a minimum length of 22 ft (Note 4) with 5 % 16 to 22 ft (Note 3).

NOTE 3—This value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and purchaser.

10. Workmanship, Finish, and Appearance

10.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to assure compliance with 11.2.

10.2 Surface imperfections that penetrate more than 12 ½ % of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

10.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

10.2.2 Repaired in accordance with the repair welding provisions of 10.5.

10.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

10.2.4 The defective pipe may be rejected.

10.3 To provide a workmanlike finish and basis for evaluating conformance with 10.2, the pipe manufacturer shall remove by grinding the following:

10.3.1 Mechanical marks, abrasions and pits, any of which imperfections are deeper than 1/16 in. [1.6 mm], and

10.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 10.1 to be deeper than 5 % of the nominal wall thickness.

10.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 10.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

10.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

10.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

10.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 530/A 530M.

10.7 The finished pipe shall be reasonably straight.

11. General Requirements

11.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

12. Mechanical Required

12.1 *Transverse or Longitudinal Tensile Test and Flattening Test*—For material heat treated in a batch-type furnace, tests shall be made on 5 % of the pipe from each lot. When heat treated by the continuous process, tests shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than 2 pipes.

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TABLE 3 Tensile Requirements

	Grade 1		Grade 3		Grade 4		Grade 6		Grade 7		Grade 8		Grade 9		Grade 10		Grade 11	
	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa
Tensile strength, min	55 000	380	65 000	450	60 000	415	60 000	415	65 000	450	100 000	690	63 000	435	80 000	550	65 000	450
Yield strength, min	30 000	205	35 000	240	35 000	240	35 000	240	35 000	240	75 000	515	46 000	315	65 000	450	35 000	240
	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	
Elongation in 2 in. or 50 mm, (or 4D), min, %:																		
Basic minimum elongation for walls 5/16 in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section	35	25	30	20	30	16.5	30	16.5	30	22	22	...	28	...	22	...	18[A]	
When standard round 2-in. or 50-mm gage length or proportionally smaller size test specimen with the gage length equal to 4D (4 times the diameter) is used	28	20	22	14	22	12	22	12	22	14	16	...	...	...	16	...	...	
For strip tests, a deduction for each 1/32 in. [0.8 mm] decrease in wall thickness below 5/16 in. [8 mm] from the basic minimum elongation of the following percentage	1.75[B]	1.25[B]	1.50[B]	1.00[B]	1.50[B]	1.00[B]	1.50[B]	1.00[B]	1.50[B]	1.00[B]	1.25[B]	...	1.50[B]	...	1.25[B]	...	...	

Wall Thickness		Elongation in 2 in. or 50 mm, min, %[C]															
		Grade 1		Grade 3		Grade 4		Grade 6		Grade 7		Grade 8		Grade 9		Grade 10	
in.	mm	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse
5/16 (0.312)	8	35	25	30	20	30	16	30	16	30	22	22	...	28	...	22	...
9/32 (0.281)	7.2	33	24	28	19	28	15	28	15	28	21	21	...	26	...	21	...
1/4 (0.250)	6.4	32	23	27	18	27	15	27	15	27	20	20	...	25	...	20	...
7/32 (0.219)	5.6	30	...	26	...	26	...	26	...	26	...	18	...	24	...	18	...
3/16 (0.188)	4.8	28	...	24	...	24	...	24	...	24	...	17	...	22	...	17	...
5/32 (0.156)	4	26	...	22	...	22	...	22	...	22	...	16	...	20	...	16	...
1/8 (0.125)	3.2	25	...	21	...	21	...	21	...	21	...	15	...	19	...	15	...
3/32 (0.094)	2.4	23	...	20	...	20	...	20	...	20	...	13	...	18	...	13	...
1/16 (0.062)	1.6	21	...	18	...	18	...	18	...	18	...	12	...	16	...	12	...

[A] Elongation of Grade 11 is for all walls and small sizes tested in full section.

[B] The following table gives the calculated minimum values

[C] Calculated elongation requirements shall be rounded to the nearest whole number.

Note—The preceding table gives the computed minimum elongation values for each 1/32-in. [0.80-mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

Grade	Direction of Test	Equation
1	Longitudinal	$E = 56t + 17.50$ [$E = 2.19t + 17.50$]
	Transverse	$E = 40t + 12.50$ [$E = 1.56t + 12.50$]
3	Longitudinal	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32t + 10.00$ [$E = 1.25t + 10.00$]
4	Longitudinal	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32t + 6.50$ [$E = 1.25t + 6.50$]
6	Longitudinal	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32t + 6.50$ [$E = 1.25t + 6.50$]
7	Longitudinal	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32t + 11.00$ [$E = 1.25t + 11.00$]
8 and 10	Longitudinal	$E = 40t + 9.50$ [$E = 1.56t + 9.50$]
9	Longitudinal	$E = 48t + 13.00$ [$E = 1.87t + 13.00$]

where:
E = elongation in 2 in. or 50 mm, in %, and
t = actual thickness of specimen, in. [mm].

NOTE 4—The term "lot" applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace. When final heat treatment is in a batch-type furnace, the lot shall

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TABLE 4 Impact Requirements for Grades 1, 3, 4, 6, 7, 9, and 10

Size of Specimen, mm	Minimum Average Notched Bar Impact Value of Each Set of Three Specimens[A]		Minimum Notched Bar Impact Value of One Specimen Only of a Set[A]	
	ft·lbf	J	ft·lbf	J
10 by 10	13	18	10	14
10 by 7.5	10	14	8	11
10 by 6.67	9	12	7	9
10 by 5	7	9	5	7
10 by 3.33	5	7	3	4
10 by 2.5	4	5	3	4

[A]Straight line interpolation for intermediate values is permitted.

include only that pipe which is heat treated in the same furnace charge.

12.2 *Hydrostatic Test*—Each length of pipe shall be subjected to the hydrostatic test.

12.3 *Impact Test*—One notched bar impact test, consisting of breaking three specimens, shall be made from each heat represented in a heat-treatment load on specimens taken from the finished pipe. This test shall represent only pipe from the same heat and the same heat-treatment load, the wall thicknesses of which do not exceed by more than ¼ in. [6.3 mm] the wall thicknesses of the pipe from which the test specimens are taken. If heat treatment is performed in continuous or batch-type furnaces controlled within a 50°F [30°C] range and equipped with recording pyrometers so that complete records of heat treatment are available, then one test from each heat in a continuous run only shall be required instead of one test from each heat in each heat-treatment load.

12.4 *Impact Tests (Welded Pipe)*—On welded pipe, additional impact tests of the same number as required in 12.2 or 12.3 shall be made to test the weld.

12.5 Specimens showing defects while being machined or prior to testing may be discarded and replacements shall be considered as original specimens.

12.6 Results obtained from these tests shall be reported to the purchaser or his representative.

13. Specimens for Impact Test

13.1 Notched bar impact specimens shall be of the simple beam, Charpy-type, in accordance with Test Methods E 23, Type A with a V notch. Standard specimens 10 by 10 mm in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable subsize specimens shall be used. Charpy specimens of width along the notch larger than 0.394 in. [10 mm] or smaller than 0.099 in. [2.5 mm] are not provided for in this specification.

13.2 Test specimens shall be obtained so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the pipe while the axis of the notch shall be perpendicular to the surface. On wall thicknesses of 1 in. [25 mm] or less, the specimens shall be obtained with their axial plane located at the midpoint; on wall thicknesses over 1 in. [25 mm], the specimens shall be obtained with their axial plane located ½ in. [12.5 mm] from the outer surface.

13.3 When testing welds the specimen shall be, whenever diameter and thickness permit, transverse to the longitudinal axis of the pipe with the notch of the specimen in the welded joint and perpendicular to the surface. When diameter and thickness do not permit obtaining transverse specimens, longitudinal specimens in accordance with 13.2 shall be obtained; the bottom of the notch shall be located at the weld joint.

14. Impact Test

14.1 Except when the size of the finished pipe is insufficient to permit obtaining subsize impact specimens, all material furnished to this specification and marked in accordance with Section 16 shall be tested for impact resistance at the minimum temperature for the respective grades as shown in Table 5.

14.1.1 Special impact tests on individual lots of material may be made at other temperatures as agreed upon between the manufacturer and the purchaser.

14.1.2 When subsize Charpy impact specimens are used and the width along the notch is less than 80 % of the actual wall thickness of the original material, the specified Charpy impact test temperature for Grades 1, 3, 4, 6, 7, 9, and 10 shall be lower than the minimum temperature shown in Table 5 for the respective grade. Under these circumstances the temperature reduction values shall be by an amount equal to the difference (as shown in Table 6) between the temperature reduction corresponding to the actual material thickness and the temperature reduction corresponding to the Charpy specimen width actually tested. Appendix X1 shows some examples of how the temperature reductions are determined.

14.2 The notched bar impact test shall be made in accordance with the procedure for the simple beam, Charpy-type test of Methods E 23.

14.3 Impact tests specified for temperatures lower than 70°F [20°C] should be made with the following precautions. The impact test specimens as well as the handling tongs shall be cooled a sufficient time in a suitable container so that both reach the desired temperature. The temperature shall be measured with thermocouples, thermometers, or any other suitable devices and shall be controlled within 3°F [2°C]. The specimens shall be quickly transferred from the cooling device to the anvil of the Charpy impact testing machine and broken with a time lapse of not more than 5 s.

15. Hydrostatic or Nondestructive Electric Test

15.1 Each pipe shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise

TABLE 5 Impact Temperature

Grade	Minimum Impact Test Temperature	
	°F	°C
1	−50	−45
3	−150	−100
4	−150	−100
6	−50	−45
7	−100	−75
8	−320	−195
9	−100	−75
10	−75	−60

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TABLE 6 Impact Temperature Reduction

Specimen Width Along Notch or Actual Material Thickness		Temperature Reduction, Degrees Colder[A]	
in.	mm	°F	°C
0.394	10 (standard size)	0	0
0.354	9	0	0
0.315	8	0	0
0.295	7.5 (3/4 std. size)	5	3
0.276	7	8	4
0.262	6.67 (2/3 std. size)	10	5
0.236	6	15	8
0.197	5 (1/2 std. size)	20	11
0.158	4	30	17
0.131	3.33 (1/3 std. size)	35	19
0.118	3	40	22
0.099	2.5 (1/4 std. size)	50	28

[A]Straight line interpolation for intermediate values is permitted.

specified in the purchase order.[7]

15.2 The hydrostatic test shall be in accordance with Specification A 530/A 530M.

15.3 *Nondestructive Electric Test*:

Nondestructive electric tests shall be in accordance with Practice E 213 or E 309. Unless specifically called out in the purchase order, the selection of the nondestructive electric test will be at the option of the manufacturer. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

15.3.1 The following information is for the benefit of the user of this specification:

15.3.2 The reference standards defined in 15.3.3 through are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

15.3.3 The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep, defects.

15.3.4 The eddy-current testing (ET) referenced in this specification. (Practice E 309), has the capability of detecting significant discontinuities, especially the short abrupt type.

15.3.5 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

15.4 *Time of Examination*:

15.4.1 Nondestructive testing for specification acceptance shall be performed after all mechanical processing, heat treatments, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

15.5 *Surface Condition*:

15.5.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

15.5.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

15.6 *Extent of Examination*:

15.6.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except as in

15.6.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

15.7 *Operator Qualifications*:

15.7.1 The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent recognized and documented standard.

15.8 *Test Conditions*:

15.8.1 For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide good signal-to-noise ratio.

15.8.2 The maximum eddy-current coil frequency used shall be as follows:

On specified walls up to 0.050 in.—100 KHz max
On specified walls up to 0.150 in.—50 KHz max
On specified above 0.150 in.—10 KHz max

15.8.3 *Ultrasonic*—For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.00 MHz and the maximum nominal transducer size shall be 1.5 in.

(1) If the equipment contains a reject notice filter setting, this shall remain off during calibration and testing unless linearity can be demonstrated at that setting.

15.9 *Reference Standards*:

15.9.1 Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS, or outside diameter and schedule or wall thickness), surface finish and heat treatment condition as the pipe to be examined.

15.9.2 *For Ultrasonic Testing*, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of each notch shall not exceed 12½ % of the specified nominal wall thickness of the pipe or 0.004 in., whichever is greater. The width of the notch shall not exceed twice the depth. Notches shall be placed on both the OD and ID surfaces.

15.9.3 *For Eddy-Current Testing*, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

(1) Drilled Hole—The reference standard shall contain three or more holes, equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. One hole shall be drilled in the weld, if visible. Alternately, the producer of welded pipe may choose to drill one hole in the weld and run the calibration standard through

[7] Society for Nondestructive Testing, 1711 Arlingate Plaza, PO Box 28518, Columbus, OH, 43228-0518.

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the test coils three times with the weld turned at 120° on each pass. The hole diameter shall vary with NPS as follows:

NPS Designator	Hole Diameter
½	0.039 in. (1 mm)
above ½ to 1¼	0.055 in. (1.4 mm)
above 1¼ to 2	0.071 in. (1.8 mm)
above 2 to 5	0.067 in. (2.2 mm)
above 5	0.106 in. (2.7 mm)

(2) Transverse Tangential Notch—Using a round tool or file with a ¼in. (6.4 mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding 12½ % of the specified nominal wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

(3) Longitudinal Notch—A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12½ % of the specified wall thickness of the pipe or 0.004 in., whichever is greater. The length of the notch shall be compatible with the testing method.

15.9.4 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

15.10 *Standardization Procedure*:

15.10.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness). Grade and heat treatment condition, and at intervals not exceeding 4 h. More frequent standardization may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

15.10.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss, process shutdown or when a problem is suspected.

15.10.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the pipe to be tested.

15.10.4 The signal-to-noise ratio for the reference standard shall be 2½ to 1 or greater. Extraneous signals caused by identifiable causes such a dings, scratches, dents, straightener marks, etc., shall not be considered noise. The rejection amplitude shall be adjusted to be at least 50 % of full scale of the readout display.

15.10.5 Upon any standardization, the rejection amplitude has decreased by 29 % (3 dB) of peak height from the last standardization, the pipe since the last calibration shall be rejected. The test system settings may be changed, or the transducer(s), coil(s) or sensor(s) adjusted, and the unit restandardized, but all pipe tested since the last acceptable standardization must be retested for acceptance.

15.11 *Evaluation of Imperfections*:

15.11.1 Pipes producing a signal equal to or greater than the lowest signal produced by the reference standard(s) shall be identified and separated from the acceptable pipes. The area producing the signal may be reexamined.

15.11.2 Such pipes shall be rejected if the test signal was produced by imperfections that cannot be identified or was produced by cracks or crack-like imperfections. These pipes may be repaired per Sections 11 and 12. To be accepted, a repaired pipe must pass the same non-destructive test by which it was rejected, and it must meet the minimum wall thickness requirements of this specification.

15.11.3 If the test signals were produced by visual imperfections such as in the following:

15.11.3.1 Scratches,
15.11.3.2 Surface roughness,
15.11.3.3 Dings,
15.11.3.4 Straightener marks,
15.11.3.5 Cutting chips,
15.11.3.6 Steel die stamps,
15.11.3.7 Stop marks, or
15.11.3.8 Pipe reducer ripple.

The pipe may be accepted based on visual examination provided the imperfection is less than 0.004 in. (0.1 mm) or 12½ % of the specified wall thickness (whichever is greater).

15.11.4 Rejected pipe may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed. To be accepted, retested pipe shall meet the test requirement.

If the imperfection is explored to the extent that it can be identified as non-rejectable, the pipe may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness.

16. Product Marking

16.1 Except as modified in 15.1.1, in addition to the marking prescribed in Specification A 530/A 530M, the marking shall include whether hot finished, cold drawn, seamless or welded, the schedule number and the letters "LT" followed by the temperature at which the impact tests were made, except when a lower test temperature is required because of reduced specimen size, in which case, the higher impact test temperature applicable to a full-size specimen should be marked.

16.1.1 When the size of the finished pipe is insufficient to obtain subsize impact specimens, the marking shall not include the letters LT followed by an indicated test temperature unless Supplementary Requirement S1 is specified.

16.1.2 When the pipe is furnished in the quenched and tempered condition, the marking shall include the letters "QT", and the heat treatment condition shall be reported to the purchaser or his representative.

17. Keywords

17.1 low temperature service; seamless steel pipe; stainless steel pipe; steel pipe; temperature service applications; low

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SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the contract or order.

S1. Subsize Impact Specimens

S1.1 When the size of the finished pipe is insufficient to permit obtaining subsize impact specimens, testing shall be amatter of agreement between the manufacturer and the purchaser.

APPENDIX

(Nonmandatory Information)

X1. DETERMINATION OF TEMPERATURE REDUCTIONS

X1.1 Under the circumstances stated in 14.1.2, the impact test temperatures specified in Table 5 must be lowered. The following examples are offered to describe the application of the provisions of 14.1.2.

X1.1.1 When subsize specimens are used (see 10.1) and the width along the notch of the subsize specimen in 80 % or greater of the actual wall thickness of the original material, the provisions of 14.1.2 do not apply.

X1.1.1.1 For example, if the actual wall thickness of pipe was 0.200 in. [5.0 mm] and the width along the notch of the largest subsize specimen obtainable is 0.160 in. [4 mm] or greater, no reduction in test temperature is required.

X1.1.2 When the width along the subsize specimen notch is less than 80 % of the actual wall thickness of the pipe, the required reduction in test temperature is computed by taking the difference between the temperature reduction values shown in Table 6 for the actual pipe thickness and the specimen width used.

X1.1.2.1 For example, if the pipe were 0.262 in. [6.67 mm] thick and the width along the Charpy specimen notch was 3.33 mm (1/3 standard size), the test temperature would have to be lowered by 25°F [14°C]. That is, the temperature reduction corresponding to the subsize specimen is 35°F [19°C]; the temperature reduction corresponding to the actual pipe thickness is 10°F [5°C]; the difference between these two values is the required reduction in test temperature.

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Designation: A 351/A 351M – 00

An American National Standard
Used in USDOE-NE Standards

Standard Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts[1]

This standard is issued under the fixed designation A 351/A 351M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification[2] covers austenitic and austenitic-ferritic (duplex) steel castings for valves, flanges, fittings, and other pressure-containing parts (Note 1).

NOTE 1—Carbon steel castings for pressure-containing parts are covered by Specification A 216/A 216M, and low-alloy steel castings by Specification A 217/A 217M.

1.2 A number of grades of austenitic and austenitic-ferritic steel castings are included in this specification. Since these grades possess varying degrees of suitability for service at high temperatures or in corrosive environments, it is the responsibility of the purchaser to determine which grade shall be furnished. Selection will depend on design and service conditions, mechanical properties, and high-temperature or corrosion-resistant characteristics, or both.

1.2.1 Because of thermal instability, Grades CE20N, CF3A, CF3MA, and CF8A are not recommended for service at temperatures above 800°F [425°C].

1.2.2 Because of embrittlement phases, Grade CD4MCu is not recommended for service at temperatures above 600°F [316°C].

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service[3]

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service[3]

A 488/A 488M Practice for Steel Castings, Welding, Qualification of Procedures and Personnel[3]

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts[3]

E 165 Test Method for Liquid Penetrant Examination[4]

E 709 Guide for Magnetic Particle Examination[4]

2.2 *Manufacturers Standardization Society of the Valve and Fittings Industry Standard:*

SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Components (Visual Method)[5]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

3.2 The post weld heat treatment requirements of Supplementary Requirement S11 may be specified when austenitic castings other than HK, HT, or CT15C are to be subjected to severe corrosive service.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 Supplementary requirements desired, including the standards of acceptance.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-351/SA-351M in Section II of that code.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] Available from Manufacturers' Standardization Society of the Valve and Fittings Industry, 1815 N. Fort Myer Drive, Arlington, VA 22209.

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5. Process

5.1 The steel shall be made by the electric furnace process with or without separate refining such as argon-oxygen decarburization (AOD).

6. Heat Treatment

6.1 All castings shall receive a heat treatment at the temperature specified in Table 1, followed by a quench in water or rapid cool by other means except as noted.

NOTE 2—Proper heat treatment of these alloys is usually necessary to enhance corrosion resistance and in some cases to meet mechanical properties. Minimum heat-treat temperatures are specified; however, it is sometimes necessary to heat-treat at higher temperatures, hold for some minimum time at temperature and then rapidly cool the castings in order to enhance the corrosion resistance and meet mechanical properties.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

8. Tensile Properties

8.1 Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Table 3.

TABLE 1 Heat-Treatment Requirements

Grade	Temperature, min	
	°F	°C
HK30, HK40, HT30, CT15C	as-cast	as-cast
CF3, CF3A, CF8, CF8A, CF3M, CF3MA, CF8M, CF3MN, CG3M, CF10, CF10M, CG8M, CD4MCu	1900	1040
CF10SMnN, CF8C, CF10MC	1950	1065
CD3MWCuN	2010	1100
CN7M, CG6MMN, CE8MN	2050	1120
CK3MCuN, CN3MN, CH8, CH10, CH20, CK20	2100	1150
CE20N[A]	2225	1220

[A]Grade shall be quenched in water or the castings may be furnace cooled to 2050°F [1120°C] minimum, held for 15 min minimum and then quenched in water or rapidly cooled by other means.

9. Quality

9.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP 55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

9.2 When additional inspection is desired, Supplementary Requirements S5, S6, and S10 may be ordered.

9.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

10. Repair by Welding

10.1 Repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

10.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2}[65 cm^2], shall be radiographed to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S6 specified, weld repairs shall be inspected by liquid penetrant examination to the same standards that are used to inspect the castings.

NOTE 3—When austenitic steel castings are to be used in services where they will be subject to stress corrosion, the purchaser should so indicate in his order and such castings should be solution-heat treated following all weld repairs.

11. Keywords

11.1 austenitic stainless steel; duplex stainless steel; pressure containing parts; stainless steel; steel castings

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TABLE 2 Chemical Requirements

NOTE 1—Tungsten is a new element for Table 2.

Element, % (max, except where range is given)	CF3, CF3A	CF8, CF8A	CF3M, CF-3MA	CF8M	CF3MN	CF8C	CF10	CF-10M (J92-901)	CH8	CH10	CH20	CK20	HK30	HK40	HT30	CF-10MC	CN7M	CN-3MN	CD-4MCu	CE8MN	CG-6MMN	CG8M	CF10S-MnN	CT15C	CK-3MCuN	CE20N	CG-3M (J92-999)	CD3M-WCuN[A]
Carbon	0.03	0.08	0.03	0.08	0.03	0.08	0.04–0.10	0.04–0.10	0.08	0.04–0.10	0.04–0.20	0.04–0.20	0.25–0.35	0.35–0.45	0.25–0.35	0.10	0.07	0.03 max	0.04	0.08	0.06	0.08	0.10	0.05–0.15	0.025	0.20	0.03	0.03
Manganese	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	2.00	1.50	1.50	2.00 max	1.00	1.00	4.00–6.00	1.50	7.00–9.00	0.15–1.50	1.20	1.50	1.50	1.00
Silicon	2.00	2.00	1.50	1.50	1.50	2.00	2.00	1.50	1.50	2.00	2.00	1.75	1.75	1.75	2.50	1.50	1.50	1.00 max	1.00	1.50	1.00	1.50	3.50–4.50	0.50–1.50	1.00	1.50	1.50	1.00
Sulfur	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.010 max	0.04	0.040	0.030	0.04	0.030	0.03	0.010	0.040	0.04	0.025
Phosphorus	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040 max	0.04	0.040	0.040	0.04	0.060	0.03	0.045	0.040	0.04	0.030
Chromium	17.0–21.0	18.0–21.0	17.0–21.0	18.0–21.0	17.0–21.0	18.0–21.0	18.0–21.0	18.0–21.0	22.0–26.0	22.0–26.0	22.0–26.0	23.0–27.0	23.0–27.0	23.0–27.0	13.0–17.0	15.0–18.0	19.0–22.0	20.0–22.0	24.5–26.5	22.5–25.5	20.50–23.50	18.0–21.0	16.0–18.0	19.0–21.0	19.5–20.5	23.0–26.0	18.0–21.0	24.0–26.0
Nickel	8.0–12.0	8.0–11.0	9.0–13.0	9.0–12.0	9.0–13.0	9.0–12.0	8.0–11.0	9.0–12.0	12.0–15.0	12.0–15.0	12.0–15.0	19.0–22.0	19.0–22.0	19.0–22.0	33.0–37.0	13.0–16.0	27.5–30.5	23.5–25.5	4.75–6.00	8.0–11.0	11.50–13.50	9.0–13.0	8.0–9.0	31.0–34.0	17.5–19.5	8.0–11.0	9.0–13.0	6.5–8.5
Molybdenum	0.50	0.50	2.0–3.0	2.0–3.0	2.0–3.0	0.50	0.50	2.0–3.0	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1.75–2.25	2.0–3.0	6.0–7.0	1.75–2.25	3.0–4.5	1.50–3.00	3.0–4.0	...	...	6.0–7.0	0.50	3.0–4.0	3.0–4.0
Columbium (niobium)	...	...	...	...	...	[B]	...	...	...	...	...	...	...	...	...	[C]	...	...	...	...	0.10–0.30	...	...	0.50–1.50	...	...	...	...
Vanadium	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.10–0.30	...	...	...	...	...	...	...
Nitrogen	...	...	...	...	0.10–0.20	...	...	...	...	...	...	...	...	...	...	...	...	0.18–0.26	...	0.10–0.30	0.20–0.40	...	0.08–0.18	...	0.18–0.24	0.08–0.20	...	0.20–0.30
Copper	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3.0–4.0	0.75 max	2.75–3.25	...	...	...	...	...	0.50–1.00	...	...	0.5–1.0
Tungsten	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.5–1.0
Iron	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Bal	...	...

[A] % Cr + 3.3 % Mo + 16 % N ≥ 40.
[B] Grade CF8C shall have a columbium content of not less than 8 times the carbon content but not over 1.00 %.
[C] Grade CF10MC shall have a columbium content of not less than 10 times the carbon content but not over 1.20 %.

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TABLE 3 Tensile Requirements

	CF3	CF-3A	CF8	CF-8A	CF-3M	CF-3MA	CF-8M	CF-3MN	CF-8C	CF10	CF-10M (J92-901)	CH8	CH10	CH20	CK20	HK30	HK40	HT30	CF-10MC	CN-7M	CN-3MN	CD-4MCu	CE-8MN	CG 6M-MN	CG-8M	CF10S-MnN	CT-15C	CK-3M-CuN	CE20N	CG-3M (J92-999)	CD3M-WCuN
Tensile strength, min, ksi [MPa]	70 [485]	77 [530]	70 [485]	77 [530]	70 [485]	80 [550]	70 [485]	75 [515]	70 [485]	70 [485]	70 [485]	65 [450]	70 [485]	70 [485]	65 [450]	65 [450]	62 [425]	65 [450]	70 [485]	62 [425]	80 [550]	100 [690]	95 [655]	85 [585]	75 [515]	85 [585]	63 [435]	80 [550]	80 [550]	75 [515]	100 (700)
Yield strength,[A] min, ksi [MPa]	30 [205]	35 [240]	30 [205]	35 [240]	30 [205]	37 [255]	30 [205]	37 [255]	30 [205]	30 [205]	30 [205]	28 [195]	30 [205]	30 [205]	28 [195]	35 [240]	35 [240]	28 [195]	30 [205]	25 [170]	38 [260]	70 [485]	65 [450]	42.5 [295]	35 [240]	42.5 [295]	25 [170]	38 [260]	40 [275]	35 [240]	65 (450)
Elongation in 2 in. or 50 mm,[B] min, %	35.0	35.0	35.0	35.0	30.0	30.0	30.0	35.0	30.0	35.0	30.0	30.0	30.0	30.0	30.0	10.0	10.0	15.0	20.0	35.0	35	16.0	25.0	30.0	25.0	30.0	20.0	35	30.0	25	25.0
Reduction of area, min,%	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

[A] Determine by the 0.2 % offset method.
[B] When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S2. Destruction Tests

S5. Radiographic Inspection

S6. Liquid Penetrant Inspection

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 165 or Practice E 709.

S11. Post Weld Heat Treatment

S11.1 All austenitic castings, except Grades HK, HT, and CT15C, which have been subjected to weld repairs, shall be given a post weld solution heat treatment.

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Designation: A 587 – 96

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Standard Specification for Electric-Resistance-Welded Low-Carbon Steel Pipe for the Chemical Industry[1]

This standard is issued under the fixed designation A 587; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification[2] covers electric-resistance-welded low-carbon steel pipe intended for use as process lines.

1.2 Pipe ordered under this specification shall be suitable for severe forming operations involving flanging in all sizes and bending to close radii up to and including NPS 4.

1.3 This specification covers NPS ½ through 10, plus additional sizes. The corresponding outside diameters and wall thicknesses for NPS ½ through 10 are listed in Table 1, as are the dimensions for the additional sizes.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.4 The values stated in inch-pound units are to be regarded as the standard.

1.5 The following precautionary caveat pertains only to the test method portion, Sections 6, 12, and 13, of this specification: *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless[3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[4]

A 530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe[3]

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[3]

E 213 Practice for Ultrasonic Inspection of Metal Pipe and Tubing[5]

E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing[5]

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation[5]

E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products[5]

3. Ordering Information

3.1 Orders for material under this specification should include the following as required to describe the desired material adequately:

3.1.1 Quantity (feet or number of pieces),

3.1.2 Name of material (electric-resistance-welded steel pipe),

3.1.3 Size (NPS or outside diameter and wall thickness),

3.1.4 Length (definite cut length or random),

3.1.5 Test report required (see 14.2),

3.1.6 Specification number, and

3.1.7 Special requirements.

4. Materials and Manufacture

4.1 *Process*—The steel shall be aluminum killed steel made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

4.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

4.3 *Manufacture*—The pipe shall be made by electric resistance welding.

4.4 *Heat Treatment*—Pipe furnished in the as-welded condition shall be normalized at a temperature above the upper critical temperature. Cold-drawn pipe shall be normalized after the final cold-draw pass.

5. Chemical Composition

5.1 *Heat Analysis*—An analysis of each heat of steel shall be made to determine the percentages of the elements specified. The chemical composition thus determined shall conform

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys, and is the direct responsibility of Subcommittee A01.09 on Carbon Steel Tubular Products.

Current edition approved Oct. 10, 1996. Published October 1997. Originally published as A 587 – 68. Last previous edition A 587 – 93.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-587 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

[4] *Annual Book of ASTM Standards*, Vol 01.03.

[5] *Annual Book of ASTM Standards*, Vol 03.03.

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TABLE 1 Tolerance for Outside Diameter and Wall Thickness

NPS Designator	Outside Diameter	Wall Thickness					
		Min	Nom	Max	Min	Nom	Max
		Inches					
—	0.8125 ± 0.004	0.095	0.103	0.111	0.129	0.140	0.151
½	0.840 ± 0.006	0.095	0.103	0.111	0.125	0.140	0.151
¾	1.050 ±0.006	0.099	0.108	0.117	0.135	0.147	0.159
—	1.0625 ± 0.006	0.099	0.108	0.117	0.135	0.147	0.159
—	1.3125 ± 0.006	0.116	0.126	0.136	0.157	0.171	0.185
1	1.315 ± 0.006	0.116	0.126	0.136	0.157	0.171	0.185
1 ¼	1.660 ± 0.007	0.121	0.132	0.143	0.167	0.182	0.197
—	1.875 ± 0.008	0.127	0.138	0.149	0.175	0.190	0.205
1 ½	1.900 ± 0.008	0.127	0.158	0.149	0.175	0.190	0.205
2	2.375 ± 0.010	0.135	0.147	0.159	0.191	0.208	0.225
3	3.500 ± 0.015	0.189	0.206	0.223	0.262	0.286	0.310
4	4.500 ± 0.017	0.207	0.226	0.245	0.295	0.322	0.349
6	6.625 ± .030	0.245	0.267	0.289	0.378	0.412	0.446
8	8.625 ± .040	0.282	0.308	0.334	0.438	0.478	0.518
10	10.750 ± .050	0.319	0.348	0.377	0.520	0.567	0.614
		Millimetres					
—	20.64 ± 0.10	2.41	2.62	2.82	3.28	3.56	3.84
½	21.30 ± 0.15	2.41	2.62	2.82	3.28	3.56	3.84
¾	26.70 ± 0.15	2.51	2.74	2.97	3.43	3.73	4.04
—	26.99 ± 0.15	2.51	2.74	2.97	3.43	3.73	4.04
—	33.34 ± 0.15	2.95	3.20	3.45	3.99	4.34	4.70
1	33.40 ± 0.15	2.95	3.20	3.45	3.99	4.34	4.70
1 ¼	42.16 ± 0.18	3.07	3.35	3.63	4.24	4.62	5.00
—	47.63 ± 0.20	3.22	3.51	3.78	4.45	4.83	5.21
1 ½	48.30 ± 0.020	3.22	3.51	3.78	4.45	4.83	5.21
2	60.33 ± 0.25	3.43	3.73	4.04	4.85	5.28	5.72
3	88.90 ± 0.38	4.80	5.23	5.66	6.66	7.26	7.87
4	114.30 ± 0.43	5.26	5.74	6.22	7.49	8.18	8.87
6	168.28 ± 0.76	6.22	9.32	7.34	9.60	10.47	11.33
8	219.08 ± 1.02	7.16	7.82	8.48	11.13	12.14	13.16
10	273.05 ± 1.27	8.10	8.84	9.58	13.21	14.40	15.60

to the requirements specified in Table 2 and the chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

5.2 *Product Analysis*—When requested on the purchase order, a product analysis shall be made by the supplier from one pipe or coil of steel per heat. The chemical composition thus determined shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Table 2.

5.3 *Retests*—If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or pipe shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise, all remaining material in the heat shall be rejected or, at the option of the producer, each length of flat-rolled stock or pipe may be individually tested for acceptance. Lengths of flat-rolled stock or pipe which do not meet the requirements of the specification shall be rejected.

5.4 Supplying an alloy grade of steel that specifically requires the addition of any element other than those listed in Table 2 is not permitted.

TABLE 2 Chemical Composition Requirements

Element	Composition, %
Carbon, max	0.15
Manganese	0.27–0.63
Phosphorus, max	0.035
Sulfur, max	0.035
Aluminum	0.02–0.100

6. Mechanical Requirements

6.1 *Tensile Properties*:

6.1.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

6.1.2 The yield strength shall be determined by the drop of the beam, by the halt in the gage of the testing machine, by the use of dividers, or by other approved methods. When a definite yield point is not exhibited, the yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen, or to a total extension of 0.5 % of the gage length under load, shall be determined.

6.1.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than ¾ in. (19 mm) from the center of the gage length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

6.2 *Flattening Test*:

6.2.1 A section of pipe not less than 4 in. (102 mm) in length shall be flattened cold between parallel plates in two steps. The weld shall be placed 90° from the direction of the applied force. During the first step, which is a test for ductility, no cracks or breaks, except as provided for in 6.2.5, shall occur on the inside or outside surfaces until the distance between the

TABLE 3 Tensile Requirements

Tensile strength, min, psi (MPa)	48 000 (331)
Yield strength, min, psi (MPa)	30 000 (207)
Elongation in 2 in. or 50 mm, min, %	40

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plates is less than the value of H, calculated by the following equation:

$$H = [(1 + e)t]/[e + t/D]$$

where:

H = distance between flattening plates, in.,
t = specified wall thickness of the pipe, in.,
D = specified outside diameter of the pipe, in., and
e = deformation per unit length (0.09 for low-carbon steel).

6.2.2 During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

6.2.3 Surface imperfections in the test specimens before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

6.2.4 Superficial ruptures resulting from surface imperfections shall not be cause for rejection.

6.2.5 When low D-to-t ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than 10.

6.3 *Reverse Flattening Test*—A section 4 in. (102 mm) in length of pipe in sizes down to and including 1 3/16 in. (20.6 mm) in outside diameter shall be split longitudinally 90° on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There shall be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

6.4 *Flange Test*—A section of pipe not less than 4 in. (102 mm) in length shall be capable of having a flange turned over at a right angle to the body of the pipe without cracking or showing flaws. This flange, as measured from the outside of the pipe, shall be not less than ⅛ in. (3.2 mm) nor more than ½ in. (12.7 mm). Within these limits, the width of the flange shall be not less than the percentages specified in Table 4.

7. Dimensions and Permissible Variations

7.1 *Permissible Variations in Outside Diameter and Wall Thickness*—The outside diameter and wall thickness variations shall not exceed the limits prescribed in Table 1.

7.2 *Permissible Variations in Straightness*—Each pipe shall be straight within 0.030 in. (0.76 mm) maximum deflection in any 3 ft (0.91 m) length to 8 NPS. For 8 NPS and above, pipe shall be straight within 0.060 in. (1.52 mm) maximum deflection in any 3 ft (0.91 m) length. Galvanized pipe shall be reasonably straight.

7.3 *Lengths*:

7.3.1 Pipe may be ordered in definite cut lengths or in random lengths as provided herein.

TABLE 4 Flange Requirements

Outside Diameter of Pipe, in.	Width of Flange, % of OD
Over ¾ to 2 ½, incl	15
Over 2 ½ to 3 ¾, incl	12 ½
Over 3 ¾ to 4 ½, incl	10
Over 4 ½ to 6 ⅝, incl	7 ½
Over 6 ⅝	5

7.3.2 When ordered in definite cut lengths, the variation in length shall not exceed the amounts prescribed in Table 5.

7.3.3 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft (4.9 to 6.7 m) with 5 % 12 to 16 ft (3.7 to 4.9 m), or in double random lengths with a minimum average of 35 ft (10.7 m) and a minimum length of 22 ft (6.7 m) with 5 % 16 to 22 ft (4.9 to 6.7 m).

8. Workmanship, Finish, and Appearance

8.1 The finished pipe shall be free of injurious defects and shall have a workman-like finish. Minor defects may be removed by grinding, provided the wall thickness is not reduced to less than the minimum thickness permitted for the ordered nominal wall thickness.

8.2 The pipe shall have smooth ends free of burrs and free of scale except that the pipe may have a superficial "blue" oxide film on the surfaces.

8.3 For NPS ½to 1½ inclusive, the inside diameter welding flash shall be removed so that the remaining flash does not exceed 0.006 in. (0.15 mm). For NPS over 1½, the remaining inside diameter welding flash shall not exceed 0.010 in. (0.25 mm).

8.4 For all nominal sizes, the outside diameter welding flash shall be removed flush with the outside diameter contour.

8.5 Undercut flash must be smoothly blended into the pipe wall.

8.6 The intent of the flash conditions as prescribed in 8.3, 8.4, and 8.5 is to obtain a surface contour suitable for flanging.

9. Number of Tests

9.1 Two tensile tests as specified in 6.1 shall be made from each heat.

9.2 The flattening test as specified in 6.2 shall be made on two lengths of pipe from each lot of 250 lengths or fraction thereof.

9.3 The reverse flattening test specified in 6.3 shall be made on one length of pipe from each lot of 250 lengths or fraction thereof.

9.4 The flange test as specified in 6.4 shall be made on specimens from two lengths of pipe from each lot of 250 lengths or fraction thereof.

10. Retests

10.1 If the results of the mechanical tests of any heat or lot do not conform to the requirements specified, retests may be made on additional pipe of double the original number from the same heat or lot, each of which shall conform to the requirements specified.

11. Retreatment

11.1 If a heat or lot fails to conform to the test requirements,

TABLE 5 Permissible Variations in Length[A]

Outside Diameter, in.	Cut Length, in. (mm) Over	Under
Under 2	⅛ (3.2)	0
2 and over	3/16 (4.8)	0

[A]These permissible variations in length apply to pipe before bending. They apply to cut lengths up to and including 24 ft (7.3 m). For lengths over 24 ft, an additional over-tolerance of ⅛ in. for each 10 ft (3.0 m) or fraction thereof shall be permissible, up to a maximum of ½ in. (12.7 mm).

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that heat or lot may be reheat treated and resubmitted for tests. Not more than one reheat treatment shall be permitted.

12. Test Specimens and Methods of Testing

12.1 The test specimens and the tests required by this specification shall conform to those described in Test Methods and Definitions A 370.

12.2 Test specimens shall be taken from the ends of finished pipe prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free from burrs and flaws.

12.3 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

13. Nondestructive Test

13.1 The nondestructive test shall be made instead of the hydrostatic test.

13.1.1 The test shall provide a 360° inspection for sizes up to and including 3½ in. (88.9 mm) outside diameter.

13.1.2 For pipe larger than 3½ in. (88.9 mm) outside diameter, nondestructive inspection of the weld and heat affected zone is required.

13.2 Each pipe shall be tested with a nondestructive test in accordance with Practices E 213, E 273, E 309, or E 570. Except as provided in 13.6.2, it is the intent of this test to reject pipe with imperfections that produce test signals equal to or greater than that of the calibration standard. In order to accommodate the various types of nondestructive testing equipment and techniques in use, and manufacturing practices employed, any one of the following calibration standards may be used, at the option of the producer, to establish a minimum sensitivity level for rejection:

13.3 For eddy-current testing, the calibration pipe shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection. For welded pipe, they shall be placed in the weld if visible.

13.3.1 *Drilled Hole*—A hole not larger than 0.031 in. (0.79 mm) in diameter shall be drilled radially and completely through the pipe wall, taking care to avoid distortion of the pipe while drilling.

13.3.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼-in. 6.4 mm diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe, preferably in the weld area. Said notch shall have a depth not exceeding 12½ % of the specified wall thickness of the pipe or 0.004 in. (0.10 mm), whichever is greater.

13.3.3 *Longitudinal Notch*—A notch 0.031 in. (0.79 mm) or less in width shall be machined in a radial plane parallel to the pipe axis on the outside surface of the pipe, to a depth not exceeding 12½ % of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

13.4 For ultrasonic testing, the longitudinal calibration reference notches shall be at the option of the producer, any one of the three common notch shapes shown in Practices E 213 or E 273. The depth of the notch shall not exceed 12½ % of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater. For welded pipe, the notch shall be placed in the weld, if visible.

13.5 For flux leakage testing, each of the longitudinal calibration notches shall be a straight sided notch not over 12½ % of the wall thickness in depth and not over 1.0 in. (25 mm) in length. Both outside diameter and inside diameter notches shall be placed in the tube located sufficiently apart to enable separation and identification of the signals.

13.6 Pipe producing a signal equal to or greater than the calibration defect shall be subject to rejection. The area producing the signal may be examined.

13.6.1 Test signals produced by imperfections that cannot be identified, or produced by cracks or crack-like defects shall result in rejection of the pipe subject to rework and retest.

13.6.2 Test signals produced by imperfections such as those listed below may be judged as injurious or noninjurious depending on visual observation or their severity or the type of signal they produce on the testing equipment used, or both:

13.6.2.1 Dinges,

13.6.2.2 Straightener marks,

13.6.2.3 Loose inside diameter bead and cutting chips,

13.6.2.4 Scratches,

13.6.2.5 Steel die stamps,

13.6.2.6 Chattered flash trim,

13.6.2.7 Stop marks, or

13.6.2.8 Tube reducer ripple.

13.6.3 Any imperfection of the above type exceeding 0.004 in. (0.102 mm) or 12½ % of the specified wall thickness (whichever is greater) in depth shall be considered injurious.

13.6.3.1 If the imperfection is judged as injurious, the pipe shall be rejected but may be reconditioned and retested providing the dimensional requirements are met.

13.6.3.2 If the imperfection is explored to the extent that it can be identified as noninjurious, the pipe may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness.

14. Inspection

14.1 The inspector shall have entry at all times while work on an order is being done to all parts of the manufacturer's works that concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. All tests and inspection shall be made prior to shipment.

14.2 When inspection at the place of manufacture has been waived by customer, the manufacturer shall furnish a statement that the material has been tested and has met all the requirements of this specification. A certificate or report shall be made available to customer when all the requirements of this specification have been met. When Supplementary Requirement S1 is furnished, certificates or reports furnished shall bear the notation "S-1."

15. Rejection

15.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and

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test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

15.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

16. Product Marking

16.1 Each length of pipe NPS 1½ and larger shall be legibly marked by either stenciling or stenciling and light die marking. The die marking shall include the manufacturer's logo or symbol and the stenciling shall include the name or brand of the manufacturer, size, heat number, and the specification number. Such marking shall be applied starting within 8 in. (203 mm) of the end of each length.

16.2 For NPS under 1½ the markings prescribed in 16.1 may be applied to tags and securely attached to the bundle, bale, or other unit, prepared for shipment.

16.3 A tag shall be securely attached to each bundle of pipe shipped indicating the name of the manufacturer, size, wall thickness, length, and specification.

16.4 *Bar Coding*—In addition to the requirements in 16.1, 16.2, and 16.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

17. Packaging

17.1 The manufacturer, at his option, will box, crate, carton, or package in secured lifts, or bundle to ensure safe delivery. Special packaging requiring extra operations other than those normally used by the manufacturer must be specified on the order.

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements described below may be included in the purchaser's order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirements details not fully described shall be agreed upon between the purchaser and the supplier, but shall not negate any of the requirements in the body of the specification.

S1. Hydrostatic Testing

S1.1 Hydrostatic testing shall be in accordance with Specification A 530/A 530M. When this supplement is furnished the pipe shall be marked "S-1."

S2. Galvanizing

S2.1 Galvanizing shall be in accordance with Specification A 53, except that the rate of application shall be 1.3 minimum to 1.7 maximum oz per ft^2.

S3. Surface Coatings

S3.1 All surfaces shall be coated; the exterior with a hard drying lacquer, and the interior with a suitable rust inhibitor.

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Standard Specification for Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures[1]

This standard is issued under the fixed designation A 691; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification[2] covers carbon and alloy steel pipe, electric-fusion-welded with filler metal added, fabricated from pressure-vessel-quality plate of several analyses and strength levels and suitable for high-pressure service at high temperatures. Heat treatment may or may not be required to attain the desired mechanical properties or to comply with applicable code requirements. Supplementary requirements are provided for use when additional testing or examination is desired.

1.2 The specification nominally covers pipe 16 in. (405 mm) in outside diameter and larger with wall thicknesses up to 3 in. (75 mm) inclusive. Pipe having other dimensions may be furnished provided it complies with all other requirements of this specification.

1.3 Several grades and classes of pipe are provided.

1.3.1 *Grade* designates the type of plate used as listed in Table 1.

1.3.2 *Class* designates the type of heat treatment performed in the manufacture of the pipe, whether the weld is radiographically examined, and whether the pipe has been pressure tested as listed in 1.3.3.

1.3.3 Class designations are as follows (Note 1):

Class	Heat Treatment on Pipe	Radiography, see Section	Pressure Test, see Section
10	none	none	none
11	none	9	none
12	none	9	8.3
13	none	none	8.3
20	stress relieved, see 5.3.1	none	none
21	stress relieved, see 5.3.1	9	none
22	stress relieved, see 5.3.1	9	8.3
23	stress relieved, see 5.3.1	none	8.3
30	normalized, see 5.3.2	none	none
31	normalized, see 5.3.2	9	none
32	normalized, see 5.3.2	9	8.3
33	normalized, see 5.3.2	none	8.3
40	normalized and tempered, see 5.3.3	none	none
41	normalized and tempered, see 5.3.3	9	none
42	normalized and tempered, see 5.3.3	9	8.3
43	normalized and tempered, see 5.3.3	none	8.3
50	quenched and tempered, see 5.3.4	none	none
51	quenched and tempered, see 5.3.4	9	none
52	quenched and tempered, see 5.3.4	9	8.3
53	quenched and tempered, see 5.3.4	none	8.3

NOTE 1—Selection of materials should be made with attention to temperature of service. For such guidance, Specification A 20/A 20M may be consulted.

1.4 Optional requirements of a supplementary nature are provided, calling for additional tests and control of repair welding, when desired.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

A 204/A 204M Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum[3]

A 299/A 299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon[3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[4]

A 387/A 387M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum[3]

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[3]

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe[5]

A 537/A 537M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel[3]

E 165 Practice for Liquid Penetrant Inspection Method[6]

E 350 Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron[7]

E 709 Practice for Magnetic Particle Examination[6]

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloysand is the direct responsibility of Subcommittee A01.09on Carbon Steel Tubular Products.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-691 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.04.

[4] *Annual Book of ASTM Standards*, Vol 01.03.

[5] *Annual Book of ASTM Standards*, Vol 01.01.

[6] *Annual Book of ASTM Standards*, Vol 03.03.

[7] *Annual Book of ASTM Standards*, Vol 03.05.

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TABLE 1 Plate Materials

Pipe Grade	Type of Steel	ASTM Specification		HB, max[A]
		Number	Grade	
CM-65	carbon-molybdenum steel	A 204/A 204M	A	201
CM-70	carbon-molybdenum steel	A 204/A 204M	B	201
CM-75	carbon-molybdenum steel	A 204/A 204M	C	201
CMSH-70	carbon-manganese-silicon steel, normalized	A 537/A 537M	1	
CMS-75	carbon-manganese-silicon steel	A 299/A 299M	...	...
CMSH-80	carbon-manganese-silicon steel, quenched and tempered	A 537/A 537M	2	
½ CR	½ % chromium, ½ % molybdenum steel	A 387/A 387M	2	201
1CR	1 % chromium, ½ % molybdenum steel	A 387/A 387M	12	201
1¼ CR	1¼ % chromium, ½ % molybdenum steel	A 387/A 387M	11	201
2¼ CR	2¼ % chromium, 1 % molybdenum steel	A 387/A 387M	22	201
3CR	3 % chromium, 1 % molybdenum steel	A 387/A 387M	21	201
5CR	5 % chromium, ½ % molybdenum steel	A 387/A 387M	5	225
9CR	9 % chromium, 1 % molybdenum steel	A 387/A 387M	9	241
91	9 % chromium, 1 % molybdenum, vanadium, columbium	A 387/A 387M	91	241

[A] Hardness values listed are applicable to S3.

2.2 *ASME Boiler and Pressure Vessel Code:*[8]
Section II, Material Specifications
Section III, Nuclear Power Plant Components
Section VIII, Unfired Pressure Vessels
Section IX, Welding Qualifications

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 A *lot* shall consist of 200 ft (61 m) or fraction thereof of pipe from the same heat of steel.

3.1.1.1 The description of a lot may be further restricted by use of Supplementary Requirement S12.

4. Ordering Information

4.1 The inquiry and order for material under this specification should include the following information:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of the material (steel pipe, electric-fusion-welded),

4.1.3 Specification number,

4.1.4 Grade and class designations (see 1.3),

4.1.5 Size (inside or outside diameter, nominal or minimum wall thickness),

4.1.6 Length (specific or random),

4.1.7 End finish,

4.1.8 Purchase options, if any (see 5.2.3, 11.3, 11.4, 13.1), and

4.1.9 Supplementary requirements, if any (refer to S1 through S12).

5. Materials and Manufacture

5.1 *Materials*—The steel plate material shall conform to the requirements of the applicable plate specification for the pipe grade ordered as listed in Table 1 .

5.2 *Welding*:

5.2.1 The joints shall be double-welded full-penetration welds made in accordance with procedures and by welders or welding operators qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

5.2.2 The welds shall be made either manually or automatically by an electric process involving the deposition of filler metal.

5.2.3 The welded joints shall have positive reinforcement at the center of each side of the weld, but no more than ⅛in. (3.2 mm). This reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be smooth, and the deposited metal shall be fused smoothly and uniformly into the plate surface.

5.2.4 When radiographic examination in accordance with 9.1 is to be used, the weld reinforcement shall be governed by the more restrictive provisions of UW-51 of Section VIII of the ASME Boiler and Pressure Vessel Code instead of 5.2.3 of this specification.

5.3 *Heat Treatment*—All classes other than 10, 11, 12, and 13 shall be heat treated in a furnace controlled to ± 25°F (14°C) and equipped with a recording pyrometer so that heating records are available. Heat treating after forming and welding shall be to one of the following:

5.3.1 Classes 20, 21, 22, and 23 pipe shall be uniformly heated within the post-weld heat-treatment temperature range indicated in Table 2 for a minimum of 1 h/in. of thickness or for 1 h, whichever is greater.

5.3.2 Classes 30, 31, 32, and 33 pipe shall be uniformly heated to a temperature in the austenitizing range and not exceeding the maximum normalizing temperature indicated in Table 2 and subsequently cooled in air at room temperature.

5.3.3 Classes 40, 41, 42, and 43 pipe shall be normalized in accordance with 5.3.2. After normalizing, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at temperature for a minimum of ½h/in. of thickness or for ½ h, whichever is greater, and air cooled.

5.3.4 Classes 50, 51, 52, and 53 pipe shall be uniformly heated to a temperature in the austenitizing range, and not exceeding the maximum quenching temperature indicated in Table 2 and subsequently quenched in water or oil. After quenching, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at that temperature for a minimum of ½ h/in. of thickness or for ½ h, whichever is greater, and air cooled.

5.4 Grade 91 shall be produced only to classes 4X and 5X.

[8] Available from American Society of Mechanical Engineers, 345 East 47th St., New York, NY 10017.

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TABLE 2 Heat Treatment Parameters

Pipe Grade	ASTM Specification	Post-Weld Heat-Treat Temperature Range (Stress Relieving), °F (°C)	Normalizing Temperature, max unless otherwise noted, °F (°C)	Quenching Temperature, max unless otherwise noted, °F (°C)	Tempering Temperature, min, °F (°C)
CM-65	A 204/A 204M	1100 to 1200 (590 to 650)	1700 (925)	...	...
CM-70	A 204/A 204M	1100 to 1200 (590 to 650)	1700 (925)	...	...
CM-75	A 204/A 204M	1100 to 1200 (590 to 650)	1700 (925)	...	...
CMSH-70	A 537/A 537M	1100 to 1200 (590 to 650)	1700 (925)	...	...
CMS-75	A 299/A 299M	1100 to 1200 (590 to 650)	1700 (925)	...	...
CMSH-80	A 537/A 537M	1100 to 1200 (590 to 650)	[A]	1700 (925)	1100 to 1250 (590 to 675)
½CR	A 387/A 387M	1100 to 1300 (590 to 705)	1850 (1010)	1700 (925)	1150 to 1375 (620 to 745)
1CR	A 387/A 387M	1100 to 1350 (590 to 730)	1850 (1010)	1700 (925)	1150 to 1375 (620 to 745)
1¼CR	A 387/A 387M	1100 to 1375 (590 to 745)	1850 (1010)	1700 (925)	1150 to 1375 (620 to 745)
2¼CR	A 387/A 387M	1200 to 1400 (650 to 760)	1850 (1010)	1700 (925)	1250 to 1400 (675 to 760)
3CR	A 387/A 387M	1200 to 1400 (650 to 760)	1850 (1010)	1700 (925)	1250 to 1400 (675 to 760)
5CR	A 387/A 387M	1200 to 1400 (650 to 760)	1850 (1010)	1650 (900)	1300 to 1400 (705 to 760)
9CR	A 387/A 387M	1325 to 1375 (715 to 745)	[B]	...	1325 to 1375 (715 to 745)
91	A 387/A 387M	1350 to 1420 (730 to 770)	1900 to 2000 (1040 to 1095)	1900 min (1040 min)	1350 to 1440 (730 to 780)

[A] Requires quenching and tempering.

[B] 9 CR steel is an air-hardenable steel, at times retaining austenite down to near atmospheric temperature. Good practice is to allow the steel to cool to 150°F or lower before subjecting the steel to a tempering treatment or post-weld heat treatment.

In addition, post-weld heat treatment is required after weld repair.

6. General Requirements

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M, unless otherwise provided herein.

7. Chemical Requirements

7.1 *Product Analysis of Plate*—The pipe manufacturer shall make an analysis of each mill heat of plate material. The product analysis so determined shall meet the requirements of the plate specification to which the material was ordered.

7.2 *Product Analysis of Weld*—The pipe manufacturer shall make an analysis of finished deposited weld metal from each 200 ft (61 m) or fraction thereof. Analysis shall conform to the welding procedure for deposited weld metal.

7.3 Analysis may be taken from the mechanical test specimens. The results of the analyses shall be reported to the purchaser.

7.4 If the analysis of one of these tests specified in 7.1 or 7.2 does not conform to the requirements specified, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified. Nonconforming pipe shall be rejected.

8. Mechanical Requirements

8.1 *Tension Test*:

8.1.1 *Requirements*—Transverse tensile properties of the welded joint shall meet the minimum requirements for ultimate tensile strength of the specified plate material.

8.1.2 *Number of Tests*—One test specimen shall be made to represent each lot of finished pipe.

8.1.3 *Test Specimen Location and Orientation*—The test specimen shall be made transverse to the weld at the end of the finished pipe and may be flattened cold before final machining to size.

8.1.4 *Test Method*—The test specimen shall be made in accordance with QW-150 in Section IX of the ASME Boiler and Pressure Vessel Code. The test specimen shall be tested at room temperature in accordance with Test Methods and Definitions A 370.

8.2 *Transverse-Guided-Weld-Bend Tests*:

8.2.1 *Requirements*—The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. (3.2 mm) in any direction be present in the weld metal or between the weld and the pipe metal after bending. Cracks that originate along the edges of the specimens during testing, and that are less than ¼ in. (6.3 mm) in any direction shall not be considered.

8.2.2 *Number of Tests*—One test (two specimens) shall be made to represent each lot of finished pipe.

8.2.3 *Test Specimen Location and Orientation*—Two bend test specimens shall be taken transverse to the weld at the end of the finished pipe. As an alternative, by agreement between the purchaser and the manufacturer, the test specimens may be taken from a test plate of the same material as the pipe, the test plate being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal weld seam.

8.2.4 *Test Method*—Bend tests shall be made in accordance with Test Methods and Definitions A 370, A 2.5.1.7. For wall thicknesses over ⅜in. (9.5 mm) but less than ¾ in. (19.0 mm) side-bend tests may be made instead of the face and root-bend tests. For wall thicknesses ¾ in. and over both specimens shall be subjected to the side-bend test.

8.3 *Pressure Test*—Classes X2 and X3, pipe shall be tested in accordance with Section 20 of Specification A 530.

9. Radiographic Examination

9.1 The full length of each weld of classes X1 and X2 shall be radiographically examined in accordance with requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Paragraph UW-51.

9.2 Radiographic examination may be performed prior to heat treatment.

10. Rework

10.1 *Elimination of Surface Imperfections*—Unacceptable

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surface imperfections shall be removed by grinding or machining. The remaining thickness of the section shall be no less than the minimum specified in Section 11. The depression after grinding or machining shall be blended uniformly into the surrounding surface.

10.2 *Repair of Base Metal Defects by Welding*:

10.2.1 The manufacturer may repair, by welding, base metal where defects have been removed, provided the depth of the repair cavity as prepared for welding does not exceed ⅓ of the nominal thickness, and the requirements of 10.2.2, 10.2.3, 10.2.4, 10.2.5, and 10.2.6 are met. Base metal defects in excess of these may be repaired with prior approval of the customer.

10.2.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair welding.

10.2.3 The welding procedure and welders or welding operators are to be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10.2.4 The full length of the repaired pipe shall be heat treated after repair in accordance with the requirements of the pipe class specified.

10.2.5 Each repair weld of a defect where the cavity, prepared for welding, has a depth exceeding the lesser of ⅜ in. (9.5 mm) or 10 % of the nominal thickness shall be examined by radiography in accordance with the methods and the acceptance standards of Section 9.

10.2.6 The repair surface shall be blended uniformly into the surrounding base metal surface and examined and accepted in accordance with Supplementary Requirements S6 or S8.

10.3 *Repair of Weld Metal Defects by Welding*:

10.3.1 The manufacturer may repair weld metal defects if he meets the requirements of 10.2.3, 10.2.4, 10.3.2, 10.3.3, and 10.4.

10.3.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the repair cavity examined and accepted in accordance with Supplementary Requirements S7 or S9.

10.3.3 The weld repair shall be blended uniformly into the surrounding metal surfaces and examined and accepted in accordance with 9.1 and with Supplementary Requirements S7 or S9.

10.4 *Retest*—Each length of repaired pipe of a class requiring a pressure test shall be hydrostatically tested following repair.

11. Dimensions, Mass, and Permissible Variations

11.1 The wall thickness and weight for welded pipe furnished to this specification shall be governed by the requirements of the specification to which the manufacturer ordered the plate.

11.2 Permissible variations in dimensions at any point in a length of pipe shall not exceed the following:

11.2.1 *Outside Diameter*—Based on circumferential measurement, ± 0.5 % of the specified outside diameter.

11.2.2 *Out-of-Roundness*—The difference between major and minor outside diameters, 1 %.

11.2.3 *Alignment*—Using a 10-ft (3-m) straightedge placed so that both ends are in contact with the pipe, ⅛in. (3.2 mm).

11.2.4 *Thickness*—The minimum wall thickness at any point in the pipe shall not be more than 0.01 in. (0.3 mm) under the specified nominal thickness.

11.3 Circumferential welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

11.4 Lengths with unmachined ends shall be within −0, +½in. (−0, +13 mm) of that specified. Lengths with machined ends shall be as agreed between the manufacturer and the purchaser.

12. Workmanship, Finish, and Appearance

12.1 The finished pipe shall be free of injurious defects and shall have a workmanlike finish. This requirement is to mean the same as the identical requirement that appears in Specification A 20/A 20M with respect to steel plate surface finish.

13. Product Marking

13.1 The marking shall be stenciled using a suitable heat-resistant paint or metal stamped using low-stress stamps. Wall thicknesses under 0.500 in. (12.7 mm) shall not be metal stamped without prior approval. The purchaser may specify that material 0.500 in. (12.7 mm) and over shall not be metal stamped.

13.2 In addition to the marking provision of Specification A 530, the class marking in accordance with 1.3.3 shall follow the grade marking, for example, 3CR-33.

13.3 *Bar Coding*—In addition to the requirements in 13.1 and 13.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

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SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser, Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Tension and Bend Tests

S1.1 Tension tests in accordance with 8.1 and bend tests in accordance with 8.2 shall be made on specimens representing each length of pipe.

S2. Charpy V-Notch Test (for pipe with nominal wall thickness of ½in. (12.7 mm) and greater)

S2.1 *Requirements*—The acceptable test energies shall be as shown in Table A1.15 of Specification A 20/A 20M for the applicable plate specification unless otherwise stated in the order. As an alternative, the test temperature may be 10°F (−12°C).

S2.2 *Number of Specimens*—Each test shall consist of at least three specimens.

S2.2.1 One base-metal test shall be made from one pipe length per heat, per heat-treat charge, and per nominal wall thickness.

S2.2.2 One weld-metal and one heat-affected zone (HAZ) metal test shall be made in accordance with NB 4335 of Section III of the ASME Boiler and Pressure Vessel Code.

S2.3 *Test Specimen Location and Orientation:*

S2.3.1 Base-metal specimens of stress-relieved, normalized, and normalized and tempered pipe shall be taken in accordance with the provisions for tension specimens in the body of this specification.

S2.3.2 Base-metal specimens of quenched and tempered pipe shall be taken in accordance with the provisions of NB 2225 of Section III of the ASME Boiler and Pressure Vessel Code.

S3. Hardness Tests

S3.1 Hardness determination shall be made on both ends of each length of pipe to the parent metal, weld, and the heat-affected zone and must meet the hardness requirements in Table 1.

S4. Product Analysis

S4.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical requirements prescribed in the applicable specification listed in Table 1 shall be rejected.

S5. Metallography

S5.1 The manufacturer shall furnish one photomicrograph to show the microstructure at 100× magnification of the weld metal or base metal of the pipe in the as-finished condition. The purchaser shall state in the order: the material, base metal or weld, and the number and locations of tests to be made. This test is for information only.

S6. Magnetic Particle Examination of Base Metal

S6.1 All accessible surfaces of the pipe shall be examined in accordance with Practice E 709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. (610 mm) in diameter and greater, and inside surfaces of pipe less than 24 in. in diameter for a distance of one pipe diameter from the ends.

S6.2 Butt-weld end preparations are to be completely magnetic-particle examined in accordance with Practice E 709.

S6.3 *Acceptance Standards*, shall be by agreement between the manufacturer and the purchaser.

S7. Magnetic Particle Examinations of Weld Metal

S7.1 All accessible welds shall be examined in accordance with Practice E 709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. (610 mm) in diameter and greater, and inside surfaces of pipe less than 24 in. in diameter for a distance of one pipe diameter from the ends.

S7.2 Butt-weld end preparations are to be completely magnetic-particle examined in accordance with Practice E 709.

S7.3 *Acceptance Standards*, shall be by agreement between the manufacturer and the purchaser.

S8. Liquid Penetrant Examination of Base Metal

S8.1 All accessible surfaces of the pipe shall be examined in accordance with Practice E 165. Accessible is as defined in S7.1.

S8.2 Butt-weld end preparations are to be completely liquid penetrant examined in accordance with Practice E 165.

S8.3 *Acceptance Standards*, shall be by agreement between the manufacturer and the purchaser.

S9. Liquid Penetrant Examination of Weld Metal

S9.1 All accessible surfaces of the pipe shall be examined in accordance with Practice E 165. Accessible is as defined in S6.1.

S9.2 *Acceptance Standards*, shall be by agreement between the manufacturer and the purchaser.

S10. Ultrasonic Test

S10.1 *Plate in Flat:*

S10.1.1 One hundred percent on one surface shall be scanned.

S10.1.2 Straight search shall be used in accordance with Specification A 435/A435M.

S10.1.3 Acceptance standards shall be in accordance with Specification A 435/A 435M or as by agreement between the manufacturer and the purchaser.

S11. Repair Welding

S11.1 Repair of base metal defects by welding shall be done only with customer approval.

S12. Description of Term

S12.1 *lot*—all pipe of the same mill heat of plate material

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and wall thickness (within ±¼ in. (6.4 mm)) heat treated in one furnace charge. For pipe that is not heat treated or that is heat treated in a continuous furnace, a lot shall consist of each 200 ft (61 m) or fraction thereof of all pipe of the same mill heat of plate material and wall thickness (within ±¼ in. (6.4 mm)), subjected to the same heat treatment. For pipe heat treated in a batch-type furnace that is automatically controlled within a 50°F (28°C) range and is equipped with recording pyrometers so that heating records are available, a lot shall be defined the same as for continuous furnaces.

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Designation: A 727/A 727M – 00

An American National Standard

Standard Specification for Carbon Steel Forgings for Piping Components with Inherent Notch Toughness[1]

This standard is issued under the fixed designation A 727/A 727M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification[2] covers forged carbon steel piping components intended primarily for service in pressure piping systems from −20 to +650°F [−30 to +345°C] where inherent notch toughness is desired, but where notch toughness testing is not required. Included are forged or ring-rolled flanges, forged fittings, and valves made to specified dimensions, or to dimensional standards such as the ANSI and API specifications referenced in Section 2.

1.2 This specification is limited to forgings with maximum finished section thicknesses no larger than 2 in. [51 mm].

1.3 It shall be the responsibility of the purchaser to determine whether material meeting the requirements of this specification is satisfactory for the service application.

1.4 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified by the purchaser in the order.

NOTE 1—There are no provisions for impact testing in this specification. When impact testing is required, refer to Specification A 350/A 350M.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A 961, the following list of standards apply to this specification.

2.2 *ASTM Standards:*

A 788 Specification for Steel Forgings, General Requirements[3]

A 961 Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications[4]

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[5]

2.3 *ASME Boiler and Pressure Vessel Codes:*[6]

Section II, Material Specifications, Part C

SFA 5.5 Low-Alloy Steel Covered Arc-Welding Electrodes

B 16.5 Steel Pipe Flanges and Flanged Fittings

B 16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves

B 16.11 Forged Steel Fittings, Socket-Welding and Threaded

B 16.30 Unfired Pressure Vessel Flange Dimensions

2.4 *API Standards:*[7]

600 Steel Gate Valves with Flanged or Butt-Welding Ends

602 Compact Design Carbon Steel Gate Valves for Refinery Use

605 Large Diameter Carbon Steel Flanges

3. General Requirements and Ordering Information

3.1 Product furnished to this specification shall conform to the requirements of Specification A 961, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 961 constitutes nonconformance with this specification. In case of a conflict between the requirements of this specification and Specification A 961, this specification shall prevail.

3.2 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the following:

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-727 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.05.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

[5] *Annual Book of ASTM Standards*, Vol 03.05.

[6] Available from American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016–5990.

[7] Available from American Petroleum Institute, 1801 K Street, N.W., Washington, DC 20037.

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3.2.1 Additional requirements (see 15.1 and 15.2).

4. Materials and Manufacture

4.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace, and shall be fully killed, fine-grain practice.

4.2 Forgings shall be manufactured from ingots, blooms, billets, slabs, or bars. These items shall be forged, rolled, or strandcast.

4.3 A sufficient discard shall be made from the ingot to secure freedom from injurious piping and undue segregation.

4.4 The finished product shall be a forging as defined by the Terminology section of Specification A 788.

5. Heat Treatment

5.1 Following plastic working, the forging manufacturer shall heat treat the forgings by normalizing, or normalizing and tempering, or quenching and tempering.

5.1.1 *Normalizing*—The procedure for normalizing shall consist of uniformly heating the forgings to a temperature between 1550 and 1700°F [845 and 925°C], holding a sufficient time to attain uniform temperature throughout, and cooling in still air. The forging shall be at a temperature below 1000°F [540°C] before heating for normalizing.

5.1.2 *Quenching*—The procedure for quenching shall consist of uniformly heating the forging to a temperature between 1550 and 1700°F [845 and 925°C], holding a sufficient time to attain uniform temperature throughout, and quenching into a suitable liquid medium. The forging shall be at a temperature below 1000°F [540°C] before heating for quenching.

5.1.3 *Tempering*—The procedure for tempering shall consist of reheating the forging subsequent to normalizing or quenching to a temperature of at least 1100°F [595°C], but not above the lower transformation temperature, for 30 min/in. [30 min/25 mm] of maximum section thickness, with minimum holding time at tempering temperature not less than 30 min.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

6.2 Steels to which lead has been added shall not be used.

7. Mechanical Requirements

7.1 *Tension Tests*:

7.1.1 *Requirements*—The material shall conform to requirements for tensile properties prescribed in Table 2.

7.1.1.1 The test specimen shall be obtained from a rough or finished production forging, or prolongation thereof, or it may be obtained from separately forged test blanks from the same heat of steel as the production forging. The test blank shall be reduced by forging in a manner similar to that for the products represented, shall receive approximately the same hot working and reduction, be of the same nominal thickness, and receive the same heat treatment as the finished products represented. The test material shall be treated in the same furnace at the same time as the forging it represents, subject to the requirements of 7.1.2.1.

7.1.2 *Number of Tests*—One tension test at room temperature shall be made for each nominal wall thickness ±¼ in. [±6 mm] from each heat in each heat treatment charge.

TABLE 1 Chemical Requirements

Elements	Composition, %
Carbon	
Heat Analysis	0.25 max
Product Analysis	0.28 max
Manganese	
Heat Analysis	0.90 to 1.35
Product Analysis	0.84 to 1.41
Phosphorus	
Heat Analysis	0.035 max
Product Analysis	0.043 max
Sulfur	
Heat Analysis	0.025 max
Product Analysis	0.033 max
Silicon	
Heat Analysis	0.15 to 0.30
Product Analysis	0.13 to 0.32
Nickel	
Heat Analysis	0.40[A]
Product Analysis	0.43
Chromium	
Heat Analysis	0.30[AB]
Product Analysis	0.34
Molybdenum	
Heat Analysis	0.12[AB]
Product Analysis	0.13
Copper	
Heat Analysis	0.40[A]
Product Analysis	0.43
Columbium (Nb)	
Heat Analysis	0.02
Product Analysis	0.03
Vanadium	
Heat Analysis	0.05
Product Analysis	0.055

[A] The sum of copper, nickel, chromium and molybdenum shall not exceed 1.00 % on heat analysis.

[B] The sum of chromium and molybdenum shall not exceed 0.32 % on heat analysis.

TABLE 2 Tensile Requirements

Tensile strength, ksi [MPa]	60.0 to 85.0 [415 to 585]
Yield strength, min, ksi [MPa][A]	36.0 [250]
Elongation in 2 in. or 50 mm, min, %	22
Reduction of area, min, %	30

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

7.1.2.1 If heat treatment is performed in either a continuous or a batch-type furnace controlled within ±25°F [±14°C] of the required heat-treatment temperature, and equipped with recording pyrometers so that complete records of heat treatment are available and if the same heat treating cycles are used on the forgings represented by the tension test, then one tension test per nominal wall thickness ±¼ in. [±6 mm] from each heat shall be required, instead of one tension test per nominal wall thickness from each heat in each heat-treatment charge.

7.1.3 *Test Locations and Orientations*— The test specimen shall be removed from the midwall of the heaviest section of the forging or test blank.

7.1.3.1 The test specimen shall have its longitudinal axis located parallel to the direction of major working of the forging or test blank, except for flanges and rings the test specimen shall be in the tangential direction.

7.1.4 *Test Method*—Testing shall be performed in accordance with Test Methods and Definitions A 370 using the

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largest feasible of the round specimens. The gage length for measuring elongation shall be four times the diameter of the test section.

7.2 *Hardness Test*:

7.2.1 *Requirements*—If the production forgings are liquid-quenched and tempered, hardness of the forgings shall not exceed 187 HB after heat treatment. The purchaser may verify that the requirement has been met by testing at any location on the forgings provided such testing does not render the forgings useless.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made from samples taken preferably during the pouring of the heat. The results shall conform to Table 1.

9. Product Analysis

9.1 A product analysis may be made by the purchaser on samples taken in accordance with Practice E 59. The results shall conform to Table 1.

10. Hydrostatic Test

10.1 Forgings manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the finished forging. Such tests shall be conducted by the forging manufacturer only when Supplementary Requirement S8 in Specification A 961 is specified.

11. Rework and Retreatment

11.1 If the results of mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings represented, and shall retest to the applicable requirements.

11.2 Individually tested forgings meeting all requirements shall be acceptable.

12. Repair by Welding

12.1 Repair of defects by welding shall be permitted at the discretion of the forging manufacturer.

12.2 Repair by welding shall be made using welding procedures and welders qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. When forgings are heat treated after repair welding, the qualification test plates shall be subjected to the same heat treatment. The mechanical properties of the qualification test plates shall conform to Section 7.

12.3 The weld metal shall be deposited using low-alloy steel electrodes E 7015-A1, E 7016-A1, or E 7018-A1 complying with ASME SFA-5.5.

12.4 Forgings repair welded in the normalized, normalized and tempered, or the quenched and tempered conditions shall be stress-relieved after repair welding at 1100°F [595°C] minimum, but not higher than the temperature previously used for tempering the base metal of the same forging, or shall be reheat treated in accordance with Section 5.

13. Inspection

13.1 All tests and inspections shall be made at the place of manufacture, unless otherwise agreed, except for product analysis (see 9.1).

14. Rejection and Rehearing

14.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

15. Certification

15.1 For forgings made to specified dimensions, when agreed to by the purchaser, and for forgings made to dimensional standards, application of identification marks as required in Section 16 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification.

15.2 When test reports are required, they shall include certification that all requirements of this specification have been met. The reports shall show the results of all required tests, the heat number or manufacturer's heat identification, a description of the heat treatment used, and shall be traceable to the forging represented. The specification designation included on test reports shall include year of issue and revision letter, if any.

16. Product Marking

16.1 Identification marks consisting of the specification designation, manufacturer's name or symbol, (Note 2) the heat number or manufacturer's heat identification, size, and service rating, if applicable, shall be permanently placed on each forging in a position that will not affect the usefulness of the forging. When size does not permit complete marking, identification marks may be omitted in the sequence specified in SP 25, except that the word "steel" shall not be substituted for the specification designation. The specification number marked on the forgings need not include specification year of issue and revision letter.

NOTE 2—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

16.1.1 If the forgings have been quenched and tempered the letters "QT" shall be stamped on the forgings following the Specification designation.

16.1.2 Forgings repaired by welding shall be marked with the letter "W" following the specification designation.

16.2 When test reports are required, additional marks shall be used as necessary to identify the part with the test report.

16.3 *Bar Coding*—In addition to the requirements in 16.1 and 16.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

17. Keywords

17.1 carbon equivalent; pipe fittings; steel; piping applications; pressure containing parts; steel flanges; steel forgings; carbon; steel valves; temperature service applications; low

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SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification.

S1. Carbon Equivalent

S1.1 The maximum carbon equivalent, based on heat analysis shall be 0.45 for forgings with a maximum section thickness of 2 in. or less, and 0.46 for forgings with a maximum section thickness of greater than 2 in.

S1.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S1.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

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Designation: A 813/A 813M – 01

An American National Standard

Standard Specification for Single- or Double-Welded Austenitic Stainless Steel Pipe[1]

This standard is issued under the fixed designation A 813/A 813M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers two classes of fit-up and alignment quality straight-seam single- or double-welded austenitic steel pipe intended for high-temperature and general corrosive service.

NOTE 1—When the impact test criterion for a low-temperature service would be 15 ft·lbf [20 J] energy absorption or 15 mils [0.38 mm] lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades 304, 304L, and 347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by the Chemical Plant and Refinery Piping Code, ANSI B31.3 for service at temperatures as low as –425°F [–250°C] without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as –325°F [–200°C] without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10 %, are required to be impact tested under the rules of ASME Section VIII Division 1 when service temperatures are lower than –50°F [–45°C]

1.2 Grades TP304H, TP304N, TP316H, TP316N, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP316, TP321, TP347, and TP348, and are intended for high-temperature service.

1.3 Two classes of pipe are covered as follows:

1.3.1 *Class SW*—Pipe, single-welded with no addition of filler metal and

1.3.2 *Class DW*—Pipe, double-welded with no addition of filler metal.

1.4 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.5 Table 1 lists the dimensions of welded stainless steel pipe as shown in ANSI B36.19. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 480/A 480M Specification for the General Requirements of Flat-rolled Stainless and Heat Resisting Steel Plate, Sheet and Strip[2]

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[2,3]

A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe[3]

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing[4]

E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings[4]

E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel, and Similar Alloys[4]

E 527 Practice for Numbering Metals and Alloys (UNS)[3]

2.2 *ANSI Standards:*

B1.20.1 Pipe Threads, General Purpose[5]

B36.10 Welded and Seamless Wrought Steel Pipe[5]

B36.19 Stainless Steel Pipe[5]

2.3 *ASME Boiler and Pressure Vessel Code:*

Section VIII Division 1, Pressure Vessels[6]

2.4 *Other Standard:*

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing[7]

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.10 on Steel Tubing.

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[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

[6] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[7] Society for Nondestructive Testing, 1711 Arlingate Plaza, PO Box 28518, Columbus, OH, 43228-0518.

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TABLE 1 Dimensions of Welded and Seamless Stainless Steel Pipe[A]

NOTE 1—Table 1 is based on Table number 1 of the American National Standard for Stainless Steel Pipe (ANSI B36.19-1965).
NOTE 2—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[B]		Schedule 10S[B]		Schedule 40S		Schedule 80S	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
⅛	0.405	10.29	...	...	0.049[C]	1.24	0.068	1.73	0.095	2.41
¼	0.540	13.72	...	...	0.065[C]	1.65	0.088	2.24	0.119	3.02
⅜	0.675	17.15	...	...	0.065[C]	1.65	0.091	2.31	0.126	3.20
½	0.840	21.34	0.065[C]	1.65	0.083[C]	2.11	0.109	2.77	0.147	3.73
¾	1.050	26.67	0.065[C]	1.65	0.083[C]	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065[C]	1.65	0.109[C]	2.77	0.133	3.38	0.179	4.55
1¼	1.660	42.16	0.065[C]	1.65	0.109[C]	2.77	0.140	3.56	0.191	4.85
1½	1.900	48.26	0.065[C]	1.65	0.109[C]	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065[C]	1.65	0.109[C]	2.77	0.154	3.91	0.218	5.54
2½	2.875	73.03	0.083	2.11	0.120[C]	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120[C]	3.05	0.216	5.49	0.300	7.62
3½	4.000	101.60	0.083	2.11	0.120[C]	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120[C]	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109[C]	2.77	0.134[C]	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134[C]	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109[C]	2.77	0.148[C]	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134[C]	3.40	0.165[C]	4.19	0.365	9.27	0.500[C]	12.70[C]
12	12.750	323.85	0.156[C]	3.96	0.180[C]	4.57	0.375[C]	9.52[C]	0.500[C]	12.70[C]
14	14.000	355.60	0.156[C]	3.96	0.188	4.78	...	...	...	...
16	16.000	406.40	0.165[C]	4.19	0.188	4.78	...	...	...	...
18	18.000	457.20	0.165[C]	4.19	0.188	4.78	...	...	...	...
20	20.000	508.00	0.188[C]	4.78	0.218[C]	5.54	...	...	...	...
22	22.000	558.80	0.188[C]	4.78	0.218[C]	5.54	...	...	...	...
24	24.000	609.60	0.218[C]	5.54	0.250	6.35	...	...	...	...
30	30.000	762.00	0.250	6.35	0.312	7.92	...	...	...	...

[A]For pipe sizes not listed, the dimensions and tolerances shall be by agreement between the purchaser and producer.
[B]Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).
[C]These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10-1979).

3. Ordering Information

3.1 Orders for material under this specification should include the following as required, to describe the desired material adequately:

3.1.1 Quantity (feet, centimetres, or number of lengths),

3.1.2 Name of material (austenitic steel pipe),

3.1.3 Class (1.3). If not specified by the purchaser, the producer shall have the option to furnish either single-welded (SW) or double-welded (DW) pipe,

3.1.4 Grade (Table 2),

3.1.5 Size (NPS or outside diameter and schedule number or average wall thickness),

3.1.6 Length (specific or random), (Section 9),

3.1.7 End finish (section on Ends of Specification A 999/A 999M),

3.1.8 Optional requirements (hydrostatic or nondestructive electric test, Section 13,) (Supplementary Requirements S1 to S6),

3.1.9 Test report required (Section on Certification of Specification A 999/A 999M),

3.1.10 Specification number, and

3.1.11 Special requirements or exceptions to the specification.

4. Materials and Manufacture

4.1 *Manufacture*:

4.1.1 The pipe shall be made by a machine-welding or an automatic-welding process, welding from one or both sides and producing full penetration welds with no addition of filler metal in the welding operation.

4.1.2 Weld repairs, with the addition of compatible filler metal, may be made to the weld joint in accordance with the requirements of the section on Repair by Welding of Specification A 999/A 999M.

4.1.3 The pipe shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

4.2 *Heat Treatment*:

4.2.1 Except as provided in 4.2.5 and 4.2.6, all pipe shall be furnished in the heat-treated condition, except pipe sizes over NPS 6 may be furnished in the unheat-treated condition when specified in the order. When the pipe is furnished without final heat treatment, each pipe shall be marked HT-O and when a material test report for such pipe is furnished to the purchaser, the report shall indicate that the pipe has not been heat-treated. The heat-treatment procedure, except for H grades, N08367, and S31254, shall consist of heating the pipe to a minimum temperature of 1900°F [1040°C] and quenching in water or rapidly cooling by other means.

4.2.2 All H grades shall be furnished in the solution-treated condition. If cold working is involved in processing, the minimum solution treating temperature for Grades TP321H, TP347H, and TP348H shall be 2000°F [1100°C] and for Grades TP304H and TP316H, 1900°F [1040°C]. If the H Grade is hot rolled, the minimum solution treating temperatures for Grades TP321H, TP347H, and TP348H shall be 1925°F [1050°C], and for Grades TP304H and TP316H, 1900°F [1040°C].

4.2.3 The heat-treatment procedure for S31254 shall consist of heating the pipe to a minimum temperature of 2100°F

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TABLE 2 Chemical Requirements

Grade	UNS Designation[A]	Composition, %														
		Carbon, max[B]	Manganese, max[B]	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Titanium	Columbium	Tantalum, max	Nitrogen[C]	Vanadium	Copper	Cerium	Cobalt
TP304	S30400	0.08	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	...	...	...	...	...	...	...	...	...
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	...	...	...	...	...	...	...	...	...
TP304L	S30403	0.030[D]	2.00	0.045	0.030	1.00 max	8.0–12.0	18.0–20.0	...	...	...	...	...	...	...	...	...
TP304N	S30451	0.08	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...	...	...	...
TP304LN	S30453	0.030	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...	...	...	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00 max	12.0–16.0	22.0–24.0	...	...	10 × C min, 1.10 max	...	...	...	...	...	...
TP309S	S30908	0.08	2.00	0.045	0.030	1.00 max	12.0–15.0	22.0–24.0	...	...	...	...	...	...	...	...	...
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	...	...	10 × C min, 1.10 max	...	...	...	...	...	...
TP310S	S31008	0.08	2.00	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	...	...	...	...	...	...	...	...	...
TP316	S31600	0.08	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...	...
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...	...
TP316L	S31603	0.030[D]	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...	...
TP316N	S31651	0.08	2.00	0.045	0.030	1.00 max	10.0–15.0	16.0–18.0	2.00–3.00				0.10–0.16	...	...	...	...
TP316LN	S31653	0.030[D]	2.00	0.045	0.030	1.00 max	10.0–13.0	16.0–18.0	2.00–3.00	...	...	...	0.10–0.16	...	...	...	...
TP317	S31700	0.08	2.00	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...	...	...	...	...	...
TP317L	S31703	0.030	2.00	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...	...	...	...	...	...
TP321	S32100	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	...	[E]	...	...	...	...	...	...	...
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	...	[F]	...	...	...	...	...	...	...
TP347	S34700	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	...	...	[G]	...	...	...	...	...	...
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	...	...	[H]	...	...	...	...	...	...
TP348	S34800	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	...	...	[G]	0.10	...	...	...	...	0.20 max
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	...	...	[H]	0.10	...	...	...	...	0.20 max
TPXM-10	S21900	0.08	8.0–10.0	0.045	0.030	1.00 max	5.5–7.5	19.0–21.5	...	...	...	...	0.15–0.40	...	...	...	...
TPXM-11	S21903	0.04	8.0–10.0	0.045	0.030	1.00 max	5.5–7.5	19.0–21.5	...	...	...	...	0.15–0.40	...	...	...	...
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.5–18.5	17.0–19.0	...	...	...	...	...	...	...	...	...
TPXM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00 max	11.5–13.5	20.5–23.5	1.50–3.00	...	0.10–0.30	...	0.20–0.40	0.10–0.30	...	...	...
TPXM-29	S24000	0.08	11.5–14.5	0.060	0.030	1.00 max	2.3–3.7	17.0–19.0	...	...	...	...	0.20–0.40	...	...	...	...
...	S31254	0.020	1.00	0.030	0.010	0.80 max	17.5–18.5	19.5–20.5	6.0–6.5	...	...	...	0.18–0.22	...	0.50–1.00	...	...
...	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	...	...	...	...	0.14–0.20	...	...	0.03–0.08	...
...	N08367	0.030	2.00	0.040	0.030	1.00 max	23.5–25.5	20.0–22.0	6.0–7.0	...	...	...	0.18–0.25	...	0.75 max	...	...

[A]New designation established in accordance with ASTM E 527 and SAE J1086 Practice for Numbering Metals and Alloys (UNS).

[B]Maximum, unless otherwise indicated.

[C]The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

[D]For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.044 in. [1 mm] in minimum wall thickness).

[E]The titanium content shall be not less than five times the carbon content and not more than 0.70 %.

[F]The titanium content shall be not less than four times the carbon content and not more than 0.70 %.

[G]The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.0 %.

[H]The columbium plus tantalum content shall be not less than eight times the carbon content and not more than 1.10 %.

[1150°C] and quenching in water or rapidly cooling by other means.

4.2.4 UNS N08367 should be solution anncaled from 2025°F [1107°C] minimum followed by rapid quenching.

4.2.5 Except for H Grades and S31254, pipe sizes over NPS 6 may be furnished in the unheat-treated condition when specified in the order.

4.2.6 H Grades and S31254 in pipe sizes NPS 6 may be furnished in the unheat-treated condition when specified in the order, provided the heat treatment of 4.2.2 or 4.2.3, as applicable, is applied by the purchaser.

4.2.7 When the pipe is furnished without final heat treatment, each pipe shall be marked HT-O and when a material test report for such pipe is furnished to the purchaser, the report shall indicate that the pipe has not been heat-treated.

5. Chemical Composition

5.1 The steel shall conform to the chemical composition in Table 2.

5.2 When specified on the purchase order, a product analysis shall be supplied from one tube or coil of steel per heat. The product analysis tolerance of Specification A 480/A 480M shall apply.

6. Product Analysis

6.1 At the request of the purchaser, an analysis of one length of flat-rolled stock from each heat, or one pipe from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel.

NPS Number	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5 inclusive	200 or fraction thereof
6 and over	100 or fraction thereof

6.2 The results of these analyses shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 5.

6.3 If the analysis of one of the tests specified in 6.1 does not conform to the requirements specified in Section 5, an analysis of each length of flat-rolled stock from each heat or pipe from the same heat or lot may be made, and all pipe conforming to the requirements shall be accepted.

6.4 For referee purposes, Test Methods, Practices, and Terminology A 751 shall be used.

7. Tensile Requirements

7.1 The tensile properties of the material shall conform to the requirements prescribed in Table 3.

TABLE 3 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
TP304L	S30403	70 [485]	25 [170]
TP316L	S31603	70 [485]	25 [170]
TP304	S30400	75 [515]	30 [205]
TP304H	S30409	75 [515]	30 [205]
TP309Cb	S30940	75 [515]	30 [205]
TP309S	S30908	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP316	S31600	75 [515]	30 [205]
TP316H	S31609	75 [515]	30 [205]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
TP321	S32100	75 [515]	30 [205]
TP321H	S32109	75 [515]	30 [205]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21903	90 [620]	50 [345]
TPXM-15	S38100	75 [515]	30 [205]
TPXM-29	S24000	100 [690]	55 [380]
TPXM-19	S20910	100 [690]	55 [380]
TP304N	S30451	80 [550]	35 [240]
TP316N	S31651	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
TP316LN	S31653	75 [515]	30 [205]
...	S31254	94 [650]	44 [300]
...	S30815	87 [600]	45 [310]
...	N08367		
	$t \le 0.187$	100 [690]	45 [310]
	$t > 0.187$	95 [655]	45 [310]

8. Permissible Variations in Dimensions

8.1 Permissible variations in dimensions shall not exceed the following at any point in each length of pipe.

8.1.1 *Specified Diameter*—The outside diameter shall be based on circumferential measurement and shall not exceed the tolerances stated as follows:

8.1.1.1 For sizes up to and including NPS 1¼, ±0.010 in. [±0.25 mm],

8.1.1.2 For sizes NPS 1½ up to and including NPS 6, ±0.020 in. [±0.5 mm],

8.1.1.3 For sizes NPS 8 up to and including NPS 18, ±0.030 in. [±0.75 mm],

8.1.1.4 For sizes NPS 20 up to and including NPS 24, ±0.040 in. [±1 mm], and

8.1.1.5 For sizes NPS 30, ±0.050 in. [±1.25 mm].

8.1.1.6 Outside diameter tolerances closer than shown above may be obtained by agreement between the pipe manufacturer and purchaser.

8.1.2 *Out-of-Roundness*—The difference between the major and the minor outside diameter shall not be more than 1.5 % of the specified outside diameter.

8.1.3 *Alignment (Camber)*—Using a 10-ft [3.0-m] straightedge placed so that both ends are in contact with the pipe, the camber shall not be more than 3/16in. [4.8 mm].

8.1.4 *Thickness*—The wall thickness at any point in the pipe excluding the weld, shall not be more than 12 % under or over the nominal thickness for wall thickness less than 0.188 in. [4.8 mm] and not more than 0.030 in. [0.8 mm] under or over the nominal thickness for wall thickness 0.188 in. [4.8 mm] and greater. Weld reinforcement not to exceed 20 % of the wall thickness is permitted on each of the inside and outside surfaces of the pipe.

9. Lengths

9.1 Pipe lengths shall be in accordance with the following regular practice:

9.1.1 Unless otherwise agreed upon, all sizes up to and including NPS 8 are available in a length up to 24 ft (Note 2)

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with the permissible range of 15 to 24 ft (Note 2). Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

NOTE 2—The value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and purchaser.

9.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and not more than ¼ in. [6 mm] over that specified.

10. Workmanship, Finish, and Appearance

10.1 The finished pipes shall be free of injurious imperfections and shall have a workmanlike finish. Minor imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted in Section 8.

11. Examination of Double-Welded Pipe

11.1 Both ends of each double-welded (Class DW) pipe shall be visually examined to determine that complete fusion was attained between the two welds. In lieu of examining the ends of the pipe, this examination may be performed on cropped ends removed from both ends of each double welded pipe.

12. Mechanical Tests Required

12.1 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes. Pipe size greater than NPS 6 shall be tested using the transverse tension test with the weld centered in the gage length of the test specimen. Test specimens shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as prolongation of the pipe longitudinal weld seam.

NOTE 3—The term lot, for mechanical tests, applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment: (*1*) in a continuous heat-treatment furnace, or (*2*) in a batch-type heat-treatment furnace, equipped with recording pyrometers and automatically controlled within a 50°F [30°C] range, the larger of: (*a*) each 200 ft [60 m] or fraction thereof or (*b*) that pipe heat treated in the same batch furnace charge.

12.2 *Flattening Test*—For material heat treated in a batch-type furnace, flattening tests shall be made on 5 % of the pipe from each heat-treated lot. For material heat treated by the continuous process, this test shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than two lengths of pipe.

12.2.1 For pipe where the diameter equals or exceeds NPS 10, a transverse-guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A 370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5 % of the lot shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

13. Hydrostatic or Nondestructive Electric Test

13.1 Each pipe shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

13.2 The hydrostatic test shall be in accordance with Specification A 999/A 999M.

13.3 *Nondestructive Examination*—Each pipe shall be examined with a nondestructive test in accordance with Practice E 213, or E 426. Unless specifically called out by the purchaser, the selection of the nondestructive electric test will be at the option of the manufacturer. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

13.3.1 The following information is for the benefit of the user of this specification:

13.3.1.1 The reference standards defined in 13.9.1-13.9.4 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

13.3.1.2 The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep, defects.

13.3.1.3 The eddy-current testing (ET) referenced in this specification, (Practice E 426), has the capability of detecting significant discontinuities, especially the short abrupt type.

13.3.1.4 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

13.4 *Time of Examination*:

13.4.1 Nondestructive testing for specification acceptance shall be performed after all mechanical processing, heat treatments, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

13.5 *Surface Condition*:

13.5.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

13.5.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

13.6 *Extent of Examination*:

13.6.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except as in 13.5.2.

13.6.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other

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nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

13.7 *Operator Qualifications*:

13.7.1 The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent recognized and documented standard.

13.8 *Test Conditions*:

13.8.1 For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide good signal-to-noise ratio.

13.8.2 The maximum eddy-current coil frequency used shall be as follows:

On specified walls up to 0.050 in.—100 KHz max

On specified walls up to 0.150 in.—50 KHz max

On specified walls above 0.150 in.—10 KHz max

13.8.3 *Ultrasonic*—For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.00 MHz and the maximum nominal transducer size shall be 1.5 in.

(1) If the equipment contains a reject notice filter setting, this shall remain off during calibration and testing unless linearity can be demonstrated at that setting.

13.9 *Reference Standards*:

13.9.1 Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS, or outside diameter and schedule or wall thickness), surface finish and heat treatment condition as the pipe to be examined.

13.9.2 *For Ultrasonic Testing*, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of each notch shall not exceed 12½ % of the specified nominal wall thickness of the pipe or 0.004 in., whichever is greater. The width of the notch shall not exceed twice the depth. Notches shall be placed on both the OD and ID surfaces.

13.9.3 *For Eddy-Current Testing*, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

(1) Drilled Hole—The reference standard shall contain three or more holes, equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. One hole shall be drilled in the weld, if visible. Alternately, the producer of welded pipe may choose to drill one hole in the weld and run the calibration standard through the test coils three times with the weld turned at 120° on each pass. The hole diameter shall vary with NPS as follows:

NPS Designator	Hole Diameter
½	0.039 in. [1 mm]
above ½ to 1¼	0.055 in. [1.4 mm]
above 1¼ to 2	0.071 in. [1.8 mm]
above 2 to 5	0.087 in. [2.2 mm]
above 5	0.106 in. [2.7 mm]

(2) Transverse Tangential Notch—Using a round tool or file with a ¼ in. [6.4 mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding 12½ % of the specified nominal wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

(3) Longitudinal Notch—A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12½ % of the specified wall thickness of the pipe or 0.004 in., whichever is greater. The length of the notch shall be compatible with the testing method.

13.9.4 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

13.10 *Standardization Procedure*:

13.10.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness), Grade and heat treatment condition, and at intervals not exceeding 4 h. More frequent standardization may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

13.10.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss, process shutdown or when a problem is suspected.

13.10.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the pipe to be tested.

13.10.4 The signal-to-noise ratio for the reference standard shall be 2½ to 1 or greater. Extraneous signals caused by identifiable causes such as dings, scratches, dents, straightener marks, etc., shall not be considered noise. The rejection amplitude shall be adjusted to be at least 50 % of full scale of the readout display.

13.10.5 If upon any standardization, the rejection amplitude has decreased by 29 % (3 dB) of peak height from the last standardization, the pipe since the last calibration shall be rejected. The test system settings may be changed, or the transducer(s), coil(s) or sensor(s) adjusted, and the unit restandardized, but all pipe tested since the last acceptable standardization must be retested for acceptance.

13.11 *Evaluation of Imperfections*:

13.11.1 Pipes producing a signal equal to or greater than the lowest signal produced by the reference standard(s) shall be identified and separated from the acceptable pipes. The area producing the signal may be reexamined.

13.11.2 Such pipes shall be rejected if the test signal was produced by imperfections that cannot be identified or was produced by cracks or crack-like imperfections. These pipes may be repaired per Sections 4 and 10. To be accepted, a repaired pipe must pass the same non-destructive test by which it was rejected, and it must meet the minimum wall thickness requirements of this specification.

13.11.3 If the test signals were produced by visual imperfections such as:

(1) Scratches,

(2) Surface roughness,

(3) Dings,

(4) Straightener marks,

(5) Cutting chips,

(6) Steel die stamps,

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(7) Stop marks, or

(8) Pipe reducer ripple.

The pipe may be accepted based on visual examination provided the imperfection is less than 0.004 in. [0.1 mm] or 12½ % of the specified wall thickness (whichever is greater).

13.11.4 Rejected pipe may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed. To be accepted, retested pipe shall meet the test requirement.

13.11.5 If the imperfection is explored to the extent that it can be identified as non-rejectable, the pipe may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness.

14. Product Marking

14.1 In addition to that specified in Specification A 999/A 999M, the marking shall include the manufacturer's private identifying mark and identified as either single welded (SW) or double welded (DW) as applicable. For Grades TP304H, TP316H, TP321H, TP347H, and TP348H, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weights.

14.2 When heat treatment of the pipe is not performed, the pipe shall be marked HT-O.

14.3 When a hydrostatic test of the pipe is not performed, the pipe shall be marked NH.

15. General Requirements

15.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipes NPS 5 and larger in nominal size, there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5, there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 5 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This applies only to pipe NPS 8 and larger in nominal size.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be tested, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound welds and reasonably uniform material free of injurious laminations, cracks, and similar objectionable imperfections. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable imperfections, the length shall be rejected subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Radiographic Examination

S5.1 Weld soundness shall be determined through radiographic examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S6. Corrosion Requirements

S6.1 *Boiling Nitric Acid Test*—Except for Grade TP 321, coupons representing finished pipe made of nonmolybdenum-bearing material (0.50 % and less molybdenum) shall meet the requirements of Practice C of Practices A 262. The condition of the test specimens and the corrosion rates are as follows: Types 304L, 304LN, 347, and 348 shall be tested in the sensitized condition (heated for 1 h at 1240°F [670°C]) and the rate of

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penetration when the solution is tested in accordance with Practice C shall not exceed 0.0020 in. [0.05 mm] per month. All other nonmolybdenum-bearing types, except for Grade TP 321, shown in Table 2, shall be tested in the annealed and unsensitized condition and the rate of penetration shall not exceed 0.0015 in. [0.038 mm] per month.

S6.2 *Acidified Copper Sulfate Test*—Coupons representing finished pipe made of molybdenum-bearing material (over 0.50 % molybdenum) and Type 321 shall meet the requirements of Practice E of Practices A 262. The condition of the test specimen is as follows: Types 316L, 316LN, 317L, and 321 shall be tested in the sensitized condition (heated for 1 h at 1240°F [670°C]). All molybdenum-bearing types shown in Table 2 shall be tested in the annealed and unsensitized condition. All specimens shall meet the requirements of the prescribed bend tests.

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Designation: A 814/A 814M – 01

An American National Standard

Standard Specification for Cold-Worked Welded Austenitic Stainless Steel Pipe[1]

This standard is issued under the fixed designation A 814/A 814M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers two classes of flanged and cold-bending quality cold-worked straight-seam single or double welded austenitic steel pipe intended for high-temperature and general corrosive services.

NOTE 1—When the impact test criterion for a low-temperature service would be 15 ft-lbf [20 J] energy absorption or 15 mils [0.38 mm] lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades 304, 304L, and 347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by the Chemical Plant and Refinery Piping Code, ANSI B31.3 for service at temperatures as low as −425°F [−250°C] without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as −325°F [−200°C] without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10 %, are required to be impact tested under the rules of ASME Section VIII Division 1 when service temperatures are lower than −50°F [−45°C].

1.2 Grades TP304H, TP304N, TP316H, TP316N, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP316, TP321, TP347, and TP348, and are intended for high-temperature service.

1.3 Two classes of pipe are covered as follows:

1.3.1 *Class SW*—Pipe, single-welded with no addition of filler metal and

1.3.2 *Class DW*—Pipe, double-welded with no addition of filler metal.

1.4 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.5 Table 1 lists the dimensions of cold-worked single- or double-welded stainless steel pipe. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 751 Test Methods, Practices, and Definitions for Chemical Analysis of Steel Products[2,3]

A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe[3]

E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings[4]

E 527 Practice for Numbering Metals and Alloys (UNS)[3]

2.2 *ANSI Standards:*[5]

B 1.20.1 Pipe Threads, General Purpose

B 36.10 Welded and Seamless Wrought Steel Pipe

B 36.19 Stainless Steel Pipe

2.3 *ASME Boiler and Pressure Vessel Code:*

Section VIII Division 1, Pressure Vessels[6]

3. Ordering Information

3.1 Orders for material under this specification should include the following as required, to describe the desired material adequately:

3.1.1 Quantity (feet, centimetres, or number of lengths),

3.1.2 Name of material (austenitic steel pipe),

3.1.3 Class (1.3). If not specified by the purchaser, the producer shall have the option to furnish either single-welded (SW) or double-welded (DW) pipe,

3.1.4 Grade (Table 2),

3.1.5 Size (NPS or outside diameter and schedule number or average wall thickness),

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.10 on Steel Tubing.

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[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

[6] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

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TABLE 1 Pipe Dimensions[A]

NOTE 1—For pipe sizes not listed and for pipe ordered to the "M" designation of this specification, the dimensions and tolerances shall be by agreement between the purchaser and producer.

NPS No.	Outside Diameter	Outside Diameter Tolerance	Schedule	Wall	
				Thickness	Tolerance
⅛	0.405	+0.004	10	0.049	±0.004
		−0.002	40	0.068	±0.005
			80	0.095	±0.006
¼	0.540	+0.005	10	0.065	±0.005
		−0.003	40	0.088	±0.006
			80	0.119.	±0.009
⅜	0.675	+0.006	10	0.065	±0.005
		−0.004	40	0.091	±0.006
			80	0.126	±0.010
½	0.840	+0.007	5	0.065	±0.005
		−0.005	10	0.083	±0.006
			40	0.109	±0.009
			80	0.147	±0.011
¾	1.060	+0.010	5	0.065	±0.005
		−0.007	10	0.083	±0.006
			40	0.113	±0.009
			80	0.154	±0.011
1	1.315	+0.010	5	0.065	±0.005
		−0.007	10	0.109	±0.009
			40	0.133	±0.011
			80	0.179	±0.014
1¼	1.660	+0.012	5	0.065	±0.005
		−0.0080	10	0.109	±0.009
			40	0.140	±0.011
			80	0.191	±0.014
1½	1.900	+0.015	5	0.065	±0.005
		−0.008	10	0.109	±0.009
			40	0.145	±0.011
			80	0.200	±0.015
2	2.375	+0.018	5	0.065	±0.005
		−0.008	10	0.109	±0.009
			40	0.154	±0.011
			80	0.218	±0.015
2½	2.875	+0.020	5	0.065	±0.005
		−0.009	10	0.120	±0.010
			40	0.203	±0.015
			80	0.276	±0.020
3	3.500	+0.025	5	0.083	±0.006
		−0.010	10	0.120	±0.010
			40	0.216	±0.015
			80	0.300	±0.020
3½	4.000	+0.025	5	0.083	±0.006
		−0.010	10	0.120	±0.010
			40	0.226	±0.018
			80	0.318	±0.020
4	4.500	+0.025	5	0.083	±0.006
		−0.010	10	0.120	±0.010
			40	0.237	±0.019
			80	0.337	±0.020

[A]All dimensions in inches.

3.1.6 Length (specific or random) (Section 10),

3.1.7 End finish (Section on Ends of Specification A 999/A 999M),

3.1.8 Optional requirements (Section 9), (Supplementary Requirements S 1 to S 8),

3.1.9 Test report required (Section on Certification of Specification A 999/A 999M),

3.1.10 Specification designation, and

3.1.11 Special requirements or exceptions to the specification.

4. Materials and Manufacture

4.1 *Manufacture*:

4.1.1 The pipe shall be made by a machine-welding or an automatic-welding process, welding from one or both sides and producing full penetration welds with no addition of filler metal in the welding operation.

4.1.2 Weld repairs, with the addition of compatible filler metal, may be made to the weld joint in accordance with the requirements of the section on Repair by Welding of Specification A 999/A 999M.

4.1.3 Prior to final heat treatment of the pipe, the weld bead must be cold-worked by methods such as forging, planishing, drawing, swaging or bead rolling so as to obtain a flush condition on the inside and outside of the pipe. Undercuts shall be limited to shallow rounded depressions of less than 0.005 in. [0.127 mm] deep on either the inside or outside surface of the pipe with no encroachment of the minimum permitted wall thickness.

4.1.4 The pipe shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

4.2 *Heat Treatment*:

4.2.1 All pipe shall be furnished in the heat-treated condition. The heat-treatment procedure, except for H grades, N 08367 and S 31254, shall consist of heating the pipe to a minimum temperature of 1900°F [1040°C] and quenching in water or rapidly cooling by other means.

4.2.2 All H grades shall be furnished in the solution-treated condition. The minimum solution treating temperature for Grades TP321H, TP347H, and TP348H shall be 2000°F [1100°C] and for Grades TP304H and TP316H, 1900°F [1040°C]. If the H grade is hot-rolled, the minimum solution treating temperatures for Grades TP321H, TP347H, and TP348H shall be 1925°F [1050°C] and for Grades TP304H and TP316H, 1900°F [1040°C].

4.2.3 The heat-treatment procedure for S 31254 shall consist of heating the pipe to a minimum temperature of 2100°F [1150°C] and quenching in water or rapidly cooling by other means.

4.2.4 UNS N 08367 should be solution annealed from 2025°F minimum followed by rapid quenching.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

6. Product Analysis

6.1 At the request of the purchaser, an analysis of one length of flat-rolled stock from each heat, or one pipe from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel:

NPS Number	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5 inclusive	200 or fraction thereof
6 and over	100 or fraction thereof

6.2 The results of these analyses shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 6.

6.3 If the analysis of one of the tests specified in 7.1 does not conform to the requirements specified in Section 6, an analysis of each length of flat-rolled stock from each heat or

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TABLE 2 Chemical Requirements

Grade	UNS Designation [A]	Composition, %														
		Carbon, max [H]	Manganese, max [H]	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Titanium	Columbium plus Tantalum	Tantalum, max	Nitrogen [G]	Vanadium	Copper	Cerium
TP304	S30400	0.08	2.00	0.045	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	...	...	...	...
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	...	...	...	...
TP304L	S30403	0.035 [B]	2.00	0.045	0.030	0.75 max	8.00–13.0	18.0–20.0	...	...	...	...	...	...	...	...
TP 304N	S30451	0.08	2.00	0.045	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...	...	...
TP304LN	S30453	0.035	2.00	0.045	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...	...	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	0.75 max	12.00–16.00	22.00–24.00	0.75 max	...	10 × C min, 1.10 max	...	...	...	0.75 max	...
TP309S	S30908	0.08	2.00	0.045	0.030	0.75 max	12.00–15.00	22.00–24.00	0.75 max	...	...	...	...	...	0.75 max	...
TP310Cb	S31040	0.08	2.00	0.045	0.030	0.75 max	19.00–22.00	24.00–26.00	0.75 max	...	10 × C min, 1.10 max	...	...	...	0.75 max	...
TP310S	S31008	0.08	2.00	0.045	0.030	0.75 max	19.00–22.00	24.00–26.00	0.75 max	...	...	...	...	...	0.75 max	...
TP316	S31600	0.08	2.00	0.045	0.030	0.75 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	0.75 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...
TP316L	S31603	0.035 [B]	2.00	0.045	0.030	0.75 max	10.0–15.0	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...
TP316N	S31651	0.08	2.00	0.045	0.030	0.75 max	10.0–14.0	16.0–18.0	2.00–3.00				0.10–0.16	...	...	...
TP316LN	S31653	0.035	2.00	0.045	0.030	0.75 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...	0.10–0.16	...	...	...
TP317	S31700	0.08	2.00	0.045	0.030	0.75 max	11.0–14.0	18.0–20.0	3.00–4.00	...	...	...	...	...	...	...
TP317L	S31703	0.035	2.00	0.045	0.030	0.75 max	11.0–15.0	18.0–20.0	3.00–4.00	...	...	...	...	...	...	...
TP321	S32100	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	[C]	...	...	...	...	...	...
TP 321H	S32109	0.04–0.10	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	[D]	...	...	...	...	...	...
TP347	S34700	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[E]	...	...	...	...	...
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[F]	...	...	...	...	...
TP348	S34800	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[E]	0.10	...	...	...	...
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[F]	0.10	...	...	...	...
TPXM-10	S21900	0.08	8.00–10.00	0.040	0.030	1.00 max	5.50–7.50	19.00–21.50	...	...	...	...	0.15–0.40	...	...	...
TPXM-11	S21903	0.04	8.00–10.00	0.040	0.030	1.00 max	5.50–7.50	19.00–21.50	...	...	...	...	0.15–0.40	...	...	...
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.50–18.50	17.0–19.0	...	...	...	...	...	...	...	...
TPXM-19	S20910	0.060	4.00–6.00	0.040	0.030	1.00 max	11.50–13.50	20.50–23.50	1.50–3.00	...	0.10–0.30	...	0.20–0.40	0.10–0.30	...	...
TPXM-29	S24000	0.080	11.50–14.50	0.060	0.030	1.00 max	2.25–3.75	17.0–19.0	...	...	...	...	0.20–0.40	...	...	...
...	S31254	0.020	1.00	0.030	0.010	0.60 max	17.50–18.50	19.50–20.50	6.00–6.50	...	...	...	0.180–0.220	...	0.50–1.00	...
...	S30815	0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	...	...	...	...	0.14–0.20	...	...	0.03–0.08

[A] New designation established in accordance with ASTM E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

[B] For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.044 in. [1 mm] in minimum wall thickness).

[C] The titanium content shall be not less than five times the carbon content and not more than 0.70 %.

[D] The titanium content shall be not less than four times the carbon content and not more than 0.60 %.

[E] The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.00 %.

[F] The columbium plus tantalum content shall be not less than eight times the carbon content and not more than 1.0 %.

[G] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

[H] Maximum, unless otherwise indicated.

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pipe from the same heat or lot may be made, and all pipe conforming to the requirements shall be accepted.

6.4 For referee purposes, the Test Methods and Practices and Terminology of A 751 shall be used.

7. Tensile Requirements

7.1 The tensile properties of the material shall conform to the requirements prescribed in Table 3.

8. Permissible Variations in Dimensions

8.1 *Specified Diameter*—The diameter at any point in each length of pipe shall be within the tolerance specified in Table 1.

8.2 *Alignment (Camber)*—Using a 3-ft [1.0-m] straightedge placed so that both ends are in contact with the pipe, the camber shall not be more than 0.030-in. [0.8-mm].

8.3 *Thickness*—The wall thickness at any point in the pipe shall be within the thickness tolerance specified in Table 3, except that for pipe in which the wall thickness exceeds 0.188-in. [4.8-mm] a weld reinforcement of up to 0.015-in. [0.38-mm] is permitted on the inside of the pipe.

9. Lengths

9.1 Pipe lengths shall be in accordance with the following regular practice.

9.1.1 Unless otherwise agreed upon, all sizes up to and including NPS 4 are available in a length up to 24 ft (Note 2) with the permissible range of 15 of 24 ft (Note 2).

TABLE 3 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
TP304L	S30403	70 [485]	25 [170]
TP316L	S31603	70 [485]	25 [170]
TP304	S30400	75 [515]	30 [205]
TP304H	S30409	75 [515]	30 [205]
TP309CB	S30940	75 [515]	30 [205]
TP309S	S30908	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP316	S31600	75 [515]	30 [205]
TP316H	S31609	75 [515]	30 [205]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
TP321	S32100	75 [515]	30 [205]
TP321H	S32109	75 [515]	30 [205]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21903	90 [620]	50 [345]
TPXM-15	S38100	75 [515]	30 [205]
TPXM-29	S24000	100 [690]	55 [380]
TPXM-19	S20910	100 [690]	55 [380]
TP304N	S30451	80 [550]	35 [240]
TP316N	S31651	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
TP316LN	S31653	75 [515]	30 [205]
...	S31254	94 [650]	44 [300]
...	S30815	87 [600]	45 [310]
...	N08367		
	t≤0.187	100 [690]	45 [310]
	t>0.187	95 [655]	45 [310]

NOTE 2—The value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and purchaser.

9.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and not more than ¼ in. [6 mm] over that specified.

9.1.3 No jointers are permitted unless otherwise specified.

10. Workmanship, Finish, and Appearance

10.1 The finished pipes shall be free of injurious imperfections and shall have a workmanlike finish. Minor imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted in Section 9.

11. General Requirements

11.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

12. Examination of Double-Welded Pipe

12.1 Both ends of each double-welded (Class DW) pipe shall be visually examined to determine that complete fusion was attained between the two welds. In lieu of examining the ends of the pipe, this examination may be performed on cropped ends removed from both ends of each double welded pipe.

13. Mechanical Tests Required

13.1 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes.

NOTE 3—The term "lot", for mechanical tests, applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment (*1*) in a continuous heat-treatment furnace, or (2) in a batch-type heat-treatment furnace, equipped with recording pyrometers and automatically controlled within a 50°F [30°C] range, the larger of (*a*) Each 200 ft [60 m] or fraction thereof or, (*b*) That pipe heat treated in the same batch furnace charge.

13.2 *Flattening Test*—For material heat treated in a batch-type furnace, flattening tests shall be made of 5 % of the pipe from each heat-treated lot. For material heat treated by the continuous process, this test shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than two lengths of pipe.

13.2.1 For pipe where the diameter equals or exceeds NPS 10, a transverse-guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A 370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5 % of the lot shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

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13.3 *Hydrostatic Test*—Each length of pipe shall be subjected to the hydrostatic test in accordance with Specification A 999/A 999M.

14. Product Marking

14.1 In addition to the marking specified in Specification A 999/A 999M, the marking shall include the manufac-turer's identifying mark and double-welded pipe shall be identified with the mark (DW). For Grades TP304H, TP316H, TP321H, TP347H, TP348H, and S 30815, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe NPS 5 and larger in nominal size, there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 in nominal size there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 6 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This applies only to pipe NPS 8 and larger in nominal size.

S2.2 If a specimen from any length fails to conform to the tensile properties specified, that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound welds and reasonably uniform material free of injurious laminations, cracks, and similar objectionable imperfections. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable imperfections, the length shall be rejected subject to the removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Eddy Current Examination

S5.1 Pipe soundness shall be determined through eddy-current examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S6. Ultrasonic Examination

S6.1 Pipe soundness shall be determined through ultrasonic examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S7. Corrosion Requirements

S7.1 *Boiling Nitric Acid Test*—Except for Grade TP 321, coupons representing finished pipe made of nonmolyb-denum-bearing material (0.50 % and less molybdenum) shall meet the requirements Practice C of Practices A 262. The condition of the test specimens and the corrosion rates are as follows: Types 304L, 304LN, 347, and Type 348 shall be tested in the sensitized condition (heated for 1 h at 1240°F [670°C]) and the rate of penetration shall not exceed 0.0020 in. [0.05 mm]/month. All other nonmolybdenum-bearing types, except for Grade TP 321, shown in Table 2 shall be tested in the annealed and unsensitized condition and the rate of penetration when solution tested in accordance with Practice C shall not exceed 0.0015 in./month [0.038 mm/month].

S7.2 *Acidified Copper Sulfate Test*—Coupons representing finished pipe made of molybdenum-bearing material (over 0.50 % molybdenum) and Type 321 shall meet the requirements of Practice E of Practices A 262. The condition of the test specimen is as follows: Types 316L, 316LN, 317L and 321 shall be tested in the sensitized condition (heated for 1 h at 1240°F [670°C]). All molybdenum-bearing types shown in Table 2 shall be tested in the annealed and unsensitized condition. All specimens shall meet the requirements of the prescribed bend tests.

S8. Flange Test

S8.1 A section of pipe shall be capable of having a flange turned over at a right angle to the body of the pipe without

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cracking. The width of the flange shall be not less than 15 % of the oustide diameter of the pipe.

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Designation: A 858/A 858M – 00

An American National Standard

Standard Specification for Heat-Treated Carbon Steel Fittings for Low-Temperature and Corrosive Service[1]

This standard is issued under the fixed designation A 858/A 858M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers heat-treated wrought carbon steel piping fittings with lowered carbon content of seamless and electric fusion-welded construction covered by the latest revisions in ANSI B 16.9, ANSI B 16.11, ANSI B 16.28, MSS-SP-75, and MSS-SP-79. Fittings differing from these ASME and MSS standards shall be furnished in accordance with Supplementary Requirement S58 of Specification A 960. These fittings are for use in pressure components where inherent notch toughness and optimum sulfide-cracking resistance are required, such as oil and gas industry piping and distribution systems.

1.2 Optional supplementary requirements are provided for fittings when a greater degree of examination is desired. One or more of the supplementary requirements may be specified in the order.

1.3 This specification does not cover cast-welding fittings or fittings machined from castings.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. Combining values from the two systems may result in nonconformance with this specification. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Unless the other specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A 960, the following list of standards apply to this specification.

2.2 *ASTM Standards:*

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe[2]

A 960 Specification for Common Requirements for Wrought Steel Pipe Fittings[2]

2.3 *ASME Boiler and Pressure Vessel Code:*

Section V Nondestructive Examination[3]

Section VIII Division 1, Pressure Vessels[3]

3. Ordering Information

3.1 In addition to the requirements of Specification A 960, the following ordering information applies: requirements for certification of the test report.

4. General Requirements

4.1 Products furnished to this specification shall conform to the requirements of Specification A 960, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 960 constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 960, this specification shall prevail.

5. Materials

5.1 The material for fittings shall be fully killed fine-grain material made by a melting process that is intended to produce rounded, well dispersed, fine sulfide inclusions, that promote good notch toughness, assists in the resistance to hydrogen induced cracking, and for weldability suitable for field-welding.

5.2 Starting materials shall consist of plate, sheet, forgings, forging quality bar and seamless or fusion welded tubular products with filler metal added. The chemical composition shall conform to Table 1.

5.3 A starting material that specifically requires the addition of any element beyond those listed in Table 1 is not permitted. This does not preclude the use of deoxidizers.

5.4 Starting materials shall not require a preheat for field welding provided that the restrictions of *ASME Boiler and Pressure Vessel Code*, Section VIII, Paragraph UW-30 are complied with.

6. Manufacture

6.1 Forging or shaping operations may be performed by

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] *Annual Book of ASTM Standards*, Vol 01.01.

[3] Available from American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

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TABLE 1 Chemical Requirements

	Composition %	
	Heat Analysis	
Carbon	0.20	
Manganese	0.90–1.35	All values are
Phosphorus	0.030	maximum unless a
Sulfur	0.010	range is shown
Silicon	0.15–0.40[A]	
Nickel	0.50[B]	
Chromium	0.30[B]	
Molybdenum	0.20[B]	
Copper	0.35[B]	

[A] When vacuum carbon deoxidation is used, the silicon shall be 0.10 % maximum, and on product analysis shall not exceed 0.12 %.

[B] The combined total of nickel, chromium, molybdenum, and copper shall not exceed 1.0 %.

hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion welding, machining, or by a combination of these operations.

6.2 All welds including welds in tubular products from which the fittings are made shall be:

6.2.1 Made by welders, welding operators, and welding procedures qualified under the provisions of *ASME Boiler and Pressure Vessel Code*, Section IX,

6.2.2 Heat treated in accordance with Section 7 of this specification, and

6.2.3 Radiographically examined throughout the entire length of each weld in accordance with Articles 1 and 2 of *ASME Boiler and Pressure Vessel Code*, Section V with the acceptance limits in accordance with Paragraph UW-51 in Section VIII of that same code.

6.3 The welded joints of the fittings shall be furnished in accordance with the requirements of Paragraph UW-35(a) of *ASME Boiler and Pressure Vessel Code*, Section VIII.

6.4 All butt-weld tees manufactured by cold-forming methods shall be liquid-penetrant or magnetic-particle examined by one of the methods specified in Specification A 960. This examination shall be performed in accordance with a written procedure and shall be performed after final heat treatment. Only the side wall area of the tees need be examined. This area is defined by a circle that covers the area from the weld bevel of the branch outlet to the center line of the body or run. Internal and external surfaces shall be examined when size permits accessibility. No cracks shall be permitted. Other imperfections shall be treated in accordance with Section 14 on finish. After the removal of any crack, the tees shall be re-examined by the original method. Acceptable tees shall be marked with the symbol PT or MT, as applicable, to indicate compliance. NDE personnel shall be qualified in accordance with SNT-TC-1A.

6.5 All caps machined from bar stock shall be examined by liquid penetrant or magnetic particle in accordance with Supplementary Requirement S69 or S70 with personnel qualifications, acceptance criteria and marking as in 5.4.

7. Heat Treatment

7.1 All fittings shall be furnished in the heat-treated condition. Fittings formed above the transformation temperature or upon which welding is performed, shall be cooled to below the lower criteria temperature prior to heat treatment. Fittings shall subsequently be heat treated by normalizing, quenching, and tempering or stress-relieving in accordance with Specification A 960.

8. Chemical Composition Requirements

8.1 The chemical composition of the steel shall conform to the requirements prescribed in Table 1.

8.2 The steel shall not contain any unspecified elements for the ordered grade to the extent that it conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

8.3 An analysis of each heat of steel shall be made from a sample taken preferably during the pouring of the heat. The results shall conform to Table 1.

8.4 The fittings manufacturer shall make a product analysis per heat from either the starting material or from a fitting in accordance with Specification A 960.

8.5 Weld metal used in the construction of the fittings shall conform to the tensile and impact requirements of 9.4 and 11.1 after heat treatment in accordance with Section 7. A chemical analysis shall be performed on deposited weld metal for each heat of filler metal or, for submerged arc welding, each heat of filler metal and batch of flux. The weld metal shall be deposited in accordance with the qualified weld procedure.

8.6 Only the carbon content of the deposited weld-metal composition need comply with the requirements of Table 1. The total nickel content of the deposited weld metal shall not exceed 1.0 %.

9. Tensile Requirements

9.1 The tensile properties of the fitting material shall conform to the requirements listed in Table 2.

9.2 Tension test specimens shall be taken from a fitting after final heat treatment or from a test piece of the same heat and nominal thickness that was heat-treated in a charge with the fittings it represents.

9.3 One tensile test is required for each heat of fittings of the same section thickness and heat treated in either a continuous- or batch-type furnace, controlled within a range of 50°F [28°C] and equipped with recording pyrometers.

9.4 In addition, fittings containing welds shall have one center-weld tension test made with the axis transverse to the weld seam for each heat of filler metal, or each heat of filler metal and batch of flux for submerged arc welds, for fittings of the same section thickness and heat treated in either a continuous or batch-type furnace controlled within a range of 50°F [28°C] and equipped with recording pyrometers. Only the ultimate tensile strength need meet the minimum requirements of Table 2.

10. Hardness Requirements

10.1 Fittings shall have a maximum hardness of 22 HRC (235 HB).

11. Notch Toughness Properties

11.1 The notch toughness properties of the fittings shall conform to the requirements listed in Table 2. The testing shall be performed in accordance with Methods and Definitions A 370. Full-size Charpy, V-notch, Type A specimens shall be

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TABLE 2 Mechanical Requirements

Yield strength, min, 0.2 % offset, ksi [MPa]	36 [250]
Tensile strength, min, ksi [MPa]	70 [485]-95 [485]
Elongation:	
Standard round specimen, or small-size proportional specimen, min, % in 4D	22
Rectangular specimen, for section thickness 5/16 in. [7.94 mm] and over, and for small sizes tested in full section; min, % in 2 in. [50 mm].	30
Rectangular specimen for section thickness less than 5/16 in. [7.94 mm]; min, % in 2 in. [50 mm]. Width of specimen 1½ in. [40 mm].	[A]
Reduction of area (round specimen only); min, %.	40
Toughness:	
C_v energy absorption[B]; measured at –50°F [–46°C]:	
Specimen size, mm	Average/min, ft-lbs [J]
10 × 10	20/16 [27/22]
10 × 7.5	17/13 [23/18]
10 × 5	13/11 [18/15]

[A] For each 1/32 in. [0.79 mm] decrease in section thickness below 5/16 in. [7.94 mm] a deduction 1.5 % from the 30 % shown above is permitted. Where the section thickness lies between two values defined above, the minimum elongation value is determined by the following equation:

$$E = 48t + 15.00$$

where:

E = elongation in 2 in. [50 mm], and

t = actual thickness of specimen, in.

[B] These requirements are intended to minimize fracture initiation. The requirements are not intended to give assurance against fracture propagation.

used whenever possible. Small size specimens shall be used only when the material thickness does not permit full size specimens. The impact specimens shall not be flattened after heat treatment. All base metal specimens shall be removed with the axis of the specimens longitudinal to the direction of primary metal flow. Weld metal specimens shall have the axis transverse to the weld seam.

11.2 One set of impact tests (three specimens) shall be made to represent the base metal and one set of impact tests (three specimens) shall be made to represent the weld metal on the same frequency as the tension tests.

11.3 The test temperature shall be –50°F [–46°C].

12. Dimensions

12.1 Dimensional requirements for NPS 14 and smaller fittings are provided by ANSI B 16.9, B 16.11, B 16.28, or MSS-SP-79.

12.2 Dimensional requirements for fittings larger than NPS 14 up through NPS 48 are provided in MSS-SP-75, except as modified by 12.3

12.3 Fittings of a size or shape differing from the standards in 12.1 and 12.2 but meeting all the other requirements of this specification, may be furnished in accordance with Supplementary Requirement S58 of Specification A 960.

13. Finish and Appearance

13.1 See Specification A 960 for specific requirements.

14. Repair by Welding (Base Metal)

14.1 Repair welding, by the manufacturer, is permissible in accordance with Specification A 960 and the following:

14.1.1 The deposited weld metal shall conform to the requirements of 8.5 and 8.6. Electrodes for the shielded metal-arc process shall be of the low-hydrogen type.

14.1.2 Sections thicker than 1 in. [25 mm] shall also be radiographed after repair welding in accordance with 6.2.

14.1.3 All fittings repaired by welding shall be thermally treated after repair by either complete reheat treatment or post-weld heat treatment at least 50°F [28°C] below the tempering temperature if tempering has been performed.

14.1.4 Indications discovered by nondestructive examination shall, after heat treatment, be again examined by the same NDE method as used in the original determination.

14.1.5 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

15. Hydrostatic Test

15.1 Hydrostatic testing is not required by this specification.

15.2 Every fitting shall be capable of withstanding without failure, leakage, or impairment of serviceability, a hydrostatic test pressure of 1½ times its pressure rating or 1½ times the piping design pressure.

16. Rejection and Rehearing

16.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection shall be reported to the producer or supplier promptly in writing. In case of dissatisfaction with the results of the tests, the producer or supplier may make claim for a rehearing.

17. Certification

17.1 When requested by the purchaser, the manufacturer shall provide a certificate of compliance to this specification (including year date). In addition, if requested to provide test reports, the manufacturer shall also provide the following, where applicable:

17.1.1 Chemical analysis results, (Section 8 and Table 1), base metal only, and

17.1.2 Tensile property results, (Section 9 and Table 2), including the yield strength and tensile strength in ksi, and elongation and reduction of area in percent for the base metal. Transverse-weld tensile strength shall be reported in ksi.

17.1.3 Impact test results, (Section 11 and Table 2), base metal and weld metal, report specimen size and test temperature, and

17.1.4 Type heat treatment, (Section 7),

17.1.5 Radiographic examination results, and

17.1.6 Any supplemental testing required by the purchase order.

18. Product Marking

18.1 Identification marking shall consist of the manufacturer's symbol or name (Note 1), specification number (year date not needed), size, and nominal wall thickness or schedule, and heat code identity. In addition, quenched and tempered fittings shall be marked with the symbol QT, and cold-formed tees shall be marked as prescribed in 6.4.

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NOTE 1—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component complies with this specification.

18.2 Fittings that have been repaired by welding shall be marked with the letter W following the designation number.

18.3 Marking shall be by low-stress die stamps or interrupted dot stamps and shall be in accordance with MSS-SP-25.

18.4 If the impact test temperature is other than −50°F [−46°C], the impact test temperature shall be marked on the fitting.

18.5 *Bar Coding*—In addition to the requirements in 18.1, 18.2, 18.3, and 18.4, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

19. Keywords

19.1 corrosive service applications; pipe fittings–steel; piping applications; pressure containing parts; temperature service applications–low

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Designation: B 42 – 98

Standard Specification for Seamless Copper Pipe, Standard Sizes[1]

This standard is issued under the fixed designation B 42; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification[2] covers seamless copper pipe in all nominal or standard pipe sizes, both regular and extra-strong, suitable for use in plumbing, boiler feed lines, and for similar purposes.[3]

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*

B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing[4]

B 170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes[4]

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[4]

E 8 Test Methods for Tension Testing of Metallic Materials[5]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[6]

E 53 Methods for Chemical Analysis of Copper[7]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[7]

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)[7]

E 243 Practice for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes[8]

E 478 Test Methods for Chemical Analysis of Copper Alloys[9]

E 527 Practice for Numbering Metals and Alloys (UNS)[10]

3. Terminology

3.1 *Definitions:*

3.1.1 *lengths*—straight pieces of the product.

3.1.1.1 *standard*—uniform lengths recommended in a Simplified Practice Recommendation or established as a Commercial Standard.

3.1.2 *tube, seamless*—a tube produced with a continuous periphery in all stages of the operations.

3.1.2.1 *pipe*—a seamless tube conforming to the particular dimensions commercially known as Nominal or Standard Pipe Sizes.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *capable of*—as used in this specification, the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Type of copper, if required,

4.1.2 Temper (see 6.1),

4.1.3 Pipe size, regular or extra-strong, (see 10.2),

4.1.4 Length (see 10.3),

4.1.5 Total length of each size,

4.1.6 If material is required to meet *ASME Boiler and Pressure Vessel Code*,

4.1.7 Certification, if required (see 18.1),

4.1.8 Mill test report, if required (see 20.1),

4.1.9 Hydrostatic test, if required, and

4.1.10 Pneumatic test, if required.

4.2 In addition, when material is purchased for agencies of the U.S. Government, it shall conform to the Supplementary

[1] This specification is under the jurisdiction of ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.04 on Pipe and Tube.

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[2] For *ASME Boiler and Pressure Vessel Code* applications, see related Specification SB-42 in Section II of that Code.

[3] The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix "C" and a suffix "00." The suffix can be used to accommodate composition variations of the base alloy.

[4] *Annual Book of ASTM Standards*, Vol 02.01.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

[6] *Annual Book of ASTM Standards*, Vol 14.02.

[7] *Annual Book of ASTM Standards*, Vol 03.05.

[8] *Annual Book of ASTM Standards*, Vol 03.03.

[9] *Annual Book of ASTM Standards*, Vol 03.06.

[10] *Annual Book of ASTM Standards*, Vol 01.01.

***A Summary of Changes section appears at the end of this standard.**

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Requirements as defined herein when specified in the contract or purchase order.

5. Chemical Composition

5.1 The material shall conform to the following chemical requirements:

Copper (incl silver), min, %	99.9
Phosphorus, max, %	0.04

5.2 The pipe shall be produced from one of the following coppers, and unless otherwise specified, anyone of them is permitted to be furnished:

Copper UNS No.	Previously Used Designation	Type of Copper
C10200	OF	Oxygen-free without residual deoxidants
C10300		Oxygen-free, extra-low phosphorus
C10800		Oxygen-free, low phosphorus
C12000	DLP	Phosphorized, low residual phosphorus
C12200	DHP	Phosphorized, high residual phosphorus

5.3 When the copper is specified, the material shall conform to the chemical requirements specified in Table 1.

5.4 These specification limits do not preclude the possible presence of other elements. When required, limits for unnamed elements are to be established by agreement between manufacturer or supplier and purchaser.

5.4.1 The major element that is not analyzed shall be determined by difference between the sum of those elements analyzed and 100 %. By agreement between manufacturer and purchaser, it is permitted to establish limits and required analysis for elements not specified.

6. Temper

6.1 All pipe shall normally be furnished in the O61 (annealed), H55 (light drawn), or H80 (hard drawn) temper, as prescribed in Practice B 601, and shall have the properties shown in Table 2.

6.2 When pipe is required for bending, it shall be so specified in the purchase order, and the pipe shall be furnished in the temper agreed upon between the manufacturer or supplier and the purchaser.

7. Expansion Test

7.1 Pipe ordered in the annealed (O) condition, selected for test, shall withstand an expansion of 25 % of the outside diameter when expanded in accordance with Test Method B 153. The expanded pipe shall show no cracking or rupture visible to the unaided eye. Pipe ordered in the drawn (H) condition is not subject to this test.

TABLE 1 Chemical Requirements

Copper UNS No.	Copper (incl Silver), min, %	Phosphorus, %
C10200[A]	99.95	...
C10300	99.95[B]	0.001 to 0.005
C10800	99.95[B]	0.005 to 0.012
C12000	99.90	0.004 to 0.012
C12200	99.9	0.015 to 0.040

[A] Oxygen in C10200 shall be 10 ppm max.
[B] Copper + silver + phosphorus.

TABLE 2 Tensile Requirements

Temper Designation		Pipe Size Nominal or Standard, in.	Tensile Strength, min, ksi[A] (MPa)[B]	Yield Strength,[C] min, ksi[A] (MPa)[B]
Standard	Former			
O61	annealed	all	30 (294)	9 (88)[D]
H80	hard drawn	⅛–2, incl	45 (310)	40 (280)
H55	light drawn	2–12, incl	36 (250)	30 (210)

[A] ksi = 1000 psi.
[B] See Appendix X1.
[C] At 0.5 % extension under load.
[D] Light-straightening operation is permitted.

NOTE 1—The term "unaided eye," as used herein, permits the use of corrective spectacles necessary to obtain normal vision.

7.2 As an alternative to the expansion test for pipe over 4 in. (102 mm) in diameter in the annealed condition, a section 4 in. in length shall be cut from the end of one of the lengths for a flattening test. This 4-in. specimen shall be flattened so that a gage set at three times the wall thickness will pass over the pipe freely throughout the flattened part. The pipe so tested shall develop no cracks or flaws visible to the unaided eye (Note 1) as a result of this test. In making the flattening test, the elements shall be slowly flattened by one stroke of the press.

8. Microscopical Examination

8.1 The pipe shall be made from copper that is free of cuprous oxide as determined by microscopical examination at a 75× magnification. When Copper UNS No. C12200 is supplied, microscopical examination for cuprous oxide is not required.

9. Nondestructive Testing

9.1 The material shall be tested in the final size but is permitted to be tested before the final anneal or heat treatment, when these thermal treatments are required, unless otherwise agreed upon by the manufacturer or supplier and purchaser.

9.2 *Eddy-Current Test*—Each piece of material from ⅛-in. up to and including 2½-in. nominal outside diameter, or within the capabilities of the eddy-current tester, shall be subjected to an eddy-current test. Testing shall follow the procedures of Practice E 243, except for determination of "end effect." The material shall be passed through an eddy-current testing unit adjusted to provide information on the suitability of the material for the intended application.

9.2.1 Notch-depth standards rounded to the nearest 0.001 in. (0.025 mm) shall be 10 % of the nominal wall thickness. The notch depth tolerance shall be ±0.0005 in. (0.013 mm). Alternatively, when a manufacturer uses speed-insensitive equipment that allows the selection of a maximum imbalance signal, a maximum imbalance signal of 0.3 % is permitted to be used.

9.2.2 Material that does not actuate the signaling device of the eddy-current test shall be considered as conforming to the requirements of this test. Material with discontinuities indicated by the testing unit is permitted to be reexamined or retested, at the option of the manufacturer, to determine whether the discontinuity is cause for rejection. Signals that are found to have been caused by minor mechanical damage, soil, or moisture shall not be cause for rejection of the material

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provided the dimensions of the material are still within prescribed limits and the material is suitable for its intended application.

9.3 *Hydrostatic Test*—When specified, the material shall stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 6000 psi (41 MPa), determined by the following equation for thin hollow cylinders under tension. The material need not be tested at a hydrostatic pressure of over 1000 psi (6.9 MPa) unless so specified.

$$P = 2St/(D - 0.8t) \quad (1)$$

where:

P = hydrostatic pressure, psi (or MPa);
t = wall thickness of the material, in. (or mm);
D = outside diameter of the material in. (or mm); and
S = allowable stress of the material, psi (or MPa).

9.4 *Pneumatic Test* When specified, the material shall be subjected to an internal air pressure of 60 psi (415 kPa) minimum for 5 s without showing evidence of leakage. The test method used shall permit easy visual detection of any leakage, such as by having the material under water or by the pressure-differential method. Any evidence of leakage shall be cause for rejection.

10. Dimensions and Permissible Variations

10.1 For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the limiting values for any dimensions shall be sufficient cause for rejection.

10.2 *Standard Dimensions, Wall Thickness, and Diameter Tolerances*—The standard dimensions, wall thickness, and diameter tolerances shall be in accordance with Table 3.

10.3 *Length and Length Tolerances* The standard length of copper pipe is 12 ft (3.66 m) with a tolerance of ±½ in. (13 mm).

10.4 *Roundness*:

10.4.1 For drawn unannealed pipe in straight lengths, the

TABLE 3 Standard Dimensions, Weights, and Tolerances

NOTE 1—All tolerances plus and minus except as otherwise indicated.

Nominal or Standard Pipe Size, in.	Outside Diameter, in. (mm)	Average Outside Diameter Tolerance,[A] in. (mm) All Minus	Wall Thickness, in. (mm)	Tolerance,[B] in. (mm)	Theoretical Weight, lb/ft (kg/m)
		Regular			
⅛	0.405 (10.3)	0.004 (0.10)	0.062 (1.57)	0.004 (0.10)	0.259 (0.385)
¼	0.540 (13.7)	0.004 (0.10)	0.082 (2.08)	0.005 (0.13)	0.457 (0.680)
⅜	0.675 (17.1)	0.005 (0.13)	0.090 (2.29)	0.005 (0.13)	0.641 (0.954)
½	0.840 (21.3)	0.005 (0.13)	0.107 (2.72)	0.006 (0.15)	0.955 (1.42)
¾	1.050 (26.7)	0.006 (0.15)	0.114 (2.90)	0.006 (0.15)	1.30 (1.93)
1	1.315 (33.4)	0.006 (0.15)	0.126 (3.20)	0.007 (0.18)	1.82 (2.71)
1¼	1.660 (42.2)	0.006 (0.15)	0.146 (3.71)	0.008 (0.20)	2.69 (4.00)
1½	1.900 (48.3)	0.006 (0.15)	0.150 (3.81)	0.008 (0.20)	3.20 (4.76)
2	2.375 (60.3)	0.008 (0.20)	0.156 (3.96)	0.009 (0.23)	4.22 (6.28)
2½	2.875 (73.0)	0.008 (0.20)	0.187 (4.75)	0.010 (0.25)	6.12 (9.11)
3	3.500 (88.9)	0.010 (0.25)	0.219 (5.56)	0.012 (0.30)	8.76 (13.0)
3½	4.000 (102)	0.010 (0.25)	0.250 (6.35)	0.013 (0.33)	11.4 (17.0)
4	4.500 (114)	0.012 (0.30)	0.250 (6.35)	0.014 (0.36)	12.9 (19.2)
5	5.562 (141)	0.014 (0.36)	0.250 (6.35)	0.014 (0.36)	16.2 (24.1)
6	6.625 (168)	0.016 (0.41)	0.250 (6.35)	0.014 (0.36)	19.4 (28.9)
8	8.625 (219)	0.020 (0.51)	0.312 (7.92)	0.022 (0.56)	31.6 (47.0)
10	10.750 (273)	0.022 (0.56)	0.365 (9.27)	0.030 (0.76)	46.2 (68.7)
12	12.750 (324)	0.024 (0.61)	0.375 (9.52)	0.030 (0.76)	56.5 (84.1)
		Extra Strong			
⅛	0.405 (10.3)	0.004 (0.10)	0.100 (2.54)	0.006 (0.15)	0.371 (0.552)
¼	0.540 (13.7)	0.004 (0.10)	0.123 (3.12)	0.007 (0.18)	0.625 (0.930)
⅜	0.675 (17.1)	0.005 (0.13)	0.127 (3.23)	0.007 (0.18)	0.847 (1.26)
½	0.840 (21.3)	0.005 (0.13)	0.149 (3.78)	0.008 (0.20)	1.25 (1.86)
¾	1.050 (26.7)	0.006 (0.15)	0.157 (3.99)	0.009 (0.23)	1.71 (2.54)
1	1.315 (33.4)	0.006 (0.15)	0.182 (4.62)	0.010 (0.25)	2.51 (3.73)
1¼	1.660 (42.2)	0.006 (0.15)	0.194 (4.93)	0.010 (0.25)	3.46 (5.15)
1½	1.900 (48.3)	0.006 (0.15)	0.203 (5.16)	0.011 (0.28)	4.19 (6.23)
2	2.375 (60.3)	0.008 (0.20)	0.221 (5.61)	0.012 (0.30)	5.80 (8.63)
2½	2.875 (73.0)	0.008 (0.20)	0.280 (7.11)	0.015 (0.38)	8.85 (13.2)
3	3.500 (88.9)	0.010 (0.25)	0.304 (7.72)	0.016 (0.41)	11.8 (17.6)
3½	4.000 (102)	0.010 (0.25)	0.321 (8.15)	0.017 (0.43)	14.4 (21.4)
4	4.500 (114)	0.012 (0.30)	0.341 (8.66)	0.018 (0.46)	17.3 (25.7)
5	5.562 (141)	0.014 (0.36)	0.375 (9.52)	0.019 (0.48)	23.7 (35.3)
6	6.625 (168)	0.016 (0.41)	0.437 (11.1)	0.027 (0.69)	32.9 (49.0)
8	8.625 (219)	0.020 (0.51)	0.500 (12.7)	0.035 (0.89)	49.5 (73.7)
10	10.750 (273)	0.022 (0.56)	0.500 (12.7)	0.040 (1.0)	62.4 (92.9)

[A] The average outside diameter of a tube is the average of the maximum and minimum outside diameters as determined at any one cross section of the pipe.
[B] Maximum deviation at any one point.

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roundness tolerances shall be as follows:

t/d (ratio of Wall Thickness to Outside Diameter)	Roundness Tolerances as Percent of Outside Diameter (Expressed to the Nearest 0.001 in. (0.025 mm))
0.01 to 0.03, incl	1.5
Over 0.03 to 0.05, incl	1.0
Over 0.05 to 0.10, incl	0.8
Over 0.10	0.7

10.4.2 Compliance with the roundness tolerance shall be determined by taking measurements on the outside diameter only, irrespective of the manner in which the pipe dimensions are specified.

10.4.3 The deviation from roundness is measured as the difference between major and minor diameters as determined at any one cross section of the tube.

10.5 *Squareness of Cut*—The departure from squareness of the end of any pipe shall not exceed the following:

Outside Diameter, in. (mm)	Tolerance
Up to ⅝ (15.9), incl	0.010 in. (0.25 mm)
Over ⅝ (15.9)	0.016 in./in. (0.016 mm/mm) of diameter

10.6 *Straightness Tolerance*—For pipe of H (drawn) tempers of Nominal Pipe Sizes from ¼ to 12 in. inclusive, the maximum curvature (depth of arc) shall not exceed ½ in. (13 mm) in any 10-ft (3048-mm) portion of the total length. For H temper pipe of other sizes, and for the O611 (annealed) temper, no numerical values are established, however, the straightness of the pipe shall be suitable for the intended application.

11. Workmanship, Finish, and Appearance

11.1 The material shall be free of defects of a nature that interfere with normal commercial applications. It shall be well cleaned and free of dirt.

12. Sampling

12.1 *Sampling*—The lot size, portion size, and selection of sample pieces shall be as follows:

12.1.1 *Lot Size*—The lot size shall be as follows:

Pipe Size, in.	Lot Weight, lb (kg)
Up to 1½, incl	5 000 (2270) or fraction thereof
Over 1½ to 4, incl	10 000 (4550) or fraction thereof
Over 4	40 000 (18 100) or fraction thereof

12.1.2 *Portion Size*—Sample pieces shall be taken for test purposes from each lot according to the following schedule:

Number of Pieces in Lot	Number of Sample Pieces to be Taken[A]
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2 % of total number of pieces in the lot, but not to exceed ten sample pieces

[A] Each sample piece shall be taken from a separate tube.

13. Number of Tests and Retests

13.1 *Chemical Analysis*—Samples for chemical analysis shall be taken in accordance with Practice E 55. Drillings, millings, and so forth shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 12.1.2 and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

13.1.1 Instead of sampling in accordance with Practice E 55, the manufacturer shall have the option of determining conformance to chemical composition as follows: Conformance shall be determined by the manufacturer by analyzing samples taken at the time the castings are poured or samples taken from the semifinished product. If the manufacturer determines the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product. The number of samples taken for determination of chemical composition shall be as follows:

13.1.1.1 When samples are taken at the time the castings are poured, at least one sample shall be taken for each group of castings poured simultaneously from the same source of molten metal.

13.1.1.2 When samples are taken from the semifinished product, a sample shall be taken to represent each 10 000 lb (4550 kg) or fraction thereof, except that not more than one sample shall be required per piece.

13.1.1.3 Because of the discontinuous nature of the processing of castings into wrought products, it is not practical to identify specific casting analysis with a specific quantity of finished material.

13.1.1.4 In the event that heat identification or traceability is required, the purchaser shall specify the details desired.

13.2 *Retests*:

13.2.1 If any test specimen shows defective machining or develops flaws, it shall be discarded and another specimen substituted.

13.2.2 If a bend test specimen fails because of conditions of bending more severe than required by the specification, a retest shall be permitted on a new sample piece or on the remaining portion of the first sample piece.

13.2.3 If the results of the test on one of the specimens fail to meet the specified requirements, two additional specimens shall be taken from different sample pieces and tested. The results of the tests on both of these specimens shall meet the specified requirements. Failure of more than one specimen to meet the specified requirements for a particular property shall be cause for rejection of the entire lot.

13.2.4 If the chemical analysis fails to conform to the specified limits, analysis shall be made on a new composite sample prepared from additional pieces selected in accordance with 12.1. The results of this retest shall comply with the specified requirements.

14. Test Methods

14.1 The properties enumerated in this specification shall, in case of disagreement, be determined in accordance with the following applicable test methods:

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Test	ASTM Designation[A]
Chemical analysis	B 170[B], E 53, E 62, E 478
Tension	E 8
Expansion (pin test)	B 153
Eddy current	E 243

[A] See 2.1.

[B] Reference to Specification B 170 is to the suggested chemical methods in the annex thereof. When Committee E-1 has tested and published methods for assaying the low-level impurities in copper, the Specification B 170 annex will be eliminated.

14.2 Tension test specimens shall be of the full section of the pipe and shall conform to the requirements of the Specimens for Pipe and Tube section of Test Methods E 8 unless the limitations of the testing machine preclude the use of such a specimen. Test specimens conforming to Type No. 1 of Fig. 13, Tension Test Specimens for Large-Diameter Tubular Products, of Test Methods E 8 is permitted to be used when a full-section specimen cannot be tested.

14.3 Whenever tension test results are obtained from both full-size and machined test specimens and they differ, the results obtained from full-size test specimens shall be used to determine conformance to the specification requirements.

14.4 Tension test results on material covered by this specification are not seriously affected by variations in speed of testing. A considerable range of testing speed is permissible; however, it is recommended that the rate of stressing to the yield strength not exceed 100 ksi (700 MPa)/min. Above the yield strength, it is recommended that the movement per minute of the testing machine head under load not exceed 0.5 in./in. (0.5 mm/mm) of gage length (or distance between grips for full-section specimens).

15. Significance of Numerical Limits

15.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Practice E 29.

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	nearest unit in the last right-hand place of figures of the specified limit
Tensile strength Yield strength	nearest ksi (nearest 5 MPa)

16. Inspection

16.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with the specified requirements.

17. Rejection and Rehearing

17.1 Material that fails to conform to the requirements of this specification shall be subject to rejection. Rejection is to be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer or supplier shall have the option to make claim for a rehearing.

18. Certification

18.1 When specified on the purchase order, the manufacturer shall furnish to the purchaser a certificate stating that each lot has been sampled, tested, and inspected in accordance with this specification and has met the requirements. When material is specified to meet the requirements of *ASME Boiler and Pressure Vessel Code*, the certification requirements are mandatory.

19. Packaging and Package Marking

19.1 The material shall be separated by size, composition, and temper and prepared for shipment in such a manner as to ensure acceptance by common carrier for transportation and to afford protection from the normal hazards of transportation.

19.2 Each shipping unit shall be legibly marked with the purchase order number, metal or alloy designation, temper, size, total length or piece count or both, and name of supplier. The specification number shall be shown, when specified.

20. Mill Test Report

20.1 When specified on the purchase order, the manufacturer shall furnish to the purchaser a test report showing results of tests required by the specification.

21. Keywords

21.1 copper pipe; extra strong; regular; standard sizes

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SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U. S. Government.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

S1.1.1 *Federal Standards:*[11]

Fed. Std. No. 102 Preservation, Packaging and Packing Levels

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 185 Identification Marking of Copper and Copper-Base Alloy Mill Products

S1.1.2 *Military Standard:*[11]

MIL-STD-129 Marking for Shipment and Storage

S1.1.3 *Military Specification:*[11]

MIL-C-3993 Packaging of Copper and Copper-Base Alloy Mill Products

S2. Quality Assurance

S2.1 *Responsibility for Inspection:*

S2.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer shall use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

S3. Identification Marking

S3.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 185 except that the ASTM specification number and the alloy number shall be used.

S4. Preparation for Delivery

S4.1 *Preservation, Packaging, Packing:*

S4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade, or class and shall be preserved and packaged, Level A or C, and packed, Level A, B, or C, as specified in the contract or purchase order, in accordance with the requirements of MIL-C-3993.

S4.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

[11] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, ATTN: NPODS.

APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = kg \cdot m/s^2$). The derived SI unit for pressure or stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since 1 ksi = 6 894 757 Pa, the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2.

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SUMMARY OF CHANGES

Committee B05 has identified the location of selected changes to this standard since the last issue (B 42 - 96) that may impact the use of this standard.

(*1*) Section 10.6, Straightness Tolerance, was added to include straightness requirements.

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Designation: B 61 – 93

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Standard Specification for Steam or Valve Bronze Castings[1]

This standard is issued under the fixed designation B 61; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification[2] establishes requirements for a high-grade steam-metal or valve-bronze alloy (Copper Alloy UNS No. C92200[3]) used for component castings of valves, flanges, and fittings.

1.2 The castings covered are used in products that may be manufactured in advance and supplied from stock by the manufacturer or other dealer.

1.3 The values stated in inch-pound units are to be regarded as the standard. Metric values given in parenthesis are for information only.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*

B 208 Practice for Preparing Tension Test Specimens for Copper-Base Alloys for Sand, Permanent Mold, Centrifugal, and Continuous Castings[4]

B 824 Specification for General Requirements for Copper Alloy Castings[4]

E 527 Practice for Numbering Metals and Alloys (UNS)[5]

2.3 *MSS Standards:*

SP-25 Standard Marking System for Valves, Fittings, Flanges and Unions[6]

3. Ordering Information

3.1 Orders for castings under this specification shall include the following:

3.1.1 Quantity of castings required,

3.1.2 Copper Alloy UNS No. (Table 1),

3.1.3 Specification title, number, and year of issue,

3.1.4 Pattern or drawing number and condition (as-cast, machined, etc.),

3.1.5 Chemical analysis of residual elements if specified in the purchase order (Specification B 824),

3.1.6 Pressure test requirements, if specified in the purchase order (Specification B 824),

3.1.7 Soundness requirements, if specified in the purchase order (Specification B 824),

3.1.8 Certification, if specified in the purchase order (Specification B 824),

3.1.9 Foundry test report, if specified in the purchase order (Specification B 824),

3.1.10 Witness inspection, if specified in the purchase order (Specification B 824),

3.1.11 ASME boiler and pressure vessel application (Section 9), and

3.1.12 Product marking, if specified in the purchase order (Specification B 824 and Section 10).

3.2 When material is purchased for agencies of the U.S. Government, the Supplementary Requirements in Specification B 824 may be specified.

4. Chemical Composition

4.1 The alloy shall conform to the chemical requirements for major elements specified in Table 1.

4.2 These specification limits do not preclude the presence of other elements. Limits may be established for unnamed elements by agreement between manufacturer or supplier and purchaser. Copper or zinc may be given as remainder and may be taken as the difference between the sum of all elements analyzed and 100 %. When all named elements in Table 1 are analyzed, their sum shall be as follows:

Copper plus named elements, 99.3 % minimum. (1)

4.3 It is recognized that residual elements may be present in cast copper base alloys. Analysis shall be made for residual elements only when specified in the purchase order (Specification B 824).

5. Mechanical Properties

5.1 Mechanical properties shall be determined from separately cast test bars and shall meet the requirements shown in Table 2.

[1] This practice is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.05 on Castings and Ingots for Remelting.

Current edition approved Feb. 15, 1993. Published April 1993. Originally published as B 61 – 27 T. Last previous edition B 61 – 90.

[2] For *ASME Boiler and Pressure Vessel Code* applications see related Specification SB-61 of that Code.

[3] The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix "C" and a suffix "00". The suffix can be used to accommodate composition variations of the base alloy.

[4] *Annual Book of ASTM Standards*, Vol 02.01.

[5] *Annual Book of ASTM Standards*, Vol 01.01.

[6] Available from Manufacturers Standardization Society of the Valve and Fittings Industry, 127 Park Street NE, Vienna, VA 22180.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Chemical Requirements, Copper Alloy UNS No. C92200

Major Elements	Composition, % max (Except as indicated)
Copper	86.0–90.0
Tin	5.5–6.5
Lead	1.0–2.0
Zinc	3.0–5.0
Nickel incl Cobalt	1.0[A]
Residual Elements	**Composition, % max (Except as indicated)**
Iron	0.25
Antimony	0.25
Sulfur	0.05
Phosphorus	0.05
Aluminum	0.005
Silicon	0.005

[A] In determining copper minimum, copper may be calculated as copper plus nickel.

TABLE 2 Tensile Properties

Tensile strength, min, ksi[A] (MPa[B])	34 (235)
Yield strength,[C] min, ksi[A] (MPa[B])	16 (110)
Elongation in 2 in. (50.8 mm), min %	24

[A] ksi = 1000 psi.
[B] See Appendix.
[C] Yield strength shall be determined as the stress producing an elongation under load of 0.5 % that is, 0.01 in. (0.25 mm) in a gage length of 2 in. (51 mm).

6. Casting Repair

6.1 Castings shall not be plugged, welded, burned-in or impregnated.

7. General Requirements

7.1 Material furnished under this specification shall conform to the applicable requirements of Specification B 824.

8. Sampling

8.1 Copper Alloy UNS No. C92200 test bar castings shall be cast to the form and dimensions shown in Figs. 2, 3, or 4 of Practice B 208.

9. Certification

9.1 When material is specified to meet the requirements of *ASME Boiler and Pressure Vessel Code*, the certification requirements of Specification B 824 are mandatory.

10. Product Marking

10.1 Valves, flanges, and fittings shall be marked in accordance with the latest revision of the Standard Marking System for Valves, Fittings, Flanges, and Unions (No. SP-25) of the Manufacturers Standardization Society of the Valve and Fittings Industry, and in such position as not to injure the usefulness of the casting.

11. Keywords

11.1 Navy M castings; steam bronze castings; valve castings

APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = kg \cdot m/s^2$). The derived SI unit for pressure or stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since 1 ksi = 6 894 757 Pa the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2.

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SUMMARY OF CHANGES

This section identifies principle changes to this specification since the last issue.

1. Paragraph 1.1 was rewritten
2. The entire specification was revised to comply with Specification B 824 General Requirements for Copper Alloy Castings.

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Designation: B 62 – 93

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Standard Specification for Composition Bronze or Ounce Metal Castings[1]

This standard is issued under the fixed designation B 62; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification[2] establishes requirements for an alloy having a composition of copper, tin, lead, and zinc, used for component castings of valves, flanges, and fittings. The common trade name of this alloy is 85-5-5-5; the correct identification is Copper Alloy UNS No. C83600.[3]

1.2 The castings covered are used in products that may be manufactured in advance and supplied from stock from the manufacturer or other dealer.

1.3 The values stated in inch-pound units are to be regarded as the standard. Metric values given in parentheses are for information only.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*

B 208 Practice for Preparing Tension Test Specimens for Copper-Base Alloys for Sand, Permanent Mold, Centrifugal, and Continuous Castings[4]

B 824 Specification for General Requirements for Copper-Alloy Castings[4]

E 527 Practice for Numbering Metals and Alloys[5]

2.3 *MSS Standards:*

SP-25 Standard Marking System for Valves, Fittings, Flanges and Unions[6]

3. Ordering Information

3.1 Orders for castings under this specification shall include the following:

3.1.1 Quantity of castings required,

3.1.2 Copper Alloy UNS No. (Table 1),

3.1.3 Specification title, number, and year of issue,

3.1.4 Pattern or drawing number and condition (as-cast, machined, etc),

3.1.5 Chemical analysis of residual elements, if specified in the purchase order (Specification B 824),

3.1.6 Pressure test requirements, if specified in the purchase order (Specification B 824),

3.1.7 Soundness requirements, if specified in the purchase order (Specification B 824),

3.1.8 Certification, if specified in the purchase order (Specification B 824),

3.1.9 Foundry test report, if specified in the purchase order (Specification B 824),

3.1.10 Witness inspection, if specified in the purchase order (Specification B 824),

3.1.11 ASME Boiler and Pressure Vessel application (Section 9), and

3.1.12 Product marking, if specified in the purchase order (Specification B 824 and Section 10).

3.2 When material is purchased for agencies of the U.S. Government, the Supplementary Requirements in Specification B 824 may be specified.

4. Chemical Composition

4.1 The alloy shall conform to the requirements for major elements specified in Table 1.

4.2 These specification limits do not preclude the presence of other elements. Limits may be established for unnamed elements by agreement between manufacturer or supplier and purchaser. Copper or zinc may be given as remainder and may be taken as the difference between the sum of all elements analyzed and 100 %. When all named elements in Table 1 are analyzed, their sum shall be as follows:

$$\text{Copper Plus Named Elements, 99.3 \% Minimum} \quad (1)$$

4.3 It is recognized that residual elements may be present in cast copper base alloys. Analysis shall be made for residual

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[1] This practice is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.05 on Castings and Ingots for Remelting.

Current edition approved March 15, 1993. Published May 1993. Originally published as B 62-26T. Last previous edition B 62-90.

[2] For *ASME Boiler and Pressure Vessel Code* applications see related Specification SB-61 of that Code.

[3] The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix "C" and a suffix "00". The suffix can be used to accommodate composition variations of the base alloy.

[4] *Annual Book of ASTM Standards*, Vol 02.01.

[5] *Annual Book of ASTM Standards*, Vol 01.01.

[6] Available from Manufacturers Standardization Society of the Valve and Fittings Industry, 127 Park Street NE, Vienna, VA 22180.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Chemical Requirements Copper Alloy UNS No. C83600

Major Elements	Composition, % max (Except as Indicated)
Copper	84.0–86.0
Tin	4.0–6.0
Lead	4.0–6.0
Zinc	4.0–6.0
Nickel incl Cobalt	1.0[A]
Residual Elements	**Composition, % max (Except as Indicated)**
Iron	0.30
Antimony	0.25
Sulfur	0.08
Phosphorus	0.05
Aluminum	0.005
Silicon	0.005

[A] In determining copper minimum, copper may be calculated as copper plus nickel.

elements only when specified in the purchase order (Specification B 824).

5. Mechanical Properties

5.1 Mechanical properties shall be determined from separately cast test bars and shall meet the requirements shown in Table 2.

TABLE 2 Tensile Properties

Tensile strength, min, ksi[A] (MPa[B])	30 (205)
Yield strength,[C] min, ksi[A] (MPa[B])	14 (95)
Elongation in 2 in. or 50 mm, min, %	20

[A] ksi = 1000 psi.
[B] See Appendix.
[C] Yield strength shall be determined as the stress producing an elongation under load of 0.5 %; that is, 0.01 in. (0.25 mm) in a gage length of 2 in. (51 mm).

6. Casting Repair

6.1 Castings shall not be repaired, plugged, welded or burned-in.

7. General Requirements

7.1 Material furnished under this specification shall conform to the applicable requirements of Specification B 824.

8. Sampling

8.1 Copper Alloy UNS No. C83600 test bar castings shall be cast to the form and dimensions shown in Figs. 2, Figs. 3, or Figs. 4 of Practice B 208.

9. Certification

9.1 When material is specified to meet the requirements of *ASME Boiler and Pressure Vessel Code*, the certification requirements of Specification B 824 are mandatory.

10. Packaging and Package Marking

10.1 Valves, flanges, and fittings shall be marked in accordance with the latest revision of the Standard Marking System for Valves, Fittings, Flanges, and Unions (No. SP-25) of the Manufacturers Standardization Society of the Valve and Fittings Industry, and in such position as not to injure the usefulness of the casting.

11. Keywords

11.1 copper-alloy castings; ounce metal castings; red brass castings; valve castings

APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = kg \cdot m/s^2$). The derived SI unit for pressure or stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since 1 ksi = 6 894 757 Pa the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2.

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SUMMARY OF CHANGES

This section identifies principle changes to this specification since the last issue.

1. Paragraph 1.1 was rewritten.

2. The entire specification was revised to comply with Specification B 824.

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Standard Specification for Nickel Rod and Bar[1]

This standard is issued under the fixed designation B 160; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification[2] covers nickel (UNS N02200)* and low carbon nickel (UNS N02201)* in the form of hot-worked and cold-worked rod and bar in the conditions shown in Table 1.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

B 162 Specification for Nickel Plate, Sheet, and Strip[3]

B 880 General Requirements for Chemical Check Analysis of Nickel, Nickel Alloys, and Cobalt Alloys[3]

E 8 Test Methods for Tension Testing of Metallic Materials[4]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[4]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[5]

E 39 Test Methods for Chemical Analysis of Nickel[6]

E 140 Hardness Conversion Tables for Metals[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *bar*—material of rectangular (flats), hexagonal, or square solid section up to and including 10 in. (254 mm) in width and ⅛ in. (3.2 mm) and over in thickness in straight lengths.

NOTE 1—Hot-worked rectangular bar in widths 10 in. (254 mm) and under may be furnished as hot-rolled plate with sheared or cut edges in accordance with Specification B 162, provided the mechanical property requirements of Specification B 160 are met.

3.1.2 *rod*—material of round solid section furnished in straight lengths.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for the safe and satisfactory performance of material ordered under this specification. Examples of such requirements include, but are not limited to, the following:

4.1.1 ASTM designation and year of issue.

4.1.2 UNS number.

4.1.3 *Section*—Rod (round) or bar (square, hexagonal, or rectangular).

4.1.4 *Dimensions*—Dimensions including length.

4.1.5 Condition.

4.1.6 Finish.

4.1.7 *Quantity*—feet or number of pieces.

4.1.8 *Certification*— State if certification or a report of test results is required (Section 15).

4.1.9 *Samples for Product (Check) Analysis*—State whether samples for product (check) analysis should be furnished.

4.1.10 *Purchaser Inspection*—If purchaser wishes to witness tests or inspection of material at place of manufacture, the purchase order must so state indicating which test or inspections are to be witnessed.

5. Chemical Composition

5.1 The material shall conform to the composition limits specified in Table 2.

5.2 If a product (check) analysis is performed by the purchaser, the material shall be done per ASTM B 880 and the material shall conform to the product (check) analysis variations defined in Table 1 of ASTM B 880.

6. Mechanical and Other Requirements

6.1 *Mechanical Properties*—The material shall conform to the mechanical properties specified in Table 1.

7. Dimensions and Permissible Variations

7.1 *Diameter, Thickness, or Width*—The permissible variations from the specified dimensions as measured on the diameter or between parallel surfaces of cold-worked rod and bar shall be as prescribed in Table 3, and of hot-worked rod and bar as prescribed in Table 4.

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[1] This specification is under the jurisdiction of ASTM Committee B-2 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.07 on Refined Nickel and Cobalt and Their Alloys.

Current edition approved May 10, 1999. Published June 1999. Originally published as B 160 – 41 T. Last previous edition B 160 – 93.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SB-160 in Section II of that Code.

* New designations established in accordance with ASTM E527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

[3] *Annual Book of ASTM Standards*, Vol 02.04.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] *Annual Book of ASTM Standards*, Vol 03.05.

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TABLE 1 Mechanical Properties

Condition and Diameter or Distance Between Parallel Surfaces, in. (mm)	Tensile Strength, min, psi (MPa)	Yield Strength (0.2 % offset), min. psi (MPa)[A]	Elongation in 2 in. or 50 mm or 4*D*,min %
Nickel (UNS N02200)			
Cold-worked (as worked):			
Rounds, 1 (25.4) and under	80 000 (550)	60 000 (415)	10[B]
Rounds over 1 to 4 (25.4 to 101.6) incl.	75 000 (515)	50 000 (345)	15
Squares, hexagons, and rectangles, all sizes	65 000 (450)	40 000 (275)	25[B]
Hot-worked:			
All sections, all sizes	60 000 (415)	15 000 (105)	35[C]
Rings and disks[D]	—	—	—
Annealed:			
Rods and bars, all sizes	55 000 (380)	15 000 (105)	40[B]
Rings and disks[E]	—	—	—
Forging quality			
All sizes	[F]	[F]	[F]
Low-Carbon Nickel (UNS N02201)			
Hot-worked:			
All sections, all sizes	50 000 (345)	10 000 (70)	40[C]
Annealed:			
All products, all sizes	50 000 (345)	10 000 (70)	40[B]

[A] See 12.2.
[B] Not applicable to diameters or cross sections under 3/32 in. (2.4 mm).
[C] For hot-worked flats 5/16 in. (7.9 mm) and under in thickness the elongation shall be 25%, min.
[D] Hardness B45 to B80, or equivalent.
[E] Hardness B45 to B70 or equivalent.
[F] Forging quality is furnished to chemical requirements and surface inspection only. No tensile properties are required.

TABLE 2 Chemical Requirements

Element	Composition Limits, %	
	Nickel (UNS N02200)	Low-Carbon Nickel (UNS N02201)
Nickel, min[A]	99.0	99.0
Copper, max	0.25	0.25
Iron, max	0.40	0.40
Manganese, max	0.35	0.35
Carbon, max	0.15	—
Carbon, max	—	0.02
Silicon, max	0.35	0.35
Sulfur, max	0.01	0.01

[A] Element shall be determined arithmetically by difference.

TABLE 3 Permissible Variations in Diameter or Distance Between Parallel Surfaces of Cold-Worked Rod and Bar

Specified Dimension, in. (mm)[A]	Permissible Variations from Specified Dimension, in. (mm)	
	+	−
Rounds:		
1/16 (1.6) to 3/16 (4.8), excl	0	0.002 (0.05)
3/16 (4.8) to 1/2 (12.7), excl	0	0.003 (0.08)
1/2 (12.7) to 15/16 (23.8), incl	0.001 (0.03)	0.002 (0.05)
Over 15/16 (23.8) to 1 15/16 (49.2), incl	0.0015 (0.04)	0.003 (0.08)
Over 1 15/16 (49.2) to 2 1/2 (63.5), incl	0.002 (0.05)	0.004 (0.10)
Over 2 1/2 (63.5) to 3 (76.2), incl	0.0025 (0.06)	0.005 (0.13)
Over 3 (76.2) to 3 (88.9), incl	0.003 (0.08)	0.006 (0.15)
Over 3 1/2 (88.9) to 4 (101.6), incl	0.0035 (0.09)	0.007 (0.18)
Hexagons, squares, rectangles:		
1/2 (12.7) and less	0	0.004 (0.10)
Over 1/2 (12.7) to 7/8 (22.2), incl	0	0.005 (0.13)
Over 7/8 (22.2) to 1 1/4 (31.8), incl	0	0.007 (0.18)
Over 1 1/4 (31.8) to 2 1/4 (57.2), incl	0	0.009 (0.23)
Over 2 1/4 (57.2) to 3 (76.2), incl	0	0.011 (0.28)
Over 3 (76.2) to 3 1/2 (88.9), incl	0	0.015 (0.38)
Over 3 1/2 (88.9) to 4 (101.6), incl	0	0.017 (0.43)

[A] Dimensions apply to diameter of rounds, to distance between parallel surfaces of hexagons and squares, and separately to width and thickness of rectangles.

7.2 *Out-of-Round*— Hot-worked rods and cold-worked rods (except "forging quality"), all sizes, in straight lengths, shall not be out-of-round by more than one half the total permissible variations in diameter shown in Tables 3 and 4, except for hot-worked rods 1/2 in. (12.7 mm) in diameter and under, which may be out-of-round by the total permissible variations in diameter shown in Table 4.

7.3 *Corners*—Cold-worked bars will have practically exact angles and sharp corners.

7.4 *Machining Allowances for Hot-Worked Materials*— When the surfaces of hot-worked products are to be machined, the allowances prescribed in Table 5 are recommended for normal machining operations.

7.5 *Length*—The permissible variations in length of cold-worked and hot-worked rod and bar shall be as prescribed in Table 6.

7.5.1 Rods and bars ordered to random or nominal lengths will be furnished with either cropped or saw-cut ends; material ordered to cut lengths will be furnished with square saw-cut or machined ends.

7.6 *Straightness*:

7.6.1 The permissible variations in straightness of cold-worked rod and bar as determined by the departure from straightness shall be as prescribed in Table 7.

7.6.2 The permissible variations in straightness of precision straightened cold-worked rod as determined by the departure from straightness shall be as prescribed in Table 8.

7.6.2.1 In determining straightness in the standard 42-in. (1.07-m) distance between supports or, when specified, in determining straightness in lengths not in excess of those shown in Table 8, the rod shall be placed on a precision table equipped with ballbearing rollers and a micrometer or dial indicator. The rod shall then be rotated slowly against the indicator, and the deviation from straightness in any portion of the rod between the supports shall not exceed the permissible

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TABLE 4 Permissible Variations in Diameter or Distance Between Parallel Surfaces of Hot-Worked Rod and Bar

Specified Dimension, in. (mm)[A]	Permissible Variations from Specified Dimensions, in. (mm)	
	+	−
Rod and bar, hot-worked:		
1 (25.4) and under	0.016 (0.41)	0.016 (0.41)
Over 1 (25.4) to 2 (50.8), incl	0.031 (0.79)	0.016 (0.41)
Over 2 (50.8) to 4 (101.6), incl	0.047 (1.19)	0.031 (0.79)
Over 4 (101.6)	0.125 (3.18)	0.063 (1.60)
Rod, rough-turned or rough-ground:		
Under 1 (25.4)	0.005 (0.13)	0.005 (0.13)
1 (25.4) and over	0.031 (0.79)	0
Forging quality rod:[B]		
Under 1 (25.4)	0.005 (0.13)	0.005 (0.13)
1 (25.4) and over	0.031 (0.79)	0

[A] Dimensions apply to diameter of rods, to distance between parallel surfaces of hexagons and squares, and separately to width and thickness of rectangles.

[B] Spot grinding is permitted to remove minor surface imperfections. The depth of these spot ground areas shall not exceed 3 % of the diameter of the rod.

variations prescribed in Table 8. The deviation from straightness (throw in one revolution) is defined as the difference between the maximum and minimum readings of the dial indicator in one complete revolution of the rod.

7.6.3 The permissible variations in straightness of hot-worked rod and bar as determined by the departure from straightness shall be as specified in Table 9.

8. Workmanship, Finish, and Appearance

8.1 The material shall be uniform in quality and condition, smooth, commercially straight or flat, and free of injurious imperfections.

9. Sampling

9.1 *Lot—Definition:*

9.2 A lot for chemical analysis shall consist of one heat.

9.2.1 A lot for mechanical properties testing shall consist of all material from the same heat, nominal diameter of thickness, and condition.

9.2.1.1 Where material cannot be identified by heat, a lot shall consist of not more than 500 lb (227 kg) of material in the same size and condition.

9.3 *Test Material Selection:*

9.3.1 *Chemical Analysis*—Representative samples from each lot shall be taken during pouring or subsequent processing.

9.3.1.1 Product (check) analysis shall be wholly the responsibility of the purchaser.

9.3.2 *Mechanical Properties*—Samples of the material to provide test specimens for mechanical properties shall be taken from such locations in each lot as to be representative of that lot.

10. Number of Tests

10.1 *Chemical Analysis*—One test per lot.

10.2 *Tension*—One test per lot.

10.3 *Hardness*—One test per lot.

11. Specimen Preparation

11.1 Tension test specimens shall be taken from material in the final condition and tested in the direction of fabrication.

11.1.1 All rod and bar shall be tested in full cross-section size when possible. When a full cross-section size test cannot be performed, the largest possible round specimen shown in Test Methods E 8 shall be used. Longitudinal strip specimens shall be prepared in accordance with Test Methods E 8 for rectangular bar up to ½ in. (12.7 mm), inclusive, in thicknesses that are too wide to be pulled full size.

11.2 Hardness test specimens shall be taken from material in the final condition.

11.3 In order that the hardness determinations may be in reasonable close agreement, the following procedure is suggested:

11.3.1 For rod, under ½ in. (12.7 mm) in diameter, hardness readings shall be taken on a flat surface prepared by filing or grinding approximately 1/16 in. (1.6 mm) from the outside surface of the rod.

11.3.2 For rod, ½ in. (12.7 mm) in diameter and larger, and for hexagonal, square, and rectangular bar, all sizes, hardness readings shall be taken on a cross section midway between the surface and center of the section.

12. Test Methods

12.1 The chemical composition, mechanical, and other properties of the material as enumerated in this specification shall be determined, in case of disagreement, in accordance with the following methods:

Test	ASTM Designation
Chemical Analysis	E 39
Tension	E 8
Rockwell Hardness	E 18
Hardness Conversion	E 140
Rounding Procedure	E 29

12.2 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated below, in accordance with the rounding method of Practice E 29:

Test	Rounded Unit for Observed Or Calculated Value
Chemical composition, hardness, and tolerances (when expressed in decimals)	Nearest unit in the last right-hand place of figures of the specified limit. If two choices are possible, as when the digits dropped are exactly a 5, or a 5 followed only by zeros, choose the one ending in an even digit, with zero defined as an even digit.
Tensile strength and yield strength	Nearest 1000 psi (6.9 MPa)
Elongation	Nearest 1 %

13. Inspection

13.1 Inspection of the material shall be made as agreed upon between the manufacturer and the purchaser as part of the purchase contract.

14. Rejection and Rehearing

14.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

15. Certification

15.1 When specified in the purchase order or contract, a

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TABLE 5 Normal Machining Allowances for Hot-worked Material

Finished-Machined Dimensions for Finishes as Indicated Below, in. (mm)[A]	Normal Machining Allowance, in. (mm)			
	On Diameter, for Rods	Distance Between Parallel Surface, for Hexagonal and Square Bar	For Rectangular Bar	
			On Thickness	On Width
Hot-worked:[B]				
Up to 7/8 (22.2), incl	1/8 (3.2)	1/8 (3.2)	1/8 (3.2)	3/16 (4.8)
Over 7/8 to 1 7/8 (22.2 to 47.6), incl	1/8 (3.2)	3/16 (4.8)	1/8 (3.2)	3/16 (4.8)
Over 1 7/8 to 2 7/8(47.6 to 73.0), incl	3/16 (4.8)	1/4 (6.4)	—	3/16 (4.8)
Over 2 7/8 to 3 13/16(73.0 to 96.8), incl	1/4 (6.4)	—	—	3/16 (4.8)
Over 3 13/16 (96.8)	1/4 (6.4)	—	—	3/8 (9.5)
Hot-worked rods:				
Rough-turned or Rough-ground:[C]				
15/16 to 4 (23.8 to 101.6), incl in diameter	1/16 (1.6)	—	—	—
Over 4 to 12 (101.6 to 304.8), incl in diameter	1/8 (3.2)	—	—	

[A] Dimensions apply to diameter of rods, to distance between parallel surfaces of hexagonal and square bar, and separately to width and thickness of rectangular bar.
[B] The allowances for hot-worked material in Table 5 are recommended for rods machined in lengths of 3 ft (0.91 m) or less and for bars machined in lengths of 2 ft (0.61 m) or less. Hot-worked material to be machined longer lengths should be specified showing the finished cross-sectional dimension and the length in which the material will be machined in order that the manufacturer may supply material with sufficient oversize, including allowance for out-of-straightness.
[C] Applicable to 3 ft (0.91 m) max length.

TABLE 6 Permissible Variations in Length of Rods and Bars

Random mill lengths:	
Hot-worked	6 to 24 ft (1.83 to 7.31 m) long with not more than 25 weight % between 6 and 9 ft (1.83 and 2.74 m)[A]
Cold-worked	6 to 20 ft (1.83 to 6.1 m) long with not more than 25 weight % between 6 and 10 ft (1.83 and 3.05 m).
Multiple lengths	Furnished in multiples of a specified unit length, within the length limits indicated above. For each multiple, an allowance of 1/4 in. (6.4 mm) will be made for cutting, unless otherwise specified. At the manufacturer's option, individual specified unit lengths may be furnished.
Nominal lengths	Specified nominal lengths having a range of not less than 2 ft (610 mm) with no short lengths allowed.[B]
Cut lengths	A specified length to which all rods and bars will be cut with a permissible variation of +1/8 in. (3.2 mm), – 0 for sizes 8 in. (203 mm) and less in diameter or distance between parallel surfaces. For larger sizes, the permissible variation shall be +1/4 in. (6.4 mm), – 0.

[A] For hot-worked sections weighing over 25 lb/ft (37 kg/m) and for smooth forged products, all sections, short lengths down to 2 ft (610 mm) may be furnished.
[B] For cold-worked rods and bars under 1/2 in. (12.7 mm) in diameter or distance between parallel surfaces ordered to nominal or stock lengths with a 2-ft (610 mm) range, at least 93 % of such material shall be within the range specified; the balance may be in shorter lengths but in no case shall lengths less than 4 ft (1220 mm) be furnished.

TABLE 7 Permissible Variations in Straightness Of Cold-Worked Rods And Bars

Specified Diameter or Distance Between Parallel Surfaces, in. (mm)[A]	Permissible Variations in Lengths Indicated, in. (mm)
Rounds:	Depth of Chord:
1/2 (12.7) to 4 (101.6), incl	0.030 (0.76) per ft (305 mm) of length
Hexagons, squares, rectangles:	
1/2 (12.7) to 4 (101.6), incl	0.030 (0.76) per ft (305 mm) of length

[A] Material under 1/2 in. (12.7 mm) shall be reasonably straight and free of sharp bends and kinks.

manufacturer's certification shall be furnished to the purchaser stating that material has been manufactured, tested, and inspected in accordance with this specification, and that the test results on representative samples meet specification requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

16. Product Marking

16.1 The following information shall be marked on the material or included on the package, or on a label or tag attached thereto: The name of the material or UNS Number, heat number, condition (temper), ASTM Specification B 160, the size, gross, tare, and net weight, consignor and consignee address, contract or order number, or such other information as may be defined in the contract or order.

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TABLE 8 Permissible Variations in Straightness of Precision-Straightened Cold-Worked Nickel (UNS N02200) Shafting

Specified Diameter of Shafting, in.	Standard Distance Between Supports	Permissible Variations (Throw in One Revolution) from Straightness, in.
½ to 15/16, incl	42 in.	0.005
Over 15/16 to 1 15/16, incl	42 in.	0.006
Over 1 15/16 to 2½, incl	42 in.	0.007
Over 2½ to 4, incl	42 in.	0.008
¾ to 15/16, incl	Specified lengths of 3 to 10 ft	0.004 + 0.0025 for each foot or fraction thereof in excess of 3 ft.
Over 15/16 to 4, incl	Specified lengths of 20 ft and less	0.005 + 0.0015 for each foot or fraction thereof in excess of 3 ft.
Specified Diameter of Shafting, mm	**Standard Distance Between Supports**	**Permissible Variations (Throw in One Revolution) from Straightness, mm**
12.7 to 23.8 incl	1067 mm	0.13
Over 23.8 to 49.2, incl	1067 mm	0.15
Over 49.2 to 63.5, incl	1067 mm	0.18
Over 63.5 to 101.6, incl	1067 mm	0.20
19.1 to 23.8 incl	specified lengths of 914 to 3050 mm	10.2 + 0.2 for each metre or fraction thereof in excess of 914 mm
Over 23.8 to 101.6, incl	specified lengths of 6100 mm and less	12.7 + 0.13 for each metre or fraction thereof in excess of 914 mm

TABLE 9 Permissible Variations in Straightness of Hot-Worked Rods and Bars[A]

Finish	Permissible Variations, in./ft. (mm/m)[B]
Rods and bars, hot-worked	0.050 (4.2)[C]
Rounds—hot-worked, rough-ground, or rough-turned	0.050 (4.2)[C]

[A] Not applicable to forging quality.

[B] Material under ½ in. (12.7 mm) shall be reasonably straight and free of sharp bends and kinks.

[C] The maximum curvature (depth of chord) shall not exceed the values indicated multiplied by the length in feet.

APPENDIX

(Nonmandatory Information)

X1. CONDITIONS AND FINISHES

X1.1 The various conditions and finishes in which nickel (UNS N02200) and low-carbon nickel (UNS N02201) rods and bars are procurable are as indicated below.

X1.2 Low-carbon nickel (UNS N02201) is intended essentially for fused caustic and other fused salts and for temperatures above 600°F (316°C). For such applications the manufacturer should be consulted.

X1.2.1 *Hot-Worked*— With a tightly adherent, black, mill oxide surface.

X1.2.2 *Hot-Worked Rough-Ground*—Similar to X1.2.1 except rough-ground.

X1.2.3 *Hot-Worked, Rough-Turned*—Similar to X1.2.1 except rough-turned with a broad-nosed tool similar to a bar peeling operation and thus may not be straight. Intended generally for machining where an overhauled surface is desired, essentially for machined step down shafts or parts machined in short lengths of 3 ft (914 mm) or less.

X1.2.4 *Hot-Worked Forging Quality*—Rough-turned and spot-ground, as necessary, for sizes 1 in. (25.4 mm) in diameter and over; rough-ground and spot-ground for sizes under 1 in. in diameter. Material is selected from heats of known, good hot malleability.

NOTE X1.1—For sizes 4 in. (101.6 mm) in diameter and less, cold-worked rod may be used also for forging by virtue of the fact such rod have been overhauled for removal of mechanical surface defects prior to cold drawing. In such cases, the user should run pilot forging tests to ensure himself that such material has the desired hot-malleability range.

X1.2.5 *Hot-Worked, Annealed*—Soft with a tightly adherent oxide that may vary from dark to light.

X1.2.6 *Hot-Worked, Annealed and Pickled*—Same as X1.2.5 except descaled for removal of mill oxide. Provides for better surface inspection than does hot-worked material and often employed where welding is involved where removal of mill oxide is desired.

NOTE X1.2—Annealing prior to pickling may be required in order to reduce the mill oxide since uniform pickling of an unreduced oxide is difficult.

X1.2.7 *Cold-Worked, As-worked*—Hot-worked overhauled, cold-worked, and straightened with a smooth bright finish.

X1.2.8 *Cold-worked Annealed*—Hot-worked overhauled, cold-worked, and straightened. Annealed for softness and with a dull matte finish.

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Used in USNRC-RDT Standards
An American National Standard

Standard Specification for Nickel Seamless Pipe and Tube[1]

This standard is issued under the fixed designation B 161; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification[2] covers nickel (UNS N02200)* and low-carbon nickel (UNS N02201)* in the form of cold-worked seamless pipe and tube in the conditions shown in Table 1 and Table X1.1.

1.1.1 Hot-worked material is available. Properties are to be agreed upon between the manufacturer and purchaser.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

B 829 Specification for General Requirements for Nickel and Nickel Alloy Seamless Pipe and Tube[3]

3. General Requirement

3.1 Material furnished under this specification shall conform to the applicable requirements of Specification B 829 unless otherwise provided herein.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for the safe and satisfactory performance of material ordered under this specification. Examples of such requirements include, but are not limited to, the following:

4.1.1 Alloy name or UNS number.

4.1.2 ASTM designation and year of issue.

4.1.3 *Condition* (see Appendix X2).

4.1.4 *Finish* (see Appendix X2).

4.1.5 *Dimensions*:

4.1.5.1 *Tube*—Specify outside diameter and nominal or minimum wall.

4.1.5.2 *Pipe*—Specify standard pipe size and schedule.

4.1.5.3 *Length*—Cut to length or random.

4.1.6 *Quantity*—Feet or number of pieces.

4.1.7 *Hydrostatic Pressure Requirements*— Specify test pressure if other than required by Specification B 829.

4.1.8 *Certification*— State if certification is required.

4.1.9 *Samples for Product (Check) Analysis*—State whether samples for product (check) analysis should be furnished (see 5.2).

4.1.10 *Purchaser Inspection*—If purchaser wishes to witness tests or inspection of material at place of manufacture, the purchase order must so state indicating which tests or inspections are to be witnessed.

4.1.11 *Small-Diameter and Light-Wall Tube (Converter Sizes)*—See Appendix X1.

5. Chemical Composition

5.1 The material shall conform to the composition limits specified in Table 1 of Specification B 829.

5.2 If a product (check) analysis is performed by the purchaser, the material shall conform to the product (check) analysis variations in Table 2.

TABLE 2 Chemical Requirements

Element	Composition,%	
	Nickel (UNS N02200)	Low-Carbon Nickel (UNS N02201)
Ni,[A] min	99.0	99.0
Cu, max	0.25	0.25
Fe, max	0.40	0.40
Mn, max	0.35	0.35
C, max	0.15	—
C, max	—	0.02
Si, max	0.35	0.35
S, max	0.01	0.01

[A] Element shall be determined arithmetically by difference.

6. Mechanical and Other Properties

6.1 *Tension Test*— The material shall conform to the tensile properties specified in Table 1. The sampling and specimen preparation are as covered in Specification B 829

6.1.1 Tensile properties for material specified as small-diameter and light-wall tube (converter sizes) shall be as prescribed in Table X1.1.

6.2 *Hydrostatic Test*— If any pipe or tube shows leaks during hydrostatic testing, it shall be rejected.

[1] This specification is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.07 on Refined Nickel and Cobalt and Their Alloys.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SB-161 in Section II of that Code.

* New designation established in accordance with ASTM E527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

[3] *Annual Book of ASTM Standards,* Vol 02.04.

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TABLE 1 Mechanical Properties

Condition and Size	Tensile Strength, min, psi (MPa)		Yield Strength (0.2 % offset), min, psi (MPa)		Elongation in 2 in. or 50 mm (or 4*D*), min, %	
	Nickel (UNS N02200)	Low-Carbon Nickel (UNS N02201)	Nickel (UNS N02200)	Low-Carbon Nickel (UNS N02201)	Nickel (UNS N02200)	Low-Carbon Nickel (UNS N02201)
Annealed:						
5 in. (127 mm) and under outside diameter	55 000 (380)	50 000 (345)	15 000 (105)	12 000 (80)	35	35
Over 5 in. (127 mm) in outside diameter	55 000 (380)	50 000 (345)	12 000 (80)	10 000 (70)	40	40
Stress-Relieved:						
All sizes	65 000 (450)	60 000 (415)	40 000 (275)	30 000 (205)	15	15

7. Dimensions and Permissible Variations

7.1 Permissible variations for material specified as small-diameter and light-wall tube (converter size) shall conform to the permissible variations prescribed in Table X1.2.

8. Number of Tests

8.1 *Chemical Analysis*—One test per lot.

8.2 *Tension*—One test per lot.

8.3 *Hydrostatic*— Each piece in each lot.

9. Test Methods

9.1 *Hydrostatic Test*— Each pipe or tube with an outside diameter ⅛ in. (3 mm) and larger and with wall thickness of 0.015 in. (0.38 mm) and over shall be tested based on allowable fiber stress for material in the condition furnished, as follows:

	UNS N02200	UNS N02201
Annealed:		
5 in. (127 mm) outside diameter and under	10 000 psi (70 MPa)	8000 psi (55 MPa)
Over 5 in. outside diameter	8000 psi (55 MPa)	6700 psi (45 MPa)
Stress-Relieved:		
All sizes	16 200 psi (110 MPa)	15 000 psi (105 MPa)

9.1.1 When so agreed upon by the manufacturer and purchaser, pipe or tube may be tested to 1½times the allowable fiber stress given above.

APPENDIXES

(Nonmandatory Information)

X1. CONVERTER SIZES

X1.1 Small-diameter and light-wall tube in outside diameters 1¼in. (31.8 mm) and under may be furnished in the conditions listed in Table X1.1 when so specified. The material is furnished in a limited range of sizes and the manufacturer should be consulted as to the various outside diameters and wall thicknesses that may be furnished. Material will have a bright finish. Such material shall conform to the applicable requirements in Table X1.1 and Table X1.2.

TABLE X1.1 Mechanical Properties[A] of Small-Diameter and Light-Wall Tubing (Converter Sizes)

Condition	Tensile Strength, psi (MPa)	Yield Strength (0.2 % offset), min, psi (MPa)	Elongation in 2 in. or 50 mm, min, %
Nickel UNS N02200			
Annealed[B]	75 000 (515) max	15 000 (105)	33
Half-hard[C]	80 000 (550) min	40 000 (275)	12
Full hard[D]	95 000 (655) min	75 000 (515)	4
Low-Carbon Nickel UNS N02201			
Annealed[D]	70 000 (480) max	12 000 (85)	35
Half-hard[C]	70 000 (480) min	30 000 (205)	12
Full hard[D]	85 000 (585) min	65 000 (450)	4

[A] Not applicable to outside diameters under ⅛in. (3.2 mm) and wall thicknesses under 0.015 in. (0.38 mm).
[B] This condition is sometimes designated as "No. 1 Temper."
[C] This condition is sometimes designated as "No. 2 Temper."
[D] This condition is sometimes designated as "No. 3 Temper."

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TABLE X1.2 Permissible Variations for Small-Diameter and Light-Wall Tube (Converter Sizes)[A,B,C,D,E,F,G]

Specified Outside Diameter, in. (mm)	Outside Diameter		Inside Diameter		Wall Thickness, %	
	Plus	Minus	Plus	Minus	Plus	Minus
Under 3/32 (2.4)	0.002 (0.05)	0	0	0.002 (0.05)	10	10
3/32 to 3/16 (2.4 to 4.8), excl	0.003 (0.08)	0	0	0.003 (0.08)	10	10
3/16 to 1/2 (4.8 to 12.7), excl	0.004 (0.10)	0	0	0.004 (0.10)	10	10
1/2to 1 1/4 (12.7 to 31.8), incl	0.005 (0.13)	0	0	0.005 (0.13)	10	10

[A] *Ovality, Normal Wall Tube—As-Drawn (No. 2 and 3) Tempers*—Ovality will be held within the outside diameter tolerances shown in the table.

Annealed (No. 1) Temper—Ovality will be held within 2 % of the theoretical average outside diameter.

[B] *Ovality, Light-Wall Tube—As-Drawn (No. 2 and 3)Tempers* —Up to but not including 1¼ in. (31.8 mm) in outside diameter, ovality will be held within 2 % of the theoretical average outside diameter.

Annealed (No. 1) Temper—Ovality will be held within 3 % of the theoretical average outside diameter.

[C] *Wall Tolerances, Light-Wall Tube*—The plus and minus wall tolerance shown in the table shall apply down to and including 0.005 in. (0.13 mm) in wall thickness. For wall thicknesses less than 0.005 in. (0.13 mm), the tolerance shall be ± 0.0005 in. (0.013 mm).

[D] *Random Lengths*:

Where nominal random lengths on tubing ⅛in. (3.2 mm) and larger in outside diameter are specified, a length tolerance of + 3½ft (1.06 m) applies to the nominal length. This is a total spread of 7 ft (2.10 m).

Random lengths in sizes ⅛ in. (3.2 mm) and larger in outside diameter shall be subject to a length range of 5 to 24 ft (1.50 to 7.30 m). Long random lengths are subject to a range of 15 to 22 ft (4.57 to 6.70 m).

Random lengths in sizes up to, but not including ⅛in. (3.2 mm) in outside diameter, and fragile light-wall tubes over this outside diameter are subject to the length range of 1 to 15 ft (0.30 to 4.57 m).

[E] *Cut Lengths*—Tolerances on cut lengths shall be in accordance with Table .

[F] *Straightness*—Round tubing is subject to a straightness tolerance of one part in 600 [equivalent to a depth of arc of 0.030 in. (0.76 mm) in any 3 ft (0.91 m) of length].

[G] When specified, the tolerance spreads of this table may be applied as desired. However, when not specified, the tolerances in this table will apply. It should be noted that inside diameter tolerances are based upon the outside diameter range.

X2. CONDITIONS AND FINISHES NORMALLY SUPPLIED

X2.1 Scope

X2.1.1 This appendix lists the conditions and finishes in which pipe and tube (other than converter sizes) are normally supplied. These are subject to change, and the manufacturer should be consulted for the latest information available.

X2.2 Nickel (UNS N02200)

X2.2.1 *Annealed*—Soft, with a dull matte finish.

X2.2.2 *Stress-Relieved*— Thermally treated below the annealing temperature to relieve the major portion of the internal stresses, with a thin, light to medium-dark surface.

X2.3 Low-Carbon Nickel (UNS N02201)

X2.3.1 *Annealed*—Similar to X2.2.1.

X2.3.2 *Stress-Relieved*— Similar to X2.2.2.

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Standard Specification of Nickel-Copper Alloy (UNS N04400)* Seamless Pipe and Tube[1]

This standard is issued under the fixed designation B 165; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification[2] covers nickel-copper alloy UNS N04400* in the form of cold-worked seamless pipe and tube in the conditions shown in Tables 1 and X1.1.

1.1.1 Hot worked material is available. Properties and permissible tolerances are to be agreed upon between the manufacturer and purchaser.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

E 8 Test Methods of Tension Testing of Metallic Materials[3]

E 29 Practice For Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

E 76 Test Methods for Chemical Analysis of Nickel-Copper Alloys[5]

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 *average diameter*—average of the maximum and minimum outside diameters, as determined at any one cross-section of the pipe or tube.

3.1.2 *pipe*—tube conforming to the particular dimensions commercially known as pipe sizes, see Table X2.1.

3.1.3 *seamless pipe or tube*—pipe or tube produced with a continuous periphery in all stages of the operations.

3.1.4 *tube*—hollow product of round or any other cross-section having a continuous periphery.

4. Ordering Information

4.1 Orders for material to this specification shall include information with respect to the following:

4.1.1 Alloy name or UNS number.

4.1.2 ASTM designation and year of issue.

4.1.3 *Condition* (see Appendix X3).

4.1.4 *Finish* (see Appendix X3).

4.1.5 *Dimensions:*

4.1.5.1 *Tube*—Specify outside diameter and nominal or minimum wall.

4.1.5.2 *Pipe*—Specify standard pipe size and schedule.

4.1.5.3 *Length*—Cut to length or random.

4.1.6 *Quantity*—Feet or number of pieces.

4.1.7 *Hydrostatic Pressure Requirements*—Specify test pressure if other than required by 12.3.1.

4.1.8 *Certification*—State if certification or a report of test results is required (Section 15).

4.1.9 *Samples for Product (Check) Analysis*—State whether samples for product (check) analysis should be furnished (see 5.2).

4.1.10 *Purchaser Inspection*—If purchaser wishes to witness tests or inspection of material at place of manufacture, the purchase order must so state indicating which tests or inspections are to be witnessed (Section 13).

4.1.11 *Small-Diameter and Light-Wall Tube (Converter Sizes)*—See Appendix X1.

5. Chemical Composition

5.1 The material shall conform to the composition limits specified in Table 2.

5.2 If a product (check) analysis is performed by the purchaser, the material shall conform to the product (check) analysis variations in Table 2.

6. Mechanical and Other Requirements

6.1 *Tension Test*—The material shall conform to the tensile properties specified in Table 1.

6.1.1 Tensile properties for material specified as small-diameter and light-wall tube (converter sizes) shall be in accordance with Table X1.1

6.2 *Hydrostatic Test*—If any pipe or tube shows leaks during hydrostatic testing, it shall be rejected.

7. Dimensions and Permissible Variations

7.1 *Diameter and Wall Thickness*—The permissible variations in the outside diameter and wall thickness shall conform to the permissible variations prescribed in Table 3.

7.2 *Length*—When material is ordered cut-to-length, the length shall conform to the permissible variations prescribed in Table 4.

7.3 *Straightness*—material shall be reasonably straight and free of bends and kinks.

7.4 *Ends*—Ends shall be plain cut and deburred.

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[1] This specification is under the jurisdiction of ASTM Committee B-2 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.07 on Refined Nickel and Cobalt, and Alloys Containing Nickel or Cobalt or Both as Principal Constituents.

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* New designation established in accordance with ASTM Practice E 527 and SAE J1086, Recommended Practice for Numbering Metals and Alloys (UNS).

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SB-165 in Section II of that code.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 03.05.

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TABLE 1 Mechanical Properties of Pipe and Tube

Condition and Size	Tensile Strength, min, psi (MPa)	Yield Strength, min. (0.2% offset), min, psi (MPa)	Elongation in 2 in. or 50 mm (or 4 *D*), min, %
Annealed:			
5 in. (127 mm) outside diameter and under	70 000 (480)	28 000 (195)	35
Over 5 in. (127 mm) outside diameter	70 000 (480)	25 000 (170)	35
Stress-Relieved:			
All sizes	85 000 (585)	55 000 (380)	15

7.5 Permissible variations for material specified as small-diameter and light-wall tube (converter size) shall conform to the permissible variations prescribed in Table X1.2.

8. Workmanship, Finish and Appearance

8.1 The material shall be uniform in quality and temper, smooth, commercially straight, and free of injurious imperfections.

9. Sampling

9.1 *Lot Definition:*

9.1.1 A lot for chemical analysis shall consist of one heat.

9.1.2 A lot for all other testing shall consist of all material from the same heat, nominal size (excepting length), and condition.

9.1.2.1 Where material cannot be identified by heat, a lot shall consist of not more than 500 lb (227 kg) of material in the same condition and nominal size (excepting length).

9.2 *Test Material Selection:*

9.2.1 *Chemical Analysis*—Representative samples from each lot shall be taken during pouring or subsequent processing.

9.2.1.1 Product (Check) Analysis shall be wholly the responsibility of the purchaser.

9.2.2 *Mechanical and other Properties*—Samples of the material to provide test specimens for mechanical and other properties shall be taken from such locations in each lot as to be representative of that lot. Test specimens shall be taken from material in the final condition.

TABLE 2 Chemical Requirements

Element	Composition Limits, %	Product (Check) Analysis Variations, under min or over max, of the Specified Limit of Element
Ni[A]	63.0 min	0.45
Cu	28.0 min	0.15
	34.0 max	0.20
Fe	2.5 max	0.05
Mn	2.0 max	0.04
C	0.3 max	0.02
Si	0.5 max	0.03
S	0.024 max	0.005

[A] Element shall be determined arithmetically by difference.

10. Number of Tests

10.1 *Chemical Analysis*—One test per lot.

10.2 *Tension*—One test per lot.

10.3 *Hydrostatic*—Each piece in each lot.

11. Specimen Preparation:

11.1 *Room Temperature Tensile Specimen*—Material shall be tested in the direction of fabrication. Whenever possible, all pipe and tube shall be tested in full tubular size. When testing in full tubular size is not possible, longitudinal strip specimens, or the largest possible round specimen, shall be used. In the event of disagreement when full tubular testing is not possible, a longitudinal strip specimen with reduced gauge length as contained in Test Methods E 8 shall be used.

12. Test Methods

12.1 *Chemical Composition*—In case of disagreement, the chemical composition shall be determined in accordance with Test Methods E 76.

12.2 *Tension Test*—Tension testing shall be conducted in accordance with Test Methods E 8.

12.3 *Hydrostatic Test*—Each pipe or tube with an outside diameter ⅛ in. (3 mm) and larger and with wall thickness of 0.015 in. (0.38 mm) and over shall be tested by the manufacturer to an internal hydrostatic pressure of 1000 psi (6.9 MPa) provided that the fiber stress calculated in accordance with the following equation does not exceed the allowable fiber stress, *S*, indicated below:

$$P = 2St/D$$

where:

P = hydrostatic test pressure, psi (or MPa)

S = allowable fiber stress, for material in the condition (temper) furnished as follows:

Annealed:	
5 in. (127 mm) outside diameter and under	17 500 psi (120 MPa)
Over 5 in. (127 mm) outside diameter	16 700 psi (115 MPa)
Stress-relieved:	
All sizes	21 200 psi (145 MPa)

t = minimum wall thickness, in. (or mm), equal to the specified nominal wall minus the permissible minus wall tolerance, or the specified minimum wall thickness, and,

D = outside diameter of the pipe or tube, in. (or mm).

12.3.1 When so agreed upon between the manufacturer and purchaser, pipe or tube may be tested to 1½ times the allowable fiber stress given above.

12.4 *Rounding Method*—For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value, or a calculated value, shall be rounded as indicated below, in accordance with the rounding method of Practice E 29:

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Test	Rounded Unit for Observed or Calculated Value
Chemical composition and tolerances (when expressed in decimals)	nearest unit in the last right-hand place of figures of the specified limit. If two choices are possible, as when the digits dropped are exactly a 5 or a 5 followed only by zeros, choose the one ending in an even digit with zero defined as an even digit.
Tensile strength, yield strength	nearest 1000 psi (6.9 MPa)
Elongation	nearest 1 %

TABLE 4 Permissible Variations in Length[A]

Outside Diameter, in. (mm)	Cut Length, in. (mm)	
	Over	Under
Under 2 (50.8)	1/8 (3.2)	0
2 (50.8) and over	3/16 (4.8)	0

[A] These permissible variations in length apply to pipe or tube in straight lengths. They apply to cut lengths up to and including 24 ft (7.3 m). For lengths over 24 ft, an additional over-tolerance of 1/8 in. (3.2 mm) for each 10 ft (3.0 m) or fraction thereof shall be permissible up to a maximum additional over-tolerance of 1/2 in. (12.7 mm).

13. Inspection

13.1 Inspection of the material shall be agreed upon between the purchaser and the supplier as part of the purchase contract.

14. Rejection and Rehearing

14.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

15. Certification

15.1 When specified in the purchase order or contract, a manufacturer's certification shall be furnished to the purchaser stating that material has been manufactured, tested, and inspected in accordance with this specification, and that the test results on representative samples meet specification requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

16. Product Marking

16.1 The following information shall be marked on the material or included on the package, or on a label or tag attached thereto: The name of the material or UNS number, heat number, condition (temper), this specification number, the size, gross, tare and net weight, consignor and consignee address, contract or order number, or such other information as may be defined in the contract or order.

TABLE 3 Permissible Variations for Outside Diameter and Wall Thickness of Seamless Cold Worked Pipe and Tube[A,B]

Nominal Outside diameter, in. (mm)	Permissible Variations					
	Outside Diameter, in. (mm)		% of Thickness of Specified Nominal Wall		% of Thickness of Specified Minimum Wall	
	+	−	+	−	+	−
Over 0.400 (10) to 5/8 (16), excl	0.005 (0.13)	0.005 (0.13)	15.0	15.0	30	0
5/8 (16) to 1 1/2 (38), incl	0.0075 (0.19)	0.0075 (0.19)	10.0	10.0	22	0
Over 1 1/2 (38) to 3 (76), incl	0.010 (0.25)	0.010 (0.25)	10.0	10.0	22	0
Over 3 (76) to 4 1/2 (114), incl	0.015 (0.38)	0.015 (0.38)	10.0	10.0	22	0
Over 4 1/2 (114) to 6 (152), incl	0.020 (0.51)	0.020 (0.51)	12.5	12.5	28	0
Over 6 (152) to 6 5/8 (168), incl	0.025 (0.64)	0.025 (0.64)	12.5	12.5	28	0
Over 6 5/8 (168) to 8 5/8 (219), incl	0.031 (0.79)	0.031 (0.79)	12.5	12.5	28	0

[A] *Ovality*—The permissible variations in this table apply to individual measurements, including out-of-roundness (ovality) except for the following:

For pipe and tube having a nominal wall thickness of 3 % or less of the nominal outside diameter, the mean outside diameter shall conform to the permissible variations of this table and individual measurements (including ovality) shall conform to the plus and minus values of the table, with the values increased by 0.5 % of the nominal outside diameter.

For pipe and tube over 4 1/2 in. (114 mm) in outside diameter with a nominal wall thickness greater than 3 % of the nominal outside diameter, the mean outside diameter shall conform to the permissible variations of this table and individual measurements shall not exceed twice the permissible variations of the table.

[B] *Eccentricity*—The permissible variations in this table apply to individual measurements including eccentricity.

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SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U. S. Government.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchased form a part of this specification to the extent referenced herein:

S1.1.1 *Federal Standards:*

Fed. Std. No. 102 Preservation, Packaging and Packing Levels[6]

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[6]

Fed. Std. No. 182 Continuous Identification Marking of Nickel and Nickel-Base Alloys[6]

S1.1.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[6]

S2. Quality Assurance

S2.1 *Responsibility for Inspection:*

S2.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

S3. Identification Marking

S3.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 182, except that the ASTM specification number and the alloy number shall be used.

S4. Preparation for Delivery

S4.1 *Preservation, Packaging, Packing:*

S4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade, or class and shall be preserved and packaged, level A or C, packed level A, B, or C as specified in the contract or purchase order.

S4.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

[6] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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APPENDIXES

(Nonmandatory Information)

X1. CONVERTER SIZES

X1.1 Small-diameter and light-wall tube in outside diameters 1¼ in. (31.8 mm) and under may be furnished in the conditions listed in Table X1.1 when so specified. The material is furnished in a limited range of sizes and the manufacturer should be consulted as to the various outside diameters and wall thicknesses that may be furnished. Material will have a bright finish. Such material shall conform to the applicable requirements in Tables X1.1 and X1.2.

TABLE X1.1 Mechanical Properties[A] of Small-Diameter and Light-Wall Tubing (Converter Sizes)

Condition	Tensile Strength, psi (MPa)	Yield Strength (0.2 % offset) min, psi (MPa)	Elongation in 2 in. or 50 mm, (or 4 *D*), min, %
Annealed[B]	85 000 (585) max	28 000 (195)	32
Half-hard[C]	85 000 (585) min	55 000 (380)	12
Full hard[D]	110 000 (760) min	90 000 (620)	3

[A] Not applicable to outside diameters under ⅛ in. (3.2 mm) and wall thicknesses under 0.015 in. (0.38 mm).
[B] This condition is sometimes designated as "No. 1 Temper."
[C] This condition is sometimes designated as "No. 2 Temper."
[D] This condition is sometimes designated as "No. 3 Temper."

TABLE X1.3 Tolerances on Cut Lengths of Light-Wall Tube

Length, ft (cm)	Tube Size, in. (mm)	Permissible Variations, in. (mm)	
		Over	Under
Under 1 (30)	up to 1.250 (31.8), incl	1/32 (0.8)	0 (0)
1 to 4 (30 to 122), incl	up to 1.250 (31.8), incl	1/16 (1.6)	0 (0)
Over 4 to 10 (122 to 300), incl	up to 1.250 (31.8), incl	3/32 (2.4)	0 (0)
Over 10 (300)	up to 1.250 (31.8), incl	3/16 (4.8)	0 (0)

TABLE X1.2 Permissible Variations for Small-Diameter and Light-Wall Tube (Converter Sizes)[A,B,C,D,E,F,G]

Specified Outside Diameter, in. (mm)	Outside Diameter		Inside Diameter, in. (mm)		Wall Thickness, %	
	+	−	+	−	+	−
Under 3/32 (2.4)	0.002 (0.05)	0 (0)	0 (0)	0.002 (0.05)	10	10
3/32 to 3/16 (2.4 to 4.8), excl	0.003 (0.08)	0 (0)	0 (0)	0.003 (0.08)	10	10
3/16 to ½ (4.8 to 12.7), excl	0.004 (0.10)	0 (0)	0 (0)	0.004 (0.10)	10	10
½ to 1¼ (12.7 to 31.8), incl	0.005 (0.13)	0 (0)	0 (0)	0.005 (0.13)	10	10

[A] *Ovality, Normal Wall Tube*—As-Drawn (No. 2 and 3) Tempers—Ovality will be held within the outside diameter tolerances shown in the table.
Annealed (No. 1) Temper—Ovality will be held within 2 % of the theoretical average outside diameter.
[B] *Ovality, Light-Wall Tube—As-Drawn (No. 2 and 3) Tempers*—Up to but not including 1¼ in. (31.8 mm) in outside diameter, ovality will be held within 2 % of the theoretical average outside diameter.
Annealed (No. 1) Temper—Ovality will be held within 3 % of the theoretical average outside diameter.
[C] *Wall Tolerances, Light-Wall Tube*—The plus and minus wall tolerance shown in the table shall apply down to and including 0.005 in. (0.13 mm) in wall thickness. For wall thicknesses less than 0.005 in. (0.13 mm), the tolerance shall be ±0.0005 in. (0.013 mm).
[D] *Random Lengths:*
Where nominal random lengths on tubing ⅛ in. (3.2 mm) and larger in outside diameter are specified, a length tolerance of ±3½ ft (106 cm) applies to the nominal length. This is a total spread of 7 ft (210 cm).
Random lengths in sizes ⅛ in. (3.2 mm) and larger in outside diameter shall be subject to a length range of 5 to 24 ft (150 to 730 cm). Long random lengths are subject to a range of 15 to 22 ft (457 to 670 cm).
Random lengths in sizes up to, but not including ⅛ in. (3.2 mm) in outside diameter, and fragile light-wall tubes over this outside diameter are subject to the length range of 1 to 15 ft (30 to 457 cm).
[E] *Cut Lengths*—Tolerances on cut lengths shall be in accordance with Table X1.3.
[F] *Straightness*—Round tubing is subject to a straightness tolerance of one part in 600 (equivalent to a depth of arc of 0.030 in. (0.76 mm) in any 3 ft (91 cm) of length).
[G] When specified, the tolerance spreads of this table may be applied as desired. However, when not specified, the tolerances in this table will apply. It should be noted that inside diameter tolerances are based upon the outside diameter range.

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X2. PIPE SCHEDULES

X2.1 The schedules of pipe shown in Table X2.1 are regularly available. Other schedules may be furnished, and the manufacturer should be consulted. Table X2.1 is published for information only.

TABLE X2.1 Pipe Schedules[A]

Nominal Pipe Size in.	Outside Diameter in. (mm)	Nominal Wall Thickness, in. (mm)			
		Schedule No. 5 in. (mm)	Schedule No. 10 in. (mm)	Schedule No. 40 in. (mm)	Schedule No. 80 in. (mm)
⅛	0.405 (10.3)	...	0.049 (1.2)	0.068 (1.7)	0.095 (2.4)
¼	0.540 (13.7)	...	0.065 (1.6)	0.088 (2.2)	0.119 (3.0)
⅜	0.675 (17.1)	...	0.065 (1.6)	0.091 (2.3)	0.126 (3.2)
½	0.840 (21.3)	0.065 (1.6)	0.083 (2.1)	0.109 (2.8)	0.147 (3.7)
¾	1.050 (26.7)	0.065 (1.6)	0.083 (2.1)	0.113 (2.8)	0.154 (3.9)
1	1.315 (33.4)	0.065 (1.6)	0.109 (2.8)	0.133 (3.4)	0.179 (4.5)
1¼	1.660 (42.2)	0.065 (1.6)	0.109 (2.8)	0.140 (3.6)	0.191 (4.8)
1½	1.900 (48.3)	0.065 (1.6)	0.109 (2.8)	0.145 (3.7)	0.200 (5.1)
2	2.375 (60.3)	0.065 (1.6)	0.109 (2.8)	0.154 (3.9)	0.218 (5.5)
2½	2.875 (73.0)	0.083 (2.1)	0.120 (3.0)	0.203 (5.2)	0.276 (7.0)
3	3.500 (88.9)	0.083 (2.1)	0.120 (3.0)	0.216 (5.5)	0.300 (7.6)
3½	4.000 (101.6)	0.083 (2.1)	0.120 (3.0)	0.226 (5.7)	0.318 (8.1)
4	4.500 (114.3)	0.083 (2.1)	0.120 (3.0)	0.237 (6.0)	0.337 (8.6)
5	5.563 (141.3)	0.109 (2.8)	0.134 (3.4)	0.258 (6.5)	0.375 (9.5)
6	6.625 (168.3)	0.109 (2.8)	0.134 (3.4)	0.280 (7.1)	0.432 (10.9)
8	8.625 (219.1)	...	...	0.322 (8.2)	0.500 (12.7)

[A] The pipe schedules shown above conform with standards adopted by the American National Standards Institute.

X3. CONDITIONS AND FINISHES NORMALLY SUPPLIED

X3.1 Scope

X3.1.1 This appendix lists the conditions and finishes in which pipe and tube (other than converter sizes) are normally supplied. These are subject to change, and the manufacturer should be consulted for the latest information available.

X3.2 Nickel-Copper Alloy (UNS N04400)

X3.2.1 *Annealed*—Soft, with a dull matte finish.

X3.2.2 *Stress-Relieved*—Thermally treated below the annealing temperature to relieve the major portion of the internal stresses, with a thin, light- to medium-dark surface.

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Designation: B 241/B 241M – 00

Used in USNRC-RDT standards

Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube[1]

This standard is issued under the fixed designation B 241/B 241M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification[2] covers aluminum and aluminum–alloy seamless pipe in the alloys (Note 1) and tempers shown in Table 1 [Table 2] and extruded round seamless tube in the alloys and tempers shown in Table 3 [Table 4] intended for pressure applications. The standard sizes for seamless pipe are listed in Table 16.7 of ANSI H35.2 and H35.2M. Nonstandard alloys, tempers, and sizes of pipe are produced as seamless extruded tube.

NOTE 1—Throughout this specification, use of the term *alloy*, in the general sense, includes aluminum as well as aluminum alloy.

NOTE 2—For other seamless drawn tubes, see Specification B 210 or Specification B 483. For extruded tube see Specification B 221, and for structural pipe and tube see Specification B 429.

1.2 Alloy and temper designations are in accordance with ANSI H35.1 and H35.1M. The equivalent Unified Numbering System alloy designations are those of Table 5 preceded by A9, for example, A91100 for aluminum 1100 in accordance with Practice E 527.

1.3 For acceptance criteria for inclusion of new aluminum and aluminum alloys in this specification, see Annex A2.

1.4 The values stated in either inch-pound or SI units are to be regarded separately as standard. The SI units are shown either in brackets or in separate tables. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems will result in nonconformance with this specification.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*

B 557 Test Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products[3]

B 557M Test Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products [Metric][3]

B 594 Practice for Ultrasonic Inspection of Aluminum-Alloy Wrought Products for Aerospace Applications[3]

B 597 Practice for Heat Treatment of Aluminum Alloys[3]

B 647 Test Method for Indentation Hardness of Aluminum Alloys by Means of a Webster Hardness Gage[3]

B 648 Test Method for Indentation Hardness of Aluminum Alloys by Means of a Barcol Impressor[3]

B 660 Practices for Packaging/Packing of Aluminum and Magnesium Products[3]

B 666/B 666M Practice for Identification Marking of Aluminum Products[3]

B 807 Practice for Extrusion Press Solution Heat Treatment of Aluminum Alloys[3]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[4]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[5]

E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum Base Alloys[6]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[6]

E 227 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[6]

E 527 Practice for Numbering Metals and Alloys (UNS)[7]

E 607 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique, Nitrogen Atmosphere[8]

E 716 Practices for Sampling Aluminum and Aluminum Alloys for Spectrochemical Analysis[8]

E 1004 Test Method for Electromagnetic (Eddy-Current) Measurements of Electrical Conductivity[9]

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[1] This specification is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.03 on Aluminum Alloy Wrought Products.

Current edition approved May 10, 2000. Published August 2000. Originally published as B 241–49T. Last previous edition B 241/B 241M–99.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SB-241/SB-241M in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 02.02.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] *Annual Book of ASTM Standards*, Vol 03.05.

[7] *Annual Book of ASTM Standards*, Vol 01.01.

[8] *Annual Book of ASTM Standards*, Vol 03.06.

[9] *Annual Book of ASTM Standards*, Vol 03.03.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Tensile Property Limits for Pipe, Inch-Pound Units[A,B]

Alloy	Temper	Pipe Size, in.	Tensile Strength, min, ksi	Yield Strength (0.2 % Offset), min, ksi	Elongation in 2 in. or 4 × Diameter, min, %[C]
3003	H18	Under 1	27.0	24.0	4
	H112	1 and over	14.0	5.0	25
6061	T6 (Extruded)	Under 1	38.0	35.0	8
		1 and over	38.0	35.0	10[D]
	T6 (Drawn)	Under 1	42.0	35.0	8[E]
		1 and over	38.0	35.0	10[F]
6063	T6	All	30.0	25.0	8
6351	T5	All	38.0	35.0	10[D]
	T6	All	42.0	37.0	10[G]

[A] The basis for establishment of tensile property limits is shown in Annex A1.
[B] For purposes of determining conformance with this specification, each value for tensile strength and yield strength shall be rounded to the nearest 0.1 ksi, and each value for elongation shall be rounded to the nearest 0.5 %, both in accordance with the rounding-off method of Practice E 29.
[C] Elongation of full-section and cut-out sheet-type specimens is measured in 2 in.; of round specimens, in 4 × specimen diameter.
[D] For wall thicknesses less than 0.250 in., the minimum elongation is 8 %.
[E] For wall thickness 0.050 to 0.259 in., the minimum elongation is 10 %.
[F] For wall thickness 0.260 to 0.500 in., the minimum elongation is 12 %.
[G] For wall thickness less than 0.125 in., the minimum elongation is 8 %.

TABLE 2 Tensile Property Limits for Pipe [SI Units][A,B]

Alloy[C]	Temper[C] (Product)	Pipe Size, Designation	Tensile Strength, min, MPa	Yield Strength (0.2 % Offset), min, MPa	Elongation,[C] min, %	
					in 50 mm	in 5 × Diameter (5.65 $\sqrt{A}$)
3003	H18	Under 1	185	165	4	...
	H112	1 and over	95	35	25	22
6061	T6 (Extruded)	Under 1	260	240	8	...
		1 and over	260	240	10[D]	9
	T6 (Drawn)	Under 1	290	240	8[E]	...
		1 and over	260	240	10[F]	9
6063	T6	All	205	170	8	7
6351	T5	All	260	240	10[D]	9
	T6	All	290	255	10[G]	9

[A] The basis for establishment of mechanical property limits is shown in Annex A1.
[B] For purposes of determining conformance with this specification, each value for ultimate strength and yield strength shall be rounded to the nearest 1 MPa, and each value for elongation shall be rounded to the nearest 0.5 %, both in accordance with the rounding-off method of Practice E 29.
[C] Elongations in 50 mm apply for pipe tested in full-section and to sheet type specimens taken from pipes having a wall up to 12.50 mm thick. Elongations in 5*D* (5.65 $\sqrt{A}$), where *D* and *A* are diameter and cross-sectional area of the specimens respectively, apply to round test specimens machined from wall thicknesses over 6.30 mm.
[D] For wall thicknesses up through 6.30 mm the minimum elongation is 8 %.
[E] For wall thicknesses over 1.25 through 6.60 mm, the minimum elongation is 10 %.
[F] For wall thicknesses over 6.60 through 12.50 mm, the minimum elongation is 12 %.
[G] For wall thicknesses up through 3.20 mm the minimum elongation is 8 %.

E 1251 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Argon Atmosphere, Point-to-Plane, Unipolar Self-Initiating Capacitor Discharge[8]

G 47 Test Method for Determining Susceptibility to Stress-Corrosion Cracking of High-Strength Aluminum Alloy Products[10]

2.3 *ANSI Standards:*

H35.1 Alloy and Temper Designation Systems for Aluminum[3]

H35.1(M) Alloy and Temper Designation Systems for Aluminum[3]

H35.2 Dimensional Tolerances for Aluminum Mill Products[3]

H35.2(M) Dimensional Tolerances for Aluminum Mill Products[3]

2.4 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[11]

2.5 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[11]

2.6 *Military Specification:*

MIL-H-6088 Heat Treatment of Aluminum Alloys[11]

3. Terminology

3.1 *Definitions:*

3.1.1 *alclad seamless pipe or alclad seamless tube*—a composite pipe or tube product composed of a seamless aluminum alloy core having on either the inside or the outside surface a metallurgically bonded aluminum or aluminum-alloy coating that is anodic to the core, thus electrolytically protecting the core against corrosion.

3.1.2 *extruded seamless round tube*—an extruded hollow product having a round cross section and a uniform wall thickness, which does not contain any line junctures resulting from method of manufacture.

[10] *Annual Book of ASTM Standards*, Vol 03.02.

[11] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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3.1.3 *producer*—the primary manufacturer of the material.

3.1.4 *seamless pipe*—extruded or drawn seamless tube having certain standardized sizes of outside diameter and wall thickness commonly designated by "Nominal Pipe Sizes" and American National Standards Institute (ANSI) Schedule Numbers.

3.1.5 *supplier*—jobber or distributor as distinct from producer.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *capable of*—the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material to this specification shall include the following information:

4.1.1 This specification designation (which includes the number, the year, and the revision letter, if applicable),

NOTE 3—For inch-pound orders specify B 241; for metric orders specify B 241M. Do not mix units.

4.1.2 Quantity in pieces or pounds [kilograms],

4.1.3 Alloy (Section 7),

4.1.4 Temper (Section 9),

4.1.5 Pipe size and schedule number (Table 16.7 of ANSI H35.2 and H35.2M), or outside diameter and wall thickness (extruded tube), and

4.1.6 Length.

4.2 Additionally, orders for material to this specification shall include the following information when required by the purchaser:

4.2.1 Whether solution treatment at the press is unacceptable (8.2),

4.2.2 Whether heat treatment in accordance with Practice B 597 is required (8.3),

4.2.3 Whether pipe size under 1 shall be extruded only (5.1 and Table 1 or [Table 2], Footnote F),

4.2.4 Whether threaded ends are required (see 15.2),

4.2.5 Whether inspection or witness of inspection and tests by the purchaser's representative is required prior to material shipment (Section 16),

4.2.6 Whether marking for identification is required (Section 19), and whether marking of lot number for alloys 2014 and 2024 in the T3- and T4-type tempers and alloy 6061 in the T6-type tempers is required (19.2),

4.2.7 Whether Practices B 660 applies and, if so, the levels of preservation, packaging, and packing required (19.3),

4.2.8 Whether certification of the material is required (Section 20),

4.2.9 Requirements for tensile property and dimensional tolerance for sizes not specifically covered (9.1.2 and 14.2), and

4.2.10 Whether ultrasonic inspection is required (Section 16, Table 6 [Table 7]).

5. Materials and Manufacture

5.1 The pipe and tube shall be produced from hollow extrusion ingot (cast in hollow form, or drilled, or pierced from solid ingot) and shall be extruded by use of the die and mandrel method. Pipe and tube may be subsequently cold drawn at the option of the producer.

6. Quality Assurance

6.1 *Responsibility for Inspection and Tests*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser in the order or at the time of contract signing. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections and tests are deemed necessary to ensure that material conforms to prescribed requirements.

6.2 *Lot Definition*—An inspection lot shall be defined as follows:

6.2.1 For heat-treated tempers, an inspection lot shall consist of an identifiable quantity of material of the same mill form, alloy, temper, and nominal dimensions traceable to a heat-treat lot or lots, and subjected to inspection at one time.

6.2.2 For nonheat-treated tempers, an inspection lot shall consist of an identifiable quantity of material of the same mill form alloy, temper, and nominal dimensions subjected to inspection at one time.

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TABLE 3 Tensile Property Limits for Extruded Tube, Inch-Pound Units[A,B]

Temper	Specified Section or Wall Thickness, in.	Area, in.[2]	Tensile Strength, ksi		Yield Strength (0.2 % Offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %[C]
			Min	Max	Min	Max	
			Aluminum 1060				
O	all	all	8.5	14.0	2.5	...	25
H112	all	all	8.5	...	2.5	...	25
F[D]	all	all	...	...	...	...	...
			Aluminum 1100				
O	all	all	11.0	15.5	3.0	...	25
H112	all	all	11.0	...	3.0	...	25
F[D]	all	all	...	...	...	...	...
			Alloy 2014				
O	all	all	...	30.0	...	18.0	12
T4, T4510[E], T4511[E]	all	all	50.0	...	35.0	...	12
T42	all	all	50.0	...	29.0	...	12
T6, T6510[E], T6511[E]	up thru 0.499	all	60.0	...	53.0	...	7
	0.500–0.749	all	64.0	...	58.0	...	7
	0.750 and over	up thru 25	68.0	...	60.0	...	7
		over 25 thru 32	68.0	...	58.0	...	6
T62	up thru 0.749	all	60.0	...	53.0	...	7
	0.750 and over	up thru 25	60.0	...	53.0	...	7
		over 25 thru 32	60.0	...	53.0	...	6
F[D]	all	all	...	...	...	...	...
			Alloy 2024				
O	all	all	...	35.0	...	19.0	12
T3, T3510[E], T3511[E]	up thru 0.249	all	57.0	...	42.0	...	10
	0.250–0.749	all	60.0	...	44.0	...	10
	0.750–1.499	all	65.0	...	46.0	...	10
	1.500 and over	up thru 25	70.0	...	48.0	...	10
		over 25 thru 32	68.0	...	46.0	...	8
T42	up thru 0.749	all	57.0	...	38.0	...	12
	0.750–1.499	all	57.0	...	38.0	...	10
	1.500 and over	up thru 25	57.0	...	38.0	...	10
		over 25 thru 32	57.0	...	38.0	...	8
T81, T8510[E], T8511[E]	0.050–0.249	all	64.0	...	56.0	...	4
	0.250–1.499	all	66.0	...	58.0	...	5
	1.500 and over	up thru 32	66.0	...	58.0	...	5
F[D]	all	all	...	...	...	...	...
			Alloy 2219				
O	all	all	...	32.0	...	18.0	12
T31, T3510[E], T3511[E]	up thru 0.499	up thru 25	42.0	...	26.0	...	14
	0.500-2.999	up thru 25	45.0	...	27.0	...	14
T62	Up thru 0.999	up thru 25	54.0	...	36.0	...	6
	1,000 and over	up thru 25	54.0	...	36.0	...	6
T81, T8510[E], T8511[E]	up thru 2.999	up thru 25	58.0	...	42.0	...	6
F[D]	all	all	...	...	...	...	...
			Alloy 3003				
O	all	all	14.0	19.0	5.0	...	25
H112	all	all	14.0	...	5.0	...	25
F[D]	all	all	...	...	...	...	...

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TABLE 3 *Continued*

Temper	Specified Section or Wall Thickness, in.	Area, in.[2]	Tensile Strength, ksi		Yield Strength (0.2 % Offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %[C]
			Min	Max	Min	Max	
			Alclad Alloy 3003				
O	all	all	13.0	18.0	4.5	...	25
H112	all	all	13.0	...	4.5	...	25
F[D]	all	all	...	...	...	...	...
			Alloy 5052				
O	all	all	25.0	35.0	10.0	...	...
F[D]	all	all	...	...	...	...	...
			Alloy 5083				
O	all	up thru 32	39.0	51.0	16.0	...	14
H111	all	up thru 32	40.0	...	24.0	...	12
H112	all	up thru 32	39.0	...	16.0	...	12
F[D]	all	all	...	...	...		...
			Alloy 5086				
O	all	up thru 32	35.0	46.0	14.0	...	14
H111	all	up thru 32	36.0	...	21.0	...	12
H112	all	up thru 32	35.0	...	14.0	...	12
F[D]	all	all	...	...	...	...	...
			Alloy 5454				
O	all	up thru 32	31.0	41.0	12.0	...	14
H111	all	up thru 32	33.0	...	19.0	...	12
H112	all	up thru 32	31.0	...	12.0	...	12
F[D]	all	all	...	...	...	...	...
			Alloy 5456				
O	all	up thru 32	41.0	53.0	19.0	...	14
H111	all	up thru 32	42.0	...	26.0	...	12
H112	all	up thru 32	41.0	...	19.0	...	12
F[D]	all	all	...	...	...	...	...
			Alloy 6061				
O	all	all	...	22.0	...	16.0	16
T1	up thru 0.625	all	26.0	...	14.0	...	16
T4 T4510[E] T4511[E]	all	all	26.0	...	16.0	...	16
T42	all	all	26.0	...	12.0	...	16
T51	up thru 0.625	all	35.0	...	30.0	...	8
T6, T62 T6510[E] T6511[E]	up thru 0.249	all	38.0		35.0	...	8
	0.250 and over	all	38.0	...	35.0	...	10
F[D]	all	all	...	...	...	...	...
			Alloy 6063				
O	all	all	...	19.0	...	...	18
T1[F]	up thru 0.500	all	17.0	...	9.0	...	12
	0.501–1.000	all	16.0	...	8.0	...	12
T4, T42	up thru 0.500	all	19.0	...	10.0	...	14
	0.501–1.000	all	18.0	...	9.0	...	14
T5	up thru 0.500	all	22.0	...	16.0	...	8
	0.501–1.000	all	21.0	...	15.0	...	8
T52	up thru 1.000	all	22.0	30.0	16.0	25.0	8
T6, T62	up thru 0.124	all	30.0	...	25.0	...	8
	0.125–1.000	all	30.0	...	25.0	...	10
F[D]	all	all	...	...	...	...	...

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TABLE 3 *Continued*

Temper	Specified Section or Wall Thickness, in.	Area, in.[2]	Tensile Strength, ksi		Yield Strength (0.2 % Offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %[C]
			Min	Max	Min	Max	
			Alloy 6066				
O	all	all	...	29.0	...	18.0	16
T4, T4510,[E] T4511[E]	all	all	40.0	...	25.0	...	14
T42	all	all	40.0	...	24.0	...	14
T6, T6510,[E] T6511[E]	all	all	50.0	...	45.0	...	8
T62	all	all	50.0	...	42.0	...	8
			Alloy 6162				
T5, T5510,[E] T5511[E]	up thru 1.000	all	37.0	...	34.0	...	7
T6, T6510,[E]	up thru 0.249	all	38.0	...	35.0	...	8
T6511[E]	0.250–0.499	all	38.0	...	35.0	...	10
			Alloy 6351				
T4	up thru 0.749	all	32.0	...	19.0	...	16
T6	up thru 0.124	...	42.0	...	37.0	...	8
	0.125-0.749	...	42.0	...	37.0	...	10
			Alloy 7075				
O	all	...	...	40.0	...	24.0	10
T6, T62 T6510[E] T6511[E]	up thru 0.249	all	78.0	...	70.0	...	7
	0.250–0.499	all	81.0	...	73.0	...	7
	0.500–1.499	all	81.0	...	72.0	...	7
	1.500–2.999	all	81.0	...	72.0	...	7
T73 T73510 T73511	0.062–0.249	all	68.0	...	58.0	...	7
	0.250–1.499	up thru 25	70.0	...	61.0	...	8
	1.500–2.999	up thru 25	69.0	...	59.0	...	8
F[D]	all	all	...	...	...	...	...
			Alloy 7178				
O	all	up thru 32	...	40.0	...	24.0	10
T6 T6510[E] T6511[E]	up thru 0.061	all	82.0	...	76.0	...	5
	0.062–0.249	up thru 20	84.0	...	76.0	...	5
	0.250–1.499	up thru 25	87.0	...	78.0	...	5
	1.500–2.499	up thru 25	86.0	...	77.0	...	5
		over 25 thru 32	84.0	...	75.0	...	5
	2.500–2.999	up thru 32	82.0	...	71.0	...	5
T62	up thru 0.061	all	79.0	...	73.0	...	5
	0.062–0.249	up thru 20	82.0	...	74.0	...	5
	0.250–1.499	up thru 25	86.0	...	77.0	...	5
	1.500–2.499	up thru 25	86.0	...	77.0	...	5
		over 25 thru 32	84.0	...	75.0		5
	2.500–2.999	up thru 32	82.0	...	71.0	...	5
F[D]	all	all	...	...	...	...	...

[A] The basis for establishment of mechanical property limits is shown in Annex A1.

[B] To determine conformance to this specification, each value for ultimate strength and for yield strength shall be rounded to the nearest 0.1 ksi and each value for elongation to the nearest 0.5%, both in accordance with the rounding-off method of Practice E 29.

[C] Elongation of full-section and cut-out sheet-type specimens is measured in 2 in.; of round specimens, in 4 × specimen diameter. See 9.1.1 for conditions under which measurements are not required.

[D] Tests for tensile properties in the F temper are not required.

[E] For stress-relieved tempers (T3510, T3511, T4510, T4511, T5510, T5511, T6510, T6511, T73510, T73511, T8510, T8511), characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic tempers.

[F] Formerly designated T42 temper. When properly aged (precipitation heat-treated) 6063-T1 extruded products are designated T5.

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TABLE 4 Tensile Property Limits for Extruded Tube [SI Units][A,B]

Temper	Specified Wall Thickness, mm		Area, mm²		Tensile Strength, MPa		Yield Strength (0.2 % offset), MPa		Elongation,[C] %, min	
	over	through	over	through	min	max	min	max	in 50 mm	in 5 × diameter (5.65 √A)
Aluminum 1060										
O	all		all		60	95	15	...	25	22
H112	all		all		60	...	15	...	25	22
F[D]	all		all		...	...	...	...	...	...
Aluminum 1100										
O	all		all		75	105	20	...	25	22
H112	all		all		75	...	20	...	25	22
F[D]	all		all		...	...	...	...	...	...
Alloy 2014										
O	all		all		...	205	...	125	12	10
T4, T4510[E], T4511[E]	all		all		345	...	240	...	12	10
T42[F]	all		all		345	...	200	...	12	10
T6, T6510[E], T6511[E]	...	12.50	all		415	...	365	...	7	6
	12.50	18.00	all		440	...	400	...	...	6
	18.00	...	...	16 000	470	...	415	...	...	6
	18.00	...	16 000	20 000	470	...	400	...	...	5
T62[F]	...	18.00	all	...	415	...	365	...	7	6
	18.00	...	...	16 000	415	...	365	...	...	6
	18.00	...	16 000	20 000	415	...	365	...	...	5
F[D]	all		all	...	...	...	...	...	...	...
Alloy 2024										
O	all		all		...	240	...	130	12	10
T3, T3510[E], T3511[E]	...	6.30	all		395	...	290	...	10[H]	...
	6.30	18.00	all		415	...	305	...	10[H]	9[H]
	18.00	35.00	all		450	...	315	...	...	9
	35.00	...	...	16 000	485	...	360[I]	...	...	9
	35.00	...	16 000	20 000	470	...	330[J]	...	...	7
T42[F]	...	18.00	all	...	395	...	260	...	12	10
	18.00	35.00	all		395	...	260	...	...	9
	35.00	...	...	16 000	395	...	260	...	...	9
	35.00	...	16 000	20 000	395	...	260	...	...	...
T81, T8510[E], T8511[E]	1.20	6.30	all		440	...	385	...	4	7
	6.30	35.00	all		455	...	400	...	5	4
	35.00	...	...	20 000	455	...	400	...	...	4
F[D]	all		all		...	...	...	...	...	...
Alloy 2219										
O	all		all		...	220	...	125	12	10
T31, T3510[E], T3511[E]	...	12.50	...	16 000	290	...	180	...	14	12
	12.50	80.00	...	16 000	310	...	185	...	...	12
T62[F]	...	25.00	...	16 000	370	...	250	...	6	5
	25.00	...	...	20 000	370	...	250	...	...	5
T81, T8510[E], T8511[E]	...	80.00	...	16 000	400	...	290	...	6	5
F[D]	all		all		...	...	...	...	...	...
Alloy 3003										
O	all	...	all		95	130	35	...	25	22
H112	...	1.60	all		95	...	35	...	...	...
	1.60	...	all		95	...	35	...	25	22
F[D]	all		all		...	...	...	...	...	...

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TABLE 4 *Continued*

Temper	Specified Wall Thickness, mm		Area, mm²		Tensile Strength, MPa		Yield Strength (0.2 % offset), MPa		Elongation,[C] %, min	
	over	through	over	through	min	max	min	max	in 50 mm	in 5 × diameter (5.65 $\sqrt{A}$)
Alclad Alloy 3003										
O	all		all		90	125	30	...	25	22
H112	all		all		90	...	30	...	25	22
F[D]	all		all		...	...	...	...	...	...
Alloy 5052										
O	all		all		170	240	70	...	...	...
F[D]	all		all		...	...	...	...	...	...
Alloy 5083										
O	all		...	20 000	270	350	110	...	14	12
H111	all		...	20 000	275	...	165	...	12	10
H112	all		...	20 000	270	...	110	...	12	10
F[D]	all		all		...	...	...	...	...	...
Alloy 5086										
O	all		...	20 000	240	315	95	...	14	12
H111	all		...	20 000	250	...	145	...	12	10
H112	all		...	20 000	240	...	95	...	12	10
F[D]	all		all		...	...	...	...	...	...
Alloy 5454										
O	all		...	20 000	215	285	85	...	14	12
H111	all		...	20 000	230	...	130	...	12	10
H112	all		...	20 000	215	...	85	...	12	10
F[D]	all		all		...	...	...	...	...	...
Alloy 5456										
O	all		...	20 000	285	365	130	...	14	12
H111	all		...	20 000	290	...	180	...	12	10
H112	all		...	20 000	285	...	130	...	12	10
F[D]	all		all		...	...	...	...	...	...
Alloy 6061										
O	all		all		...	150	...	110	16	14
T1	...	16.00	all		180	...	95	...	16	14
T4 T4510[E] T4511[E]	all		all		180	...	110	...	16	14
T42[F]	all		all		180	...	85	...	16	14
T51	...	16.00	all		240	...	205	...	8	7
T6, T62[F] T6510[E] T6511[E]	... 6.30	6.30 ...	all all		260 260	... ...	240 240	... ...	8 10	... 9
F[D]	all		all		...	...	...	...	...	...
Alloy 6063										
O	all		all		...	130	...	...	18	16
T1	...	12.50	all		115	...	60	...	12	10
	12.50	25.00	all		110	...	55	...	...	10
T4, T42[F]	...	12.50	all		130	...	70	...	14	12
	12.50	25.00	all		125	...	60	...	...	12
T5	...	12.50	all		150	...	110	...	8	7
	12.50	25.00	all		145	...	105	...	...	7
T52	...	25.00	all		150	205	110	170	8	7
T6	...	3.20	all		205	...	170	...	8	...
	3.20	25.00	all		205	...	170	...	10	9
F[D]	all		all		...	...	...	...	...	...

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TABLE 4 *Continued*

Temper	Specified Wall Thickness, mm		Area, mm²		Tensile Strength, MPa		Yield Strength (0.2 % offset), MPa		Elongation,[C] %, min	
	over	through	over	through	min	max	min	max	in 50 mm	in 5 × diameter (5.65 $\sqrt{A}$)
Alloy 6066										
O	all		all		...	200	...	125	16	14
T4, T4510[E] T4511[E]	all		all		275	...	170	...	14	12
T42	all		all		275	...	165	...	14	12
T6, T6510[E] T6511[E]	all		all		345	...	310	...	8	7
T62	all		all		345	...	290	...	8	7
Alloy 6162										
T5, T5510[E] T5511[E]	...	25.00	all		255	...	235	...	7	6
T6, T6510[E] T6511[E]	...	6.30	all		260	...	240	...	8	...
	6.30	12.50	all		260	...	240	...	10	9
Alloy 6351										
T4	...	19.00	all		220	...	130	...	16	14
T6	...	3.20	...	...	290	...	255	...	8	
	3.20	25.00	...	...	290	...	255	...	10	9
Alloy 7075										
O	all		all		...	275	...	165	10	9
T6, T62[F] T6510[E] T6511[E]	...	6.30	all		540	...	485	...	7	...
	6.30	12.50	all		560	...	505	...	7	6
	12.50	70.00	all		560	...	495	...	...	6
T73 T73510[E] T73511[E]	1.60	6.30	...	13 000	470	...	400	...	7	...
	6.30	35.00	...	16 000	485	...	420	...	8	7
	35.00	70.00	...	18 000	475	...	405	...	...	7
F[D]	all		all		...	...	...	...	...	...
Alloy 7178										
O	all		...	20 000	...	275	...	165	10	9
T6 T6510[E] T6511[E]	...	1.60	all		565	...	525	...	...	...
	1.60	6.30	...	13 000	580	...	525	...	5	...
	6.30	35.00	...	16 000	600	...	540	...	5	4
	35.00	60.00	...	16 000	595	...	530	...	...	4
	35.00	60.00	16 000	20 000	580	...	515	...	...	4
	60.00	80.00	...	20 000	565	...	490	...	...	4
T62[F]	...	1.60	all		545	...	505	...	...	...
	1.60	6.30	...	13 000	565	...	510	...	5	...
	6.30	35.00	...	16 000	595	...	530	...	5	4
	35.00	60.00	...	16 000	595	...	530	...	...	4
	35.00	60.00	16 000	20 000	580	...	515	...	...	4
	60.00	80.00	...	20 000	565	...	490	...	...	4
F[D]	all	all		...	...	...	...	...	...	

[A] The basis for establishment of tensile property limits is shown in Annex A1.

[B] To determine conformance to this specification, each value for tensile strength and yield strength shall be rounded to the nearest 1 MPa and each value for elongation to the nearest 0.5 %, both in accordance with the rounding-off method of Practice E 29.

[C] Elongations in 50 mm apply for shapes tested in full section and for sheet-type specimens machined from material up through 12.5 mm in thickness having parallel surfaces. Elongations in 5 *D* (5.65 $\sqrt{A}$), where *D* and *A* are diameter and cross-sectional area of the specimen, respectively, apply to round test specimens machined from thicknesses over 6.30. See 9.1.1 for conditions under which measurements are not required.

[D] No mechanical properties are specified or guaranteed.

[E] For stress-relieved tempers (T3510, T3511, T4510, T4511, T5510, T5511, T6510, T6511, T73510, T73511, T76510, T76511, T8510, T8511), characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic tempers.

[F] Material in the T42 and T62 tempers is not available from the material producers.

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TABLE 5 Chemical Composition Limits[A,B,C]

Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Titanium	Other Elements[D]		Aluminum
									Each	Total[E]	
1060	0.25	0.35	0.05	0.03	0.03	...	0.05	0.03	0.03[F]	...	99.60 min[G]
1100	0.95 Si + Fe		0.05–0.20	0.05	...	...	0.10	...	0.05	0.15	99.00 min[G]
2014	0.50–1.2	0.7	3.9–5.0	0.40–1.2	0.20–0.8	0.10	0.25	0.15[H]	0.05	0.15	remainder
2024	0.50	0.50	3.8–4.9	0.30–0.9	1.2–1.8	0.10	0.25	0.15[H]	0.05	0.15	remainder
2219	0.20	0.30	5.8–6.8	0.20–0.40	0.02	...	0.10	0.02–0.10	0.05[I]	0.15[I]	remainder
3003	0.6	0.7	0.05–0.20	1.0–1.5	...	...	0.10	...	0.05	0.15	remainder
Alclad 3003[J]	...	...	...	...	...	...	...	...	...	...	...
5052	0.25	0.40	0.10	0.10	2.2–2.8	0.15–0.35	0.10	...	0.05	0.15	remainder
5083	0.40	0.40	0.10	0.40–1.0	4.0–4.9	0.05–0.25	0.25	0.15	0.05	0.15	remainder
5086	0.40	0.50	0.10	0.20–0.7	3.5–4.5	0.05–0.25	0.25	0.15	0.05	0.15	remainder
5454	0.25	0.40	0.10	0.50–1.0	2.4–3.0	0.05–0.20	0.25	0.20	0.05	0.15	remainder
5456	0.25	0.40	0.10	0.50–1.0	4.7–5.5	0.05–0.20	0.25	0.20	0.05	0.15	remainder
6061[K]	0.40–0.8	0.7	0.15–0.40	0.15	0.8–1.2	0.04–0.35	0.25	0.15	0.05	0.15	remainder
6063	0.20–0.6	0.35	0.10	0.10	0.45–0.9	0.10	0.10	0.10	0.05	0.15	remainder
6066	0.9–1.8	0.50	0.7–1.2	0.6–1.1	0.8–1.4	0.40	0.25	0.20	0.05	0.15	remainder
6162	0.40–0.8	0.50	0.20	0.10	0.7–1.1	0.10	0.25	0.10	0.05	0.15	remainder
6351	0.7–1.3	0.50	0.10	0.40–0.8	0.40–0.8	...	0.20	0.20	0.05	0.15	remainder
7072[L]	0.7 Si + Fe		0.10	0.10	0.10	...	0.8–1.3	...	0.05	0.15	remainder
7075	0.40	0.50	1.2–2.0	0.30	2.1–2.9	0.18–0.28	5.1–6.1	0.20[M]	0.05	0.15	remainder
7178	0.40	0.50	1.6–2.4	0.30	2.4–3.1	0.18–0.28	6.3–7.3	0.20	0.05	0.15	remainder

[A] Limits are in weight [mass] percent maximum unless shown as a range or stated otherwise.

[B] Analysis shall be made for the elements for which limits are shown in this table.

[C] For purposes of determining conformance to these limits, an observed value or a calculated value obtained from analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the specified limit, in accordance with the rounding-off method of Practice E 29.

[D] *Others* includes listed elements for which no specific limit is shown as well as unlisted metallic elements. The producer may analyze samples for trace elements not specified in the specification. However, such analysis is not required and may not cover all metallic *Others* elements. Should any analysis by the producer or the purchaser establish that an *Others* element exceeds the limit of *Each* or that the aggregate of several *Others* elements exceeds the limit of *Total*, the material shall be considered nonconforming.

[E] *Other Elements*—Total shall be the sum of unspecified metallic elements 0.010 % or more, rounded to the second decimal before determining the sum.

[F] Vanadium 0.05 % maximum.

[G] The aluminum content shall be calculated by subtracting from 100.00 % the sum of all metallic elements present in amounts of 0.010 % or more each, rounded to the second decimal before determining the sum.

[H] A maximum limit of 0.20 % for zirconium + titanium is permitted upon agreement between the purchaser and producer.

[I] Vanadium 0.05–0.15 %; zirconium, 0.10–0.25 %. The total for other elements does not include vanadium and zirconium.

[J] Alloy 3003 clad with alloy 7072.

[K] Beginning in the 1965 issue, the requirements for alloy 6062 were combined with alloy 6061 by revision of the minimum chromium content of 6061 from 0.15 to 0.04. This action cancelled alloy 6062.

[L] Cladding on alclad 3003.

[M] A maximum limit of 0.25 % for zirconium + titanium is permitted upon agreement between the purchaser and producer.

TABLE 6 Ultrasonic Discontinuity Limits[A] for Seamless Extruded Tube, Inch-Pound Units

Alloy	Wall Thickness, in.	Max Weight per Piece, lb	Max Width: Thickness Ratio	Discontinuity Class[B]
2024	0.500 & over	600	10:1	B
7075	0.500–1.499	600	10:1	B
7178	1.500 & over	600	10:1	A

[A] Discontinuities in excess of those listed in this table shall be allowed, subject to the approval of the procuring activity, if it is established that they will be removed by machining or that they are in noncritical areas.

[B] The discontinuity class limits are defined in Section 11, Discontinuity Class Limits, of Practice B 594.

TABLE 7 Ultrasonic Discontinuity Limits[A] for Seamless Extruded Tube, [SI Units]

Alloy	Wall Thickness, mm		Max Mass per Piece, kg	Max Width: Thickness Ratio	Discontinuity Class[B]
	Over	Through			
2024	12.50	...	300	10:1	B
7075	12.50	35.00	300	10:1	B
7178	35.00	...	300	10:1	A

[A] Discontinuities in excess of those listed in this table shall be allowed, subject to the approval of the procuring activity, if it is established that they will be removed by machining or that they are in noncritical areas.

[B] The discontinuity class limits are defined in Section 11, Discontinuity Class Limits, of Practice B 594.

7. Chemical Composition

7.1 *Limits*—The material shall conform to the chemical composition limits specified in Table 5. Conformance shall be determined by analyzing samples taken when the ingots are poured, or analyzing samples taken from the finished or semifinished product. If the producer has determined the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product.

NOTE 4—It is standard practice in the United States aluminum industry to determine conformance to the chemical composition limits prior to further processing of ingots into wrought products. Due to the continuous nature of the process, it is not practical to keep a specific ingot analysis identified with a specific quantity of finished material.

7.2 *Number of Samples*—The number of samples taken for determination of chemical composition shall be as follows:

7.2.1 When samples are taken at the time the ingots are poured, at least one sample shall be taken for each group of ingots poured simultaneously from the same source of molten metal.

7.2.2 When samples are taken from the finished or semifinished product, a sample shall be taken to represent each 4000 lb [2000 kg], or fraction thereof, in the shipment, except that not more than one sample shall be required per piece.

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7.3 *Methods of Sampling*—Samples for determination of chemical composition shall be taken in accordance with one of the following methods:

7.3.1 Samples for chemical analysis shall be taken from the material by drilling, sawing, milling, turning, or clipping a representative piece or pieces to obtain a sample of not less than 75 g. Sampling shall be in accordance with Practice E 55.

7.3.2 Sampling for spectrochemical analysis shall be in accordance with Practices E 716. Samples for other methods of analysis shall be suitable for the form of material being analyzed and the type of analytical method used.

NOTE 5—It is difficult to obtain a reliable analysis of each of the components of clad materials using material in its finished state. A reasonably accurate determination of the core composition can be made if the cladding is substantially removed prior to analysis. The cladding composition is more difficult to determine because of the relatively thin layer and because of diffusion of core elements to the cladding. The correctness of cladding alloy used can usually be verified by a combination of metallographic examination and spectrochemical analysis of the surface at several widely separated points.

7.4 *Methods of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (Test Methods E 34) or spectrochemical (Test Methods E 227, E 607, and E 1251) methods. Other methods may be used only when no published ASTM test method is available. In case of dispute, the methods of analysis shall be agreed upon between the producer and the purchaser.

8. Heat Treatment

8.1 Producer or supplier heat treatment for the production of T1 and T5-type tempers shall be in accordance with Practice B 807, and for the production of T3, T4, T6, T7, and T8-type tempers, except as noted in 8.2 or unless otherwise specified in 8.3, in accordance with MIL-H-6088.

8.2 Alloys 6061, 6063, and 6351 may be solution heat-treated and quenched at the extrusion press in accordance with Practice B 807 for the production of T4 and T6-type tempers, as applicable.

8.3 When specified, heat treatment for the production of T3, T4, T6, T7, and T8-type tempers shall be in accordance with Practice B 597.

9. Tensile Properties

9.1 *Limits*—The material shall conform to the tensile property requirements specified in Table 1 [Table 2] and Table 3 [Table 4] as applicable.

9.1.1 The elongation requirements shall not be applicable to the following:

9.1.1.1 Material of such dimensions that a standard test specimen cannot be taken in accordance with Test Methods B 557 [B 557M].

9.1.1.2 Tubes less than 0.062 in. [up through 1.60 mm] in wall thickness.

9.1.2 Tensile property limits for sizes not covered in Table 3 and [Table 4] shall be as agreed upon between the producer and purchaser and shall be so specified in the contract or purchase order.

9.2 *Number of Specimens*:

9.2.1 For material having a nominal weight of less than 1 lb/linear ft [up through 1.7 kg/linear m], one tension test specimen shall be taken for each 1000 lb [500 kg] or fraction thereof in the lot.

9.2.2 For material having a nominal weight of 1 lb or more/linear ft [over 1.7 kg/linear m], one tension test specimen shall be taken for each 1000 ft [300 m] or fraction thereof in the lot.

9.2.3 Other procedures for selecting samples may be employed if agreed upon by the producer and the purchaser.

9.3 *Test Methods*—The tension tests shall be made in accordance with Test Methods B 557 [B 557M].

10. Producer Conformation of Heat Treatment Response

10.1 The producer shall determine that heat treatable alloys supplied in the O or F tempers (within the size limits specified in Table 3 and [Table 4]) respond to heat treatment in accordance with the following:

10.1.1 Alloys 2014, 2024, 6061, and 6063 shall, after proper solution heat treatment and natural aging for not less than 4 days at room temperature, conform to the properties specified in Table 3 and [Table 4] for T42 temper material. The heat-treated samples may be tested prior to 4 days natural aging but if they fail to conform to the T42 temper properties, the tests may be repeated after completion of the 4 days natural aging without prejudice.

10.1.2 Alloys 2024, 2219, 6061, 6063, 7075, and 7178 shall, after proper solution heat treatment and precipitation heat treatment, conform to the properties specified in Table 3 and [Table 4] for T62 temper material.

10.2 *Number of Specimens*—The number of specimens from each lot of O and F temper material shall be as specified in 9.2.

10.3 *Quality Assurance Screening of Extrusion Press Heat Treated Pipe and Tube*—Pipe and tube heat-treated at the extrusion press shall conform to all the requirements of Section 9. In addition, hardness tests shall be performed on each extruded length or, with the approval of the purchaser, on samples selected in accordance with a mutually agreeable sampling plan. The minimum hardness control value shall be in accordance with Table 8 [Table 9] for pipe and with Table 10 [Table 11] for tube for the type of hardness tester used. The specific type of hardness tester shall be left to the discretion of the producer, but the test method shall be in accordance with Test Methods B 647, B 648, or E 18, as applicable.

10.3.1 Individual pieces within a lot that fail to conform to the minimum applicable hardness values may be accepted provided that samples from the two pieces exhibiting the lowest minimum hardness values are tension tested and found to conform to the requirements of Table 1 [Table 2] for pipe or Table 3 [Table 4] for tube.

NOTE 6—It may be necessary in the case of 6XXX—naturally aged tempers to allow for the elapse of four days subsequent to heat treatment for the material to attain its expected strength. Material in these tempers that has been tested for mechanical properties prior to an elapse of four days and fails may be retested after four days without prejudice.

11. Heat Treatment and Reheat Treatment Capability

11.1 As-received material in the O or F temper in alloys 2014, 2024, 6061, and 6063 (within the size limits specified in Table 3 [Table 4] and without the imposition of cold work)

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TABLE 8 Hardness Screening Values for Seamless Extruded Tube, Inch-Pound Units[A]

Alloy and Temper	Specified Wall Thickness, in.	Hardness Number, min[B,C]		
		Webster	Barcol	Rockwell E
6061-T4	0.050 and over	...	64	...
-T6	0.050 through 0.075	15	76	89
	0.076 through 0.499	15	76	89
	0.500 through 1.000	15	76	...
6063-T1	0.050 through 0.500	...	50	...
-T4	0.050 through 0.500	...	60	...
-T5	0.050 through 0.500	...	65	...
-T6	0.050 through 1.000	12	72	75
6351-T6	0.050 through 0.749	16	...	...

[A] See 10.3.
[B] Alternate minimum hardness values and hardness testing devices may be used provided agreement is reached between the purchaser and supplier or producer.
[C] The hardness values shown do not guarantee material will pass the applicable mechanical property requirements but are for informational purposes only. It is the responsibility of the user of this specification to establish the relationship between the hardness values and tensile properties.

TABLE 9 Hardness Screening Values for Seamless Extruded Tube [SI Units][A]

Alloy and Temper	Specified Wall Thickness, mm	Hardness Number, Minimum[B,C]		
		Webster	Barcol	Rockwell E
6061-T4	1.25 and over	...	64	...
-T6	1.25 through 1.50	15	76	89
	over 1.50 through 12.5	15	76	89
	over 12.5 through 25.0	15	76	...
6063-T1	1.25 through 12.5	...	50	...
-T4	1.25 through 12.5	...	60	...
-T5	1.25 through 12.5	...	65	...
-T6	1.25 through 25.0	12	72	75
6351-T6	1.25 through 19.00	16	...	...

[A] See Section 10.3.
[B] Alternative minimum hardness values and hardness testing devices may be used provided agreement is reached between the purchaser and supplier or producer.
[C] The hardness values shown do not guarantee material will pass the applicable mechanical property requirements but are for informational purposes only. It is the responsibility of the user of this specification to establish the relationship between the hardness values and tensile properties.

TABLE 10 Hardness Screening Values for Seamless Pipe, Inch-Pound Units[A]

Alloy and Temper	Pipe Size, in.	Wall Thickness, in.	Hardness Number, min[B,C]		
			Webster	Barcol	Rockwell E
6061-T6	less than 1 in.	0.050 and over	16	...	...
	1 in. and over	0.050 to 0.075	15	76	89
		0.076 to 0.499	15	76	89
		0.500 through 1.000	15	76	...
6063-T6	All	0.050 through 1.000	12	72	75
6351-T5	All	0.050 through 1.000	15	76	89
-T6	All	0.050 through 1.000	16	...	...

[A] See 10.3.
[B] Alternate minimum hardness values and hardness testing devices may be used provided agreement is reached between the purchaser and supplier or producer.
[C] The hardness values shown do not guarantee material will pass the applicable mechanical property requirements but are for informational purposes only. It is the responsibility of the user of this specification to establish the relationship between the hardness values and tensile properties.

shall be capable of attaining the properties specified in Table 3 [Table 4] for T42 temper material, upon being properly solution heat-treated and natural aged for not less than 4 days at room temperature.

11.2 As-received material in the O or F temper in alloys 2014, 2219, 6061, 6063, 7075, and 7178 (within the size limits specified in Table 3 [Table 4] and without the imposition of cold work) shall be capable of attaining the properties specified in Table 3 [Table 4] for T62 tempers, upon being properly solution and precipitation heat-treated.

11.3 Material in alloys and tempers 2014-T4, T4510, T4511, T6, T6510, and T6511 and 2024-T3, T3510, T3511, T81, T8510, and T8511 shall be capable of attaining the properties specified in Table 3 [Table 4] for the T42 temper, upon being properly resolution heat-treated and natural aged for not less than 4 days at room temperature.

11.4 Material in alloys and tempers 2219-T31, T3510, T3511, T81, T8510, and T8511, 7075-T6, T6510 and T6511 and 7178-T6, T6510 and T6511 shall be capable of attaining the properties specified in Table 3 [Table 4] for T62 tempers, upon being properly resolution heat-treated and precipitation heat-treated.

11.5 Material in T31, T3510, T3511, T4, T4510, and T4511 tempers shall be capable of attaining the properties specified in Table 3 [Table 4] for the T81, T8510, T8511, T6, T6510, and T6511 tempers, respectively, upon being properly precipitation heat-treated.

12. Stress-Corrosion Resistance

12.1 Alloy 7075 extruded tube in the T73-type tempers shall be capable of exhibiting no evidence of stress-corrosion cracking when subjected to the test specified in 12.2.

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TABLE 11 Hardness Screening Values for Seamless Pipe [SI Units][A]

Alloy and Temper	Pipe Size Designation	Wall Thickness, mm	Hardness Number, Minimum[B,C]		
			Webster	Barcol	Rockwell E
6061-T6	Less than 1	1.25 and over	16	...	...
	1 and over	1.25 through 1.50	15	76	89
		over 1.50 through 12.5	15	76	89
		over 12.5 through 25.0	15	76	...
6063-T6	All	over 1.25 through 25.0	12	72	75
6351-T5	All	over 1.25 through 25.0	15	76	89
-T6	All	over 1.25 through 25.0	16	...	...

[A] See 10.3.

[B] Alternative minimum hardness values and hardness testing devices may be used provided agreement is reached between the purchaser and supplier or producer.

[C] The hardness values shown do not guarantee material will pass the applicable mechanical property requirements but are for informational purposes only. It is the responsibility of the user of this specification to establish the relationship between the hardness values and tensile properties.

12.1.1 For lot-acceptance purposes, resistance to stress-corrosion cracking for each lot shall be established by testing the previously selected tension-test samples to the criteria shown in Table 12[Table 13].

12.1.2 For surveillance purposes, each month the producer shall perform at least one stress-corrosion test in accordance with 12.2 on each of the T73-type tempers for each thickness range 0.750 in. [20.00 mm] and over listed in Table 3 [Table 4] produced that month. Each sample shall be taken from material considered acceptable in accordance with lot-acceptance criteria of Table 8 [Table 9]. A minimum of three adjacent replicate specimens shall be taken from each sample and tested. The producer shall maintain records of all lots so tested and make them available for examination at the producer's facility.

12.2 The stress-corrosion cracking test shall be performed on extruded tube with wall thickness 0.750 in. [20.00 mm] and over as follows:

12.2.1 The stress-corrosion test shall be made in accordance with Test Method G 47.

12.2.2 Specimens shall be stressed in tension in the short transverse direction with respect to the grain flow and held at constant strain. The stress level shall be 75 % of the specified minimum yield strength.

12.2.3 There shall be no visual evidence of stress-corrosion cracking in any specimen, except that the retest provisions of 17.2 shall apply.

13. Cladding

13.1 The aluminum alloy coating of clad tube shall comprise the inside surface (only) of the tube and its thickness shall be approximately 10 % of the total wall thickness of the tube.

13.2 When the thickness of the coating is to be determined on finished tube, transverse cross sections of at least three tubes from the lot shall be polished for examination with a metallurgical microscope. Using a magnification of 100 ×, the coating thickness at four points, 90° apart, in each sample shall be measured and the average of all measurements shall be taken as the thickness. In the case of tube having a diameter larger than can properly be mounted for polishing and examination, the portions of the cross section polished for examination may consist of an arc about ½ in. [13 mm] in length.

14. Dimensional Tolerances

14.1 Variations from the specified dimensions for the type of material ordered shall not exceed the permissible variations prescribed in the following tables of ANSI H35.2 [H35.2M]:

TABLE 12 Lot Acceptance Criteria for Resistance to Stress Corrosion, Inch-Pound Units

Alloy and Temper	Lot Acceptance Criteria		Lot Acceptance Status
	Electrical Conductivity[A], % IACS	Level of Tensile Properties	
7075–T73, T73510, and T73511	40.0 or greater	per specified requirements	acceptable
	38.0 thru 39.9	per specified requirements and yield strength does not exceed minimum by more than 11.9 ksi	acceptable
	38.0 thru 39.9	per specified requirements but yield strength exceeds minimum by 12.0 ksi or more	unacceptable[B]
	less than 38.0	any level	unacceptable[B]

[A] Sampling for electrical conductivity tests shall be the same as for tensile tests as specified in 9.2. Test specimens may be prepared by machining a flat, smooth surface of sufficient width for proper testing. For small sizes of tubes, a cut-out portion may be flattened and the conductivity determined on the surface. Chemical milling may be used on flat surface samples. The electrical conductivity shall be determined in accordance with Test Method E 1004 in the following locations:

Wall Thickness, in.	Location
Up thru 0.100	surface of tensile sample
0.101 thru 0.500	subsurface after removal of approximately 10 % of thickness of tensile sample
0.501 thru 1.500	subsurface at approximately center of wall thickness on a plane parallel to the longitudinal center line of the material
Over 1.500	subsurface on tensile test sample surface which is closest to the center of the wall thickness and on a plane parallel to the extrusion surface

[B] When material is found to be unacceptable, it shall be reprocessed (additional precipitation heat treatment, or re-solution heat treatment, stress relieving, straightening and precipitation heat treatment, when applicable).

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TABLE 13 Lot Acceptance Criteria for Resistance to Stress Corrosion, [SI Units]

Alloy and Temper	Lot Acceptance Criteria		Lot Acceptance Status
	Electrical Conductivity[A], % IACS	Level of Mechanical Properties	
7075-T73, T73510, and T73511	40.0 or greater	per specified requirements	acceptable
	38.0 to 39.9	per specified requirements and yield strength does not exceed minimum by more than 82 MPa	acceptable
	38.0 to 39.9	per specified requirements but yield strength exceeds minimum by 83 MPa or more	unacceptable[B]
	less than 38.0	any level	unacceptable[B]

[A] Sampling for electrical conductivity tests shall be the same as for tensile tests as specified in 9.2. Test specimens may be prepared by machining a flat, smooth surface of sufficient width for proper testing. For small sizes of tubes, a cut-out portion may be flattened and the conductivity determined on the surface. Chemical milling may be used on flat surface samples. The electrical conductivity shall be determined in accordance with Test Method E 1004 in the following locations:

Wall Thickness, mm		Location
Over	Through	
...	2.50	surface of tensile sample
2.50	12.50	subsurface after removal of approximately 10 % of thickness of tensile sample
12.50	40.00	subsurface at approximately center of wall thickness on a plane parallel to the longitudinal center line of the material
40.00	...	subsurface on tensile test sample surface which is closest to the center of the wall thickness and on a plane parallel to the extrusion surface

[B] When material is found to be unacceptable, it shall be reprocessed (additional precipitation heat treatment or re-solution heat treatment, stress relieving, straightening, and precipitation heat treatment, when applicable).

Table No.	Title
12.	Extruded Tube
12.1	Diameter, Round Tube
12.3	Wall Thickness, Round Tube
12.5	Length
12.7	Straightness, Tube in Straight Lengths
12.9	Squareness of Cut Ends
16.	Pipe
16.1	Outside Diameter
16.2	Wall Thickness
16.3	Weight
16.4	Length, Plain End Pipe
16.7	Diameters, Wall Thicknesses, Weights

14.2 Tolerances for tempers and sizes not included in ANSI H35.2 [H35.2M] shall be as agreed upon between producer and purchaser and shall be so specified in the contract or purchase order.

14.3 *Sampling for Inspection*—Examination for dimensional conformance shall be made to ensure conformance to the tolerance specified.

15. General Quality

15.1 Unless otherwise specified, the material shall be supplied in the mill finish and shall be uniform as defined by the requirements of this specification and shall be commercially sound. Any requirement not so covered is subject to negotiation between producer and purchaser.

15.2 When so specified in the contract or order, both ends of each length of pipe, or extruded tube except pipe of alloy 3003, temper H112, shall be threaded using an American National Standard Taper Pipe Thread. The variation from standard, when tested with the standard working gage, shall not exceed ±1½ turns. The threaded ends shall be free from burrs and suitably protected against damage in transit.

15.3 Each pipe and tube shall be examined to determine conformance to this specification with respect to general quality and identification marking. On approval of the purchaser however, the producer may use a system of statistical quality control for such examinations.

16. Internal Quality

16.1 When specified by the purchaser at the time of placing the contract or order, each tube 0.500 in. or greater [over 12.50 mm] in thickness, in alloys 2024, 7075, and 7178 shall be tested ultrasonically in accordance with Practice B 594 to the discontinuity acceptance limits of Table 6 [Table 7].

17. Source Inspection

17.1 If the purchaser desires that his representative inspect or witness the inspection and testing of the material prior to shipment, such agreement shall be made by the purchaser and producer as part of the purchase contract.

17.2 When such inspections or witness of inspection and testing is agreed upon, the producer shall afford the purchaser's representative all reasonable facilities to satisfy him that the material meets the requirements of this specification. Inspection and tests shall be conducted so there is no unnecessary interference with the producer's operations.

18. Retest and Rejection

18.1 If any material fails to conform to all of the applicable requirements of this specification, the inspection lot shall be rejected.

18.2 When there is evidence that a failed specimen was not representative of the inspection lot and when no other sampling plan is provided or approved by the purchaser through the contract or purchase order, at least two additional specimens shall be selected to replace each test specimen that failed. All specimens so selected for retest shall meet the requirements of the specification or the lot shall be subject to rejection.

18.3 Material in which defects are discovered subsequent to inspection may be rejected.

18.4 If material is rejected by the purchaser, the producer or supplier is responsible only for replacement of material to the purchaser. As much as possible of the rejected material shall be returned to the producer or supplier.

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19. Identification Marking of Product

19.1 When specified on the purchase order or contract all pipe and tube shall be marked in accordance with Practice B 666/B 666M.

19.2 In addition, alloys 2014, 2024, 2219, 7075, and 7178 in the T6-, T73-, and T8-type tempers and, when specified, alloys 2014 and 2024 in the T3- and T4-type tempers and alloy 6061 in the T4- and T6-type tempers shall also be marked with the lot number in at least one location on each piece.

19.3 The requirements specified in 19.1 and 19.2 are minimum marking systems that involve added information; larger characters and greater frequencies are acceptable under this specification.

20. Packaging and Package Marking

20.1 The material shall be packaged to provide adequate protection during normal handling and transportation and each package shall contain only one size, alloy, and temper of material unless otherwise agreed upon. The type of packaging and gross weight of containers shall, unless otherwise agreed upon, be at the producer's discretion, provided that they are such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

20.2 Each shipping container shall be marked with the purchase order number, material size, specification number, alloy and temper, gross and net weights, and the producer's name or trademark.

20.3 When specified in the contract or purchase order, material shall be preserved, packaged, and packed in accordance with the requirements of Practices B 660. The applicable levels shall be as specified in the contract or order. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civilian agencies and MIL-STD-129 for military agencies.

21. Certification

21.1 The supplier or producer shall, on request, furnish to the purchaser a certificate stating that the material has been sampled, tested, and inspected in accordance with this specification, and has met the requirements.

22. Keywords

22.1 aluminum alloy; seamless extruded tube; seamless pipe

ANNEXES

(Mandatory Information)

A1. BASIS FOR INCLUSION OF PROPERTY LIMITS

A1.1 Limits are established at a level at which a statistical evaluation of the data indicates that 99 % of the population obtained from all standard material meets the limit with 95 % confidence. For the products described, mechanical property limits for the respective size ranges are based on the analyses of at least 100 data from standard production material with no more than ten data from a given lot. All tests are performed in accordance with the appropriate ASTM test methods. For informational purposes, refer to "Statistical Aspects of Mechanical Property Assurance" in the Related Material section of the *Annual Book of ASTM Standards*, Vol 02.02. Mechanical property limits in this metric issue were derived from the inch-pound system limits that were developed under the above principles. As test data on metric dimensioned specimens are accumulated, some refinement of limits, particularly for elongations measured in 5D, can be anticipated.

A2. ACCEPTANCE CRITERIA FOR INCLUSION OF NEW ALUMINUM AND ALUMINUM ALLOYS IN THIS SPECIFICATION

A2.1 Prior to acceptance for inclusion in this specification, the composition of wrought or cast aluminum or aluminum alloy shall be registered in accordance with ANSI H35.1 or H35.1(M). The Aluminum Association[12] holds the Secretariat of ANSI H35 Committee and administers the criteria and procedures for registration.

A2.2 If it is documented that the Aluminum Association could not or would not register a given composition, an alternative procedure and the criteria for acceptance shall be as follows:

A2.2.1 The designation submitted for inclusion does not utilize the same designation system as described in ANSI H35.1 or H35.1(M). A designation not in conflict with other designation systems or a trade name is acceptable.

A2.2.2 The aluminum or aluminum alloy has been offered for sale in commercial quantities within the prior twelve months to at least three identifiable users.

A2.2.3 The complete chemical composition limits are submitted.

A2.2.4 The composition is, in the judgment of the responsible subcommittee, significantly different from that of any other aluminum or aluminum alloy already in the specification.

A2.2.5 For codification purposes, an alloying element is any element intentionally added for any purpose other than grain refinement and for which minimum and maximum limits are specified. Unalloyed aluminum contains a minimum of 99.00 % aluminum.

[12] The Aluminum Association, 900 19th Street, NW, Washington, DC 20006.

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A2.2.6 Standard limits for alloying elements and impurities are expressed to the following decimal places:

Less than 0.001 %	0.000X
0.001 to but less than 0.01 %	0.00X
0.01 to but less than 0.10 %	
Unalloyed aluminum made by a refining process	0.0XX
Alloys and unalloyed aluminum not made by a refining process	0.0X
0.10 through 0.55 %	0.XX
(It is customary to express limits of 0.30 through 0.55 % as 0.X0 or 0.X5.)	
Over 0.55 %	0.X, X.X, etc.
(except that combined Si + Fe limits for 99.00 % minimum aluminum must be expressed as 0.XX or 1.XX)	

A2.2.7 Standard limits for alloying elements and impurities are expressed in the following sequence: Silicon; Iron; Copper; Manganese; Magnesium; Chromium; Nickel; Zinc (Note A2.1); Titanium; Other Elements, Each; Other Elements, Total; Aluminum (Note A2.2).

NOTE A2.1—Additional specified elements having limits are inserted in alphabetical order of their chemical symbols between zinc and titanium, or are specified in footnotes.

NOTE A2.2—Aluminum is specified as *minimum* for unalloyed aluminum and as a *remainder* for aluminum alloys.

A3. PART OR IDENTIFYING NUMBERS (PINs) FOR USE BY THE DEPARTMENT OF DEFENSE

A3.1 Part numbers are essential to maintain the integrity of the Department of Defense cataloging system as multiple National Stock Numbers (NSN) exist for this product.

A3.2 Part numbers shall be formulated by selecting from the options in this specification as follows:

B241	–XXXX	-XXXX	-XX	-XX	-XX
Document Identifier	Alloy	Temper	Pipe size in 0.25 in. increments	Schedule size	Length in feet

A3.3 *Examples of Part Numbers*:

B429–6063–T6–03–40–20 indicates an ASTM B429 standard structural pipe in 6063 alloy and T6 temper that is ¾-in. pipe size, ANSI schedule 40, with a 20–ft length.

B429–3003–H112–04–10–10 indicates an ASTM B429 standard structural pipe in 3003 alloy and H112 temper that is 1-in. pipe size, ANSI schedule 10, with a 10–ft length.

SUMMARY OF CHANGES

This section identifies the principal changes to this standard that have been incorporated since the last issue.

(*1*) Deleted references to Test Method E 101.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

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Designation: B 247M – 00
METRIC

Standard Specification for Aluminum and Aluminum-Alloy Die Forgings, Hand Forgings, and Rolled Ring Forgings [Metric][1]

This standard is issued under the fixed designation B 247M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification covers aluminum-alloy (Note 1) die forgings, hand forgings, and rolled ring forgings as shown in Tables 1-3 and in Section 10 for heat-treatable alloy forgings supplied in the F and 01 tempers. The maximum thicknesses for forgings within the scope of this specification are as indicated in those tables.

NOTE 1—Throughout this specification use of the term *alloy* in the general sense includes aluminum as well as aluminum alloy.

NOTE 2—For forging stock supplied as rolled or cold-finished bar or rod see Specification B 211M. For forging stock supplied as extruded bar or rod see Specification B 221M.

1.2 Alloy and temper designations are in accordance with ANSI H35.1M. The equivalent Unified Numbering System alloy designations are those of Table 4 preceded by A9, for example, A91100 for aluminum 1100 in accordance with Practice E 527.

1.3 For acceptance criteria for inclusion of new aluminum and aluminum alloys in this specification, see Annex A2.

1.4 This specification is the metric counterpart of Specification B 247.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein.

2.2 *ASTM Standards:*

B 247 Specification for Aluminum and Aluminum-Alloy Die Forgings, Hand-Forgings, and Rolled Ring Forgings[2]

B 557M Test Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products [Metric][2]

B 594 Practice for Ultrasonic Inspection of Aluminum-Alloy Wrought Products for Aerospace Applications[2]

B 597 Practice for Heat Treatment of Aluminum Alloys[2]

B 660 Practices for Packaging/Packing of Aluminum and Magnesium Products[2]

E 10 Test Method for Brinell Hardness of Metallic Materials[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum Base Alloys[5]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[5]

E 165 Practice for Liquid Penetrant Examination[6]

E 227 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[5]

E 527 Practice for Numbering Metals and Alloys (UNS)[7]

E 607 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique, Nitrogen Atmosphere[8]

E 716 Practices for Sampling Aluminum and Aluminum Alloys for Spectrochemical Analysis[8]

E 1004 Test Method for Electromagnetic (Eddy Current) Measurements of Electrical Conductivity[7]

E 1251 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Argon Atmosphere, Point-to-Plane, Unipolar Self-Initiating Capacitor Discharge[8]

G 47 Test Method for Determining Susceptibility to Stress-Corrosion Cracking of High-Strength Aluminum Alloy Products[9]

2.3 *ANSI Standard:*

H35.1(M) Alloy and Temper Designation Systems for Aluminum[3]

2.4 *ISO Standards:*

[1] This specification is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.03 on Aluminum Alloy Wrought Products.

Current edition approved May 10, 2000. Published August 2000. Originally published as B 247M–80. Last previous edition B 247M–95a.

[2] *Annual Book of ASTM Standards*, Vol 02.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 03.05.

[6] *Annual Book of ASTM Standards*, Vol 03.03.

[7] *Annual Book of ASTM Standards*, Vol 01.01.

[8] *Annual Book of ASTM Standards*, Vol 03.06.

[9] *Annual Book of ASTM Standards*, Vol 03.02.

***A Summary of Changes section appears at the end of this standard.**

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ISO 209-1:1989 Wrought Aluminum and Aluminum Alloys—Chemical Composition and Form of Product[10]

ISO 2107:1983 Aluminum, Magnesium and their Alloys—Temper Designations[10]

2.5 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[11] (referenced in MIL-STD-649 and applies only to direct shipments to Department of Defense agencies)

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification (Eddy Current, Liquid Penetrant, Magnetic Particle, Radiographic and Ultrasonic)[11]

2.6 *Military Specification:*

MIL-H-6088 Heat Treatment of Aluminum Alloys[11]

2.7 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[11]

3. Terminology

3.1 *Definitions:*

3.1.1 *forging*—a metal part worked to a predetermined shape by one or more such processes as hammering, upsetting, pressing, rolling, etc.

3.1.2 *die forging*—a forging formed to the required shape and size by working in impression dies.

3.1.3 *blocker-type forging*—a die forging made in a single set of die impressions to the general contour of a finished part.

3.1.4 *hand forging*—a forging worked between flat or simply shaped dies by repeated strokes or blows and manipulation of the piece.

3.1.5 *rolled ring forging*—a cylindrical product of relatively short height, circumferentially rolled from a hollow section.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *capable of*—The term *capable of* as used in this specification means that the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet the requirements, the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material to this specification shall include the following information:

4.1.1 This specification designation (which includes the number, the year, and the revision letter, if applicable),

4.1.2 Quantity in pieces or kilograms,

4.1.3 Alloy (Section 7),

4.1.4 Temper (Section 8),

4.1.5 Dimensions (Section 13). A drawing is required for die forgings and for hand forgings whose shapes are not simple rectangles,

4.2 Additionally, orders for material to this specification shall include the following information when required by the purchaser:

4.2.1 For die forgings, whether tensile property and grain flow survey shall be made (see 8.2.1.1),

4.2.2 For die forgings, whether tension tests are required using specimens not parallel to the direction of grain flow and whether such test specimens shall be prepared by a specific method (see 8.3.1),

4.2.3 For hand forgings, whether tension tests shall be made in other than the long transverse and short transverse directions (see 8.3.3),

4.2.4 For rolled ring forgings, whether tension tests shall be made in the radial direction (see 8.3.4),

4.2.5 Whether it is required in tension tests that small elongations shall be measured by a special procedure (see 8.4.2),

4.2.6 Whether heat treatment in accordance with Practice B 597 is required (9.2),

4.2.7 Whether 7075-F material shall meet the requirements for T73 temper (10.3),

4.2.8 Whether ultrasonic inspection is required (Section 14 and Table 5),

4.2.9 Whether liquid-penetrant inspection is required (see 15.3),

4.2.10 Whether inspection or witness of inspection and tests by the purchaser's representative is required prior to material shipment (Section 16),

4.2.11 Whether certification is required (Section 18),

4.2.12 Whether hand forgings shall be marked for identification (Section 19), and

4.2.13 Whether Practices B 660 applies and, if so, the levels of preservation, packaging, and packing required (Section 20).

5. Materials and Manufacture

5.1 The forgings may be manufactured by pressing, hammering, or rolling, at the option of the producer.

6. Responsibility for Quality Assurance

6.1 *Responsibility for Inspection and Tests*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser in the order or at the time of contract signing. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

6.2 *Lot Definition*—An inspection lot shall be defined as follows:

6.2.1 For heat-treated tempers, an inspection lot shall consist of forgings of the same shape or group of forgings of similar size and shape of the same alloy and heat-treated in the same furnace charge. If forgings are heat-treated in a continuous furnace, forgings charged consecutively during continuous operation of the furnace shall be considered a furnace charge; for such forgings weighing 2.5 kg or less the maximum mass of a lot shall be 1000 kg; and for heavier forgings it shall be 3000 kg.

6.2.2 For nonheat-treated tempers, an inspection lot shall consist of an identifiable quantity of forgings of *similiar size*

[10] Available from American National Standards Institute, 11 W. 42nd Street, 13th Fl., New York, NY 10036.

[11] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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and shape of the same alloy and temper subjected to inspection at one time.

7. Chemical Composition

7.1 *Limits*—The forgings shall conform to the chemical composition limits specified in Table 4. Conformance shall be determined by the producer by analyzing samples taken when the ingots are poured, or samples taken from the finished or semifinished product. If the producer has determined the chemical composition during the course of manufacture, he shall not be required to sample and analyze the finished product.

NOTE 3—It is standard practice in the United States aluminum industry to determine conformance to the chemical composition limits prior to further processing of ingots into wrought products. Due to the continuous nature of the process, it is not practical to keep a specific ingot analysis identified with a specific quantity of finished material.

7.2 *Number of Samples*—The number of samples taken for determination of chemical composition shall be as follows:

7.2.1 When samples are taken at the time the ingots are poured, at least one sample shall be taken for each group of ingots poured simultaneously from the same source of molten metal.

7.2.2 When samples are taken from forgings in sizes having a nominal mass of 2.5 kg or less, a sample shall be taken to represent each 1000 kg or fraction thereof of material in the lot.

7.2.3 When samples are taken from forgings in sizes having a nominal mass of more than 2.5 kg, a sample shall be taken to represent each 3000 kg or fraction thereof of material in the lot.

7.3 *Methods of Sampling*—Samples for determination of chemical composition shall be taken in accordance with one of the following methods:

7.3.1 Samples for chemical analysis shall be taken from the material by drilling, sawing, milling, turning, or clipping a representative piece or pieces to obtain a prepared sample not less than 75 g. Sampling shall be in accordance with Practice E 55.

7.3.2 Sampling for spectrochemical analysis shall be in accordance with Practice E 716. Samples for other methods of analysis shall be taken by methods suitable for the form of material being analyzed and the type of analytical method used.

7.4 *Methods of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (Test Methods E 34) or spectrochemical (Test Methods E 227, E 607, and E 1251) methods. Other methods may be used only when no published ASTM test method is available. In case of dispute the methods of analysis shall be agreed upon between the producer and purchaser.

8. Mechanical Properties of Material as Supplied

8.1 *Limits*:

8.1.1 Die forgings shall conform to the tensile requirements in Table 1.

8.1.1.1 Die forgings shall be capable of conforming to the Brinell hardness requirements in Table 1 when measured at or near the surface, except that in case of question the basis for acceptance shall be conformance with the specified minimum tensile requirements of Table 1.

8.1.2 Hand forgings shall conform to the tensile requirements in Table 2.

8.1.3 Rolled ring forgings shall conform to the tensile property requirements in Table 3.

8.2 *Number of Specimens*:

8.2.1 For die forgings, hand forgings, and rolled ring forgings, there shall be at least one tension specimen taken from each lot (see 6.2).

8.2.1.1 For die forgings, when specified, a grain-flow pattern and tensile-property survey shall be made on a forging representative of the first production parts (see 8.3.2). It shall be repeated after any major change in forging technique.

8.3 *Test Specimen*:

8.3.1 For die forgings, unless otherwise specified by the purchaser at the time of placing the order, test specimens shall be prepared with the axis of the specimen as nearly parallel to the direction of maximum metal flow as possible, and, at the option of the forging producer, by one of the following methods:

8.3.1.1 *Method 1*—Machined from a section of the stock used in making the forgings.

8.3.1.2 *Method 2*—Machined from a coupon forged from the stock.

8.3.1.3 *Method 3*—Machined from a prolongation of the forging.

8.3.1.4 *Method 4*—Machined from one of the forgings in the lot.

NOTE 4—Test specimens obtained by Method 1, 2, or 3 will usually have different properties from those obtained by Method 4. Samples obtained by Methods 1, 2, or 3 indicate only the general strength level of the forging that would be obtained with proper heat treatment.

8.3.1.5 Specimens representing heat-treated forgings shall be heat-treated with the forgings they represent or shall be machined from coupons that have been so treated.

8.3.2 If required, a die forging representative of the first production parts shall be selected after forging techniques have been established, and shall be tested as follows:

8.3.2.1 Tension test specimens shall be taken in two directions: (*1*) substantially parallel to, and (*2*) not parallel to the forging flow lines. The locations shall be as indicated on the forging engineering drawing or, if not indicated, from generally representative areas.

8.3.2.2 A sample forging shall be sectioned at the locations of the specimens, to show the grain flow.

8.3.3 For hand forgings, the specimens shall be taken from a prolongation of the forgings or from a forging chosen to represent the lot. Tests will regularly be made only in the long transverse and short transverse directions, but when required by the purchaser tests shall also be made in the longitudinal direction.

8.3.4 For rolled ring forgings, the specimens shall be taken from a prolongation of the forging or from a forging chosen to represent the lot. Unless otherwise specified, rolled ring forging sections shall be taken from an area representative of the center of mass where size permits. Tests will regularly be made only in the tangential and axial directions, but when required by the purchaser tests shall also be made in the radial direction for informational purposes.

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8.4 *Test Methods*:

8.4.1 The tension tests shall be made in accordance with Test Methods B 557M.

8.4.2 If required when the specified elongation is less than 3 % and the elongation measured in the usual manner is less than 4 %, the elongation of round tension specimens shall be measured in accordance with 7.6.4 of Test Methods B 557M.

8.4.3 Brinell hardness tests shall be made in accordance with Test Method E 10, by applying a 500-kgf load on a 10-mm ball for 10 to 15 s. Other equivalent combinations of load and ball or alternative methods of testing may be used if desired provided that, in case of dispute, the results secured with the 500-kgf load and 10-mm ball shall be the basis of acceptance.

9. Heat Treatment

9.1 Unless otherwise specified, heat treatment for the applicable tempers designated in Tables 1-3 shall be in accordance with MIL-H-6088.

9.2 When specified, heat treatment for the applicable tempers in Tables 1-3 shall be in accordance with Practice B 597.

10. Producer Confirmation of Heat-Treat Response

10.1 In addition to the requirements of Section 8, die forgings in alloys 2014, 2018, 2025, 2218, 2219, 2618, 4032, 6061, 6066, 6151, 7075, and 7076 produced in the F and 01 tempers (within the size limits specified in Table 1) shall, after proper solution heat treatment and precipitation heat treatment, conform to the tensile properties specified in Table 1 for T6 temper forgings except for 2018, 2218, 2618, and 7076 for which T61 temper requirements apply.

10.2 In addition to the requirements of Section 8, hand forgings in alloys 2014, 2219, 2618, 6061, and 7075 produced in the F and 01 tempers (within the size limits specified in Table 2) shall, after proper solution heat treatment and precipitation heat treatment, conform to the tensile properties specified in Table 2 for T6 temper forgings except for 2618 for which T61 temper requirements apply.

10.3 Alloys 7049, 7050, and 7175 die and hand forgings in the F and O tempers and, when specified, 7075 die and hand forgings in the F and 01 tempers (within the size limits specified in Table 1 and Table 2, respectively) shall, after proper solution heat treatment and precipitation heat treatment, conform to the tensile properties specified in Table 1 and Table 2, as applicable for T73 type temper, and Section 12.

10.4 In addition to the requirements of Section 8, rolled ring forgings in alloys 2014, 2219, 2618, 6061, 6151, and 7075 produced in F and 01 tempers (within the size limits specified in Table 3) shall, after proper heat treatment, conform to the tensile properties specified in Table 3 for T6 temper forgings except for 2618 for which T61 temper requirements apply.

10.5 *Number of Specimens*—One specimen from each lot of F and 01 temper die forgings, hand forgings, and rolled ring forgings shall be tested to verify conformance with 10.1-10.4 as applicable.

11. Heat-Treatment and Reheat-Treatment Capability

11.1 As-received die and hand forgings in the F and 01 temper in alloys 2014, 2018, 2025, 2218, 2219, 2618, 4032, 6061, 6066, 6151, 7075, and 7076 (within the size limitations specified in Table 1 and Table 2) shall, after proper solution heat treatment and precipitation heat treatment, be capable of conforming to the tensile properties specified in Table 1 and Table 2 for the T6 temper except for 2018, 2218, 2618, and 7076 for which T61 temper requirements apply.

11.2 Alloy 7075 die and hand forgings in T6, T652, T73, and T7352 tempers shall, after proper resolution heat treatment and precipitation heat treatment, be capable of conforming to the tensile properties specified in Table 1 and Table 2 for the T6 temper.

11.3 Die forgings in alloy 2014-T4 shall, after proper precipitation heat treatment, be capable of conforming to the tensile properties specified in Table 1 for the T6 temper.

11.4 As-received rolled ring forgings in the F and 01 tempers in alloys 2014, 2219, 2618, 6061, 6151, and 7075 (within the size ranges specified in Table 3) shall, after proper solution heat treatment and precipitation heat treatment, be capable of conforming to the tensile properties specified in Table 3 for the T6 temper except for 2618 for which T61 temper requirements apply.

12. Stress-Corrosion Resistance

12.1 Alloys 7049 and 7075 in the T73-type tempers and 7050 and 7175 in the T74-type tempers shall be capable of exhibiting no evidence of stress-corrosion cracking when subjected to the test specified in 12.2.

12.1.1 For lot acceptance purposes, resistance to stress-corrosion cracking of each lot of alloys 7049, 7050, 7075, and 7175 in the applicable tempers shall be established by testing the previously selected tension-test samples to the criteria shown in Table 6.

12.1.2 For surveillance purposes, each month the producer shall perform at least one test for stress-corrosion resistance in accordance with 12.2 on each of the applicable alloy-tempers for each thickness range 20.00 mm and over produced that month. Each sample shall be taken from material considered acceptable in accordance with the lot acceptance criteria of Table 6. A minimum of three adjacent replicate specimens shall be taken from each sample and tested. The producer shall maintain records of all lots so tested and make them available for examination at the producer's facility.

12.2 The stress-corrosion cracking test shall be performed on material 20.00 mm and over in thickness as follows:

12.2.1 Specimens shall be stressed in tension in the short transverse direction with respect to grain flow and held at constant strain. The stress level shall be as follows:

12.2.1.1 For T73-type tempers: 75 % of the minimum yield strength or the minimum longitudinal yield strength specified in Table 1 or Table 2 as applicable.

12.2.1.2 T74-type tempers: 240 MPa for die and hand forgings up through 75.00 mm and 50 % of the minimum longitudinal yield strength specified in Table 2 for hand forgings over 75.00 mm.

12.2.2 The test corrosion test shall be made in accordance with Test Method G 47.

12.2.3 There shall be no visual evidence of stress-corrosion cracking in any specimen, except that the retest provision of 17.2 shall apply.

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13. Dimensional Tolerances

13.1 The forgings shall conform to the shape and dimensions specified in the contract or order within such dimensional tolerances as may be specified in the contract, order, or referenced drawings.

14. Internal Quality

14.1 When specified by the purchaser at the time of placing the order, each die forging not more than 150 kg, in thicknesses over 12.50 mm through 100.00 mm, in alloys 2014, 2219, 7049, 7050, 7075, and 7175, and each hand forging not more than 300 kg, in thicknesses over 25.00 mm through 200.00 mm in alloys 2014, 2219, 7049, 7050, 7075, and 7175, shall be tested ultrasonically in accordance with Practice B 594 to the discontinuity acceptance limits of Table 5. For rolled ring forgings, ultrasonic testing requirements and the applicable discontinuity acceptance limits in accordance with Practice B 594 shall be the subject of agreement between the purchaser and the producer.

15. General Quality

15.1 The forgings shall be of uniform quality and condition as defined by the requirements of this specification and shall be commercially sound. Any requirement not so covered shall be the subject of agreement between the purchaser and producer.

15.2 *Visual Inspection*—Prior to visual inspection each die forging or rolled ring forging shall be etched in an aqueous solution of sodium hydroxide to provide a surface suitable for visual or penetrant inspection. At the option of the producer, an inhibitor may be used in the sodium hydroxide.

NOTE 5—An inhibitor in the sodium hydroxide solution is desirable to prevent intergranular attack of copper-bearing alloys. A suitable solution consists of 50 g of sodium hydroxide and 2.5 g of sodium sulfide dissolved in 1 L of water. Etching time for this solution when maintained at 66 to 71°C should be 1 min. Other inhibited solutions may be used to provide the same etching effect. Subsequently, the parts shall be thoroughly rinsed in water followed by a wash in nitric acid or a chromic-sulfuric acid solution or any other equivalent solution to produce a surface suitable for visual or penetrant inspection.

15.3 Unless otherwise specified, each forging shall be inspected visually for surface defects such as seams, laps, bursts, and quench cracks.

15.3.1 When specified, each etched forging shall be penetrant inspected in accordance with Practice E 165, using post-emulsifiable penetrants or water-washable penetrants, for injurious surface defects. Penetrant inspection personnel shall be certified to NDT Level II in accordance with MIL-STD-410.

NOTE 6—All parts or areas of parts to be inspected must be clean and dry before the penetrant is applied.

16. Source Inspection

16.1 If the purchaser desires that his representative inspect or witness the inspection and testing of the forgings prior to shipment, such agreement shall be made by the purchaser and producer as part of the purchase contract.

16.2 When such inspection or witness of inspection and testing is agreed upon the producer shall afford the purchaser's representative all reasonable facilities to satisfy him that the forgings meet the requirements of this specification. Inspection and tests shall be conducted so there is no unnecessary interference with the producer's operations.

17. Retest and Rejection

17.1 If any material fails to conform to all of the applicable requirements of this specification, it shall be cause for rejection of the inspection lot.

17.2 When there is evidence that a failed specimen was not representative of the inspection lot and when no other sampling plan is provided or approved by the purchaser through the contract or purchase order, at least two additional specimens shall be selected to replace each test specimen that failed. All specimens so selected for retest shall meet the requirements of the specification or the lot shall be subject to rejection.

17.3 Material in which defects are discovered subsequent to inspection may be rejected.

17.4 If material is rejected by the purchaser, the producer or supplier is responsible only for replacement of the material to the purchaser. As much as possible of the rejected material shall be returned to the producer or supplier.

18. Certification

18.1 The producer shall, on request, furnish to the purchaser a certificate stating that each lot of forgings has been sampled, tested, and inspected in accordance with this specification and has met the requirements.

19. Identification Marking of Product

19.1 Each die forging shall be identification marked in accordance with the requirements of the forging drawing.

19.2 When specified, hand forgings shall be identification marked with the producer's name or trademark, the applicable alloy and temper designations, and the specification number. Identification characters shall have a minimum height of 6mm. The marking material shall be such as to resist obliteration during normal handling.

20. Packaging and Package Marking

20.1 The forgings shall be packaged to provide adequate protection during normal handling and transportation and each package shall contain only one size, alloy, and temper of material unless otherwise agreed upon. The type of packaging and gross mass of containers shall, unless otherwise agreed upon, be at the producer's discretion, provided they are such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

20.2 Each shipping container shall be marked with the purchase order number, forging size, specification number, alloy and temper, gross and net masses, and the producer's name or trademark.

20.3 When specified in the contract or purchase order, material shall be preserved, packaged, and packed in accordance with the requirements of Practices B 660. The applicable levels shall be as specified in the contract or order. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

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21. Keywords

21.1 aluminum alloy; die forgings; hand forgings; rolled ring forgings

TABLE 1 Mechanical Property Limits for Die Forgings[A,B]

Alloy and Temper	Specified Thickness, mm		Specimen Axis Parallel to Direction of Grain Flow[C]					Specimen Axis Not Parallel to Direction of Grain Flow[C]				Brinell Hardness[D], min
					Elongation, min,%					Elongation, min, %		
					Forgings		Separate Test Coupon (from stock or forged)[F]			Forgings		
	Over	Through	Tensile Strength[E], MPa	Yield Strength[E] (0.2 % Offset), min, MPa	in 50 mm	in 5× Diameter ($5.65\sqrt{A}$)[G]	in 5× Diameter ($5.65\sqrt{A}$)[G]	Tensile Strength[E], min, MPa	Yield Strength[E] (0.2 % Offset), min, MPa	in 50 mm	in 5× Diameter ($5.65\sqrt{A}$)[G]	
1100-H112	...	100.00	75	30	18	16	22	...	...	...	...	20
2014-T4	...	100.00	380	205	11	9	14	...	...	...	...	100
2014-T6	...	25.00	450	385	6	5	7	440	380	3	2	125
	25.00	50.00	450	385	6	5	...	440	380	2	1	125
	50.00	80.00	450	380	6	5	...	435	370	2	1	125
	80.00	100.00	435	380	6	5	...	435	370	2	1	125
2018-T61	...	100.00	380	275	7	6	9	...	...	...	...	100
2025-T6	...	100.00	360	230	11	9	14	...	...	...	...	100
2218-T61	...	100.00	380	275	7	6	9	...	...	...	...	100
2219-T6	...	100.00	400	260	8	7	9	385	250	4	3	100
2618-T61	...	100.00	400	310	4	3	5	380	290	4	3	115
3003-H112	...	100.00	95	35	18	16	22	...	...	...	...	25
4032-T6	...	100.00	360	290	3	2	4	...	...	...	...	115
5083-O	...	80.00	270	110	16	14	14	270	110	12	10	...
5083-H111	...	100.00	290	150	14	12	12	270	140	12	10	...
5083-H112	...	100.00	275	125	16	14	14	270	110	14	12	...
6061-T6	...	100.00	260	240	7	6	9	260	240	5	4	80
6066-T6	...	100.00	345	310	8	7	10	...	...	...	...	100
6151-T6	...	100.00	305	255	10	9	12	305	255	6	5	90
7049-T73	...	25.00	495	425	7	6	9	490	420	3	2	135
	25.00	50.00	495	425	7	6	9	485	415	3	2	135
	50.00	80.00	490	420	7	6	9	485	415	3	2	135
	80.00	100.00	490	420	7	6	9	485	415	2	1	135
	100.00	130.00	485	415	7	6	9	470	400	2	1	135
7050-T74[H]	...	50.00	495	425	7	6	9	470	385	5	4	135
	50.00	100.00	490	420	7	6	9	460	380	4	3	135
	100.00	130.00	485	415	7	6	9	455	370	3	2	135
	110.00	150.00	485	405	7	6	9	455	370	3	2	135
7075-T6	...	25.00	515	440	7	6	9	490	420	3	2	135
	25.00	50.00	510	435	7	6	...	490	420	3	2	135
	50.00	80.00	510	435	7	6	...	485	415	3	2	135
	80.00	100.00	505	435	7	6	...	485	415	2	1	135
7075-T73	...	80.00	455	385	7	6	...	425	365	3	2	125
	80.00	100.00	440	380	7	6	...	420	360	2	1	125
7075-T7352	...	80.00	455	385	7	6	...	425	350	3	2	125
	80.00	100.00	440	365	7	6	...	420	340	2	1	125
7076-T61	...	100.00	485	415	10	9	10	460	400	3	2	140
7175-T74[H]	...	80.00	525	455	7	6	9	490	425	4	3	...
7175-T7452[H]	...	80.00	505	435	7	6	9	470	380	4	3	...
7175-T7454[H]	...	80.00	515	450	7	6	9	485	420	4	3	...

[A] To determine conformance to this specification, each value for tensile strength and yield strength shall be rounded to the nearest 1 MPa and each value for elongation to the nearest 0.5 % (or the nearest 0.1 % if measured in accordance with 7.6.4 of Test Methods B 557M), in accordance with the rounding-off method of Practice E 29.

[B] For the basis for establishment of strength property limits, see Annex A1.

[C] These values apply to standard specimens. For the heat-treatable alloys the thicknesses shown are the maximum thickness at time of heat treatment for which the indicated properties apply. Forgings machined prior to heat treatment shall develop the properties applicable to the heat-treated thickness provided the as-forged thickness is not more than twice the heat-treated thickness.

[D] For information only. The hardness is usually measured on the surface of a forging using a 500-kgf load and 10-mm ball.

[E] Tensile property test requirements in any direction are limited to a minimum material dimension of 50 mm because of the difficulty in obtaining a tension test specimen suitable for routine control testing.

[F] These values apply to standard 12.5-mm diameter test specimens machined from the stock used in making the forgings, or from separately forged coupons representative of the forgings.

[G] A represents cross-sectional area of the specimen.

[H] Beginning with the 1985 issue the T736, T73652, and T73654 tempers were replaced by the T74, T7452, and T7454 tempers respectively as applicable to alloys 7050 and 7175.

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TABLE 2 Mechanical Property Limits for Hand Forging[A,B]

Alloy and Temper	Thickness[C], mm		Direction	Tensile Strength, min, MPa	Yield Strength (0.2% Offset), min, MPa	Elongation in 5× Diameter ($5.65\sqrt{A}$)[D]
	Over	Through				
2014-T6	...	50.00	longitudinal	450	385	7
			long transverse	450	385	2
	50.00	80.00	longitudinal	440	385	7
			long transverse	440	380	2
			short transverse	425	380	1
	80.00	100.00	longitudinal	435	380	7
			long transverse	435	380	2
			short transverse	420	370	1
	100.00	130.00	longitudinal	425	370	6
			long transverse	425	370	1
			short transverse	415	365	...
	130.00	150.00	longitudinal	420	365	6
			long transverse	420	365	1
			short transverse	405	365	...
	150.00	180.00	longitudinal	415	360	5
			long transverse	415	360	1
			short transverse	400	360	...
	180.00	200.00	longitudinal	405	350	5
			long transverse	405	350	1
			short transverse	395	350	...
2014-T652	...	50.00	longitudinal	450	385	7
			long transverse	450	385	2
	50.00	80.00	longitudinal	440	385	7
			long transverse	440	380	2
			short transverse	425	360	1
	80.00	100.00	longitudinal	435	380	7
			long transverse	435	380	2
			short transverse	420	350	1
	100.00	130.00	longitudinal	425	370	6
			long transverse	425	370	1
			short transverse	415	345	...
	130.00	150.00	longitudinal	420	365	6
			long transverse	420	365	1
			short transverse	405	345	...
	150.00	180.00	longitudinal	415	360	5
			long transverse	415	360	1
			short transverse	400	340	...
	180.00	200.00	longitudinal	405	350	5
			long transverse	405	350	1
			short transverse	395	330	...
2219-T6	...	100.00	longitudinal	400	275	5
			long transverse	380	255	3
			short transverse[E]	365	240	1
2219-T852	...	100.00	longitudinal	425	345	5
			long transverse	425	340	3
			short transverse[E]	415	315	2
2618-T61	...	50.00	longitudinal	400	325	6
			long transverse	380	290	4
			short transverse[E]	360	290	3
	50.00	80.00	longitudinal	395	315	6
			long transverse	380	290	4
			short transverse	360	290	3
	80.00	100.00	longitudinal	385	310	6
			long transverse	365	275	4
			short transverse	350	270	3
5083-O	...	80.00	longitudinal	270	110	14
			long transverse	270	110	12
5083-H111	...	100.00	longitudinal	290	150	12
			long transverse	270	140	10
5083-H112	...	100.00	longitudinal	275	125	14
			long transverse	270	110	12
6061-T6 or T652	...	100.00	longitudinal	260	240	9
			long transverse	260	240	7
			short transverse[E]	255	230	4
	100.00	200.00	longitudinal	255	235	7
			long transverse	255	235	5
			short transverse	240	220	3
7049-T73	50.00	80.00	longitudinal	490	420	8
			long transverse	490	405	3
			short transverse	475	400	2
	80.00	100.00	longitudinal	475	405	7
			long transverse	475	395	2

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TABLE 2 *Continued*

Alloy and Temper	Thickness[C], mm		Direction	Tensile Strength, min, MPa	Yield Strength (0.2% Offset), min, MPa	Elongation in 5× Diameter ($5.65\sqrt{A}$)[D]
	Over	Through				
			short transverse	460	385	1
	100.00	130.00	longitudinal	460	385	6
			long transverse	460	385	2
			short transverse	455	380	1
7049-T7352	25.00	80.00	longitudinal	490	405	8
			long transverse	490	395	3
			short transverse[E]	475	385	2
	80.00	100.00	longitudinal	475	395	7
			long transverse	475	370	2
			short transverse	460	365	1
	100.00	130.00	longitudinal	460	370	6
			long transverse	460	365	2
			short transverse	455	350	1
7050-T7452[F]	...	50.00	longitudinal	495	435	8
			long transverse	490	420	4
	50.00	80.00	longitudinal	495	425	8
			long transverse	485	415	4
			short transverse	460	380	3
	80.00	100.00	longitudinal	490	420	8
			long transverse	485	405	4
			short transverse	460	380	3
	100.00	130.00	longitudinal	485	415	8
			long transverse	475	400	3
			short transverse	455	370	2
	130.00	150.00	longitudinal	475	405	8
			long transverse	470	385	4
			short transverse	455	365	2
	150.00	180.00	longitudinal	470	400	8
			long transverse	460	370	3
			short transverse	450	350	2
	180.00	200.00	longitudinal	460	395	8
			long transverse	455	360	3
			short transverse	440	345	2
7075-T6	...	50.00	longitudinal	510	435	8
			long transverse	505	420	3
	50.00	80.00	longitudinal	505	420	8
			long transverse	490	405	3
			short transverse	475	400	2
	80.00	100.00	longitudinal	490	415	7
			long transverse	485	400	2
			short transverse	470	395	1
	100.00	130.00	longitudinal	475	400	6
			long transverse	470	385	2
			short transverse	455	385	1
	130.00	150.00	longitudinal	470	385	5
			long transverse	455	380	2
			short transverse	450	380	1
7075-T652	...	50.00	longitudinal	510	435	8
			long transverse	505	420	3
	50.00	80.00	longitudinal	505	420	8
			long transverse	490	405	3
			short transverse	475	395	1
	80.00	100.00	longitudinal	490	415	7
			long transverse	485	400	2
			short transverse	470	385	...
	100.00	130.00	longitudinal	475	400	6
			long transverse	470	385	2
			short transverse	455	380	...
	130.00	150.00	longitudinal	470	385	5
			long transverse	455	380	2
			short transverse	450	370	...
7075-T73	...	80.00	longitudinal	455	385	6
			long transverse	440	370	3
			short transverse[E]	420	360	2
	80.00	100.00	longitudinal	440	380	6
			long transverse	435	365	2
			short transverse	415	350	1
	100.00	130.00	longitudinal	425	365	6
			long transverse	420	350	2
			short transverse	400	345	1
	130.00	150.00	longitudinal	420	350	5
			long transverse	405	345	2

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TABLE 2 *Continued*

Alloy and Temper	Thickness[C], mm		Direction	Tensile Strength, min, MPa	Yield Strength (0.2% Offset), min, MPa	Elongation in 5× Diameter ($5.65\sqrt{A}$)[D]
	Over	Through				
7075-T7352	...	80.00	short transverse	395	340	1
			longitudinal	455	370	6
			long transverse	440	360	3
	80.00	100.00	short transverse[E]	420	345	2
			longitudinal	440	365	6
			long transverse	435	345	2
	100.00	130.00	short transverse	415	330	1
			longitudinal	425	350	6
			long transverse	420	330	2
	130.00	150.00	short transverse	400	315	1
			longitudinal	420	340	5
			long transverse	405	315	2
7175-T74[F]	...	80.00	short transverse	395	305	1
			longitudinal	505	435	8
			long transverse	490	415	4
	80.00	100.00	short transverse[E]	475	415	3
			longitudinal	490	420	8
			long transverse	485	400	4
	100.00	130.00	short transverse	470	395	3
			longitudinal	470	395	7
			long transverse	460	385	4
	130.00	150.00	short transverse	455	380	3
			longitudinal	450	370	7
			long transverse	440	360	4
7175-T7452[F]	...	80.00	short transverse	435	360	3
			longitudinal	490	420	8
			long transverse	475	400	4
	80.00	100.00	short transverse[E]	460	370	3
			longitudinal	470	395	8
			long transverse	460	380	4
	100.00	130.00	short transverse	450	350	3
			longitudinal	450	370	7
			long transverse	440	360	4
	130.00	150.00	short transverse	435	340	3
			longitudinal	435	350	7
			long transverse	420	340	4
			short transverse	415	315	1

[A] To determine conformance to this specification, each value for tensile strength and yield strength shall be rounded to the nearest 1 MPa and each value for elongation to the nearest 0.5 % (or the nearest 0.1 % if measured in accordance with 7.6.4 of Test Methods B 557M), in accordance with the rounding-off method of Practice E 29.

[B] For the basis for establishment of strength property limits, see Annex A1.

[C] Maximum cross-sectional area is 165 000 mm^2, except that for 2618-T61 it is 93 000 mm^2. Thickness at heat treatment is measured in the short transverse direction and applies to the dimension as-forged and before any machining operation.

[D] A represents cross-sectional area of the specimen.

[E] Tensile property test requirements in any direction are limited to a minimum material dimension of 50.00 mm because of the difficulty in obtaining a tension test specimen suitable for routine control testing.

[F] Beginning with the 1985 issue the T736 and T73652 tempers were replaced by the T74 and T7452 tempers respectively as applicable to alloys 7050 and 7175.

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TABLE 3 Mechanical Property Limits for Rolled Ring Forgings[A,B,C]

Alloy and Temper	Maximum Heat Treat Section Thickness, mm		Direction	Tensile Strength, min, MPa[D]	Yield Strength (0.2 % Offset), min, MPa[D]	Elongation, min,%	
	Over	Through				in 50 mm	in 5× Dia. ($5.65\sqrt{A}$)[E]
2014-T6 and 2014-T652[F]	...	65.00	tangential	450	380	7	6
			axial	425	380	3	2
			radial[G]	415	360	2	1
	65.00	80.00	tangential	450	380	6	5
			axial	425	360	2	1
			radial[G]	...	...	...	...
2219-T6	...	65.00	tangential	385	275	6	5
			axial	380	255	4	3
			radial[G]	365	240	2	1
2618-T61	...	65.00	tangential	380	285	6	5
			axial	380	285	5	4
			radial[G]	...	...	...	...
6061-T6 and 6061-T652[F]	...	65.00	tangential	260	240	10	9
			axial	260	240	8	7
			radial[G]	255	230	5	4
	65.00	90.00	tangential	260	240	8	7
			axial	260	240	6	5
			radial[G]	255	230	4	3
6151-T6 and 6151-T652[F]	...	65.00	tangential	305	255	5	4
			axial	305	240	4	3
			radial[G]	290	240	2	1
7075-T6 and 7075-T652[F]	...	50.00	tangential	505	425	7	6
			axial	495	420	3	2
			radial[G]	470	400	2	1
	50.00	90.00	tangential	490	415	6	5
			axial	485	405	3	2
			radial[G]	...	...	...	...

[A] To determine conformance to this specification each value for tensile strength and yield strength shall be rounded to the nearest 1 MPa and each value for elongation to the nearest 0.5 % (or the nearest 0.1 % if measured in accordance with 7.6.4 of Test Methods B 557M), in accordance with the rounding-off method of Practice E 29.

[B] Tensile property test requirements in any direction are limited to a minimum material dimension of 50.00 mm because of the difficulty in obtaining a tension test specimen suitable for routine control testing.

[C] Applicable only to rings which have an OD-to-wall thickness ratio of 10/1 or greater. Those having a smaller ratio shall be the subject of agreement between the purchaser and producer.

[D] The basis for establishment of mechanical property limits is shown in Annex A1.

[E] A represents cross-sectional area of the specimen.

[F] Forgings may be available in the T651 temper but shall be the subject of agreement between the purchaser and producer.

[G] Radial properties are not specified requirements. For wall thicknesses over 50 mm, they will be determined when specifically requested for informational purposes only.

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TABLE 4 Chemical Composition Limits[A,B,C]

Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Nickel	Zinc	Zirconium	Titanium	Other Elements[D]		Aluminum, min
											Each	Total[E]	
1100	0.95 Si + Fe		0.05–0.20	0.05	...	...	...	0.10	...	...	0.05	0.15	99.00[F]
2014	0.50–1.2	0.7	3.9–5.0	0.40–1.2	0.20–0.8	0.10	...	0.25	...	0.15[G]	0.05	0.15	remainder
2018	0.9	1.0	3.5–4.5	0.20	0.45–0.9	0.10	1.7–2.3	0.25	...	...	0.05	0.15	remainder
2025	0.50–1.2	1.0	3.9–5.0	0.40–1.2	0.05	0.10	...	0.25	...	0.15	0.05	0.15	remainder
2218	0.9	1.0	3.5–4.5	0.20	1.2–1.8	0.10	1.7–2.3	0.25	...	...	0.05	0.15	remainder
2219	0.20	0.30	5.8–6.8	0.20–0.40	0.02	...	...	0.10	0.10–0.25	0.02–0.10	0.05[H]	0.15[H]	remainder
2618	0.10–0.25	0.9–1.3	1.9–2.7	...	1.3–1.8	...	0.9–1.2	0.10	...	0.04–0.10	0.05	0.15	remainder
3003	0.6	0.7	0.05–0.20	1.0–1.5	...	...	...	0.10	...	...	0.05	0.15	remainder
4032	11.0–13.5	1.0	0.50–1.3	...	0.8–1.3	0.10	0.50–1.3	0.25	...	...	0.05	0.15	remainder
5083	0.40	0.40	0.10	0.40–1.0	4.0–4.9	0.05–0.25	...	0.25	...	0.15	0.05	0.15	remainder
6061	0.40–0.8	0.7	0.15–0.40	0.15	0.8–1.2	0.04–0.35	...	0.25	...	0.15	0.05	0.15	remainder
6066	0.9–1.8	0.50	0.7–1.2	0.6–1.1	0.8–1.4	0.40	...	0.25	...	0.20	0.05	0.15	remainder
6151	0.6–1.2	1.0	0.35	0.20	0.45–0.8	0.15–0.35	...	0.25	...	0.15	0.05	0.15	remainder
7049	0.25	0.35	1.2–1.9	0.20	2.0–2.9	0.10–0.22	...	7.2–8.2	...	0.10	0.05	0.15	remainder
7050	0.12	0.15	2.0–2.6	0.10	1.9–2.6	0.04	...	5.7–6.7	0.08–0.15	0.06	0.05	0.15	remainder
7075	0.40	0.50	1.2–2.0	0.30	2.1–2.9	0.18–0.28	...	5.1–6.1	...	0.20[I]	0.05	0.15	remainder
7076	0.40	0.6	0.30–1.0	0.30–0.8	1.2–2.0	...	...	7.0–8.0	...	0.20	0.05	0.15	remainder
7175	0.15	0.20	1.2–2.0	0.10	2.1–2.9	0.18–0.28	...	5.1–6.1	...	0.10	0.05	0.15	remainder

[A] Limits are in mass percent maximum unless shown as a range or stated otherwise.

[B] Analysis shall be made for the elements for which limits are shown in this table.

[C] For purposes of determining conformance to these limits, an observed value or a calculated value obtained from analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the specified limit, in accordance with the rounding-off method of Practice E 29.

[D] *Others* includes listed elements for which no specific limit is shown as well as unlisted metallic elements. The producer may analyze samples for trace elements not specified in the specification. However, such analysis is not required and may not cover all metallic *Others* elements. Should any analysis by the producer or the purchaser establish that an *Others* element exceeds the limit of *Each* or that the aggregate of several *Others* elements exceeds the limit of *Total*, the material shall be considered nonconforming.

[E] *Other Elements*—Total shall be the sum of unspecified metallic elements 0.010 % or more, rounded to the second decimal before determining the sum.

[F] The aluminum content shall be calculated by subtracting from 100.00 % the sum of all metallic elements present in amounts of 0.010 % or more each, rounded to the second decimal before determining the sum.

[G] Upon agreement between purchaser and producer or supplier, a zirconium-plus-titanium limit of 0.20 % maximum is permitted.

[H] Vanadium, 0.05–0.15 %.

[I] Upon agreement between purchaser and producer or supplier, a zirconium-plus-titanium limit of 0.25 % maximum is permitted.

TABLE 5 Ultrasonic Discontinuity Limits for Die and Hand Forgings[A]

Alloy	Product	Thickness, mm		Maximum Mass per Piece, kg	Discontinuity Class[B]
		Over	Through		
2014 2219 7049 7050 7075 7175	die forgings	12.50	100.00	150	B
2014 2219 7049 7050 7075 7175	hand forgings	25.00	200.00	300	A

[A] Discontinuities in excess of those listed in this table shall be allowed if it is established that they will be removed by machining or that they are in noncritical areas.

[B] The discontinuity class limits are defined in Section 11 of Practice B 594.

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TABLE 6 Lot Acceptance Criteria for the Control of Stress-Corrosion Resistance for Alloys 7049 and 7075 in T73 Type Tempers, and Alloys 7050 and 7175 in T74 Type Tempers

Alloy and Temper	Lot Acceptance Criteria		
	Electrical Conductivity, % IACS[A]	Level of Mechanical Properties	Lot Acceptance Status
7049-T73 and T7352	40.0 or greater	per specified requirements	acceptable
	38.0 through 39.9	per specified requirements and longitudinal yield strength exceeds the minimum by less than 70 MPa	acceptable
	38.0 through 39.9	per specified requirement but longitudinal yield strength exceeds the minimum by 70 MPa or more	unacceptable[B]
	less than 38.0	any level	unacceptable[B]
7050-T74[C] Die forgings and 7050-T7452[C] Hand forgings	38.0 or greater[D]	per specified requirements and SCF[E] is 220 or less	acceptable
	38.0 or greater	per specified requirements but SCF[E] is over 220	unacceptable[B]
	less than 38.0	any level	unacceptable[B]
7075-T73 and T7352 and 7175-T74[C], T7452[E] and T7454[E]	40.0 or greater	per specified requirements	acceptable
	38.0 through 39.9	per specified requirements and longitudinal yield strength exceeds the minimum by less than 85 MPa	acceptable
	38.0 through 39.9	per specified requirements but longitudinal yield strength exceeds the minimum by 85 MPa or more	unacceptable[B]
	less than 38.0	any level	unacceptable[B]

[A] Electrical conductivity measurements shall be made on the surface of the tensile sample in accordance with Test Method E 1004.
[B] Alloy 7049 material in Tempers T73 and T7352, and Alloy 7050 material in Tempers T74 and T7452, when unacceptable in accordance with the lot acceptance criteria, shall be subject to reprocessing by additional precipitation heat treatment and retested.
[C] Beginning with the 1985 issue the temper designations T736, T73652, and T73654 were replaced by the T74, T7452, and T7454 tempers respectively as applicable to Alloys 7050 and 7175.
[D] Die forgings in the T74 temper also are restricted to having yield strength, parallel to the direction of grain flow, not to exceed 495 MPa.
[E] Stress-Corrosion Susceptibility Factor (SCF) equals yield strength (XXX MPa) – 7 × electrical conductivity (XX.X % IACS).

ANNEXES

(Mandatory Information)

A1. BASIS FOR INCLUSION OF PROPERTY LIMITS

A1.1 Limits are established at a level at which a statistical evaluation of the data indicates that 99 % of the population obtained from all standard material meets the limit with 95 % confidence. For the products described, mechanical property limits for the respective size ranges are based on the analyses of at least 100 data from standard production material with no more than ten data from a given lot. All tests are performed in accordance with the appropriate ASTM test methods. For informational purposes, refer to "Statistical Aspects of Mechanical Property Assurance" in the Related Material section of the *Annual Book of ASTM Standards*, Vol 02.02. Mechanical property limits in this metric issue were derived from the inch-pound system limits that were developed under the above principles. As test data on metric dimensioned specimens are accumulated, some refinement of limits, particularly for elongations measured in 5D, can be anticipated.

A2. ACCEPTANCE CRITERIA FOR INCLUSION OF NEW ALUMINUM AND ALUMINUM ALLOYS IN THIS SPECIFICATION

A2.1 Prior to acceptance for inclusion in this specification, the composition of wrought or cast aluminum or aluminum alloy shall be registered in accordance with ANSI H35.1(M). The Aluminum Association[12] holds the Secretariat of ANSI H35 Committee and administers the criteria and procedures for registration.

A2.2 If it is documented that the Aluminum Association could not or would not register a given composition, an alternative procedure and the criteria for acceptance shall be as follows:

A2.2.1 The designation submitted for inclusion does not utilize the same designation system as described in ANSI H35.1(M). A designation not in conflict with other designation systems or a trade name is acceptable.

A2.2.2 The aluminum or aluminum alloy has been offered for sale in commercial quantities within the prior twelve months to at least three identifiable users.

A2.2.3 The complete chemical composition limits are submitted.

A2.2.4 The composition is, in the judgment of the responsible subcommittee, significantly different from that of any other aluminum or aluminum alloy already in the specification.

A2.2.5 For codification purposes, an alloying element is any element intentionally added for any purpose other than grain refinement and for which minimum and maximum limits are specified. Unalloyed aluminum contains a minimum of 99.00 % aluminum.

[12] The Aluminum Association, 900 19th St., NW, Washington, DC 20006.

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A2.2.6 Standard limits for alloying elements and impurities are expressed to the following decimal places:

Less than 0.001 %	0.000X
0.001 to but less than 0.01 %	0.00X
0.01 to but less than 0.10 %	
Unalloyed aluminum made by a refining process	0.0XX
Alloys and unalloyed aluminum not made by a refining process	0.0X
0.10 through 0.55 %	0.XX
(It is customary to express limits of 0.30 through 0.55 % as 0.X0 or 0.X5.)	
Over 0.55 %	0.X, X.X, etc.
(except that combined Si + Fe limits for 99.00 % minimum aluminum must be expressed as 0.XX or 1.XX)	

A2.2.7 Standard limits for alloying elements and impurities are expressed in the following sequence: Silicon; Iron; Copper; Manganese; Magnesium; Chromium; Nickel; Zinc (Note A2.1); Titanium; Other Elements, Each; Other Elements, Total; Aluminum (Note A2.2).

NOTE A2.1—Additional specified elements having limits are inserted in alphabetical order of their chemical symbols between zinc and titanium, or are specified in footnotes.

NOTE A2.2—Aluminum is specified as *minimum* for unalloyed aluminum and as a *remainder* for aluminum alloys.

APPENDIX

(Nonmandatory Information)

X1. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO) EQUIVALENTS OF ANSI ALLOYS AND TEMPERS

X1.1 International Organization for Standardization (ISO) equivalents of the ANSI alloys and tempers given in Table X1.1 and Table X1.2 are included in ISO 209-1: 1989, Part 1, Chemical Composition and ISO 2107: 1983.

TABLE X1.1 ISO Equivalents of Alloys in B 247M

Alloys			
ANSI	ISO	ANSI	ISO
1100	Al 99.0 Cu	5083	Al Mg4.5Mn0.7
2014	Al Cu4SiMg	6061	Al Mg1SiCu
3003	Al Mn1Cu	7050	Al Zn6CuMgZr
4043	Al Si5	7075	Zn5.5MgCu

TABLE X1.2 ISO Equivalents of Tempers in B 247M

Tempers	
ANSI	ISO
O	O
H112	M
T4	TB
T6	TF
T7	TM

SUMMARY OF CHANGES

This section identifies the principal changes to this standard that have been incorporated since the last issue.
(1) Deleted references to Test Method E 101.

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Designation: B 345/B 345M – 00

Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube for Gas and Oil Transmission and Distribution Piping Systems[1]

This standard is issued under the fixed designation B 345/B 345M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification covers seamless pipe and seamless extruded tube in the aluminum and aluminum alloys (Note 1) and tempers listed in Table 1 and Table 2, respectively. Seamless pipe and seamless tube are intended for use in applications involving internal pressure.

NOTE 1—Throughout this specification use of the term *alloy* in the general sense includes aluminum as well as aluminum alloy.

NOTE 2—For drawn seamless tubes, see Specifications B 210 and B 210M; for extruded tubes, Specifications B 221 and B 221M; for drawn seamless tubes for condensers and heat exchangers, Specifications B 234 and B 234M; for seamless pipe and seamless extruded tube, B241/B 241M; for round welded tubes, Specification B 313/B 313M; for seamless condenser and heat exchanger tubes with integral fins, Specifications B 404 and B 404M; for extruded structural pipe and tube, Specification B 429; and for drawn tube for general purpose applications, Specifications B 483 and B 483M.

1.2 Alloy and temper designations are in accordance with ANSI H35.1. The equivalent Unified Numbering System alloy designations are those of Table 3 preceded by A9, for example, A93003 for aluminum alloy 3003 in accordance with Practice E 527.

1.3 For acceptance criteria for inclusion of new aluminum and aluminum alloys in this specification, see Annex A2.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 The following documents of the issue in effect on the date of material purchase form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*

B 557 Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products[2]

B 557M Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products [Metric][2]

B 597 Practice for Heat Treatment of Aluminum Alloys[2]

B 647 Test Method for Indentation Hardness of Aluminum Alloys by Means of a Webster Hardness Gage[2]

B 648 Test Method for Indentation Hardness of Aluminum Alloys by Means of a Barcol Impressor[2]

B 660 Practices for Packaging/Packing of Aluminum and Magnesium Products[2]

B 666/B 666M Practice for Identification Marking of Aluminum Products[2]

B 807 Practice for Extrusion Press Solution Heat Treatment of Aluminum Alloys[2]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum Base Alloys[5]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[5]

E 227 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[5]

E 527 Practice for Numbering Metals and Alloys (UNS)[6]

E 607 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique, Nitrogen Atmosphere[7]

E 716 Practices for Sampling Aluminum and Aluminum Alloys for Spectrochemical Analysis[7]

E 1251 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Argon

[1] This specification is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.03 on Aluminum Alloy Wrought Products.

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[2] *Annual Book of ASTM Standards*, Vol 02.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 03.05.

[6] *Annual Book of ASTM Standards*, Vol 01.01.

[7] *Annual Book of ASTM Standards*, Vol 03.06.

*A Summary of Changes section appears at the end of this standard.

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TABLE 1 Tensile Property Limits for Extruded Seamless Pipe[A,B]

Alloy	Temper	Pipe Size, in.	Strength, min, ksi [MPa]		Elongation[C,D]	
			Tensile	Yield (0.2 % Offset)	in 2 in. [50 mm] or 4× Diameter, min, %	in 5 × D ($5.65\sqrt{A}$)
3003	H18	under 1	27.0 [185]	24.0 [165]	4	4
	H112	1 and over	14.0 [95]	5.0 [35]	25	22
6061	T6	under 1	38.0 [260]	35.0 [240]	8	...
		1 and over	38.0 [260]	35.0 [240]	10[E]	9
6063	T6	all	30.0 [205]	25.0 [170]	8	7
6351	T5	all	38.0 [260]	35.0 [240]	10[E]	9
	T6	all	42.0 [290]	37.0 [255]	10[F]	9

[A] The basis for establishment of mechanical property limits is given in Annex A1 of this specification.

[B] To determine conformance to this specification, each value for tensile strength and for yield strength shall be rounded to the nearest 0.1 ksi [MPa] and each value for elongation to the nearest 0.5 %, both in accordance with the rounding method of Practice E 29.

[C] Elongation of full-section and sheet-type specimens is measured in 2 in.; of cut-out round specimens, 4× specimen diameter.

[D] Elongations in 50 mm apply for pipe tested in full sections and for sheet-type specimens machined from material up through 12.5 mm in thickness having parallel surfaces. Elongations in 5 × D (at $5.65\sqrt{A}$), where D and A are diameter and cross-sectional area of the specimen, respectively, apply to round test specimens machined from thicknesses over 6.30 mm.

[E] The minimum elongation for a wall thickness up through 0.249 in. [6.3 mm] is 8 %.

[F] For wall thickness 0.124 in. [3.20 mm] and less, the minimum elongation is 8 %.

Atmosphere, Point-to-Plane, Unipolar Self-Initiating Capacitor Discharge[7]

2.3 *ANSI Standards:*

B2.1 Pipe Threads (except Dryseal)[8]

B36.10 Wrought Steel and Wrought Iron Pipe[8]

H35.1 Alloy and Temper Designation Systems for Aluminum[2]

H35.1M Alloy and Temper Designation Systems for Aluminum [Metric][2]

H35.2 Dimensional Tolerances for Aluminum Mill Products[2]

H35.2M Dimensional Tolerances for Aluminum Mill Products[2]

2.4 *American Welding Society Standard:*

D 10.7 Recommended Practices for Gas Shielded Arc Welding of Aluminum and Aluminum-Alloy Pipe[9]

2.5 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[10]

2.6 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[10]

3. Terminology

3.1 *Definitions:*

3.1.1 *extruded seamless pipe*—extruded seamless round tube with standardized sizes of outside diameter and wall thickness commonly designated by "Nominal Pipe Sizes" and American National Standards Institute (ANSI) "Schedule Numbers."

3.1.2 *extruded seamless alclad tube*—a composite tube product composed of an aluminum alloy core having on either the inside or outside surface a metallurgically bonded aluminum or aluminum alloy coating that is anodic to the core, thus electrolytically protecting the core against corrosion.

3.1.3 *extruded seamless round tube*—a hollow product having a round cross section and a uniform wall thickness, brought to final dimensions by extruding from a hollow ingot.

4. Ordering Information

4.1 Orders for material to this specification shall include the following information:

4.1.1 This specification designation (which includes the number, the year, and the revision letter, if applicable),

4.1.2 Quantity in pieces or weight in pounds [kilograms],

4.1.3 Alloy (Section 7),

4.1.4 Temper (Section 9),

4.1.5 Pipe size and schedule number (pipe) (see Table 16.7 of ANSI H35.2 and Table 4 of this specification), or outside diameter and wall thickness (tube),

4.1.6 For alloy Alclad 3003, state clad inside or outside (13.1),

4.1.7 End configuration (Section 11),

4.1.8 Length (Section 12),

4.2 Additionally, orders for material to this specification shall include the following information when required by the purchaser:

4.2.1 Whether solution treatment at the press is unacceptable (Section 8),

4.2.2 Whether inspection or witness of inspection and tests by the purchaser's representative is required prior to material shipment (Section 15),

4.2.3 Whether certification of the material is required (Section 17),

4.2.4 Whether marking for identification is required (Section 18), and

4.2.5 Whether Practices B 660 applies and if so, the levels of preservation, packaging, and packing required (Section 19).

5. Manufacture

5.1 The pipe and tube shall be produced from hollow extrusion ingot (cast in hollow form or pierced) and shall be extruded by use of the die and mandrel method.

5.1.1 At the option of the producer, the pipe and tube may be drawn after extrusion, provided all the requirements of this specification are met.

[8] Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

[9] Available from the American Welding Society, 2501 Northwest 7th St., Miami, FL 33125.

[10] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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TABLE 2 Tensile Property Limits for Extruded Seamless Tube[A,B]

Temper	Specified Wall Thickness, in. [mm]	Area, in.^{2}[mm^2]	Tensile Strength, ksi [MPa] min	Tensile Strength, ksi [MPa] max	Yield Strength (0.2 % offset) ksi [MPa], min	Elongation[C,D] in 2 in. [50 mm] or 4 × D min,%	Elongation[C,D] in 5 × D ($5.65\sqrt{A}$)[E]
Aluminum 1060[F]							
O	all	all	8.5 [60]	14.0 [95]	2.5 [15]	25	22
H112	all	all	8.5 [60]	... [...]	2.5 [15]	25[G]	22[G]
Alloy 3003[F]							
O	all	all	14.0 [95]	19.0 [130]	5.0 [35]	25	22
H112	all	all	14.0 [95]	... [...]	5.0 [35]	25	22
Alloy Alclad 3003[F]							
O	all	all	13.0 [90]	18.0 [125]	4.5 [30]	25	22
H112	all	all	13.0 [90]	... [...]	4.5 [30]	25	22
Alloy 5083[F]							
O	all [130.00]	up through 32.0 [20 000]	39.0 [270]	51.0 [350]	16.0 [110]	14	12
H111	all [130.00]	up through 32.0 [20 000]	40.0 [275]	... [...]	24.0 [165]	12	10
H112	all [130.00]	up through 32.0 [20 000]	39.0 [270]	... [...]	16.0 [110]	12	10
Alloy 5086[F]							
O	all [130.00]	up through 32.0 [20 000]	35.0 [240]	46.0 [315]	14.0 [95]	14	12
H111	all [130.00]	up through 32.0 [20 000]	36.0 [250]	... [...]	21.0 [145]	12	10
H112	all [130.00]	up through 32.0 [20 000]	35.0 [240]	... [...]	14.0 [95]	12	10
Alloy 6061[F]							
O[H]	all	all	... [...]	22.0 [150]	16.0[I] [...]	16	14
T1	[16.00]	all	[180]	... [...]	[95]	16	14
T4, T4510[J], T4511[J]	all	all	26.0 [180]	... [...]	16.0 [110]	16	14
T42[J]	all	all	26.0 [180]	... [...]	12.0 [85]	16	14
T51	[16.00]	all	[240]	... [...]	[205]	8	7
T6, T62[K], T6510[J], T6511[J]	up through 0.249 [6.30]	all	38.0 [260]	... [...]	35.0 [240]	8	... 9
	0.250 and over [6.30]	all	38.0 [260]	... [...]	35.0 [240]	10	
Alloy 6063[F]							
O[H]	all	... [all]	... [...]	19.0 [130]	... [...]	18	16
T1[K]	up through 0.500 [12.50]	all	17.0 [115]	... [...]	9.0 [60]	12	10
	0.501–1.000 [12.50–25.00]	all	16.0 [110]	... [...]	8.0 [55]	12 [...]	10
T4, T42[L]	up through 0.500 [12.50]	all	19.0 [130]	... [...]	10.0 [70]	14	12
	0.501–1.000 [12.50–25.00]	all	18.0 [125]	... [...]	9.0 [60]	14 [...]	12
T5	up through 0.500 [12.50]	all	22.0 [150]	... [...]	16.0 [110]	8	7
	0.501–1.000 [12.50–25.0]	all	21.0 [145]	... [...]	15.0 [105]	8 [...]	7
T52	up through 1.000 [25.00]	all	22.0 [150]	30.0 [205]	16.0[M] [110]	8	7
T6, T62[L]	up through 0.124 [3.20]	all	30.0 [205]	... [...]	25.0 [170]	8	...
	0.125–1.000 [3.20–25.00]	all	30.0 [205]	... [...]	25.0 [170]	10	7
Alloy 6070[F]							
T6, T62[L]	up through 2.999	up through 32	48.0 [330]	... [...]	45.0 [310]	6	5
Alloy 6351[F]							
T4	all	all	32.0 [220]	... [...]	19.0 [130]	16	14
T6	up through 0.124	...	42.0 [290]	... [...]	37.0 [255]	8	...
	0.125–0.749	...	42.0 [290]	... [...]	37.0 [255]	10	9

[A] The basis of establishment of mechanical property limits is given in Annex A1 of this specification.

[B] To determine conformance to this specification, each value for ultimate tensile strength and for yield strength shall be rounded to the nearest 0.1 ksi [MPa] and each value for elongation to the nearest 0.5 %, both in accordance with the rounding method of Practice E 29.

[C] Elongation of full-section and sheet-type specimens is measured in 2 in.; of cut-out round specimens, in 4× specimen diameter.

[D] For material of such dimensions that a standard test specimen cannot be taken, or for material thinner than 0.062 in., the test for elongation is not required.

[E] Elongations in 50 mm apply for tube tested in full section and for sheet-type specimens machined from material up through 12.5 mm in thickness having parallel surfaces. Elongations in 5× diameter ($5.65\sqrt{A}$), where D and A are diameter and cross-sectional area of the specimen, respectively, apply to round test specimens machined from thickness over 6.30 mm. For tube of such dimensions that a standard test specimen cannot be taken, the test for elongation is not required.

[F] These alloys are also produced in the F temper, for which no mechanical properties are specified.

[G] Maximum tensile strength and minimum elongation apply to tubes having diameters from 1.000 in. to 4.500 in. and wall thickness from 0.050 in. to 0.169 in. only. Minimum elongation applies to tubes having diameters from 25.00 to 115.00 mm and wall thickness over 1.30 through 4.30 mm only.

[H] Upon heat treatment, annealed (0 temper) material shall be capable of developing the mechanical properties applicable to T42 temper material, and upon solution and precipitation heat treatment shall be capable of developing the mechanical properties applicable to T62 temper material.

[I] Yield strength is maximum [110 MPa] max.

[J] For stress-relieved tempers (T4510, T4511, T6510 and T6511) characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.

[K] Formerly designated T42 temper. Properly aged precipitation heat-treated 6063-T1 extruded products are designated T5.

[L] While material in the T42 and T62 tempers is not available from the material producer, the properties are listed to indicate those which can usually be obtained by the user when the material is properly solution heat treated or solution and precipitation heat treated from the O (annealed) or F (as-fabricated) tempers. These properties apply when samples of material supplied in the O or F temper are heat treated by the producer to the T42 or T62 tempers to determine that the material will respond to proper thermal treatment. Properties attained by the user, however, may be lower than those listed if the material has been formed or otherwise cold or hot worked, particularly in the annealed temper, prior to solution heat treatment.

[M] Maximum yield strength is 25.0 ksi [170 MPa].

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TABLE 3 Chemical Composition[A,B,C]

Alloy	Composition, %											
	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Vanadium	Titanium	Other Elements[D] Each	Other Elements[D] Total[E]	Aluminum
1060	0.25	0.35	0.05	0.03	0.03	...	0.05	0.05	0.03	0.03	...	99.60 min[F]
3003	0.6	0.7	0.05–0.20	1.0–1.5	...	...	0.10	...	...	0.05	0.15	remainder
Alclad 3003	3003 alloy clad inside or outside with 7072 alloy											
5083	0.40	0.40	0.10	0.40–1.0	4.0–4.9	0.05–0.25	0.25	...	0.15	0.05	0.15	remainder
5086	0.40	0.50	0.10	0.20–0.7	3.5–4.5	0.05–0.25	0.25	...	0.15	0.05	0.15	remainder
6061[G]	0.40–0.8	0.7	0.15–0.40	0.15	0.8–1.2	0.04–0.35	0.25	...	0.15	0.05	0.15	remainder
6063	0.20–0.6	0.35	0.10	0.10	0.45–0.9	0.10	0.10	...	0.10	0.05	0.15	remainder
6070	1.0–1.7	0.50	0.15–0.40	0.40–1.0	0.50–1.2	0.10	0.25	...	0.15	0.05	0.15	remainder
6351	0.7–1.3	0.50	0.10	0.40–0.8	0.40–0.8	...	0.20	...	0.20	0.05	0.15	remainder
7072[H]	0.7 Si + Fe		0.10	0.10	0.10	...	0.8–1.3	...	...	0.05	0.15	remainder

[A] Limits are in percent maximum unless shown as a range or stated otherwise.

[B] Analysis shall be made for the elements for which limits are shown in this table.

[C] For purposes of determining conformance to these limits, an observed value or a calculated value obtained from analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the specified limit, in accordance with the rounding method of Practice E 29.

[D] *Others* includes listed elements for which no specific limit is shown as well as unlisted metallic elements. The producer may analyze samples for trace elements not specified in the specification. However, such analysis is not required and may not cover all metallic *Others* elements. Should any analysis by the producer or the purchaser establish that an *Others* element exceeds the limit of *Each* or that the aggregate of several *Others* elements exceeds the limit of *Total*, the material shall be considered non-conforming.

[E] *Other Elements*—Total shall be the sum of unspecified metallic elements 0.010 % or more, rounded to the second decimal before determining the sum.

[F] The aluminum content shall be calculated by subtracting from 100.00 % the sum of all metallic elements present in amounts of 0.010 % or more each, rounded to the second decimal before determining the sum.

[G] In 1965 the requirements for Alloy 6062 were combined with those of Alloy 6061 by revision of the minimum chromium content from 0.15 to 0.04. For this reason, Alloy 6062 was cancelled.

[H] Composition of cladding alloy as applied during the course of manufacture. The sample from finished tube shall not be required to conform to these limits.

TABLE 4 Nominal Size and Weight[A] of Aluminum-Alloy Pipe

Nominal Pipe Size, in.[B]	Schedule Number[C]	Nominal Outside Diameter, in. [mm]	Nominal Wall Thickness, in. [mm]	Nominal Weight per Foot, lb [kg/m][A]
14	10	14.000 [356]	0.250 [6.35]	12.70 [18.83]
	20		0.312 [7.92]	15.78 [23.38]
	30		0.375 [9.52]	18.88 [27.98]
	40		0.438 [11.13]	21.95 [32.56]
	60		0.594 [15.04]	29.42 [43.50]
	80		0.750 [19.05]	36.71 [54.45]
16	10	16.000 [406]	0.250 [6.35]	14.55 [21.53]
	20		0.312 [7.92]	18.08 [26.74]
	30		0.375 [9.52]	21.65 [32.02]
	40		0.500 [12.70]	28.63 [42.37]
	60		0.656 [16.66]	37.19 [55.02]
	80		0.844 [21.44]	47.26 [69.94]
18	40	18.000 [457]	0.562 [14.27]	36.21 [53.59]
20	40	20.000 [508]	0.594 [15.09]	42.59 [63.09]

[A] Based on density of 0.098 lb/in.^{3} [270].

[B] Other pipe sizes with outside diameters listed in Table 2 of ANSI B36.10 may be considered covered by this specification if agreed upon between the producer and the purchaser.

[C] ANSI B36.10.

6. Responsibility for Quality Assurance

6.1 *Responsibility for Inspection and Tests*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser in the order or at the time of contract signing. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

6.2 *Lot Definition*—An inspection lot shall be defined as follows:

6.2.1 For heat-treated tempers, an inspection lot shall consist of an identifiable quantity of material of the same mill form, alloy, temper, and nominal dimensions traceable to a heat-treat lot or lots, and subjected to inspection at one time.

6.2.2 For nonheat-treated tempers, an inspection lot shall consist of an identifiable quantity of material of the same mill form, alloy, temper, and nominal dimensions subjected to inspection at one time.

7. Chemical Composition

7.1 *Limits*—The pipe and tube shall conform to the chemical composition limits in Table 3. Conformance shall be determined by analyzing samples taken at the time the ingots are poured, or samples taken from the finished or semifinished product. If the producer has determined the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product.

NOTE 3—It is standard practice in the United States aluminum industry to determine conformance to the chemical composition limits prior to further processing of ingots into wrought products. Due to the continuous nature of the process, it is not practical to keep a specific ingot analysis identified with a specific quantity of finished material.

7.2 *Number of Samples*—The number of samples taken for determination of chemical composition shall be as follows:

7.2.1 When samples are taken at the time the ingots are poured, at least one sample shall be taken for each group of ingots poured simultaneously from the same source of molten metal.

7.2.2 When samples are taken from the finished or semifinished product, a sample shall be taken to represent each 4000 lb [2000 kg] or fraction thereof of material in the lot, except

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that no more than one sample shall be required per piece.

7.3 *Methods of Sampling*—Samples for determination of chemical composition shall be taken in accordance with one of the following methods:

7.3.1 Samples for chemical analysis shall be taken from the material by drilling, sawing, milling, turning, or clipping a representative piece or pieces to obtain a sample of not less than 75 g. Sampling shall be in accordance with Practice E 55.

7.3.2 Sampling for spectrochemical analysis shall be in accordance with Practices E 716. Samples for other methods of analysis shall be suitable for the form of material being analyzed and the type of analytical method used.

NOTE 4—It is difficult to obtain a reliable analysis of each of the components of clad materials using material in its finished state. A reasonably accurate determination of the core composition can be made if the cladding is substantially removed prior to analysis. The cladding composition is more difficult to determine because of the relatively thin layer and because of diffusion of core elements to the cladding. The correctness of cladding alloy used can usually be verified by a combination of a metallographic examination and spectrochemical analysis of the surface at several widely separated points.

7.4 *Methods of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (Test Methods E 34), or spectrochemical (Test Methods E 227, E 607, and E 1251) methods. Other methods may be used only when no published ASTM method is available. In case of dispute, the methods of analysis shall be agreed upon between the producer and the purchaser.

8. Heat Treatment

8.1 Producer or supplier heat treatment for the production of T1 and T5-type tempers shall be in accordance with Practice B 807, and for the production of T4 and T6-type tempers, except as noted in 8.2, shall be in accordance with Practice B 597.

8.2 Unless otherwise specified, alloys 6061, 6063, and 6351 may be solution heat treated and quenched at the extrusion press in accordance with Practice B 807 for the production of T4 and T6-type tempers, as applicable.

9. Tensile Properties

9.1 *Limits*—The material shall conform to the tensile property requirements in Table 1 or Table 2 as applicable.

9.2 *Number of Specimens*:

9.2.1 For material having a nominal weight less than 1 lb/linear ft [1.7 kg/linear m], one tension test specimen shall be taken for each 1000 lb [500 kg] or fraction thereof in the inspection lot.

9.2.2 For material having a nominal weight of 1 lb or more per linear ft [1.7 kg/linear m], one tension test specimen shall be taken for each 1000 ft [300 m] or fraction thereof in the inspection lot.

9.2.3 Other procedures for selecting samples may be used if agreed upon by the producer and purchaser.

9.3 *Test Specimens*:

9.3.1 Geometry of test specimens and the location in the product from which they are taken shall be as specified in Test Methods B 557 and B 557M.

9.4 *Test Methods*—The tension tests shall be made in accordance with Test Methods B 557 and B 557M.

9.5 *Retests*—Retests may be performed in accordance with Test Methods B 557 and B 557M.

10. Quality Assurance Screening of Extrusion Press HeatTreated Pipe and Tube

10.1 Pipe and tube heat treated at the extrusion press shall conform to all requirements of Section 9. In addition, hardness tests shall be performed on each extruded length or with the approval of the purchaser on pieces selected in accordance with a mutually acceptable sampling plan. The minimum hardness control value shall be in accordance with Table 5 for pipe and with Table 6 for tube for the type of hardness tester used. The specific type of hardness tester used shall be left to the discretion of the producer, but the test method shall be in accordance with Test Methods B 647, B 648, or E 18, as applicable.

10.2 Individual pieces within a lot that fail to conform to the minimum applicable hardness values may be accepted provided that the samples from two pieces exhibiting the lowest minimum hardness values are tension tested and found to conform to the requirements of Table 1 for pipe or Table 2 for tube.

11. End Bevels, Threads, and Grooves

11.1 When specified in the order or contract, the ends of each length of pipe shall be beveled, threaded, or grooved in accordance with 11.1.1-11.1.3.

11.1.1 Beveled ends shall be agreed upon between the producer and the purchaser.

NOTE 5—Many end configurations have been developed such as the V groove, which appear to be superior to the straight bevel under many

TABLE 5 Hardness Screening Values[A,B] for Seamless Pipe

Alloy and Temper	Pipe Size	Wall Thickness, in. [mm]	Minimum Hardness Number[C]		
			Webster	Barcol	Rockwell E
6061-T6	less than 1 in.	0.050 [1.25] and over	16	...	...
	1 in. and over	0.050 [1.25] thru 0.075 [1.50]	15	76	89
		0.076 [over 1.50] thru 0.499 [12.5]	15	76	89
		0.500 [over 12.5] thru 1.000 [25.0]	15	76	...
6063-T6	all	all [over 1.25 thru 25.0]	12	72	75
6351-T5	all	all [over 1.25 thru 25.0]	15	76	89
6351-T6	all	0.050 thru 1.000 [1.25 thru 25.0]	16	...	...

[A] See 10.1.

[B] The hardness values shown do not guarantee material will pass the applicable mechanical property requirements but are for informational purposes only. It is the responsibility of the user of this specification to establish the relationship between the hardness values and tensile properties.

[C] Alternative minimum hardness values and hardness testing devices may be used provided agreement is reached between the purchaser and supplier or producer.

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TABLE 6 Hardness Screening Values[A,B] for Seamless Extruded Tube

Alloy and Temper	Specified Wall Thickness, in. [mm]	Minimum Hardness Number[C]		
		Webster	Barcol	Rockwell E
6061-T4	0.050 [1.25] and over	...	64	...
T6	0.050 [1.25] thru 0.075 [1.50]	15	76	89
	0.076 thru 0.499 [over 1.50 thru 12.5]	15	76	89
	0.500 thru 1.000 [over 12.5 thru 25.0]	15	76	...
6063-T1	0.050 thru 0.500 [1.25 thru 12.5]	...	50	...
T4	0.050 thru 0.500 [1.25 thru 12.5]	...	60	...
T5	0.050 thru 0.500 [1.25 thru 12.5]	...	65	...
T6	0.050 thru 0.500 [1.25 thru 12.5]	12	72	75
6351-T6	0.050 thru 0.749 [1.25 thru 19.00]	16	...	...
	0.050 thru 1.000	16	...	...

[A] See 10.1.
[B] The hardness values shown do not guarantee material will pass the applicable mechanical property requirements but are for informational purposes only. It is the responsibility of the user of this specification to establish the relationship between the hardness values and tensile properties.
[C] Alternative minimum hardness values and hardness testing devices may be used providing agreement is reached between the purchaser and supplier or producer.

circumstances. The "modified vee" described in AWS D10.7 is one example.

11.1.2 Threaded ends shall be in accordance with ANSI B2.1. The threaded ends shall be free from burrs and suitably protected from damage in handling. Threading of pipe made of nonheat-treatable alloys in a temper softer than H14 is not recommended.

11.1.3 Grooved ends shall be as specified by the purchaser.

12. Dimensional Tolerances

12.1 Except for length, variations from the specified dimensions for the type of material ordered shall not exceed the permissible variations prescribed in the following tables of ANSI H35.2.

12.1.1 Index to tables in ANSI H35.2 of permissible variations for pipe 12 in. and smaller:

Table No. 16.1 Outside Diameter
Table No. 16.2 Wall Thickness
Table No. 16.3 Weight
Table No. 16.5 Straightness
Table No. 16.7 Diameter, Wall Thickness, Weight

12.1.2 Index to tables of permissible variations for extruded seamless tube:

Table No. 12.1 Diameter
Table No. 12.3 Wall Thickness
Table No. 12.7 Straightness
Table No. 12.9 Squareness of Cut Ends

12.2 Nominal sizes and weights of 14, 16, 18, and 20-in. pipe are given in Table 4. Tolerances for these sizes shall be as agreed upon.

12.3 *Length Tolerance*— Eighty-five percent or more of the ordered quantity shall be the specified length plus or minus 1 in. [25 mm]. Fifteen percent of the ordered quantity may be a minimum of 90 % of the specified length, unless other agreement is made between the purchaser and producer.

12.4 *Number of Samples*—Examinations for dimensions shall be made to ensure conformance to the tolerance specified.

13. Cladding

13.1 The cladding of alloy Alclad 3003 shall comprise either the inside surface only or the outside surface only as specified.

13.2 Alclad 3003 shall be fabricated in such a manner as to give the following approximate cladding thickness:

Alloy and Cladding	Approximate Thickness of Cladding, percent of specified wall thickness
Alclad 3003 (clad inside)	10
Alclad 3003 (clad outside)	7

13.3 When the thickness of the cladding is to be determined on finished material, transverse cross sections of at least three pieces from the lot shall be polished for examination with a metallurgical microscope. Under a magnification of 100×, the cladding thickness at four points, 90° apart, in each sample shall be measured, and the average of the twelve measurements shall be taken as the thickness. In the case of the pipe having a diameter larger than can be properly mounted for polishing and examination, each portion of the cross section polished for examination may consist of an arc about ½ in. [12 mm] in length.

14. General Quality

14.1 Pipe and tube shall be supplied in the mill finish and shall be of uniform quality and temper, sound, and free from injurious defects. Dents and surface finish conditions which do not detract from its usefulness for piping systems shall not be cause for rejection. Grinding to remove minor surface defects is permitted if the dimensional tolerances are met.

14.2 Discoloration that is characteristic of proper solution heat treatment shall not be cause for rejection.

14.3 Each pipe and tube shall be examined to determine conformance to this specification with respect to general quality and identification marking. On approval of the purchaser, however, the producer may use a system of statistical quality control for such examinations.

15. Source Inspection

15.1 If the purchaser desires that his representative inspect or witness the inspection and testing of the material prior to shipment, such agreement shall be made by the purchaser and the producer as part of the purchase contract.

15.2 When such inspection or witness of inspection and testing is agreed upon, the producer shall afford the purchaser's representative all reasonable facilities to satisfy him that the material meets the requirements of this specification. Inspection and tests shall be conducted so there is no unnecessary interference with the producer's operations.

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16. Retest and Rejection

16.1 If any material fails to conform to all of the applicable requirements of this specification, it shall be cause for rejection of the inspection lot.

16.2 When there is evidence that a failed specimen was not representative of the inspection lot and when no other sampling plan is provided or approved through the contract or purchase order, at least two additional specimens shall be selected to replace each test specimen that failed. All specimens so selected for retest shall meet the requirements of the specification or the lot shall be subject to rejection.

16.3 Material in which defects are discovered subsequent to inspection may be rejected.

16.4 If material is rejected by the purchaser, the producer or supplier is responsible only for replacement of material to the purchaser. As much as possible of the rejected material shall be returned to the producer or supplier.

17. Certification

17.1 The producer or supplier shall, on request, furnish to the purchaser a certificate stating that the material has been sampled, tested, and inspected in accordance with this specification, and has met the requirements.

18. Identification Marking of Product

18.1 When specified in the contract or purchase order, all pipe and tube shall be marked in accordance with Practice B 666/B 666M, and the marking legend shall include the word "seamless."

18.2 The foregoing requirements are minimum; marking systems which involve added information, larger characters, and greater frequencies are acceptable under this specification.

19. Packaging and Package Marking

19.1 The material shall be packaged to provide adequate protection during normal handling and transportation, and each package shall contain only one size, alloy, and temper unless otherwise agreed. The type of packing and gross weight of containers shall, unless otherwise agreed, be at the producer or supplier's discretion, provided they are such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

19.2 Each shipping container shall be marked with the purchase order number, size, schedule number, if applicable, specification number, alloy and temper, gross and net weights, and the producer's name or trademarks.

19.3 When specified in the contract or purchase order, material shall be preserved, packaged, and packed in accordance with the requirements of Practices B 660. The application levels shall be as specified in the contract or order. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

20. Keywords

20.1 aluminum alloy; extruded tube; seamless pipe; seamless tube

ANNEXES

(Mandatory Information)

A1. BASIS FOR INCLUSION OF PROPERTY LIMITS

A1.1 Limits are established at a level at which a statistical evaluation of the data indicates that 99 % of the population obtained from all standard material meets the limit with 95 % confidence. For the products described, mechanical property limits for the respective size ranges are based on the analysis of at least 100 data from standard production material with no more than ten data from a given lot. All tests are performed in accordance with the appropriate ASTM test methods. For informational purposes, refer to "Statistical Aspects of Mechanical Property Assurance" in the Related Material section of the *Annual Book of ASTM Standards*, Vol 02.02. Mechanical property limits in this metric issue were derived from the inch-pound system limits that were developed under the above principles. As test data on metric dimensioned specimens are accumulated, some refinement of limits, particularly for elongations measured in 5D, can be anticipated.

A2. ACCEPTANCE CRITERIA FOR INCLUSION OF NEW ALUMINUM AND ALUMINUM ALLOYS IN THIS SPECIFICATION

A2.1 Prior to acceptance for inclusion in this specification, the composition of wrought or cast aluminum or aluminum alloy shall be registered in accordance with ANSI H35.1. The Aluminum Association[11] holds the Secretariat of ANSI H35 Committee and administers the criteria and procedures for registration.

A2.2 If it is documented that the Aluminum Association could not or would not register a given composition, an alternative procedure and the criteria for acceptance shall be as follows:

A2.2.1 The designation submitted for inclusion does not utilize the same designation system as described in ANSI H35.1. A designation not in conflict with other designation

[11] The Aluminum Association, 900 19th Street, NW, Washington, DC 20006.

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systems or a trade name is acceptable.

A2.2.2 The aluminum or aluminum alloy has been offered for sale in commercial quantities within the prior twelve months to at least three identifiable users.

A2.2.3 The complete chemical composition limits are submitted.

A2.2.4 The composition is, in the judgment of the responsible subcommittee, significantly different from that of any other aluminum or aluminum alloy already in the specification.

A2.2.5 For codification purposes, an alloying element is any element intentionally added for any purpose other than grain refinement and for which minimum and maximum limits are specified. Unalloyed aluminum contains a minimum of 99.00 % aluminum.

A2.2.6 Standard limits for alloying elements and impurities are expressed to the following decimal places:

Less than 0.001 %	0.000X
0.001 to but less than 0.01 %	0.00X
0.01 to but less than 0.10 %	
Unalloyed aluminum made by a refining process	0.0XX
Alloys and unalloyed aluminum not made by a refining process 0.10 through 0.55 %	0.0X
(It is customary to express limits of 0.30 through 0.55 % as 0.X0 or 0.X5.)	0.XX
Over 0.55 %	0.X, X.X, etc.
(except that combined Si + Fe limits for 99.00 % minimum aluminum must be expressed as 0.XX or 1.XX)	

A2.2.7 Standard limits for alloying elements and impurities are expressed in the following sequence: Silicon; Iron; Copper; Manganese; Magnesium; Chromium; Nickel; Zinc (Note A2.1); Titanium; Other Elements, Each; Other Elements, Total; Aluminum (Note A2.2).

NOTE A2.1—Additional specified elements having limits are inserted in alphabetical order of their chemical symbols between zinc and titanium, or are specified in footnotes.

NOTE A2.2—Aluminum is specified as *minimum* for unalloyed aluminum and as a *remainder* for aluminum alloys.

APPENDIX

(Nonmandatory Information)

X1. GENERAL INFORMATION ON MINIMUM TENSILE PROPERTIES OF WELDED MATERIAL

X1.1 Table X1.1 lists the minimum tensile properties of welded aluminum alloys.

TABLE X1.1 Minimum Tensile Properties of Welded Aluminum Alloys[A]
(Gas Tungsten Arc or Gas Metal Arc Welding with No Postweld Heat Treatment)

Alloy and Temper	Tensile Strength, ksi [MPa]	Yield Strength,[B] ksi [MPa]
3003-H12, H14, H16, H18	14 [95]	7 [50]
Alclad 3003-H12, H14, H16, H18	13 [90]	6 [40]
5083-H111	39 [270]	21 [145]
5086-H111	35 [240]	18 [125]
H112	35 [240]	14 [95]
6061-T6, T651[C,D]	24 [165]	20 [140]
T6, T651[E]	24 [165]	15 [105]
6063-T5, T52, T6[C,D]	17 [115]	11 [75]
6070-T6[C,D]	24 [165]	20 [140]
6351-T6[C,D]	24 [165]	20 [140]

[A] Filler wires used and minimum tensile strengths for all alloys except 6070 and 6351 are those covered by ASME Standards and published in Aluminum Association "Aluminum Construction Manual."

[B] 0.2 % offset in 10-in. [250-mm] gage length across weld.

[C] These values apply to pipe and tube of all nominal thicknesses when welded with 5183, 5356, or 5556 alloy filler wire. These values also apply to pipe and tube of nominal wall thickness 0.375 in. [10.00 mm] and less when welded with 4043, 5154, 5254 or 5554 alloy filler wire.

[D] For pipe and tube smaller than 4 in. [100 mm] in diameter, or having *D/t* ratios less than 15, the strength values may be lower than the values shown.

[E] These values apply to pipe and tube of nominal wall thickness over 0.375 in. [10.00 mm] when welded with 4043, 5154, 5254, or 5554 alloy filler wire.

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SUMMARY OF CHANGES

This section identifies the principal changes to this standard that have been incorporated since the last issue.

(1) Deleted references to Test Method E 101.

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Standard Specification for Factory-Made Wrought Aluminum and Aluminum-Alloy Welding Fittings[1]

This standard is issued under the fixed designation B 361; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope*

1.1 This specification covers only factory-made wrought aluminum and aluminum-alloy welding fittings in contrast to field-made fittings. The term "welding fittings" applies to butt-welding or socket-end parts, such as 45° elbows, 180° return bends, 90° short radius elbows, and other types made to the dimensional standards specified by ANSI B16.9, B16.11, and B16.28.

NOTE 1—Throughout this specification use of the term *alloy* in the general sense includes aluminum as well as aluminum-alloy.

1.2 For acceptance criteria for inclusion of new aluminum and aluminum alloys in this specification, see Annex A1.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.1.1 *ASTM Standards:*

B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate[2]

B 210 Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes[2]

B 211 Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire[2]

B 221 Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Shapes and Tubes[2]

B 234 Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes for Condensers and Heat Exchangers[2]

B 241/B 241M Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube[2]

B 247 Specification for Aluminum and Aluminum-Alloy Die Forgings, Hand Forgings, and Rolled Ring Forgings[2]

B 660 Practices for Packaging/Packing of Aluminum and Magnesium Products[2]

2.1.2 *ANSI Standards:*

B16.9 Factory-Made Wrought Steel Butt-Welding Fittings[3]

B16.11 Forged Steel Fittings, Socket-Welding and Threaded[3]

B16.28 Wrought Steel Butt-Welding Short Radius Elbows and Returns[3]

H35.1 Alloy and Temper Designation Systems for Aluminum[2]

2.1.3 *AWS Standards:*

D10.7-60 Recommended Practices for Gas Shielded-Arc Welding of Aluminum and Aluminum-Alloy Pipe[4]

2.1.4 *Manufacturers' Standardization Society of the Valve and Fittings Industry:*

SP25 Standard Marking System for Valves, Fittings, Flanges and Unions[5]

2.1.5 *ASME Code:*

Section IX Boiler and Pressure Vessel Code[6]

2.1.6 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[7]

2.1.7 *Federal Standards:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[7]

3. Terminology

3.1 *Definitions:*

3.1.1 *producer*—the primary manufacturer of the fittings.

3.1.2 *supplier*—includes only the category of jobbers and distributors as distinct from producers.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *capable of*—The term *capable of* as used in this specification means that the test need not be performed by the producer of the material. However, should testing by the purchaser establish that the material does not meet these

[1] This specification is under the jurisdiction of ASTM Committee B-7 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.03 on Aluminum Alloy Wrought Products.

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[2] *Annual Book of ASTM Standards*, Vol 02.02.

[3] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[4] Available from American Welding Society, 2501 N. W. 7th Street, Miami, FL 33125.

[5] Available from Manufacturers Standardization Society of the Valve and Fittings Industry, 5203 Leesburg Pike, Suite 502, Falls Church, VA 22041.

[6] Available from American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

[7] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

*** A Summary of Changes section appears at the end of this specification.**

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requirements, the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material to this specification shall include the following information:

4.1.1 This specification designation (which includes the number, the year, and the revision letter, if applicable),

4.1.2 Size, shape, and dimensions (8.1),

4.1.3 Quantity in number of pieces,

4.1.4 Alloy (Section 5),

4.1.5 Temper (Section 5),

4.2 Additionally, orders for material to this specification shall include the following information when required by the purchaser:

4.2.1 Whether tension tests of finished fittings are required (9.1),

4.2.2 Whether hydrostatic tests are required (10.2),

4.2.3 Whether inspection or witness of inspection and tests by the purchaser's representative is required prior to material shipment (Section 11),

4.2.4 Whether Practices B 660 applies and, if so, the levels of preservation, packaging, and packing required (14.3), and

4.2.5 Whether certification is required (Section 15).

5. Material

5.1 The aluminum or aluminum-alloy material used in the manufacture of the fittings shall be in accordance with the alloy and temper specified in the order. The material shall be in the form of rod, bar, forgings, sheet, plate, seamless pipe or seamless tube, each of which conforms to all requirements of the applicable ASTM specifications for the particular form and alloy involved. The applicable ASTM specifications and alloy designations are listed in Table 1.

6. Manufacture

6.1 Forging or shaping operations may be performed by hammering, pressing, piercing, rolling, extruding, upsetting, bending, or fusion welding, or by a combination of two or more of these operations. The forming procedure shall be so applied that it will not produce injurious defects in the fittings.

6.2 Manufacturing operations necessitating welded seams or other joining by fusion welding shall have full penetration welds, excepting the lightweight fittings (Note 2), and shall be made in accordance with procedures by welders or welding operators qualified under the requirements of the ASME Boiler and Pressure Vessel Code, Section IX.

NOTE 2—Refer to SP 43, Standard Practice for Stainless Steel Butt Welding Fittings of the Manufacturers' Standardization Society of the Valve and Fittings Industry.

6.3 For welds made in accordance with the ASME Boiler and Pressure Vessel Code, Section IX, the joint shall be reinforced at the center of the weld by at least 1/16 in. (1.6 mm) but not more than 1/8 in. (3.2 mm). Unless otherwise agreed upon between the producer and the purchaser, this reinforcement may be removed at the producer's option. The contour of the reinforcement shall be smooth, with no valley or groove along the edge or in the center of the weld, and the deposited metal shall be fused smoothly and uniformly into the surface of the original material. The finish of the welded joint shall be reasonably smooth and free of irregularities, grooves, or depressions.

7. Responsibility for Quality Assurance

7.1 *Responsibility for Inspection and Tests*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract or order, the producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

7.2 *Lot Definition*—An inspection lot shall consist of all fittings of the same alloy, size, shape, and dimensions subjected to inspection at one time.

8. General Quality

8.1 The sizes, shapes, and dimensions, and, unless otherwise specified, the end preparation (Note 3), shall be as specified for fittings covered by ANSI B16.9, B16.11, and B16.28.

NOTE 3—Other types of end preparations have been developed such as the "V" groove of ANSI B16.9 and B16.11, which appear to be superior to the straight bevel under many circumstances. They may be specified when desired. The so-called "modified vee" end preparation described in AWS D10.7 is one example.

8.2 Unless otherwise specified, the material shall be supplied in the mill finish and shall be uniform as defined by the requirements of this specification and shall be commercially sound. Any requirement not so covered is subject to negotiation between producer and purchaser.

9. Tension Tests

9.1 Tension tests of the finished fittings are not required, unless otherwise agreed upon between the producer and the purchaser and so specified in the order. When tension tests are made, methods of test, test specimens, and sampling frequency shall be agreed upon between the producer and the purchaser.

10. Hydrostatic Tests

10.1 Welding fittings shall be capable of withstanding an internal hydrostatic pressure, calculated according to the following equation, without developing leaks:

$$P = 2St/D$$

where:

P = maximum hydrostatic test pressure (gage), psi (MPa) (Note 5),

S = 0.50 times the minimum specified yield strength of the designated material, psi (MPa),

t = nominal wall thickness, in. (mm) of designated schedule number (Note 6), and

D = outside diameter at bevel, in. (mm).

10.2 Hydrostatic acceptance tests shall be made only when agreed upon between the producer and the purchaser and so specified in the order.

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TABLE 1 Requirements for Aluminum and Aluminum-Alloy Materials Used in the Manufacture of Fittings

Alloy Designation[A,B]	Type of Material	Applicable ASTM Specifications			
		Pipe or Tube	Plate	Bar	Forging
WP1060[C]	99.6 % pure aluminum	B 210 B 221 B 234 B 241/B 241M	B 209	B 211 B 221	...
WP1100[C]	commercially pure low-strength aluminum	B 210 B 221 B 241/B 241M	B 209	B 211 B 221	B 247
WP3003[C]	aluminum-base manganese alloy	B 210 B 221 B 234 B 241/B 241M	B 209	B 211 B 221	B 247
WP Alclad[C] 3003	aluminum-base manganese alloy core, clad on one side (inside only) in case of pipe	B 210 B 221 B 234 B 241/B 241M	B 209		
WP5083[D]	aluminum-base magnesium-manganese alloy	B 210 B 221 B 241/B 241M	B 209	B 221	B 247
WP5086[D]	aluminum-base magnesium-manganese alloy	B 210 B 221 B 241/B 241M	B 209	B 221	
WP5154[C]	aluminum-base magnesium alloy	B 210 B 221	B 209	B 211 B 221	
WP6061	aluminum-base magnesium-silicon heat-treatable alloy	B 210 B 221 B 234 B 241/B 241M	B 209	B 211 B 221	B 247
WP6063	aluminum-base magnesium-silicon heat-treatable alloy	B 210 B 221 B 241/B 241M	...	B 221	...

[A] When fittings are of welded construction, designation shall be supplemented by the suffix "W."
[B] These alloy designations were established in accordance with ANSI H35.1, except for the letter symbols "WP," which denote wrought product.
[C] Fittings in nonheat-treatable alloys 1060, 1100, 3003, Alclad 3003, and 5154 are available only in the F or H112 tempers as covered by the applicable raw material specification.
[D] Fittings in nonheat-treatable alloys 5083 and 5086 are available in the O, F, or H112 tempers as covered by the applicable raw material specification.

NOTE 4—See Appendix X1.

NOTE 5—For nominal wall thicknesses corresponding to schedule numbers, see Specification B 241/B 241M.

11. Source Inspection

11.1 If the purchaser desires that his representative inspect or witness the inspection and testing of the material prior to shipment, such agreement shall be made by the purchaser and producer as part of the purchase contract.

11.2 When such inspection or witness of inspection and testing is agreed upon, the seller shall afford the purchaser's representative all reasonable facilities to satisfy him that the material meets the requirements of this specification. Inspection and tests shall be conducted so there is no unnecessary interference with the producer's operations.

12. Retest and Rejection

12.1 If any material fails to conform to all of the applicable requirements of this specification, it shall be cause for rejection of the inspection lot.

12.2 When there is evidence that a failed specimen was not representative of the inspection lot and when no other sampling plan is provided or approved by the purchaser through the contract or purchase order, at least two additional specimens shall be selected to replace each test specimen that failed. All specimens so selected for retest shall meet the requirements of the specification or the lot shall be subject to rejection.

12.3 Material in which defects are discovered subsequent to inspection may be rejected.

12.4 If material is rejected by the purchaser, the producer or supplier is responsible only for replacement of material to the purchaser. As much as possible of the rejected material shall be returned to the producer or supplier.

13. Identification Marking of Product

13.1 The producer's name or trademark, the size and schedule number, and the material shall be stamped (Note 7), stenciled, or otherwise suitably marked on each fitting. When the size does not permit complete marking, identification marks may be omitted in the sequence specified in SP25, of the Manufacturers' Standardization Society of the Valve and Fittings Industry. Each fitting shall be marked with the alloy designation listed in Table 1. On wall thicknesses thinner than Schedule 40, no stamps or other

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indented marking shall be used.

NOTE 6—If steel stamps are used, care should be taken so that the marking is not deep enough to cause cracks or to reduce the wall thickness of the fittings below the minimum allowed.

14. Packaging and Package Marking

14.1 The material shall be packaged to provide adequate protection during normal handling and transportation, and each package shall contain only one size, alloy, and temper of material unless otherwise agreed. The type of packaging and gross mass of containers shall, unless otherwise agreed, be at the producer's or supplier's discretion, provided that they are such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

14.2 Each shipping container shall be marked with the purchase order number, material size, specification number, alloy and temper, gross and net masses, and the producer's name or trademark.

14.3 When specified in the contract or purchase order, material shall be preserved, packaged, and packed in accordance with the requirements of Practices B 660. The applicable levels shall be as specified in the contract or order. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

15. Certification

15.1 The producer or supplier shall, on request, furnish to the purchaser a certificate stating that each lot has been sampled, tested, and inspected in accordance with this specification, and has met the requirements.

16. Keywords

16.1 aluminum alloy; welding fittings

ANNEX

(Mandatory Information)

A1. ACCEPTANCE CRITERIA FOR INCLUSION OF NEW ALUMINUM AND ALUMINUM ALLOYS IN THIS SPECIFICATION

A1.1 Prior to acceptance for inclusion in this specification, the composition of wrought or cast aluminum or aluminum alloy shall be registered in accordance with ANSI H35.1. The Aluminum Association[8] holds the Secretariat of ANSI H35 Committee and administers the criteria and procedures for registration.

A1.2 If it is documented that the Aluminum Association could not or would not register a given composition, an alternative procedure and the criteria for acceptance shall be as follows:

A1.2.1 The designation submitted for inclusion does not utilize the same designation system as described in ANSI H35.1. A designation not in conflict with other designation systems or a trade name is acceptable.

A1.2.2 The aluminum or aluminum alloy has been offered for sale in commercial quantities within the prior twelve months to at least three identifiable users.

A1.2.3 The complete chemical composition limits are submitted.

A1.2.4 The composition is, in the judgment of the responsible subcommittee, significantly different from that of any other aluminum or aluminum alloy already in the specification.

A1.2.5 For codification purposes, an alloying element is any element intentionally added for any purpose other than grain refinement and for which minimum and maximum limits are specified. Unalloyed aluminum contains a minimum of 99.00 % aluminum.

A1.2.6 Standard limits for alloying elements and impurities are expressed to the following decimal places:

Less than 0.001 %	0.000X
0.001 to but less than 0.01 %	0.00X
0.01 to but less than 0.10 %	
Unalloyed aluminum made by a refining process	0.0XX
Alloys and unalloyed aluminum not made by a refining process	0.0X
0.10 through 0.55 %	0.XX
(It is customary to express limits of 0.30 through 0.55 % as 0.X0 or 0.X5.)	
Over 0.55 %	0.X, X.X, etc.
(except that combined Si+Fe limits for 99.00 % minimum aluminum must be expressed as 0.XX or 1.XX)	

A1.2.7 Standard limits for alloying elements and impurities are expressed in the following sequence: Silicon; Iron; Copper; Manganese; Magnesium; Chromium; Nickel; Zinc (Note A1); Titanium; Other Elements, Each; Other Elements, Total; Aluminum (Note A2).

NOTE A1—Additional specified elements having limits are inserted in alphabetical order of their chemical symbols between zinc and titanium, or are specified in footnotes.

NOTE A2—Aluminum is specified as *minimum* for unalloyed aluminum and as a *remainder* for aluminum alloys.

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APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of 1 kg gives it an acceleration of 1 m/s^2 ($N = kg \cdot m/s^2$). The derived SI unit for pressure or stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference of Weights and Measures. Since 1 ksi = 6 894 757 Pa the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2.

SUMMARY OF CHANGES

This section identifies the principal changes to this standard that have been incorporated since the last issue.

(*1*) Paragraph 1.2 has been added.

(*2*) Section 4 on Ordering Information has been revised and rearranged.

(*3*) Superscript has been corrected for alloys WP Alclad 3003 and WP 5154 in Table 1.

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An American National Standard

Standard Specification for Factory-Made Wrought Nickel and Nickel Alloy Fittings[1]

This standard is issued under the fixed designation B 366; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—Specification B163 was added editorially to Table 1.

1. Scope

1.1 This specification covers wrought welding fittings for pressure piping, factory-made from nickel and nickel alloys. Threaded fittings as covered in ASME B16.11 are also covered by this specification. The term welding applies to butt-welding or socket-welding parts such as 45 and 90° elbows, 180° bends, caps, tees, reducers, lap-joint stub ends, and other types, as covered by ASME B16.9, ASME B16.11, ASME B16.28, MSS SP-43, MSS SP-95, and MSS SP-97.

1.1.1 Class WP fittings are those manufactured to the requirements of ASME B16.9, B16.11, or B16.28.

1.1.2 Class CR fittings are those manufactured to the requirements of MSS SP-43.

1.2 This specification does not apply to cast welding fittings.

1.3 Optional supplementary requirements are provided for fittings where a greater degree of examination is desired. These supplementary requirements call for additional tests. When desired, one or more of these may be specified in the order.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

B 127 Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip[2]

B 160 Specification for Nickel Rod and Bar[2]

B 161 Specification for Nickel Seamless Pipe and Tube[2]

B 162 Specification for Nickel Plate, Sheet, and Strip[2]

B 163 Specification for Seamless Nickel and Nickel Alloy Condenser and Heat-Exchanger Tubes[2]

B 164 Specification for Nickel-Copper Alloy Rod, Bar, and Wire[2]

B 165 Specification for Nickel-Copper Alloy (UNS N04400) Seamless Pipe and Tube[2]

B 166 Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06025, and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Rod, Bar, and Wire[2]

B 167 Specification for Nickel-Chromium-Iron Alloy (UNS N06600, N06601, N06690, N06025, and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Seamless Pipe and Tube[2]

B 168 Specification Nickel-Chromium-Iron Alloys UNS N06600, N06601, N06603, N06690, N06025, and N06045 and Nickel-Chromium-Cobalt-Molybdenum Alloy UNS N06617 Plate, Sheet, and Strip[2]

B 333 Specification for Nickel-Molybdenum Alloy Plate, Sheet, and Strip[2]

B 335 Specification for Nickel-Molybdenum Alloy Rod[2]

B 407 Specification for Nickel-Iron-Chromium Alloy Seamless Pipe and Tube[2]

B 408 Specification for Nickel-Iron-Chromium Alloy Rod and Bar[2]

B 409 Specification for Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip[2]

B 423 Specification for Nickel-Iron-Chromium-Molybdenum-Copper Alloy (UNS N08825 and N08221) Seamless Pipe and Tube[2]

B 424 Specification for Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and UNS N08221) Plate, Sheet, and Strip[2]

B 425 Specification for Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and UNS N08221) Rod and Bar[2]

B 434 Specification for Nickel-Molybdenum-Chromium-Iron Alloys (UNS N10003, UNS N10242) Plate, Sheet, and Strip[2]

B 435 Specification for UNS N06002, UNS N06230, and UNS R30556 Plate, Sheet, and Strip[2]

B 443 Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Plate, Sheet, and Strip[2]

B 444 Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Pipe and Tube[2]

B 446 Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Rod and Bar[2]

[1] This specification is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.07 on Refined Nickel and Cobalt and Their Alloys.

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[2] *Annual Book of ASTM Standards*, Vol 02.04.

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TABLE 1 Permissible Raw Materials

Marking[A]				Product and ASTM Designation[B]		
Corrosion-Resistant Fittings	ASME Pressure Fittings	Alloy	UNS Designation	Pipe or Tube	Plate, Sheet, or Strip	Bar Forging and Forging Stock
CRN	WPN	NI	N02200	B 161	B 162	B 160, B 564
CRNL	WPNL	Ni, Low C	N02201	B 161	B 162	B 160
CRNC[C]	WPNC[C]	Ni-Cu	N04400	B 165	B 127	B 164, B 564
CR HX	WPHX	Ni-Cr-Mo-Fe	N06002	B 619, B 622, B 626	B 435	B 572
CR HG	WPHG	Ni-Cr-Fe-Mo-Cu	N06007	B 619, B 622, B 626	B 582	B 581
CR HC 22	WPHC22	Low C-Ni-Mo-Cr	N06022	B 619, B 622, B 626	B 575	B 574, B 564
CRV602	WPV602	Ni-Cr-Fe	N06025	B 163, B 167	B 168	B 166
CR HG 30	WPHG30	Ni-Cr-Fe-Mo-Cu	N06030	B 619, B 622, B 626	B 582	B 581
CRV45TM	WPV45TM	Ni-Cr-Fe	N06045	B 163, B 167	B 168	B 166
CR2120	WP2120	Ni-Cr-Mo low C	N06058	B 619, B 622, B 626	B 575	B 564, B 574
CR5923	WP5923	Low C-Ni-Cr-Mo	N06059	B 619, B 622, B 626	B 575	B 564, B 574
CR HC 2000	WPHC2000	Low C-Ni-Cr-Mo-Cu	N06200	B 619, B 622, B 626	B 575	B 564, B 574
CRM21	WPM21	Low C-Ni-Cr-Mo-Ta	N06210	B 619, B 622, B 626	B 575	B 564, B 574
CRH230	WPH230	Ni-Cr-W-Mo	N06230	B 619, B 622, B 626	B 435	B 572, B 564
CR HC 4	WPHC4	Low C-Ni-Mo-Cr	N06455	B 619, B 622, B 626	B 575	B 574
CRNCI	WPNCI	Ni-Cr-Fe	N06600	B 167, B 516, B 517	B 168	B 166, B 564
CR603GT	WP603GT	Ni-Cr-Fe-Al	N06603	B 163, B 167, B 516, B 517	B 168	B 166, B 564
CRNCMC	WPNCMC	Ni-Cr-Mo-Cb	N06625	B 444, B 704, B 705	B 443	B 446, B 564
CRIN686	WPIN686	Low C-Ni-Cr-Mo	N06686	B 163, B 619, B 622, B 626	B 575	B 564, B 574
CR626Si	WP626Si	Ni-Cr-Mo-Si	N06219	B 444, B 704, B 705	B 443	B 446, B 564
CR HG3	WPHG3	Ni-Cr-Fe-Mo-Cu	N06985	B 619, B 622, B 626	B 582	B 581
CR20CB	WP20CB	Cr-Ni-Fe-Mo-Cu-Cb stabilized	N08020	B 464, B 468, B 729	B 463	B 472, B 473, B 462
CR3127	WP3127	Low C-Ni-Fe-Cr-Mo-Cu	N08031	B 619, B 622, B 626	B 625	B 564, B 649
CRH120	WPH120	Ni-Cr-Fe	N08120	B 407, B 514, B 515	B 409	B 408, B 564
CR330	WP330	Ni-Fe-Cr-Si	N08330	B 535, B 710	B 536	B 511, B 512
CR6XN	WP6XN	Fe-Ni-Cr-Mo-N	N08367	B 675, B 676, B 690	B 688	B 472, B 564, B 691, B 462
CRNIC	WPNIC	Ni-Fe-Cr	N08800	B 407, B 514, B 515	B 409	B 408, B 564
CRNIC10	WPNIC10	Ni-Fe-Cr	N08810	B 407, B 514, B 515	B 409	B 408, B 564
CRNIC11	WPNIC11	Ni-Fe-Cr	N08811	B 407	B 409	B 408, B 564
CRNICMC	WPNICMC	Ni-Fe-Cr-Mo-Cu	N08825	B 423, B 704, B 705	B 424	B 425, B 564
CR904L	WP904L	Low C-Ni-Fe-Cr-Mo-Cu	N08904	B 673, B 674, B 677	B 625	B 649
CR1925	WP1925	Low C-Ni-Fe-Cr-Mo-Cu	N08925	B 673, B 674, B 677	B 625	B 649
CR1925N	WP1925N	Low C-Ni-Fe-Cr-Mo-Cu-N	N08926	B 673, B 674, B 677	B 625	B 649
CR HB	WPHB	Ni-Mo	N10001	B 619, B 622, B 626	B 333	B 335
CR HN	WPHN	Ni-Mo-Cr-Fe	N10003		B 434	B 573
CR H242	WPH242	Ni-Mo-Cr-Fe	N10242	B 619, B 622, B 626	B 434	B 573, B 564
CR HC 276	WPHC276	Low C-Ni-Mo-Cr	N10276	B 619, B 622, B 626	B 575	B 574, B 564
CRB10	WPB10	Low C-Ni-Mo-Cr-Fe	N10624	B 619, B 622, B 626	B 333	B 335, B 564
CRVB4	WPVB4	Ni-Mo	N10629	B 619, B 622, B 626	B 333	B 335, B 564
CR HB2	WPHB-2	Ni-Mo	N10665	B 619, B 622, B 626	B 333	B 335, B 564
CR HB3	WPHB–3	Ni-Mo	N10675	B 619, B 622, B 626	B 333	B 335, B 564
CRH160	WPH160	Ni-Co-Cr-Si	N12160	B 619, B 622, B 626	B 435	B 564, B 572
CR3033	WP3033	Low C-Cr-Ni-Fe-N	R20033	B 619, B 622, B 626	B 625	B 564, B 649, B 472
CRH556	WPH556	Ni-Fe-Cr-Co	R30556	B 619, B 622, B 626	B 435	B 572

[A] When WP fittings are of welded construction or made from welded pipe, the symbol shall be supplemented with W or WX as applicable. If ultrasonic examination in accordance with 4.2.4.2 or 4.2.5.1 is used, the symbol shall be supplemented by WU or WXU as applicable.

[B] See 2.1 and 4.1.

[C] Yield strength shall be 25 000 psi (172 MPa) min, for all hot-formed, annealed fittings made from WPNC material.

B 462 Specification for Forged or Rolled UNS N06030, UNS N06022, UNS N06200, UNS N08020, UNS N08024, UNS N08026, UNS N08367, UNS N10276, UNS N10665, UNS N10675 and UNS R20033 Alloy Pipe Flanges, Forged Fittings, and Valves and Parts for Corrosive High-Temperature Service[2]

B 463 Specification for UNS N08020, UNS N08026, and UNS N08024 Alloy Plate, Sheet, and Strip[2]

B 464 Specification for Welded UNS N08020, N08024, and N08026 Alloy Pipe[2]

B 468 Specification for Welded UNS N08020, N08024, and N08026 Alloy Tubes[2]

B 472 Specification for UNS N06030, UNS N06022, UNS N06200, UNS N08020, UNS N08026, UNS N08024, UNS N08926, UNS N08367, UNS N10276, UNS N10665, UNS N10675, and UNS R20033 Nickel Alloy Billets and Bars for Reforging[2]

B 473 Specification for UNS N08020, UNS N08026, and UNS N08024 Nickel Alloy Bar and Wire[2]

B 511 Specification for Nickel-Iron-Chromium-Silicon Alloy Bars and Shapes[2]

B 512 Specification for Nickel-Chromium-Silicon Alloy (UNS N08330) Billets and Bars[2]

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B 514 Specification for Welded Nickel-Iron-Chromium Alloy Pipe[2]
B 515 Specification for Welded UNS N08800, UNS N08810, and UNS N08811 Alloy Tubes[2]
B 516 Specification for Welded Nickel-Chromium-Iron Alloy (UNS N06600, UNS N06603, UNS N06025, and UNS N06045) Tubes[2]
B 517 Specification for Welded Nickel-Chromium-Iron Alloy (UNS N06600, UNS N06603, UNS N06025, and UNS N06045) Pipe[2]
B 535 Specification for Nickel-Iron-Chromium-Silicon Alloys (UNS N08330 and UNS N08332) Seamless Pipe and Tube[2]
B 536 Specification for Nickel-Iron-Chromium-Silicon Alloys (UNS N08330 and N08332) Plate, Sheet, and Strip[2]
B 564 Specification for Nickel Alloy Forgings[2]
B 572 Specification for UNS NO6002, UNS N06230, and UNS R30556 Rod[2]
B 573 Specification for Nickel-Molybdenum-Chromium-Iron Alloy (UNS N10003, UNS N10242) Rod[2]
B 574 Specification for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Molybdenum-Chromium-Tantalum, Low-Carbon Nickel-Chromium-Molybdenum-Copper, and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Rod[2]
B 575 Specification for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper, Low-Carbon Nickel-Chromium-Molybdenum-Tantalum, and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip[2]
B 581 Specification for Nickel-Chromium-Iron-Molybdenum-Copper Alloy Rod[2]
B 582 Specification for Nickel-Chromium-Iron-Molybdenum-Copper Alloy Plate, Sheet, and Strip[2]
B 619 Specification for Welded Nickel and Nickel-Cobalt Alloy Pipe[2]
B 622 Specification for Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube[2]
B 625 Specification for UNS N08904, UNS N08925, UNS N08031, UNS N08932, UNS N08926, and UNS R20033 Plate, Sheet, and Strip[2]
B 626 Specification for Welded Nickel and Nickel-Cobalt Alloy Tube[2]
B 649 Specification for Ni-Fe-Cr-Mo-Cu Low-Carbon Alloy (UNS N08904), Ni-Fe-Cr-Mo-Cu-N Low-Carbon Alloys (UNS N08925, UNS N08031, and UNS N08926), and Cr-Ni-Fe-N Low Carbon Alloy (UNS R20033) Bar and Wire[2]
B 673 Specification for UNS N08904, N08925, and N08926 Welded Pipe[2]
B 674 Specification for UNS N08904, N08925, and N08926 Welded Tube[2]
B 675 Specification for UNS N08367 Welded Pipe[2]
B 676 Specification for UNS N08367 Welded Tube[2]
B 677 Specification for UNS N08904, N08925, and N08926 Seamless Pipe and Tube[2]
B 688 Specification for Chromium-Nickel-Molybdenum-Iron (UNS N08366 and UNS N08367) Plate, Sheet, and Strip[2]
B 690 Specification for Iron-Nickel-Chromium-Molybdenum Alloys (UNS N08366 and UNS N08367) Seamless Pipe and Tube[2]
B 691 Specification for Iron-Nickel-Chromium-Molybdenum Alloys (UNS N08366 and UNS N08367) Rod, Bar, and Wire[2]
B 704 Specification for Welded UNS N06625, N06219, and UNS N08825 Alloy Tubes[2]
B 705 Specification for Nickel-Alloy (UNS N06625, N06219, and N08825) Welded Pipe[2]
B 710 Specification for Nickel-Iron-Chromium-Silicon Alloy Welded Pipe[2]
E 165 Test Method for Liquid Penetrant Examination[3]
E 1916 Guide for Identification and/or Segregation of Mixed Lots of Metals[4]

2.2 *ASME Standards:*
B16.9 Wrought Steel Butt Welding Fittings[5]
B16.11 Forged Steel Fittings, Socket-Welding and Threaded[5]
B16.28 Wrought Steel Butt Welding Short Radius Elbows and Returns[5]
H34.1 Nickel Seamless Pipe and Tubing[5]
H34.2 Nickel-Copper Alloy Seamless Pipe and Tubing[5]
H34.3 Nickel-Chromium-Iron Alloy Seamless Pipe and Tubing[5]

2.3 *Manufacturers Standardization Society of the Valve and Fittings Industry Standards:*
MSS SP-25 Standard Marking Systems for Valves, Fittings, Flanges, and Unions[6]
MSS SP-43 Standard Practice for Light Weight Stainless Steel Butt Welding Fittings[6]
MSS SP-95 Sewage (D) Nipples and Bull Plugs[6]
MSS SP-97 Forged Carbon Steel Branch Outlet Fittings–Socket Welding, Threaded and Butt Welding Ends[6]
Boiler and Pressure Vessel Code, Section VIII, Division 1, Pressure Vessels and Section IX, Welding Qualifications[5]

2.5 *AWS Standards:*
A5.11 Specification for Nickel and Nickel Alloy Covered Welding Electrodes[7]
A5.14 Specification for Nickel and Nickel-Alloy Bare Welding Rods and Electrodes[7]

3. Ordering Information

3.1 Orders for fittings under this specification should include the following information:

3.1.1 Quantity, number of fittings of each kind,

[3] *Annual Book of ASTM Standards*, Vol 03.03.
[4] *Annual Book of ASTM Standards*, Vol 03.06.
[5] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.
[6] Available from Manufacturers' Standardization Society of the Valve and Fittings Industry, 1815 N. Fort Myer Drive, Arlington, VA 22209.
[7] Available from American Welding Society, 550 N.W. LeJeune Rd., Miami, FL 33135.

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3.1.2 Description of Fitting and Nominal Dimensions (standard or special),

3.1.3 Alloy Composition,

3.1.4 Class **WP***S**, **WP***W**, **WP***WX**, or **CR***** shall be specified.

3.1.4.1 Class **CR** fittings shall not be substituted for fittings ordered to Class **WP**, but Class **WP** may be substituted for Class **CR**.

3.1.4.2 Unless Class **WP***S**, **WP***W**, or **WP***WX** is specified by the purchaser, any may be furnished at the option of the supplier.

3.1.5 Heat Treatment (4.3 and Appendix X1),

3.1.6 *Purchaser Inspection*—State which tests or inspections are to be witnessed (Section 9),

3.1.7 *Samples for Product (Check) Analysis*—State whether samples shall be furnished (5.3),

3.1.8 Mill test reports (Section 11), and

3.1.9 Supplementary requirements, if any.

4. Materials and Manufacture

4.1 *Material*—The material for wrought welding fittings may consist of forgings, rods, bars, plates, sheets, and seamless or welded pipe that conform to all the requirements of the ASTM specifications for the particular product and alloy referred to in Table 1.

4.2 *Manufacture*:

4.2.1 Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, or fusion welding, or by a combination of two or more of these operations. The forming procedure shall be so applied that it will not produce injurious defects in the fittings.

4.2.2 Fittings ordered as Class **WP***S** shall be of seamless construction and shall meet all requirements of ASME B16.9, B16.11, or B16.28.

4.2.3 All classes of fittings shall have the welders, welding operators, and welding procedures qualified under the provisions of Section IX of the ASME Boiler and Pressure Vessel Code.

4.2.4 Fittings ordered as Class **WP***W** shall meet the requirements of ASME B16.9 or B16.28 and shall have all welds made by the fitting manufacturer radiographically examined throughout the entire length in accordance with Paragraph UW-51 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code, except as exempt by 4.2.4.1, and 4.2.4.2.

4.2.4.1 The weld in the starting pipe, made to one of the pipe or tube product specifications listed in Table 1, shall not require radiography, provided that no filler metal is used in making the weld.

4.2.4.2 . Instead of the radiographic examination, and at the option of the manufacturer, welds made by the fitting manufacturer may be ultrasonically examined in accordance with Appendix XII of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code.

4.2.5 Fittings ordered as Class **WP***WX** shall meet the requirements of ASME B16.9 or B16.28 and shall have all welds, whether made by the fitting manufacturer or the starting material manufacturer, radiographically examined throughout their entire length in accordance with Paragraph UW-51 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code, except as exempt by 4.2.5.1. The radiography for this class of fittings may be done either prior to or after forming at the option of the manufacturer.

4.2.5.1 Instead of the radiographic examination, and at the option of the manufacturer, welds made by the fitting manufacturer may be ultrasonically examined in accordance with Appendix XII of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code.

4.2.6 Fittings covered in MSS SP-43, MSS SP-95, or MSS SP-97 and ordered as **CR***** shall meet the requirements of MSS SP-43, MSS SP-95, or MSS SP-97, respectively, and do not require radiography.

4.2.7 All joints welded with filler metal shall be finished in accordance with the requirements of Paragraph UW-35 (a) of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code.

4.2.8 Radiographic examination of the weld buildup on cold-formed stub ends shall not be required provided that all the following steps are adhered to:

4.2.8.1 The weld procedure and welders or welding operators meet the requirements of 4.2.3.

4.2.8.2 All weld surfaces are liquid penetrant examined in accordance with Appendix 8 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

4.2.8.3 Repair of areas in the weld is permitted, but 4.2.8.1 and 4.2.8.2 must be repeated.

4.2.8.4 Fittings shall be marked with the symbol WBU following the alloy designation (for example: WPN-WBU).

4.3 *Heat Treatment*—Heat treatment, if required, shall be as agreed upon between the manufacturer and the purchaser.

5. Chemical Composition

5.1 The material shall conform to the requirements as to chemical composition for the respective material prescribed in Table 1.

5.2 Records of chemical analysis made in accordance with the applicable specification listed in Table 1 shall be certification that the material of the fitting meets the requirements of this specification.

5.3 If a product (check) analysis is made by the purchaser, the material shall conform to the requirements for product (check) analysis prescribed for the respective product in Table 1.

5.4 In fittings of welded construction, the alloy content of the deposited weld metal shall conform to that required of the base metal or for equivalent weld metal as given in the AWS Filler Metal Specification A 5.11 and A 5.14.

6. Mechanical Properties and Other Requirements

6.1 *Tensile Requirements*:

6.1.1 Material used in the manufacture of the fittings shall conform to the requirements for tensile properties as prescribed for the respective product in Table 1.

6.1.2 Finished fittings shall conform to the properties for the respective material and temper as prescribed in the specifications referred to in Table 1. When required, the properties of fittings made from forging stock shall be as agreed upon between the producer and the purchaser.

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6.1.3 Tension tests of the finished fittings are not required, unless otherwise agreed upon between the manufacturer and the purchaser.

6.2 *Hydrostatic Tests*:

6.2.1 Hydrostatic testing of wrought fittings is not required by this specification.

6.2.2 All fittings shall be capable of withstanding without failure, leakage, or impairment of their serviceability, a test pressure prescribed in the specifications for the pipe with which the fitting is recommended to be used.

7. Dimensions

7.1 Fittings or components produced in accordance with this specification shall have sizes, shapes, and dimensions in accordance with those specified in ASME 16.9, ASME 16.11, ASME 16.28, MSS SP-43, MSS SP-95, MSS SP-97, ASME H34.1, ASME H34.2, or ASME H34.3.

8. Workmanship, Finish, and Appearance

8.1 The fittings shall be free of injurious defects and have a workmanlike finish. Minor defects may be removed by grinding, provided the wall thickness is not decreased to less than the allowable specification minimum and provided the grinding is smooth and leaves no shoulders.

8.2 The fittings shall be cleaned free of scale.

9. Inspection

9.1 Inspection of the material by the purchaser at the place of manufacture shall be made as agreed upon between the purchaser and the manufacturer as part of the purchase contract.

10. Rejection and Rehearing

10.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

11. Certification

11.1 When requested by the purchaser, the manufacturer shall report to the purchaser or his representative the results of the chemical analysis made in accordance with Section 5, the results of the tension tests specified in Section 6, or the use of ultrasonic examination in accordance with 4.2.4.2 or 4.2.5.1, or a combination thereof.

12. Product Marking

12.1 The manufacturer's name or trademark, material, the size and schedule number, the designation as shown in Table 1, under" Marking," either column 1 for class CR fittings or column 2 for class WP fittings, shall be stamped, stenciled, or otherwise permanently marked on each fitting. Class WP fitting marking also must include the suffix in accordance with 4.2. On wall thicknesses thinner than 0.083 in., no steel stamps or other indented markings shall be used. When the size does not permit complete marking, identification marks may be omitted in the sequence shown in MSS SP-25.

NOTE 1—When steel stamps are used, the marking shall not be deep enough to cause cracks or to reduce the wall thickness of the fittings below the minimum allowed by the applicable specification.

13. Keywords

13.1 nickel alloy fittings

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order, in which event the supplementary requirements specified shall be made at the place of manufacture, unless otherwise agreed upon.

S1. Product Analysis (Note S2.1)

S1.1 A product analysis shall be made from each heat of base metal and, if of welded construction, from each lot (Note S2.3) number of welding material of the fittings offered for delivery. The analysis shall conform to the requirements specified in Section 5.

S2. Tension Test (Note S2.1)

S2.1 One tension test shall be made on one fitting or representative test piece (Note S2.1) per lot (Note S2.3) of fittings. If the fittings are of welded construction, the tension specimen shall include the weld and be prepared so that the weld is at the midlength location of the specimen. However, in no case shall the tensile properties of the finished fittings be less than the requirements of the pipe specifications listed in Table 1, except that weld specimens are exempt from the tensile ductility requirements.

NOTE S2.1—If the results of any of the tests specified in Sections S1 or S2 do not conform to requirements, retests may be made at the manufacturer's expense on additional fittings or representative test pieces of double the original number from the same heat or lot as defined in Section S1 or S2. If either of the additional test pieces fails, the lot shall be rejected.

NOTE S2.2—*Representative Test Piece:* Where the test specimen for the tension test cannot be taken from a fitting due to size limitations, a representative test shall be obtained. The test piece shall be from the same heat and heat treated in the same batch or charge as the fittings it represents, and shall have approximately the same amount of working. In addition, test pieces representing fittings manufactured from bars, plate, or forgings shall have a cross section equal to the greatest cross section of the fitting, and test pieces representing fittings manufactured from pipe shall have an outside diameter and wall thickness equal to those of the fitting. The test piece for fittings of welded construction shall be prepared to the

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same weld procedures and from the same heats of material as the fittings it represents.

NOTE S2.3—A lot shall consist of all fittings of the same type, size, and wall thickness, manufactured from one heat of material, and, if welding is performed, using the same size and AWS classification welding product.

S3. Liquid Penetrant Test

S3.1 All surfaces shall be liquid penetrant tested. The method shall be in accordance with Practice E 165. Acceptance limits shall be as specified by the purchaser.

S4. Hydrostatic Test

S4.1 A hydrostatic test shall be applied as agreed upon between the manufacturer and purchaser.

S5. Bar Stock Fittings

S5.1 Fittings machined from solid bar stock are not permitted.

S6. Positive Material Identification Examination

S6.1 Product shall receive Positive Material Identification to ensure that the purchaser is receiving product of the correct material grade prior to shipment of the product. This examination is a method to assure that no material grade mix-up has happened during manufacturing and marking of the product.

S6.2 Product shall receive a Positive Material Identification examination by Guide E 1916.

S6.3 The quantity examined shall be 100 % of the product.

S6.4 All product that is not of the correct material grade shall be rejected.

S6.5 The method of product marking after examination shall be agreed upon between the manufacturer and purchaser.

APPENDIX

(Nonmandatory Information)

X1. HEAT TREATMENT

X1.1 Proper heat treatment during or subsequent to fabrication may be necessary for optimum performance, and the manufacturer shall be consulted for details. The final heat treatment should be consistent with the heat treatment requirements given in the respective pipe or tube specifications.

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Standard Specification for Welded Nickel-Chromium-Iron-Alloy (UNS N06600, UNS N06603, UNS N06025, and UNS N06045) Pipe[1]

This standard is issued under the fixed designation B 517; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification[2] covers welded, cold-worked, and annealed nickel-chromium-iron alloy (UNS N06600,* N06603, N06025, and N06045) pipe for general corrosive service and heat-resisting applications.

1.2 This specification covers outside diameter and nominal wall pipe shown in ANSI B36.19. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

B 775 Specification for General Requirements for Nickel and Nickel Alloy Welded Pipe[3]

2.2 *ANSI Standard:*

B36.19 Stainless Steel Pipe[4]

3. General Requirement

3.1 Material furnished in accordance with this specification shall conform to the applicable requirements of the current edition of Specification B 775 unless otherwise provided herein.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for the safe and satisfactory performance of material ordered under this specification. Examples of such requirements include, but are not limited to, the following:

4.1.1 Alloy name or UNS number.

4.1.2 ASTM designation and year of issue.

4.1.3 Condition (temper).

4.1.4 *Dimensions*:

4.1.4.1 Nominal pipe size or outside diameter and schedule number or nominal wall thickness.

4.1.4.2 Length (specific or random).

4.1.5 Quantity (feet or metres, or number of pieces).

4.1.6 *Certification*—State if certification or a report of test results is required.

4.1.7 *Samples for Product (Check) Analysis*—State whether samples for product (check) analysis should be furnished.

4.1.8 *Purchaser Inspection*—If the purchaser wishes to witness tests or inspection of material at the place of manufacture, the purchase order must so state indicating which tests or inspections are to be witnessed.

5. Materials and Manufacture

5.1 Pipe shall be made from flat-rolled alloy by an automatic welding process with no addition of filler metal. Subsequent to welding and prior to final heat treatment, the material shall be cold worked either in both weld and base metal or in weld metal only.

5.2 Pipe shall be furnished with a scale-free finish. When bright annealing is used, descaling is not necessary.

6. Chemical Composition

6.1 The material shall conform to the requirements as to chemical composition prescribed in Table 1.

6.2 If a product (check) analysis is performed by the purchaser, the material shall conform to the product (check) analysis variations in Table 1 of Specification B 775.

7. Mechanical and Other Requirements

7.1 *Mechanical Properties*—The material shall conform to the requirements for mechanical properties prescribed in Table 2.

7.2 *Flattening Test*—Pipe shall be capable of withstanding, without cracking, flattening under a load applied gradually at room temperature until the distance between the platens is five times the wall thickness. The weld shall be positioned 90° from the direction of the applied flattening force.

7.3 *Nondestructive Test Requirements*:

7.3.1 *Category 1*—Each piece of each lot shall be subject to one of the following four tests: hydrostatic, pneumatic (air underwater), eddy current, or ultrasonic.

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[1] This specification is under the jurisdiction of ASTM Committee B-2 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.07 on Refined Nickel and Cobalt and Their Alloys.

Current edition approved Dec. 10, 1998. Published January 1999. Originally published as B 517 – 70. Last previous edition B 517 – 95.

[2] For ASME Boiler and Pressure Code applications see related Specification SB-517 in Section II of that Code.

* New designation established in accordance with ASTM E527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

[3] *Annual Book of ASTM Standards*, Vol 02.04.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Fl., New York, NY 10036.

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TABLE 1 Chemical Requirements

Element	Composition Limits,%				Product (Check) Analysis Variations, under min or over max, of the Specified Limit of Element
	N06600	N06603	N06025	N06045	
Nickel[A]	72.0 min	Bal	Bal	45.0 min	0.45
Chromium	14.0 min	24.0–26.0	24.0–26.0	26.0–29.0	0.15
	17.0 max				0.25
Iron	6.0 min	8.0–11.0	8.0–11.0	21.0–25.0	0.10
	10.0 max				0.10
Manganese	1.0	0.15 max	0.15 max	1.0 max	0.03
Carbon	0.15 max	20.0-40.0	0.15–0.25	0.05–0.12	0.01
Copper	0.5 max	0.50 max	0.10 max	0.3 max	0.03
Silicon	0.5 max	0.50 max	0.5 max	2.5–3.0	0.03
Sulfur	0.015 max	0.010 max	0.010 max	0.010 max	0.003
Aluminum	...	2.4-3.0	1.8–2.4	...	
Titanium	...	0.01–0.25	0.1–0.2	...	
Phosphorus	...	0.020 max	0.02 max	0.02 max	
Zirconium	...	0.01–0.40	0.01–0.10	...	
Yttrium	...	0.01–0.15	0.05–0.12	...	
Cerium	...	...	...	0.03–0.09	

[A] Nickel shall be determined arithmetically by difference.

TABLE 2 Mechanical Property Requirements

Alloy	Tensile Strength, min, psi (MPa)	Yield Strength, 0.2 % Offset, min, psi (MPa)	Elongation in 2 in. or 50 mm, min, %
N06600	80 000 (550)	35 000 (240)	30
N06603	94 000 (650)	43 000 (300)	25
N06025	98 000 (680)	39 000 (270)	30
N06045	90 000 (620)	35 000 (240)	30

7.3.2 *Category 2*—Each piece in each lot shall be subjected to a leak test and an electric test as follows:

7.3.2.1 *Leak Test*—Hydrostatic or pneumatic (air underwater).

7.3.2.2 *Electric Test*—Eddy current or ultrasonic.

7.4 The manufacturer shall have the option to test Category 1 or Category 2 and select the nondestructive test methods, if not specified by the purchaser.

8. Number of Tests

8.1 *Chemical Analysis*—One per lot.

8.2 *Mechanical Properties*—One test per lot.

8.3 *Flattening*—One test per lot.

8.4 *Nondestructive*—Each piece in each lot.

9. Keywords

9.1 welded pipe; N06600; N06603; N06025; N06045

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Designation: B 584 – 00

Standard Specification for Copper Alloy Sand Castings for General Applications[1]

This standard is issued under the fixed designation B 584; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This specification covers requirements for copper alloy sand castings for general applications. Nominal compositions of the alloys defined by this specification are shown in Table 1.[2] This is a composite specification replacing former documents as shown in Table 1.

NOTE 1—Other copper alloy castings are included in the following ASTM specifications: B 22, B 61, B 62, B 66, B 67, B 148, B 176, B 271, B 369, B 427, B 492, B 505, B 763, B 770, and B 806.

1.2 Component part castings produced to this specification may be manufactured in advance and supplied from stock. In such cases the manufacturer shall maintain a general quality certification of all castings without specific record or date of casting for a specific casting.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

2. Referenced Documents

2.1 *ASTM Standards:*

B 22 Specification for Bronze Castings for Bridges and Turntables[3]
B 61 Specification for Steam or Valve Bronze Castings[3]
B 62 Specification for Composition Bronze or Ounce Metal Castings[3]
B 66 Specification for Bronze Castings for Steam Locomotive Wearing Parts[3]
B 67 Specification for Car and Tender Journal Bearings, Lined[3]
B 148 Specification for Aluminum-Bronze Sand Castings[3]
B 176 Specification for Copper-Alloy Die Castings[3]
B 208 Practice for Preparing Tension Test Specimens for Copper Alloy Sand, Permanent Mold, Centrifugal, and Continuous Castings[3]
B 271 Specification for Copper-Base Alloy Centrifugal Castings[3]
B 369 Specification for Copper-Nickel Alloy Castings[3]
B 427 Specification for Gear Bronze Alloy Castings[3]
B 492 Specification for Cast Copper-Nickel Ship Tailshaft Sleeves[4]
B 505 Specification for Copper-Base Alloy Continuous Castings[3]
B 763 Specification for Copper Alloy Sand Castings for Valve Application[3]
B 770 Specification for Copper-Beryllium Alloy Sand Castings for General Applications[3]
B 806 Specification for Copper Alloy Permanent Mold Castings for General Applications[3]
B 824 Specification for General Requirements for Copper Alloy Castings[3]
B 846 Terminology for Copper and Copper Alloys[3]
E 527 Practice for Numbering Metals and Alloys (UNS)[5]

2.2 *ASME Code:*

ASME Boiler and Pressure Vessel Code[6]

3. Terminology

3.1 Definitions of terms relating to copper alloys can be found in Terminology B 846.

4. General Requirements

4.1 The following sections of Specification B 824 form a part of this specification. In the event of a conflict between this specification and Specification B 824, the requirements of this specification shall take precedence.

4.1.1 Terminology,
4.1.2 Other Requirements,
4.1.3 Dimensions, Mass, and Permissible Variations,
4.1.4 Workmanship, Finish, and Appearance,
4.1.5 Sampling,
4.1.6 Number of Tests and Retests,
4.1.7 Specimen Preparation,
4.1.8 Test Methods,
4.1.9 Significance of Numerical Limits,
4.1.10 Inspection,
4.1.11 Rejection and Rehearing,
4.1.12 Certification,
4.1.13 Test Report,

[1] This practice is under the jurisdiction of ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.05 on Castings and Ingots for Remelting.

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[2] The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix "C" and a suffix "00". The suffix can be used to accommodate composition variations of the base alloy.

[3] *Annual Book of ASTM Standards*, Vol 02.01.

[4] Discontinued—*Annual Book of ASTM Standards*, Vol 02.01.

[5] *Annual Book of ASTM Standards*, Vol 01.01.

[6] Available from the American Society of Mechanical Engineers, United Engineering Center, 345 E. 47th St., New York, NY 10017.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Nominal Compositions

Classification	Copper Alloy UNS No.	Previous Designation	Commercial Designation	Copper	Tin	Lead	Zinc	Nickel	Iron	Aluminum	Manganese	Silicon	Niobium	Bismuth
Leaded red brass	C83450	...	...	88	2½	2	6½	1	...	...	...	...	...	...
	C83600	B 145-4A	85-5-5-5 or No. 1 composition	85	5	5	5	...	...	...	...	...	...	...
	C83800	B 145-4B	commercial red brass, 83-4-6-7	83	4	6	7	...	...	...		...	...	...
Leaded semi-red brass	C84400	B 145-5A	valve composition, 81-3-7-9	81	3	7	9	...	...	...	...	...	...	...
	C84800	B 145-5B	semi-red brass, 76-2½-6½-15	76	2½	6½	15	...	...	...	...	...	...	...
Leaded yellow brass	C85200	B 146-6A	high-copper yellow brass	72	1	3	24	...	...	...	...	...	...	...
	C85400	B 146-6B	commercial No. 1 yellow brass	67	1	3	29	...	...	...	...	...	...	...
	C85700	B 146-6C	leaded naval brass	61	1	1	37	...	...	...	...	...	...	...
High-strength yellow brass	C86200	B 147-8B	high-strength manganese bronze	63	...	...	27	...	3	4	3	...	...	...
	C86300	B 147-8C	high-strength manganese bronze	61	...	...	27	...	3	6	3	...	...	...
	C86400	B 147-7A	leaded manganese bronze	58	1	1	38	...	1	½	½	...	...	...
	C86400	B 132-A												
	C86500	B 147-8A	No. 1 manganese bronze	58	...	...	39	...	1	1	1	...	...	...
	C86700	B 132-B	leaded manganese bronze	58	1	1	34	...	2	2	2	...	...	...
Silicon bronze + silicon brass	C87300	B 198-12A	silicon bronze	95	...	...	...	...	...	...	1	4	...	...
	C87400	B 198-13A	silicon brass	82	...	½	14	...	...	...	...	3½	...	...
	C87500	B 198-13B	silicon brass	82	...	...	14	...	...	...	...	4	...	...
	C87600	B 198-13C	silicon bronze	91	...	...	5	...	...	...	...	4	...	...
	C87610	B 198-12A	silicon bronze	92	...	...	4	...	...	...	...	4	...	...
Bismuth selenium brass	C89510[A]	...	sebiloy I	87	5	...	5	...	...	...	...	...	...	1.0
	C89520[B]	...	sebiloy II	86	5½	...	5	...	...	...	...	...	...	1.9
Bismuth semi-red brass	C89844	...	bismuth brass	84½	4	...	8	...	...	...	...	...	...	3
Tin bronze + leaded tin bronze	C90300	B 143-1B	modified "G" bronze, 88-8-0-4	88	8	...	4	...	...	...	...	...	...	...
	C90500	B 143-1A	"G" bronze, 88-10-0-2	88	10	...	2	...	...	...	...	...	...	...
	C92200	B 143-2A	steam or valve bronze-Navy "M"	88	6	1½	4½	...	...	...	...	...	...	...
	C92210	...	...	88	5	2	4	1	...	...	...	...	...	...
	C92300	B 143-2B	87-5-1-4, Navy PC	87	8	1	4	...	...	...	...	...	...	...
	C92600	...	87-10-1-2	87	10	1	2	...	...	...	...	...	...	...
High-lead tin bronze	C93200	B 144-3B	83-7-7-3	83	7	7	3	...	...	...	...	...	...	...
	C93500	B 144-3C	85-5-9-1	85	5	9	1	...	...	...	...	...	...	...
	C93700	B 144-3A	80-10-10	80	10	10	...	...	...	...	...	...	...	...
	C93800	B 144-3D	78-7-15	78	7	15	...	...	...	...	...	...	...	...
	C94300	B 144-3E	71-5-24	71	5	24	...	...	...	...	...	...	...	...
Nickel-tin bronze + leaded nickel-tin bronze	C94700	B 292-A	nickel-tin bronze Grade "A"	88	5	...	2	5	...	...	...	...	...	...
	C94800	B 292-B	leaded nickel-tin bronze Grade "B"	87	5	1	2	5	...	...	...	...	...	...
	C94900	...	leaded nickel-tin bronze Grade "C"	80	5	5	5	5	...	...	...	...	...	...
Spinodal alloy	C96800	...	...	82	8	...	...	10	...	...	...	...	0.2	...
Leaded nickel bronze	C97300	B 149-10A	12 % leaded nickel silver	57	2	9	20	12	...	...	...	...	...	...
	C97600	B 149-11A	20 % leaded nickel silver	64	4	4	8	20	...	...	...	...	...	...
	C97800	B 149-11B	25 % leaded nickel silver	66	5	2	2	25	...	...	...	...	...	...

[A]Selenium 0.5.
[B]Selenium 0.9.

4.1.14 Product Marking,
4.1.15 Packaging and Package Marking, and
4.1.16 Supplementary Requirements.

5. Ordering Information

5.1 Orders for castings under this specification should include the following information:

5.1.1 Specification title, number, and year of issue,

5.1.2 Quantity of castings,

5.1.3 Copper alloy UNS Number (Table 1) and temper (as-cast, heat treated, and so forth),

5.1.4 Pattern or drawing number, and condition (as-cast, machined, etc.),

5.1.5 *ASME Boiler and Pressure Vessel Code*—compliance (Section 10),

5.1.6 When material is purchased for agencies of the U.S. Government, the Supplementary Requirements of Specification B 824 may be specified.

5.2 The following options are available and should be specified in the purchase order when required:

5.2.1 Chemical analysis of residual elements (7.3),

5.2.2 Pressure test or soundness requirements (Specification B 824),

5.2.3 Approval of weld repair or impregnation, or both (Section 9),

5.2.4 Certification (Specification B 824),

5.2.5 Foundry test report (Specification B 824),

5.2.6 Witness inspection (Specification B 824), and

5.2.7 Product marking (Specification B 824).

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6. Manufacture

6.1 Copper alloy UNS Nos. C94700 and C96800 may be supplied in the heat treated condition to obtain the higher mechanical properties shown in Table 2. Suggested heat treatments for these alloys are given in Table 3. Actual practice may vary by manufacturer.

6.2 Separately cast test bar coupons representing castings made in copper alloy UNS Nos. C94700HT and C96800HT shall be heat treated with the castings.

7. Chemical Composition

7.1 The castings shall conform to the compositional requirements for named elements as shown in Table 4 for the copper alloy UNS numbers specified in the purchase order.

7.2 These specification limits do not preclude the presence of other elements. Limits may be established and analysis required for unnamed elements agreed upon between manufacturer or supplier and purchaser. Copper or zinc, when zinc is 20 % or greater, may be given as remainder and may be taken as the difference between the sum of all elements analyzed and 100 %. When all named elements in Table 4 are analyzed, their sum shall be as specified in Table 5.

7.3 It is recognized that residual elements may be present in cast copper alloys. Analysis shall be made for residual elements only when specified in the purchase order.

TABLE 2 Mechanical Requirements

Copper Alloy UNS No.	Tensile Strength, min		Yield Strength,[A] min		Elongation in 2 in. or 50 mm, min, %
	ksi[B]	MPa[C]	ksi[B]	MPa[C]	
C83450	30	207	14	97	25
C83600	30	207	14	97	20
C83800	30	207	13	90	20
C84400	29	200	13	90	18
C84800	28	193	12	83	16
C85200	35	241	12	83	25
C85400	30	207	11	76	20
C85700	40	276	14	97	15
C86200	90	621	45	310	18
C86300	110	758	60	414	12
C86400	60	414	20	138	15
C86500	65	448	25	172	20
C86700	80	552	32	221	15
C87300	45	310	18	124	20
C87400	50	345	21	145	18
C87500	60	414	24	165	16
C87600	60	414	30	207	16
C87610	45	310	18	124	20
C89510	26	184	17	120	8
C89520	25	176	17	120	6
C89844	28	193	13	90	15
C90300	40	276	18	124	20
C90500	40	276	18	124	20
C92200	34	234	16	110	22
C92210	32	225	15	103	20
C92300	36	248	16	110	18
C92600	40	276	18	124	20
C93200	30	207	14	97	15
C93500	28	193	12	83	15
C93700	30	207	12	83	15
C93800	26	179	14	97	12
C94300	24	165	...	...	10
C94700	45	310	20	138	25
C94700 (HT)	75	517	50	345	5
C94800	40	276	20	138	20
C94900	38	262	15	103	15
C96800	125	862	100[D]	689[D]	3
C96800 (HT)	135	931	120[D]	821[D]	...
C97300	30	207	15	103	8
C97600	40	276	17	117	10
C97800	50	345	22	152	10

[A] Yield strength shall be determined as the stress producing an elongation under load of 0.5 %, that is, 0.01 in. (0.254 mm) in a gage length of 2 in. or 50 mm.
[B] ksi = 1000 psi.
[C] See Appendix X1.
[D] Yield strength 0.2 %, offset.

TABLE 3 Suggested Heat Treatments

Copper Alloy UNS No.	Solution Treatment (not less than 1 h followed by water quench)	Annealing Treatment (not less than 2 h followed by air cool)
C96800	1500°F (815°C)	(Age to develop properties) 660°F (350°C)
	Solution treatment (not less than 2 h followed by water quench)	Precipitation hardening (5 h)
C94700	1425–1475°F (775–800°C)	580–620°F (305–325°C)

8. Mechanical Properties

8.1 Mechanical properties shall be determined from separately cast test bar castings, and shall meet the requirements shown in Table 2.

9. Casting Repair

9.1 The castings shall not be weld repaired without approval of the purchaser (5.2.3).

9.2 The castings shall not be impregnated without approval of the purchaser (5.2.3).

10. ASME Requirements

10.1 When specified in the purchase order to meet ASME Boiler and Pressure Vessel Code requirements, castings in copper alloy UNS Nos. C92200, C93700, and C97600 shall comply with the following:

10.1.1 Certification requirements of Specification B 824.

10.1.2 Foundry test report requirements of Specification B 824.

10.1.3 Castings shall be marked with the manufacturer's name, the copper alloy UNS number, and the casting quality factor. In addition, heat numbers or serial numbers that are traceable to heat numbers shall be marked on all pressure-containing castings individually weighing 50 lbs (22.7 kg) or more. Pressure-containing castings weighing less than 50 lbs (22.7 kg) shall be marked with either the heat number or a serial number that will identify the casting as to the month in which it was poured. Marking shall be in such a position as to not impair the usefulness of the casting.

10.2 The castings shall not be repaired, plugged, welded, or "burned in" unless permission from the purchaser has been previously secured. This will be given only when the defects are such that after the approved repair the usefulness and strength of the castings has not been impaired.

10.3 Alloys in this specification are generally weldable. Preparation for repair welding shall include inspection to ensure complete removal of the defect. Repairs shall be made utilizing welding procedures qualified in accordance with Section IX if the ASME code and repair welding shall be done

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TABLE 4 Chemical Requirements

Copper Alloy UNS No.	Composition, % Max Except as Indicated																		
	Major Elements											Residual Elements							
	Copper	Tin	Lead	Zinc	Iron	Nickel Incl. Cobalt	Alumi-num	Manga-nese	Silicon	Bismuth	Sele-nium	Iron	Anti-mony	Nickel incl. Cobalt	Sulfur	Phos-phorus	Alumi-num	Manga-nese	Silicon	Lead
C83450	87.0–89.0	2.0–3.5	1.5–3.0	5.5–7.5	...	0.75–2.0	...	...	...	...	...	0.30	0.25	...	0.08	0.05	0.005	...	0.005	...
C83600	84.0–86.0	4.0–6.0	4.0–6.0	4.0–6.0	...	1.0[A]	...	...	...	...	...	0.30	0.25	...	0.08	0.05	0.005	...	0.005	...
C83800	82.0–83.8	3.3–4.2	5.0–7.0	5.0–8.0	...	1.0[A]	...	...	...	...	...	0.30	0.25	...	0.08	0.03	0.005	...	0.005	...
C84400	78.0–82.0	2.3–3.5	6.0–8.0	7.0–10.0	...	1.0[A]	...	...	...	...	...	0.40	0.25	...	0.08	0.02	0.005	...	0.005	...
C84800	75.0–77.0	2.0–3.0	5.5–7.0	13.0–17.0	...	1.0[A]	...	...	...	...	...	0.40	0.25	...	0.08	0.02	0.005	...	0.005	...
C85200	70.0–74.0	0.7–2.0	1.5–3.8	20.0–27.0	...	...	...	...	...	...	...	0.6	0.20	1.0	0.05	0.02	0.005	...	0.05	...
C85400	65.0–70.0	0.50–1.5	1.5–3.8	24.0–32.0	...	...	...	...	...	...	...	0.7	...	1.0	...	...	0.35	...	0.05	...
C85700	58.0–64.0	0.50–1.5	0.8–1.5	32.0–40.0	...	...	...	...	...	...	...	0.7	...	1.0	...	...	0.80	...	0.05	...
C86200	60.0–66.0	0.20	0.20	22.0–28.0	2.0–4.0	...	3.0–4.9	2.5–5.0	...	...	...	...	...	1.0	...	...	...	...	...	...
C86300	60.0–66.0	0.20	0.20	22.0–28.0	2.0–4.0	...	5.0–7.5	2.5–5.0	...	...	...	...	...	1.0	...	...	...	...	...	...
C86400	56.0–62.0	0.50–1.5	0.50–1.5	34.0–42.0	0.40–2.0	...	0.50–1.5	0.10–1.0	...	...	...	...	...	1.0	...	...	...	...	...	...
C86500	55.0–60.0	1.0	0.40	36.0–42.0	0.40–2.0	...	0.50–1.5	0.10–1.5	...	...	...	...	...	1.0	...	...	...	...	...	...
C86700	55.0–60.0	1.5	0.50–1.5	30.0–38.0	1.0–3.0	...	1.0–3.0	1.0–3.5	...	...	...	...	...	1.0	...	...	...	...	...	...
C87300	94.0 min	0.20	0.25	...	...	...	...	0.8–1.5	3.6–5.0	...	...	0.20	...	...	...	...	...	...	...	...
C87400	79.0 min	...	1.0	12.0–16.0	...	...	...	...	2.5–4.0	...	...	...	...	...	...	...	0.80	...	...	...
C87500	79.0 min	...	0.50	12.0–16.0	...	...	...	...	3.0–5.0	...	...	...	...	...	...	...	0.50	...	...	...
C87600	88.0 min	...	0.50	4.0–7.0	...	...	...	...	3.5–5.5	...	...	...	...	...	...	...	...	...	...	...
C87610	90.0 min	...	0.20	3.0–5.0	...	...	...	...	3.0–5.0	...	...	0.20	...	...	...	...	...	0.25	...	...
C89510	86.0–88.0	4.0–6.0	0.25	4.0–6.0	0.30	1.0	...	...	...	0.5–1.5	0.35–0.70	...	0.25	...	0.08	0.05	0.005	...	0.005	...
C89520	85.0–87.0	5.0–6.0	0.25	4.0–6.0	0.20	1.0	...	...	...	1.6–2.2	0.8–1.1	...	0.25	...	0.08	0.05	0.005	...	0.005	...
C89844	83.0–86.0	3.0–5.0	...	7.0–10.0	...	1.0[A]	...	...	...	2.0–4.0	...	0.30	0.25	...	0.08	0.05	0.005	...	0.005	0.2
C90300	86.0–89.0	7.5–9.0	0.30	3.0–5.0	...	1.0[A]	...	...	...	...	...	0.20	0.20	...	0.05	0.05	0.005	...	0.005	...
C90500	86.0–89.0	9.0–11.0	0.30	1.0–3.0	...	1.0[A]	...	...	...	...	...	0.20	0.20	...	0.05	0.05	0.005	...	0.005	...
C92200	86.0–90.0	5.5–6.5	1.0–2.0	3.0–5.0	...	1.0[A]	...	...	...	...	...	0.25	0.25	...	0.05	0.05	0.005	...	0.005	...
C92210	86.0–89.0	4.5–5.5	1.7–2.5	3.0–4.5	...	0.7–1.0	...	...	...	...	...	0.25	0.20	...	0.05	0.03	0.005	...	0.005	...
C92300	85.0–89.0	7.5–9.0	0.30–1.0	2.5–5.0	...	1.0[A]	...	...	...	...	...	0.25	0.25	...	0.05	0.05	0.005	...	0.005	...
C92600	86.0–88.5	9.3–10.5	0.8–1.5	1.3–2.5	...	0.7[A]	...	...	...	...	...	0.20	0.25	...	0.05	0.03	0.005	...	0.005	...
C93200	81.0–85.0	6.3–7.5	6.0–8.0	2.0–4.0	...	1.0[A]	...	...	...	...	...	0.20	0.35	...	0.08	0.15	0.005	...	0.005	...
C93500	83.0–86.0	4.3–6.0	8.0–10.0	2.0	...	1.0[A]	...	...	...	...	...	0.20	0.30	...	0.08	0.05	0.005	...	0.005	...
C93700	78.0–82.0	9.0–11.0	8.0–11.0	0.8	...	1.0[A]	...	...	...	...	...	0.15	0.50	...	0.08	0.15	0.005	...	0.005	...
C93800	75.0–79.0	6.3–7.5	13.0–16.0	0.8	...	1.0[A]	...	...	...	...	...	0.15	0.80	...	0.08	0.05	0.005	...	0.005	...
C94300	67.0–72.0	4.5–6.0	23.0–27.0	0.8	...	1.0[ABC]	...	...	...	...	...	0.15	0.80	...	0.08	0.05	0.005	...	0.005	...
C94700	85.0–90.0	4.5–6.0	0.10	1.0–2.5	...	4.5–6.0	...	...	...	...	...	0.25	0.15	...	0.05	0.05	0.005	0.20	0.005	...
C94800	84.0–89.0	4.5–6.0	0.30–1.0	1.0–2.5	...	4.5–6.0	...	...	...	...	...	0.25	0.15	...	0.05	0.05	0.005	0.20	0.005	...
C94900	79.0–81.0	4.0–6.0	4.0–6.0	4.0–6.0	...	4.0–6.0	...	...	...	...	...	0.30	0.25	...	0.08	0.05	0.005	0.10	0.005	...
C96800	remainder	...	0.005	1.0	0.50	9.5–10.5	0.10	0.05–0.30	...	...	...	...	0.02	...	0.0025	0.005	...	...	...	...
C97300	53.0–58.0	1.5–3.0	8.0–11.0	17.0–25.0	1.5	11.0–14.0	...	...	...	...	...	...	0.35	...	0.08	0.05	0.005	0.50	0.15	...
C97600	63.0–67.0	3.5–4.5	3.0–5.0	3.0–9.0	1.5	19.0–21.5	...	...	...	...	...	...	0.25	...	0.08	0.05	0.005	1.0	0.15	...
C97800	64.0–67.0	4.0–5.5	1.0–2.5	1.0–4.0	1.5	24.0–27.0	...	...	...	...	...	...	0.20	...	0.08	0.05	0.005	1.0	0.15	...

[A] In determining copper minimum, copper may be calculated as copper plus nickel.
[B] It is possible that the mechanical requirements of copper alloy UNS No. C94700 (heat treated) will not be obtained if the lead content exceeds 0.01 %.
[C] Niobium 0.10–0.30 %, boron 0.001 % max, bismuth 0.001 % max, magnesium 0.0005–0.15 %, and titanium 0.01 % max.

TABLE 5 Sum of All Named Elements Analyzed

Copper Alloy UNS Number	Copper Plus Major Elements, % Minimum
C83450	99.3
C83600	99.3
C83800	99.3
C84400	99.3
C84800	99.3
C85200	99.1
C85400	98.9
C85700	98.7
C86200	99.0
C86300	99.0
C86400	99.0
C86500	99.0
C86700	99.0
C87300	99.5
C87400	99.2
C87500	99.5
C87600	99.5
C87610	99.5
C89510	99.3
C89520	99.3
C89844	99.3
C90300	99.4
C90500	99.7
C92200	99.3
C92210	99.3
C92300	99.3
C92600	99.3
C93200	99.2
C93500	99.4
C93700	99.0
C93800	98.9
C94300	99.0
C94700	99.3
C94800	99.3
C94900	99.2
C96800	99.5
C97300	99.0
C97600	99.7
C97800	99.6

by welders or welding operators meeting the qualification requirements of ASME Section IX. The following records shall be maintained:

10.3.1 A sketch or drawing showing the dimensions, depth, and location of excavations,

10.3.2 Postweld heat treatment, when applicable,

10.3.3 Weld repair inspection results,

10.3.4 Casting identification number,

10.3.5 Weld procedure identification number,

10.3.6 Welder identification, and

10.3.7 Name of inspector.

11. Sampling

11.1 Test bar castings for copper alloy UNS Nos. C86200, C86300, C86400, C86500, and C86700 shall be cast to the form and dimensions shown in Figs. 1 or 2 of Practice B 208. Test bar castings for all other alloys listed in this specification shall be cast to the form and dimensions shown in Figs. 2, 3, or 4 of Practice B 208.

11.2 When castings are specified to meet the requirements of the ASME Boiler and Pressure Vessel Code, for small remelts the lot size shall not exceed 1000 lbs (455 kg) of castings and shall consist of all of the metal from a single master heat poured from an individual melting unit or group of melting units operating during the course of one-half shift, not to exceed 5 h.

12. Test Methods

12.1 Analytical chemical methods are given in Specification B 824.

13. Keywords

13.1 copper alloy castings; copper-base alloy castings; sand castings

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APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force that when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = kg \cdot m/s^2$). The derived SI unit for pressure or stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since 1 ksi = 6 894 757 Pa, the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2.

SUMMARY OF CHANGES

Committee B05 has identified the location of selected changes to this standard since the last issue (B 584 - 98) that may impact the use of this standard.

(*1*) Table 1 revised to include Bismuth Selenium Brass C89510.
(*2*) Table 4 revised to include C89510.
(*3*) Table 5 revised to include C89510.
(*4*) Table 2 revised to include C89510.

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Standard Specification for Welded Copper-Alloy Pipe[1]

This standard is issued under the fixed designation B 608; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification establishes the requirements for arc-welded pipe for use in brackish water or seawater piping systems.

1.2 Values stated in inch-pound units are the standard. SI values given in parentheses and in the tables are for information only.

1.3 The following hazard statement pertains only to the test method described in 8.2 and 14.3.2 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

B 169 Specification for Aluminum Bronze Plate, Sheet, Strip, and Rolled Bar[2]

B 171 Specification for Copper-Alloy Plate and Sheet for Pressure Vessels, Condensers, and Heat Exchangers[2]

E 8 Test Methods for Tension Testing of Metallic Materials[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)[5]

E 76 Test Methods for Chemical Analysis of Nickel-Copper Alloys[5]

E 190 Test Method for Guided Bend Test for Ductility of Welds[3]

E 255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition[5]

E 478 Test Methods for Chemical Analysis of Copper Alloys[5]

2.2 *AWS Standards:*[6]

A 5.7 Copper and Copper-Alloy Arc-Welding Electrodes

A 5.7 Copper and Copper-Alloy Welding Rods

2.3 *ASME Standards:*[7]

Boiler and Pressure Vessel Code, Nuclear Power Plant Components, Section III, Division I

Boiler and Pressure Vessel Code, Nondestructive Examination, Section V

Boiler and Pressure Vessel Code, Pressure Vessels, Section VIII, Division I

Boiler and Pressure Vessel Code, Welding Qualifications, Section IX

3. Terminology

3.1 *Definitions:*

3.1.1 *arc-welding, n*—a group of welding processes wherein coalescence is produced by heating with an electric arc or arcs, with or without the application of pressure and with or without the use of filler metal.

3.1.2 *as-welded condition, n*—the result of forming annealed sheet or plate into tubular form and welding without subsequent heat treatment or cold work.

3.1.3 *base metal, n*—the sheet or plate from which the pipe is formed.

3.1.4 *weld reinforcement, n*—the portion of the welded joint which extends beyond the inner and outer surface of the base metal of the welded pipe.

3.2 *Terms Specific to This Specification:*

3.2.1 *capable of, adj*—possessing the required properties or characteristics, or both, necessary to conform to specification requirements when subjected to specified test(s).

3.2.2 *rehearing, n*—a petition by the manufacturer or supplier to the purchaser, as a result of material rejection, for additional testing to be conducted by the manufacturer or supplier and the purchaser. Identical samples of the product are to be tested by both parties using a method(s) specified in the product specification. Alternatively, upon agreement of both parties, an independent laboratory may be selected for the tests using the specified methods.

4. Ordering Information

4.1 Contracts or purchase orders for product furnished under this specification should include the following information:

4.1.1 ASTM specification designation and year of issue, (for example, B 608 – XX),

4.1.2 Copper alloy UNS No. required (Section 5 and Table 1),

4.1.3 Dimensions required; diameter and wall thickness (Section 10),

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.04 on Pipe and Tube.

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[2] *Annual Book of ASTM Standards*, Vol 02.01.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 03.05.

[6] Available from the American Welding Society, 2501 North West 7th Street, Miami, FL 33125.

[7] Available from the American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

*** A Summary of Changes section appears at the end of this specification.**

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4.1.4 Unit length required, and

4.1.5 When purchased for *ASME Boiler and Pressure Vessel Code* application.

4.2 The following options are available:

4.2.1 Determination of chemical composition (Section 6.1.1),

4.2.2 Guided bend test (Section 8.1),

4.2.3 Hydrostatic test (Section 8.2),

4.2.4 Radiographic examination (Section 8.3),

4.2.4.1 The number of pipe lengths to be examined,

4.2.5 Liquid penetration examination (Section 8.4),

4.2.6 Weld reinforcement removal, (Section 8.5),

4.2.7 Certification (Section 18), and

4.2.8 Test Report (Section 19).

5. Material and Manufacture

5.1 *Material:*

5.1.1 The pipe shall be made from annealed copper alloy sheet or plate that conforms to the requirements of Specification B 169 for Copper Alloys UNS Nos. C61300 and C61400 or Specification B 171 for Copper Alloys UNS Nos. C70600 and C71500.

5.2 *Manufacture:*

5.2.1 Welded joints shall be made either manually or automatically by an arc welding process.

5.2.2 Filler metal, if used in an arc-welding process, shall conform to one of the following specifications and classifications shown for each base metal:

Base Metal Copper Alloy UNS Number	Filler Metal AWS Specification	
	A5.6	A5.7
C61300	ECuAl-A2	ERCuAl-A2
C61400	ECuAl-A2	ERCuAl-A2
C70600	ECuNi	ERCuNi
C71500	ECuNi	ERCuNi

5.2.3 Welding procedures and welding operators shall be qualified in accordance with the *ASME Boiler and Pressure Vessel Code*, Section IX.

5.2.4 Each length of pipe may contain more than one longitudinal welded joint.

5.2.4.1 The welded joint shall be a full-penetration weld and may have a reinforcing bead on each side; such reinforcement shall not be more than 1/16 in. (1.6 mm) per side measured in the radial direction.

5.2.4.2 At no place shall the thickness of the weld section be less than the thickness of the adjacent base metal.

5.2.4.3 The contour of the weld bead shall be smooth, having no sharp valley or groove at the weld center or edges.

5.2.4.4 Smooth concavity of the weld bead contour is acceptable provided the minimum weld bead thickness is not less than the thickness of the adjacent base metal.

5.2.4.5 Any offset of base metal edges at a weld that is within the tolerance of 9.2.7 shall be faired at a 3 to 1 minimum taper over the width of the finished weld, or if necessary, by adding additional weld metal beyond what would otherwise be the edge of the weld. Such build-up welding shall be performed in accordance with the requirements of 5.2.3.

5.2.4.6 Weld reinforcement may be removed at the option of the manufacturer or when specified by the purchaser.

5.2.5 Weld defects shall be repaired by removal to sound metal and rewelding. A repaired weld shall meet all requirements of an original weld.

5.2.6 Base metal defects such as slivers, inclusions or laps shall be repaired by removal to sound metal. Build-up welding shall be performed when such removal reduces the wall thickness below the minimum allowed by the specification. Such build-up welding shall be performed in accordance with the requirements of 5.2.3. The thickness of the repaired section shall meet the requirements of a welded joint.

5.2.7 Pipe shall be furnished in the as-welded condition (Section 3).

NOTE 1—Although no restriction is placed on the size of pipe that may be furnished under this specification, usuage is normally limited to normal sizes 4 in. (101 mm) and larger in diameter.

6. Chemical Composition

6.1 The pipe material shall conform to the requirements of Table 1 for the specified alloy.

6.1.1 When the material of manufacturer has been certified to conform to the requirements of the strip specification to which it was ordered, the determination of composition is not required of the tube manufacturer or supplier unless specified in the contract or purchase order.

6.2 These specified limits do not preclude the presence of other elements. Limits may be established and analysis required for unnamed elements by agreement between the manufacturer or supplier and the purchaser.

6.3 When determining composition, copper may be taken as the difference between the sum of results for specified elements and 100 %.

6.4 When all elements in Table 1 for the specified alloy are determined the sum of results shall be as follows:

Copper Alloy UNS No.	Copper Plus Specified Elements, Percent, %, Minimum
C61300	99.8
C61400, C70600, C71500	99.5

7. Mechanical Property Requirements

7.1 *Transverse Tensional Strength:*

7.1.1 With the test taken across any weld, the pipe shall be capable of conforming to the value given in Table 2 for the particular alloy.

8. Performance Requirements

8.1 *Transverse Guided-Bend Test:*

8.1.1 The transverse face and root guided bend test shall be taken with the weld in the center of the test specimen and there shall be no open defects exceeding 0.125 in. (3.18 mm) measured in any direction on the convex surface of the specimen when tested in accordance with Test Methods E 190. Cracks originating from corners of the specimen shall not be considered.

8.1.2 This test is not required unless specified in the contract or purchase order.

8.2 *Hydrostatic Test:*

8.2.1 Each length of pipe shall be capable of withstanding an internal hydrostatic pressure sufficient to produce a fiber stress of 7 000 psi (48 MPa) without showing evidence of weakness, defects, or leakage.

8.2.1.1 This requirement is not recommended for pipe with an outside diameter greater than 24 in. (610 mm).

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TABLE 1 Chemical Requirements

Copper Alloy UNS Number	Copper[A]	Nickel incl Cobalt	Aluminum	Lead, max	Iron	Zinc, max	Manganese, max	Sulfur, max	Phosphorus, max	Carbon, max	Tin
				Composition, %							
C61300[B]	remainder	0.15 max	6.0–7.5	0.01	2.0–3.0	0.10	0.20	...	0.015	...	0.20–0.50
C61400	remainder	...	6.0–8.0	0.01	1.5–3.5	0.20	1.0	...	0.015	...	...
C70600	remainder	9.0–11.0	...	0.02	1.0–1.8	0.50	1.0	0.02	0.02	0.05	...
C71500	remainder	29.0–33.0	...	0.02	0.4–1.0	0.50	1.0	0.02	0.02	0.05	...

[A] Silver counting as copper.

[B] When the product is for subsequent welding applications and is so specified by the purchaser, chromium shall be 0.05 % max, cadmium 0.05 % max, zinc 0.05 % max, and zirconium 0.05 % max.

TABLE 2 Transverse Tensile Strength

Copper Alloy UNS Number	Tensile Strength, min, ksi (MPa)[A]
C61300	70 (485)
C61400	70 (485)
C70600	40 (275)
C71500	50 (345)

[A] See Appendix X1.

8.2.2 No pipe size need be subjected to a pressure gage reading greater than 1 000 psi (6 900 kPa).

8.2.3 This test is not required unless specified in the contract or purchase order.

8.3 *Radiographic Examination:*

8.3.1 When specified in the contract or purchase order, pipe shall be examined in accordance with the procedure and acceptance criteria of the *ASME Boiler and Pressure Vessel Code*, Section III, Division 1, or Section VIII, Division 1, as specified.

8.3.1.1 The number of pipe lengths to be examined shall be specified by the purchaser.

8.3.2 All welded joints in any individual length of pipe shall be radiographed completely.

8.4 *Liquid Penetration Examination:*

8.4.1 When specified in the contract or purchase order, all welded joints in all lengths of pipe shall be examined, both the inside and outside surfaces, in accordance with the procedure and acceptance criteria of the *ASME Boiler and Pressure Vessel Code*, Section III, Division 1, or Section VIII, Division 1, as specified.

9. Weld Reinforcement Removal

9.1 When specified in the contract or purchase order, weld reinforcement shall be completely removed from the inside surface and outside surface longitudinal welded joints.

9.2 Weld thickness shall conform to wall thickness requirements after removal of reinforcement.

10. Dimensions and Permissible Variations

10.1 *Dimensions:*

10.1.1 Pipe diameter shall be specified as a nominal diameter in inches as shown in Tables 3, 4, or 5.

10.1.2 Pipe wall thickness shall be that shown in Tables 3, 4, or 5 for the diameter and pressure class specified.

10.1.3 If a pipe outside diameter or wall thickness, not specified in Tables 3, 4, or 5 is desired, the diameter and the wall thickness shall be specified in decimal fractions of an inch.

TABLE 3 Standard Sizes and Wall Thickness

Copper Alloy UNS Nos. C61300 and C61400

Diameter, in.		Inch-Pound Units, Thickness, in. Pressure Class, psi[A]				
Nominal	Outside	50	75	100	150	200
4	4.50	0.094	0.094	0.094	0.094	0.094
5	5.563	0.094	0.094	0.094	0.094	0.094
6	6.625	0.094	0.094	0.094	0.094	0.094
8	8.625	0.094	0.094	0.094	0.094	0.094
10	10.75	0.094	0.094	0.094	0.125	0.125
12	12.75	0.094	0.094	0.094	0.125	0 165
14	14.00	0.125	0.125	0.125	0.125	0 165
16	16.00	0.125	0.125	0.125	0.134	0 187
18	18.00	0.125	0.125	0.125	0.165	0.187
20	20.00	0.125	0.125	0.125	0.165	0.250
24	24.00	0.125	0.125	0.134	0.187	0.250
30	30.00	0.134	0.134	0.165	0.250	0.312
36	36.00	0.134	0.165	0.187	0.312	0.375
42	42.00	0.187	0.187	0.250	0.312	0.437
48	48.00	0.187	0.187	0.250	0.375	0.437

Diameter, in.		SI Units, Thickness, mm Pressure Class, kPa[A]				
Nominal	Outside	345	517	689	1034	1379
4	4.50	2.38	2.38	2.38	2.38	2.38
5	5.563	2.38	2.38	2.38	2.38	2.38
6	6.625	2.38	2.38	2.38	2.38	2.38
8	8.625	2.38	2.38	2.38	2.38	2.38
10	10.75	2.38	2.38	2.38	3.18	3.18
12	12.75	2.38	2.38	2.38	3.18	4.19
14	14.00	3.18	3.18	3.18	3.18	4.19
16	16.00	3.18	3.18	3.18	3.40	4.76
18	18.00	3.18	3.18	3.18	4.19	4.76
20	20.00	3.18	3.18	3.18	4.76	6.35
24	24.00	3.18	3.18	3.40	4.76	6.35
30	30.00	3.40	3.40	4.19	6.35	7.94
36	36.00	3.40	4.19	4.76	7.94	9.53
42	42.00	4.76	4.76	6.35	7.94	11.1
48	48.00	4.76	4.76	6.35	9.53	11.1

[A] Pressure ratings apply to any design temperature not exceeding 350°F (176°C). Pressure ratings are calculated for each size and pressure class based on a corrosion allowance of 0.020 in. (0.508 mm), a weld efficiency of 70 %, and the thickness tolerances shown in Table 8.

10.1.4 Pipe shall be furnished in 12-ft (3.66-m) lengths unless otherwise specified.

10.1.5 Circumferential welds, of the same quality as the longitudinal welds, may be used to create pipe lengths that are ordered longer than 12 ft (3.66 m).

10.2 *Permissible Variations:*

10.2.1 *Outside Diameter*—The average outside diameter shall not vary from the specified outside diameter by more

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TABLE 4 Standard Sizes and Wall Thickness
Copper Alloy UNS No. C70600

Inch-Pound Units, Thickness, in.						
Diameter, in.		Pressure Class, psi[A]				
Nominal	Outside	50	75	100	150	200
4	4.50	0.094	0.094	0.094	0.094	0.109
5	5.563	0.094	0.094	0.094	0.094	0.125
6	6.625	0.094	0.094	0.094	0.109	0.134
8	8.625	0.094	0.094	0.094	0.148	0.165
10	10.75	0.094	0.094	0.125	0.165	0.250
12	12.75	0.094	0.125	0.134	0.187	0.250
14	14.00	0.125	0.125	0.148	0.250	0.250
16	16.00	0.125	0.125	0.165	0.250	0.312
18	18.00	0.125	0.148	0.187	0.250	0.312
20	20.00	0.125	0.148	0.187	0.312	0.375
24	24.00	0.134	0.187	0.250	0.312	0.437
30	30.00	0.148	0.250	0.312	0.437	0.500
36	36.00	0.187	0.250	0.312	0.500	0.625
42	42.00	0.250	0.312	0.375	0.562	0.687
48	48.00	0.250	0.312	0.437	0.625	0.812
SI Units Thickness, mm						
Diameter, in.		Pressure Class, kPa[A]				
Nominal	Outside	345	517	689	1034	1379
4	4.50	2.38	2.38	2.38	2.38	2.77
5	5.563	2.38	2.38	2.38	2.38	3.18
6	6.625	2.38	2.38	2.38	2.77	3.40
8	8.625	2.38	2.38	2.38	3.76	4.19
10	10.75	2.38	2.38	3.18	4.19	6.35
12	12.75	2.38	3.18	3 40	4.76	6.35
14	14.00	3.18	3.18	3.76	6.35	6.35
16	16.00	3.18	3.18	4.19	6.35	7.94
18	18.00	3.18	3.76	4.76	6.35	7.94
20	20.00	3.18	3.76	4.76	7.94	9.53
24	24.00	3.40	4.76	6.35	7.94	11.1
30	30.00	3.76	6.35	7.94	11.1	12.7
36	36.00	4.76	6.35	7.94	12.7	15.9
42	42.00	6.35	7.94	9.53	14.3	17.5
48	48.00	6.35	7.94	11.1	15.9	20.6

[A] Pressure ratings apply to any design temperature not exceeding 150°F (65°C). Pressure ratings are calculated for each size and pressure class based on a corrosion allowance of 0.020 in. (0.508 mm), a weld efficiency of 70 %, and the thickness tolerances shown in Table 8.

TABLE 5 Standard Sizes and Wall Thicknesses
Copper Alloy UNS No. C71500

Inch-Pound Units, Thickness, in.						
Diameter, in.		Pressure Class, psi[A]				
Nominal	Outside	50	75	100	150	200
4	4.50	0.094	0.094	0.094	0.094	0.094
5	5.563	0.094	0.094	0.094	0.094	0.109
6	6.625	0.094	0.094	0.094	0.094	0.125
8	8.625	0.094	0.094	0.094	0.125	0.148
10	10.75	0.094	0.094	0.125	0.148	0.165
12	12.75	0.094	0.094	0.125	0.165	0.250
14	14.00	0.125	0.125	0.125	0.187	0.250
16	16.00	0.125	0.125	0.148	0.187	0.250
18	18.00	0.125	0.125	0.165	0.250	0.312
20	20.00	0.125	0.134	0.165	0.250	0.312
24	24.00	0.125	0.165	0.187	0.312	0.375
30	30.00	0.134	0.187	0.250	0.375	0.437
36	36.00	0.165	0.250	0.312	0.437	0.500
42	42.00	0.187	0.250	0.312	0.437	0.625
48	48.00	0.187	0.312	0.375	0.500	0.687
SI Units, Thickness, mm						
Diameter, in.		Pressure Class, kPa[A]				
Nominal	Outside	345	517	689	1034	1379
4	4.50	2.38	2.38	2.38	2.38	2.38
5	5.563	2.38	2.38	2.38	2.38	2.77
6	6.625	2.38	2.38	2.38	2.38	3.18
8	8.625	2.38	2.38	2.38	3.18	3.76
10	10.75	2.38	2.38	3.18	3.76	4.19
12	12.75	2.38	2.38	3.18	4.19	6.35
14	14.00	3.18	3.18	3.18	4.76	6.35
16	16.00	3.18	3.18	3.76	4.76	6.35
18	18.00	3.18	3.18	4.19	6.35	7.94
20	20.00	3.18	3.40	4.19	6.35	7.94
24	24.00	3.18	4.19	4.76	7.94	9.53
30	30.00	3.40	4.76	6.35	9.53	11.1
36	36.00	4.19	6.35	7.94	11.1	12.7
42	42.00	4.76	6.35	7.94	11.1	15.9
48	48.00	4.76	7.94	9.53	12.7	17.5

[A] Pressure ratings apply to any design temperature not exceeding 150°F (65°C). Pressure ratings are calculated for each size and pressure class based on a corrosion allowance of 0.020 in. (0.508 mm), a weld efficiency of 70 %, and the thickness tolerances shown in Table 8.

than the tolerances specified in Table 6.

10.2.2 *Roundness*—The difference between the major and minor outside diameter at any pipe cross section shall not be greater than the differences specified in Table 7.

10.2.3 *Wall Thickness*—The wall thickness at any point of the pipe shall not vary from the specified wall thickness by more than the tolerances specified in Table 8.

10.2.4 *Length*—The length of any pipe shall be the specified length plus or minus 0.500 in. (13 mm).

10.2.5 *Straightness*—The maximum curvature (depth of arc), when measured as a deviation from a straightedge 10 ft (3.05 m) in length, shall not exceed 0.5 in. (13 mm).

10.2.6 *Squareness of Cut*—The departure from squareness of the end of any pipe shall not exceed 0.016 in./in. (0.016 mm/mm) of outside diameter.

10.2.7 *Offset*—Radial misalignment of two edges to be butt welded shall not exceed the offset tolerances specified in Table 9.

TABLE 6 Average Outside Diameter[A] Tolerances, in. (mm)

Specified Outside Diameter	Tolerance, plus and minus
Up to 8.625 (219), incl	0.031 (0.79)
Over 8.625 to 18 (219 to 457), incl	0.063 (1.6)
Over 18 to 30 (457 to 762), incl	0.094 (2.4)
Over 30 to 48 (762 to 1220), incl	0.125 (3.2)
Over 48 (1220)	0.3 %

[A] The average outside diameter of a pipe is the outside circumference at any one cross section of the pipe divided by 3.1416.

TABLE 7 Roundness[A] Requirements

Specified Outside Diameter, in. (mm)	Roundness, %[A]
Up to 8.625 (219), incl	3.0
Over 8.625 to 18 (219 to 457), incl	2.5
Over 18 to 24 (457 to 610), incl	2.0
Over 24 to 48 (610 to 1220), incl	1.5
Over 48 (1220)	1.0

[A] The roundness of a pipe is the difference between the major and minor outside pipe diameter, as determined at any one cross section, divided by the specified outside diameter and expressed in percent.

11. Workmanship, Finish, and Appearance

11.1 *Workmanship:*

11.1.1 Roundness, straightness, ovality, and uniformity of contour shall be such as to make the product suitable for the intended application.

11.2 *Finish:*

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TABLE 8 Wall Thickness Tolerances,[A] in. (mm)

Specified Wall Thickness	Tolerance, plus and minus
Up to 0.094 (2.38), incl	0.010 (0.25)
Over 0.094 to 0.134 (2.38 to 3.40), incl	0.014 (0.36)
Over 0.134 to 0.250 (3.40 to 6.35), incl	0.016 (0.41)
Over 0.250 to 0.500 (6.35 to 12.7), incl	0.023 (0.58)
Over 0.500 to 0.750 (12.7 to 19.1), incl	0.029 (0.74)
Over 0.750 to 1.000 (19.1 to 25.4), incl	0.037 (0.94)
Over 1.000 (25.4)	0.045 (1.10)

[A] Maximum deviation at any point.

TABLE 9 Weld Offset Tolerances, in. (mm)

Specified Wall Thickness (*t*)	Radial Offset Longitudinal Circumferential	
	Weld	Weld
Up to 0.125 (3.18), incl	¼ *t*	¼ *t*
Over 0.125 to 0.250 (3.18 to 6.35), incl	0.032 (0.81)	0.032 (0.81)
Over 0.250 to 0.375 (6.35 to 9.53), incl	0.047 (1.20)	0.047 (1.20)
Over 0.375 to 0.500 (9.53 to 12.7), incl	0.063 (1.60)	0.063 (1.60)
Over 0.500 to 0.750 (12.7 to 19.1), incl	0.063 (1.60)	0.094 (2.40)
Over 0.750 (19.1)	0.094 (2.40)	0.125 (3.20)

11.2.1 The inner and outer surfaces shall be such as to make the product suitable for the intended application. Repaired areas conforming to the requirements of this specification shall be acceptable.

12. Sampling

12.1 The lot size, portion size and selection of sample pieces shall be as follows:

12.1.1 *Lot Size*—A lot shall consist of the following quantity, or fraction thereof, of pipe of the same alloy UNS No., diameter and wall thickness manufactured at the same time:

Outside Diameter, in. (mm)	Lot Size, ft (m)
Up to 10.750 (273) incl	1000 (305)
Over 10.75 to 24 (273 to 610) incl	500 (152)
Over 24 to 36 (610 to 914)	200 (61)
Over 36 to 48 (914 to 1220)	100 (30.5)
Over 48 (1220)	50 (15.2)

12.1.2 *Portion Size*—The number of lengths to be selected shall be as agreed upon between the manufacturer or supplier and the purchaser.

12.1.3 *Selection of Samples*—The sample piece(s) shall be randomly selected.

12.2 *Chemical Analysis:*

12.2.1 When determination of the alloy composition is specified in the contract or purchase order, the sample shall be taken and prepared in accordance with Practice E 255 from the length(s) selected in 12.1.2.

12.3 *Other Tests:*

12.3.1 Test specimens shall be taken from the length(s) selected in 12.1.2.

13. Number of Tests and Retests

13.1 *Tests:*

13.1.1 *Chemical Analysis*—Composition shall be determined as the average of results from at least two replicate analysis for each specified element.

13.1.2 *Transverse Tensile Strength*—Conformance with test requirements shall be determined by the test result of one specimen.

13.1.3 *Transverse Guided Bend Test*—Conformance with test requirements shall be determined by the test result of one transverse root bend test and one transverse face bend test.

13.2 *Retests:*

13.2.1 *Chemical Analysis*—Should one, or more, of the elements with specified limits fail to meet the composition requirement of the product specification, a retest may be permitted from a new composite sample prepared as directed in 12.1.2 and the number of replicate determinations shall be doubled.

13.2.2 *Other Tests*—Should a test specimen fail to conform to a test requirement of the product specification, a retest may be permitted with specimens prepared from the remaining pieces of the finished product selected in 12.1.2 and the number of test specimens shall be doubled.

13.2.2.1 In the event only one sample piece was selected in 12.1.2, retest shall not be permitted.

13.2.3 All test specimen shall conform to specification requirement in retest and failure to comply shall be cause for lot rejection.

13.2.4 *Umpire Test:*

13.2.4.1 In the case where the retest does not settle the dispute, a test may be permitted by a third qualified laboratory agreeable to manufacturer or supplier and the purchaser.

13.2.4.2 The sample shall be taken and test specimens prepared as directed in this specification.

13.2.4.3 The test method to be followed shall be as specified in this specification.

14. Specimen Preparation

14.1 *Chemical Analysis:*

14.1.1 Preparation of the analytical test specimen shall be the responsibility of the reporting laboratory.

14.2 *Transverse Tensile Test:*

14.2.1 The test specimen shall conform to the requirements of Test Specimens section and Fig. 13, Standard Test Specimen for Cast Iron, of Test Methods E 8.

14.2.2 The test specimen shall be of the full thickness of the base metal and shall be taken from the end of the finished pipe and flattened cold and machined to test specimen dimensions.

14.2.3 Alternatively, the test specimen may be taken from a test plate of the same material as the pipe which has been attached to the end of the pipe and welded as a prolongation of the longitudinal seam.

14.3 *Transverse Guided Bend Test:*

14.3.1 The test specimens shall be taken from the pipe with the weld joint in the approximate center of the specimens.

14.3.2 The test specimens shall be of the full thickness of the base metal and shall be taken from the end of the finished pipe and flattened cold and cut to test specimen size as described in Test Method E 190.

15. Test Methods

15.1 Test methods used for production control or quality control, or both, for determining conformance with product property requirements are discretionary.

15.1.1 Test methods used to obtain data for preparation

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of certification and test report shall be made available to the purchaser upon request.

15.2 *Chemical Analysis:*

15.2.1 The test methods used for determining chemical composition shall, in case of dispute, be as specified in the specification under which the manufacturing material was ordered.

15.2.2 Test methods used for the determination of elements required by contractual or purchase order agreement shall be as agreed upon between the manufacturer and the purchaser.

15.3 *Other Tests:*

15.3.1 The product furnished shall conform with the mechanical and other requirements enumerated in this specification when tested in accordance with the following appropriate method:

Test	Method
Tension	E 8
Transverse Guided Bend Test	E 190
Hydrostatic	Section 14.3.2

15.3.1.1 Tensile strength shall be determined in accordance with Test Methods E 8. Test results are not seriously affected by variations in speed of testing. However, the rate of stressing to the yield strength should not exceed 50 ksi/min. Above the yield strength the movement per minute of the testing machine head under load should not exceed 0.5 in./in. (0.5 mm) of gage length (or distance between grips for full section specimens).

15.3.2 *Hydrostatic Test:*

15.3.2.1 The internal hydrostatic pressure necessary to produce the required fiber stress shall be determined by the following equation:

$$P = 2St/(D - 0.8t)$$

where:

P = Hydrostatic pressure, psi (or MPa),
t = Thickness of tube wall, in. (or mm),
D = Outside diameter of tube, in. (or mm), and
S = Allowable fiber stress of the material, psi (or MPa).

16. Significance of Numerical Limits

16.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Practice E 29.

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	nearest unit in the last right-hand place of figures of the specified limit
Tensile strength	nearest 1 ksi (nearest 5 MPa)

17. Inspection

17.1 The manufacturer shall inspect and make necessary tests to verify that the pipe furnished conforms to the requirements of this specification.

17.2 If in addition the purchaser elects to perform his own inspection, the manufacturer shall afford the inspector all reasonable facilities to satisfy him that the pipe furnished conforms to the requirements of this specification. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere with the operation of the works. When automated finishing and inspection equipment is available at a facility, purchaser and manufacturer or supplier may by mutual agreement accomplish the final inspection simultaneously.

18. Rejection and Rehearing

18.1 *Rejection:*

18.1.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection shall be reported to the manufacturer or supplier promptly and in writing.

18.1.2 Radiographic or liquid penetrate examinations by the purchaser shall not be a basis for rejection unless those examinations were specified in the contract or purchase order at the time of ordering.

18.2 *Rehearing:*

18.2.1 The manufacturer, or supplier, may make claim for a rehearing when dissatisfied with test results upon which rejection was based.

19. Certification

19.1 When specified in the contract or purchase order, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met.

19.2 Certification is mandatory when the product is for *ASME Boiler and Pressure Vessel Code* application.

20. Mill Test Report

20.1 When specified in the contract or purchase order, a report of the test results shall be furnished.

21. Product Marking

21.1 Each length of pipe shall be marked with the specification number, alloy UNS No., nominal size, pressure class, and the trademark of the manufacturer.

21.1.1 When a nonstandard size or wall thickness has been specified, the markings shall contain the exact outside diameter and wall thickness in inches instead of the nominal diameter.

22. Packaging and Package Marking

22.1 Pipe shall be prepared for shipment in such a manner as to ensure acceptance by common carrier for transportation and to provide protection from normal hazards of transportation.

23. Keywords

23.1 copper-alloy pipe; welded copper-alloy pipe; welded pipe

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APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = kg \cdot m/s^2$). The derived SI unit for pressure or stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since 1 ksi = 6 894 757 Pa, the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2.

SUMMARY OF CHANGES

The section identifies the location of selected changes to this specification that have been incorporated since the 1988 issue. For the convenience of the user, Committee B 5 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both.

(1) Scope has been revised.
(2) No retests permitted when a single test piece is taken.
(3) The Number of Tests and Retests section significantly revised.
(4) Supplementary Requirements section deleted with the former contents incorporated in the body of the text in this revision.

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An American National Standard

Standard Specification for Welded Nickel and Nickel-Cobalt Alloy Pipe[1]

This standard is issued under the fixed designation B 619; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification[2] covers welded pipe of nickel and nickel-cobalt alloys (UNS N10001; UNS N10242; UNS N10665; UNS N12160; UNS N10624; UNS N10629; UNS N10675; UNS N10276; UNS N06455; UNS N06007; UNS N06975; UNS N08320; UNS N06002; UNS N06022; UNS N06058; UNS N06059; UNS N06200; UNS N06985; UNS N06030; UNS R30556; UNS N08031; UNS N06230; UNS N06686; UNS N06210; and UNS R20033)* as shown in Table 1.

1.2 This specification covers pipe in Schedules 5S, 10S, 40S, and 80S through 8-in. nominal pipe size as set forth in ANSI B36.19 (see Table 2).

1.3 Two classes of pipe are covered as follows:

1.3.1 *Class I*—As welded and solution annealed or welded and sized and solution annealed.

1.3.2 *Class II*—Welded, cold worked, and solution annealed.

1.4 All pipe shall be furnished in the solution annealed and descaled condition. When atmosphere control is used, descaling is not necessary.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

B 775 Specification for General Requirements for Nickel and Nickel Alloy Welded Pipe[3]

2.2 *ANSI Standards:*

B36.19 Stainless Steel Pipe[4]

B2.1 Pipe Threads[4]

3. General Requirement

3.1 Material furnished under this specification shall conform to the applicable requirements of Specification B 775 unless otherwise provided herein.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for the safe and satisfactory performance of material ordered under this specification. Examples of such requirements include, but are not limited to the following:

4.1.1 *Alloy* (Table 1),

4.1.2 *Class* (see 1.3),

4.1.3 *Quantity* (feet or number of lengths),

4.1.4 *Size* (nominal size or outside diameter and schedule number or average wall thickness),

4.1.5 *Length*—Specify cut length or random,

4.1.6 *Certification*— State if certification or a report of test results is required,

4.1.7 *Purchaser Inspection*—State which tests or inspections are to be witnessed,

4.1.8 *Ends*—Plain ends cut and deburred will be furnished, unless otherwise specified, and

4.1.9 *Samples for Product (Check) Analysis*—State whether samples shall be furnished.

5. Materials and Manufacture

5.1 The pipe shall be made from flat-rolled alloy by an automatic welding process with no addition of filler metal.

5.2 Subsequent to welding and prior to final heat treatment, Class II pipes shall be cold worked either in both weld and base metal or in weld metal only. The method of cold working may be specified by the purchaser.

6. Chemical Composition

6.1 The material shall conform to the composition limits specified in Table 1.

6.2 If a product (check) analysis is made by the purchaser, the material shall conform to the requirements specified in Table 1 subject to the permissible tolerances in Table 1 of Specification B 775.

7. Mechanical Properties and Other Requirements

7.1 *Tension Test*— The tensile properties of the material at room temperature shall conform to those shown in Table 3.

7.1.1 One tension test shall be made on each lot of pipe.

7.2 *Flattening Test*— One flattening test shall be made on a specimen from one end of one pipe from each lot.

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[1] This specification is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.07 on Refined Nickel and Cobalt and Their Alloys.

Current edition approved May. 10, 2000. Published June 2000. Originally published as B 619 – 81. Last previous edition B 619 – 99a.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SB-619 in Section II of that Code.

* New designation established in accordance with Practice E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

[3] *Annual Book of ASTM Standards*, Vol 02.04.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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TABLE 1 Chemical Requirements

	Composition Limits, %																						
	Ni	Cr	Mo	Fe	W	C	Si max	Co	Mn	V	P max	S max	Ti	Cu	Cb (Nb) +Ta	Al	Zr	La	N	B	Cb (Nb)	Ta	Ni+ Mo	Mg
Ni-Mo Alloys																								
N10001	remainder[A]	1.0 max	26.0-30.0	4.0- 6.0	...	0.05 max	1.0	2.5 max	1.0 max	0.2-0.4	0.04	0.03												
N10665	remainder[A]	1.0 max	26.0-30.0	2.0 max	...	0.02 max	0.10	1.0 max	1.0 max	...	0.04	0.03												
N10675	65.0 min	1.0-3.0	27.0-32.0	1.0-3.0	3.0 max	0.01 max	0.10	3.0 max	3.0 max	0.20 max	0.030	0.010	0.20 max	0.20 max	...	0.50 max	0.10 max	...	...	...	0.20 max	0.20 max	94.0-98.0	
N10629	remainder[A]	0.5-1.5	26.0-30.0	1.0-6.0	...	0.01 max	0.05	2.5 max	1.5 max	...	0.04	0.01	...	0.5 max	...	0.1-0.5	...	...	...	...	...	...	...	
N10624	remainder[A]	6.0-10.0	21.0-25.0	5.0- 8.0	...	0.01 max	0.10	1.0 max	1.0 max	...	0.025	0.01	...	0.5 max	...	...	...	...	...	...	...	...	...	
Ni-Mo-Cr-Fe Alloy																								
N10242	remainder[A]	7.0-9.0	24.0-26.0	2.0 max		0.03 max	0.80	1.00	0.80		0.030	0.015		0.50	0.50		0.50 max			0.006				
Low C Ni-Mo-Cr Alloys																								
N10276	remainder[A]	14.5-16.5	15.0-17.0	4.0-7.0	3.0-4.5	0.010 max	0.08	2.5 max	1.0 max	0.35 max	0.04	0.03												
N06022	remainder[A]	20.0-22.5	12.5-14.5	2.0-6.0	2.5-3.5	0.015 max	0.08	2.5 max	0.50 max	0.35 max	0.02	0.02												
N06455	remainder[A]	14.0-18.0	14.0-17.0	3.0 max	...	0.015 max	0.08	2.0 max	1.0 max	...	0.04	0.03	0.70 max											
Ni-Cr-Fe-Mo-Cu Alloys																								
N06007	remainder[A]	21.0-23.5	5.5-7.5	18.0-21.0	1.0 max	0.05 max	1.0	2.5 max	1.0-2.0		0.04	0.03		1.5-2.5	1.75-2.5									
N06975	47.0-52.0	23.0-26.0	5.0-7.0	remainder[A]	...	0.03 max	1.0	...	1.0 max		0.03	0.03	0.70-1.50	0.70-1.20										
N06985	remainder[A]	21.0-23.5	6.0-8.0	18.0-21.0	1.5 max	0.015 max	1.0	5.0 max	1.0 max	...	0.04	0.03	...	1.5-2.5	0.50 max									
N06030	remainder[A]	28.0-31.5	4.0-6.0	13.0-17.0	1.5-4.0	0.03 max	0.8	5.0 max	1.5 max	...	0.04	0.02	...	1.0-2.4	0.30-1.50									
Ni-Fe-Cr-Mo Alloys																								
N08320	25.0-27.0	21.0-23.0	4.0-6.0	remainder[A]	...	0.05 max	1.0		2.5 max		0.04	0.03	4xC min											

[A]The composition of the remainder shall be determined arithmetically by difference.

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TABLE 1 Chemical Requirements *(continued)*

	Composition Limits, %																						
	Ni	Cr	Mo	Fe	W	C	Si max	Co	Mn	V	P max	S max	Ti	Cu	Cb (Nb) +Ta	Al	Zr	La	N	B	Cb (Nb)	Ta	Ni+ Mo	Mg
Ni-Cr-Mo-Fe Alloy N06002	remainder[A]	20.5-23.0	8.0-10.0	17.0-20.0	0.20-1.0	0.05-0.15	1.0	0.5-2.5	1.0 max		0.04	0.03												
Ni-Fe-Cr-Co Alloy R30556	19.0-22.5	21.0-23.0	2.5-4.0	remainder[A]	2.0-3.5	0.05-0.15	0.20-0.80	16.0-21.0	0.50-2.00	...	0.04	0.015	...	...	...	0.10-0.50	0.001-0.10	0.005-0.10	0.10-0.30	0.02 max	0.30 max	0.3-1.25		
Ni-Cr-W-Mo Alloy N06230	remainder[A]	20.0-24.0	1.0-3.0	3.0 max	13.0-15.0	0.05-0.15	0.25-0.75	5.0 max	0.30-1.00	...	0.03	0.015	...	...	...	0.20-0.50	...	0.005-0.050	...	0.015 max	...	...		
Low C-Ni-Cr-Mo Alloys N06058	balance	20.0-23.0	19.0-21.0	1.5 max	0.3 max	0.010 max	0.10 max	0.3 max	0.50 max		0.015	0.010	...	0.50 max	...	0.40 max			0.02-0.15					
N06059	balance	22.0-24.0	15.0-16.5	1.5 max	...	0.010 max	0.10	0.3 max	0.5 max	...	0.015	0.010	...	0.50 max	...	0.1-0.4	...	...	...	...	...	...	...	
Low C-Ni-Cr-Mo-Cu Alloy N06200	remainder[A]	22.0-24.0	15.0-17.0	3.00 max	...	0.010 max	0.080	2.00 max	0.50 max	...	0.025	0.010	...	1.3-1.9		0.50 max								
Low C-Ni-Fe-Cr-Mo-Cu Alloy N08031	30.0-32.0	26.0-28.0	6.0-7.0	balance	...	0.015 max	0.3	...	2.0 max	...	0.020	0.010	...	1.0-1.4	...	...	...	...	0.15-0.25	...	...	...		
Low C-Ni-Cr-Mo-W Alloy N06686	remainder[A]	19.0-23.0	15.0-17.0	5.0 max	3.0-4.4	0.010 max	0.08	...	0.75 max	...	0.04	0.02	0.02-0.25	...	...	...	...	...	...	...	...	...		
Ni-Co-Cr-Si Alloy N12160	remainder[A]	26.0-30.0	1.0 max	3.5 max	1.0 max	0.15 max	2.4-3.0	27.0-33.0	1.5 max	...	0.030	0.5	0.20-0.80	...	...	...	...	...	...	...	1.0 max	...	...	...
Cr-Ni-Fe-N Alloy R20033	30.0-33.0	31.0-35.0	0.50-2.0	balance	...	0.015 max	0.50	...	2.0 max	...	0.02	0.01	...	0.30-1.20	...	...	...	...	0.35-0.60	...	...	...	...	...
Low C-Ni-Mo-Cr-Ta Alloy N06210	remainder[A]	18.0-20.0	18.0-20.0	1.0 max	...	0.015 max	0.08	1.0 max	0.5	0.35 max	0.02	0.02	...		...		...	...	...	...	...	1.5-2.2		

[A]The composition of the remainder shall be determined arithmetically by difference.

TABLE 2 Dimensions of Welded Pipe

NOTE 1—The following table is a partial reprint of Table 1 of ANSI B36.19.
NOTE 2—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

Nominal Pipe Size,	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[A]		Schedule 10S[A]		Schedule 40S		Schedule 80S	
in.	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
⅛	0.405	10.29	...	...	0.049	1.24	0.068	1.73		
¼	0.540	13.72	...	...	0.065	1.65	0.088	2.24		
⅜	0.675	17.15	...	...	0.065	1.65	0.091	2.31		
½	0.840	21.34	0.065	1.65	0.083	2.11	0.109	2.77		
¾	1.050	26.67	0.065	1.65	0.083	2.11	0.113	2.87		
1.0	1.315	33.41	0.065	1.65	0.109	2.77	0.133	3.38		
1¼	1.660	42.16	0.065	1.65	0.109	2.77	0.140	3.56		
1½	1.900	48.26	0.065	1.65	0.109	2.77	0.145	3.68		
2	2.375	60.03	0.065	1.65	0.109	2.77	0.154	3.91	0.218	5.54
2½	2.875	73.03	0.083	2.11	0.120	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120	3.05	0.216	5.33		
3½	4.000	101.60	0.083	2.11	0.120	3.05	0.226	5.74		
4	4.500	114.30	0.083	2.11	0.120	3.05	0.237	6.02		
5	5.563	141.30	0.109	2.77	0.134	3.40	0.258	6.55		
6	6.625	168.28	0.109	2.77	0.134	3.40	0.280	7.11		
8	8.625	219.18	0.109	2.77	0.148	3.76	0.322	8.18		

[A]Schedules 5S and 10S wall thicknesses do not permit threading in accordance with ANSI B2.1-1960.

TABLE 3 Mechanical Properties of Pipe

Alloy	Tensile Strength, min, ksi (MPa)	Yield Strength (0.2 % Offset), min, ksi (MPa)	Elongation in 2 in. (50.8 mm) or 4*D*,[A] min, %
Ni-Mo Alloys			
alloy N10001	100 (690)	45 (310)	40
alloy N10665	110 (760)	51 (350)	40
alloy N10675	110 (760)	51 (350)	40
alloy N10629	110 (760)	51 (350)	40
alloy N10624	104 (720)	46 (320)	40
Ni-Mo-Cr-Fe Alloy			
alloy N10242	105 (725)	45 (310)	40
Low C Ni-Mo-Cr Alloys			
alloy N10276	100 (690)	41 (283)	40
alloy N06022	100 (690)	45 (310)	45
alloy N06455	100 (690)	40 (276)	40
Ni-Cr-Fe-Mo-Cu Alloys			
alloy N06007	90 (621)	35 (241)	35
alloy N06975	85 (586)	32 (221)	40
alloy N06985	90 (621)	35 (241)	45
alloy N06030	85 (586)	35 (241)	30
Ni-Fe-Cr-Mo Alloy (N08320)	75 (517)	28 (193)	35
Ni-Cr-Mo-Fe Alloy (N06002)	100 (690)	40 (276)	35
Ni-Fe-Cr-Co Alloy (R30556)	100 (690)	45 (310)	40
Ni-Cr-W-Mo Alloy (N06230)[B]	110 (760)	45 (310)	40
Low C-Ni-Cr-Mo Alloys			
alloy N06058	110 (760)	52 (360)	40
alloy N06059	100 (690)	45 (310)	45
Low C-Ni-Cr-Mo-Cu Alloy (N06200)	100 (690)	41 (283)	45
Ni-Fe-Cr-Mo-Cu Low Carbon Alloy (N08031)	94 (650)	40 (276)	40
Low C Ni-Cr-Mo-W Alloy (N06686)	100 (690)	45 (310)	45
Ni-Co-Cr-Si alloy (N12160)	90 (620)	35 (240)	40
Cr-Ni-Fe-N Low Carbon Alloy (R20033)	109 (750)	55 (380)	40
Low C Ni-Cr-Mo-Ta Alloy (N06210)	100 (690)	45 (310)	45

[A]*D* refers to the diameter of the tension specimen.
[B]Solution annealed at a temperature between 2200 to 2275°F (1204 to 1246°C) followed by a water quench or rapidly cooled by other means.

7.3 *Hydrostatic or Nondestructive Electric Test*—Each pipe shall be subjected to either the hydrostatic or the nondestructive electric test at the manufacturer's option.

8. Dimensions and Permissible Variations

8.1 *Wall Thickness*— Variations in wall thickness shall not exceed the specified nominal wall thickness by more than ± 12½ %, except as follows:

8.1.1 If weld beads are present on the inner surface of the pipe, they shall not exceed the wall thickness of the pipe by more than 20 % or 0.050 in. (1.27 mm), whichever is less, of the specified nominal wall thickness for Class I pipe, and 5 % or 0.005 in. (0.127 mm), whichever is less, of the specified nominal wall thickness for Class II pipe.

8.1.2 Sunken welds in Class I pipe shall not be deeper than 15 % of the specified nominal wall thickness and never deeper than 0.030 in. (0.79 mm). Class II pipe shall not have sunken welds.

8.2 *Outside Diameter*— The permissible variations in outside diameter shall not exceed the limits prescribed in Table 4, except as provided for in 8.1.2.

9. Keywords

9.1 UNS N06002; UNS N06007; UNS N06022; UNS

TABLE 4 Permissible Variations in Outside Diameter

Nominal Pipe Size, in.	Permissible Variation in Outside Diameter[A]			
	in.		mm	
⅛	+ 0.002	−0.006	+ 0.05	−0.15
¼	+ 0.003	−0.008	+ 0.08	−0.20
⅜	+ 0.004	−0.008	+ 0.08	−0.20
½	+ 0.004	−0.010	+ 0.10	−0.25
¾	+ 0.005	−0.012	+ 0.13	−0.30
1	+ 0.005	−0.012	+ 0.13	−0.30
1¼	+ 0.005	−0.012	+ 0.13	−0.30
1½	+ 0.008	−0.015	+ 0.20	−0.38
2	+ 0.010	−0.016	+ 0.25	−0.41
2½	+ 0.010	−0.016	+ 0.25	−0.41
3	+ 0.012	−0.018	+ 0.30	−0.46
3½	+ 0.012	−0.018	+ 0.30	−0.46
4	+ 0.014	−0.020	+ 0.36	−0.51
5	+ 0.063	0.031	+ 1.60	−0.79
6	+ 0.063	0.031	+ 1.60	−0.79
8	+ 0.063	0.031	+ 1.60	−0.79

[A]The permissible variations in the above table apply to individual measurements, including out of roundness (ovality).

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N06030; UNS N06058; UNS N06059; UNS N06200; UNS N06210; UNS N06230; UNS N06455; UNS N06975; UNS N06985; UNS N08031; UNS N08320; UNS N10001; UNS N10242; UNS N10276; UNS N10624; UNS N10629; UNS N10665; UNS N10675; UNS R30556; welded pipe

APPENDIX

(Nonmandatory Information)

X1. HEAT TREATMENT

X1.1 Proper heat treatment during or subsequent to fabrication is necessary for optimum performance, and the manufacturer shall be consulted for details.

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Designation: B 622 – 00

An American National Standard

Standard Specification for Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube[1]

This standard is issued under the fixed designation B 622; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification[2] covers seamless pipe and tube of nickel and nickel-cobalt alloys (UNS N10001, UNS N10242, UNS N10665, UNS N12160, UNS N10675, UNS N10276, UNS N06455, UNS N06007, UNS N08320, UNS N06975, UNS N06002, UNS N06985, UNS N06022, UNS N08135, UNS N06255, UNS N06058, UNS N06059, UNS N06200, UNS N06030, UNS N08031, UNS R30556, UNS N08535, UNS N06250, UNS N06060, UNS N06230, UNS N06686, UNS N10629, UNS N06210, UNS N10624, and UNS R20033)* as shown in Table 1.

1.2 Pipe and tube shall be supplied in the solution annealed and descaled condition. When atmosphere control is used, descaling is not necessary.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

B 880 Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys[3]

E 8 Test Methods for Tension Testing of Metallic Materials[4]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[5]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[6]

E 1473 Test Methods for Chemical Analysis of Nickel, Cobalt, and High-Temperature Alloys[7]

3. Terminology

3.1 *Definitions:*

3.1.1 *average diameter*—the average of the maximum and minimum outside diameters, or the maximum and minimum inside diameters, as determined at any cross section of the tube.

3.1.2 *pipe*—seamless tube conforming to the particular dimensions commercially known as standard pipe sizes (Appendix X2).

3.1.3 *tube*—a hollow product of round or any other cross section having a continuous periphery.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for the safe and satisfactory performance of material ordered under this specification. Examples of such requirements include, but are not limited to the following:

4.1.1 *Alloy* (Table 1).

4.1.2 *Dimensions*:

4.1.2.1 *Tube*—utside diameter, minimum or average wall thickness, and length.

4.1.2.2 *Pipe*—Standard pipe size and schedule (Appendix X2).

4.1.3 *Ends*—Plain ends cut and deburred will be furnished.

4.1.4 *Certification*— State if certification or a report of test results is required (Section 16).

4.1.5 *Samples for Check Analysis*—State whether samples for check analysis should be furnished (10.2.2).

4.1.6 *Purchaser Inspection*—If the purchaser wishes to witness tests or inspection of material at the place of manufacture, the purchase order must so state, indicating which tests or inspections are to be witnessed (Section 14).

5. Chemical Composition

5.1 The material shall conform to the composition limits specified in Table 1.

5.2 If a product (check) analysis is made by the purchaser, the material shall conform to the requirements specified in Table 1 subject to the permissible tolerances per B 880.

6. Mechanical Properties

6.1 The mechanical properties of the material at room temperature shall conform to those shown in Table 2.

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[1] This specification is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloysand is the direct responsibility of Subcommittee B02.07 on Refined Nickel and Cobalt and Their Alloys.

Current edition approved May 10, 2000. Published June 2000. Originally published as B 622 – 77. Last previous edition B 622 – 99a.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SB-622 in Section II of that Code.

* New designation established in accordance with ASTM E527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

[3] *Annual Book of ASTM Standards*, Vol 02.04.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] *Annual Book of ASTM Standards*, Vol 03.05.

[7] *Annual Book of ASTM Standards*, Vol 03.06.

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TABLE 1 Chemical Requirements

	Composition Limits, %																						
	Ni	Cr	Mo	Fe	W	C	Si max	Co	Mn	V	P max	S max	Ti	Cu	Cb (Nb) +Ta	Al	Zr	La	N	B	Cb (Nb)	Ta	Ni+ Mo	Mg
Ni-Mo Alloys																								
N10001	remainder[A]	1.0 max	26.0-30.0	4.0-6.0	...	0.05 max	1.0	2.5 max	1.0 max	0.2-0.4	0.04	0.03	...	...	...									
N10665	remainder[A]	1.0 max	26.0-30.0	2.0 max	...	0.02 max	0.10	1.0 max	1.0 max	...	0.04	0.03	...	...	...									
N10675	65.0 min	1.0-3.0	27.0-32.0	1.0-3.0	3.0 max	0.01 max	0.10	3.0 max	3.0 max	0.20 max	0.030	0.010	0.20 max	0.20 max	...	0.50 max	0.10 max	...	...	...	0.20 max	0.20 max	94.0-98.0	
N10629	remainder[A]	0.5-1.5	26.0-30.0	1.0-6.0	...	0.01 max	0.05	2.5 max	1.5 max	...	0.04	0.01	...	0.5 max	...	0.1-0.5	...	...	...	...	...	...	...	
N10624	remainder[A]	6.0-10.0	21.0-25.0	5.0- 8.0	...	0.01 max	0.10	1.0 max	1.0 max	...	0.025	0.01	...	0.5 max	...	...	...	...	...	...	...	...	...	
Ni-Mo-Cr-Fe Alloy																								
N10242	remainder[A]	7.0-9.0	24.0-26.0	2.0 max		0.03 max	0.80	1.00 max	0.80 max		0.030	0.015		0.50 max		0.50 max				0.006 max				
Low C Ni-Mo-Cr Alloys																								
N10276	remainder[A]	14.5-16.5	15.0-17.0	4.0-7.0	3.0-4.5	0.010 max	0.08	2.5 max	1.0 max	0.35 max	0.04	0.03	...	...	...									
N06022	remainder[A]	20.0-22.5	12.5-14.5	2.0-6.0	2.5-3.5	0.015 max	0.08	2.5 max	0.50 max	0.35 max	0.02	0.02	...	...	...									
N06455	remainder[A]	14.0-18.0	14.0-17.0	3.0 max	...	0.015 max	0.08	2.0 max	1.0 max	...	0.04	0.03	0.70 max	...	...									
Ni-Cr-Fe-Mo-Cu Alloys																								
N06007	remainder[A]	21.0-23.5	5.5-7.5	18.0-21.0	1.0 max	0.05 max	1.0	2.5 max	1.0-2.0	...	0.04	0.03	...	1.5-2.5	1.75-2.5									
N06975	47.0-52.0	23.0-26.0	5.0-7.0	remainder[A]	...	0.03 max	1.0	...	1.0 max	...	0.03	0.03	0.70-1.50	0.70-1.20	...									
N06985	remainder[A]	21.0-23.5	6.0-8.0	18.0-21.0	1.5 max	0.015 max	1.0	5.0 max	1.0 max	...	0.04	0.03	...	1.5-2.5	0.50 max									
N06030	remainder[A]	28.0-31.5	4.0-6.0	13.0-17.0	1.5-4.0	0.03 max	0.8	5.0 max	1.5 max	...	0.04	0.02	...	1.0-2.4	0.30-1.50									
N06255	47.0-52.0	23.0-26.0	6.0-9.0	remainder[A]	3.0 max	0.03 max	1.0	...	1.0 max	...	0.03	0.03	0.69 max	1.2 max	...									
N06250	50.0-54.0	20.0-23.0	10.1-12.0	remainder[A]	0.25-1.25	0.020 max	0.09	...	1.00 max	...	0.030	0.005	...	0.25-1.25	...									
Ni-Fe-Cr-Mo Alloys																								
N08320	25.0-27.0	21.0-23.0	4.0-6.0	remainder[A]	...	0.05 max	1.0	...	2.5 max	...	0.04	0.03	4xC min	...	...									
N08135	33.0-38.0	20.5-23.5	4.0-5.0	remainder[A]	0.20-0.80	0.030 max	0.75	...	1.00 max	...	0.03	0.03	...	0.70 max	...									

[A] See 13.1.1

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TABLE 1 Chemical Requirements *(continued)*

	Composition Limits, %																						
	Ni	Cr	Mo	Fe	W	C	Si max	Co	Mn	V	P max	S max	Ti	Cu	Cb (Nb) +Ta	Al	Zr	La	N	B	Cb (Nb)	Ta	Ni+ Mo	Mg
N06002	remainder[A]	20.5-23.0	8.0-10.0	17.0-20.0	0.20-1.0	0.05-0.15	1.0	0.5-2.5	1.0 max	...	0.04	0.03	...	...	...									
N06060	54.0-60.0	19.0-22.0	12.0-14.0	remainder[A]	0.25-1.25	0.03 max	0.50	...	1.50 max	...	0.030 max	0.005 max	...	0.25-1.25	0.50-1.25									
Ni-Fe-Cr-Co Alloy																								
R30556	19.0-22.5	21.0-23.0	2.5-4.0	remainder[A]	2.0-3.5	0.05-0.15	0.20-0.80	16.0-21.0	0.50-2.00	...	0.04	0.015	...	...	...	0.10-0.50	0.001-0.10	0.005-0.10	0.10-0.30	0.02 max	0.30 max	0.3-1.25		
Ni-Cr-W-Mo Alloys																								
N06230	remainder[A]	20.0-24.0	1.0-3.0	3.0 max	13.0-15.0	0.05-0.15	0.25-0.75	5.0 max	0.30-1.00	...	0.03	0.015	...	...	...	0.20-0.50	...	0.005-0.050	...	0.015 max	...	...		
Low C-Ni-Cr-Mo																								
N06058	balance	20.0-23.0	19.0-21.0	1.5 max	0.3 max	0.010 max	0.10 max	0.3 max	0.50 max		0.015	0.010	...	0.50 max	...	0.40 max			0.02-0.15					
N06059	balance	22.0-24.0	15.0-16.5	1.5 max	...	0.010 max	0.10	0.3 max	0.5 max	...	0.015	0.005	...	0.50 max	...	0.1-0.4	...	...	...	...	...	...	...	
Low C-Ni-Cr-Mo-Cu Alloy																								
N06200	remainder[A]	22.0-24.0	15.0-17.0	3.0 max	...	0.010 max	0.08	2.0 max	0.50 max	...	0.025	0.010	...	1.3-1.9		0.50 max								
Low C-Ni-Fe-Cr-Mo-Cu Alloys																								
N08031	30.0-32.0	26.0-28.0	6.0-7.0	balance	...	0.015 max	0.3	...	2.0 max	...	0.020	0.010	...	1.0-1.4	...	...	...	...	0.15-0.25	...	...	...		
N08535	29.0-36.5	24.0-27.0	2.5-4.0	remainder[A]	...	0.03 max	0.50	...	1.0 max	...	0.03	0.03	...	1.50 max										
Low C-Ni-Cr-Mo-W Alloy																								
N06686	remainder[A]	19.0-23.0	15.0-17.0	5.0 max	3.0-4.4	0.010 max	0.08	...	0.75 max	...	0.04	0.02	0.02-0.25	...	...	...	...	...	...	...	...	...		
Ni-Co-Cr-Si Alloy																								
N12160	remainder[A]	26.0-30.0	1.0 max	3.5 max	1.0 max	0.15 max	2.4-3.0	27.0-33.0	1.5 max	...	0.030	0.015	0.20-0.80	...	...	...	...	...	...	...	1.0 max	...	...	...
Cr-Ni-Fe-N Alloy																								
R20033	30.0-33.0	31.0-35.0	0.50-2.0	balance	...	0.015 max	0.50	...	2.0 max	...	0.02	0.01	...	0.3-1.20	...	...	...	...	0.35-0.60	...	...	...	...	...
Low C-Ni-Mo-Cr-Ta Alloy																								
N06210	remainder[A]	18.0-20.0	18.0-20.0	1.0 max	...	0.015 max	0.08	1.0 max	0.5	0.35 max	0.02	0.02	...		...		...	...	...	...	...	1.5-2.2		

[A] See 13.1.1

TABLE 2 Mechanical Properties of Pipe and Tube

Alloy	Tensile Strength, min, ksi (MPa)	Yield Strength (0.2 % Offset) min, ksi (MPa)	Elongation in 2 in. (50.8 mm) or 4D,[A] min, %
Ni-Mo			
UNS N10001	100 (690)	45 (310)	40
UNS N10665	110 (760)	51 (350)	40
UNS N10675	110 (760)	51 (350)	40
UNS N10629	110 (760)	51 (350)	40
UNS N10624	104 (720)	46 (320)	40
Ni-Mo-Cr-Fe			
UNS N10242	105 (725)	45 (310)	40
Low C Ni-Mo-Cr			
UNS N10276	100 (690)	41 (283)	40
UNS N06022	100 (690)	45 (310)	45
UNS N06455	100 (690)	40 (276)	40
Ni-Cr-Fe-Mo-Cu			
UNS N06007	90 (621)	35 (241)	35
UNS N06975	85 (586)	32 (221)	40
UNS N06985	90 (621)	35 (241)	40
UNS N06030	85 (586)	35 (241)	30
UNS N06255	85 (586)	32 (221)	40
UNS N06250	90 (621)	35 (241)	40
Ni-Fe-Cr-Mo			
UNS N08320	75 (517)	28 (193)	35
UNS N08135	73 (503)	31 (214)	40
Ni-Cr-Mo-Fe			
UNS N06002	100 (690)	40 (276)	35
UNS N06060	90 (621)	35 (241)	40
Ni-Fe-Cr-Co–R30556	100 (690)	45 (310)	40
Ni-Cr-W-Mo			
UNS N06230[B]	110 (760)	45 (310)	40
Low C-Ni-Cr-Mo			
UNS N06059	110 (760)	52 (360)	40
UNS N06059	100 (690)	45 (310)	45
Low C-Ni-Cr-Mo-Cu			
UNS N06200	100 (690)	41 (283)	45
Ni-Fe-Cr-Mo-Cu low carbon			
UNS N08031			
UNS N08535	94 (650)	40 (276)	40
	73 (503)	31 (214)	40
Low C Ni-Cr-Mo-W			
UNS N06686	100 (690)	45 (310)	45
Ni–Co–Cr–Si			
UNS N12160	90 (620)	35 (240)	40
low carbon Cr-Ni-Fe-N			
UNS R20033	109 (750)	55 (380)	40
Low carbon Ni-Mo-Cr-Ta			
UNS N06210	100 (690)	45 (310)	45

[A] *D* refers to the diameter of the tension specimen.

[B] Solution annealed at a minimum temperature of 2200° F (1204° C) followed by a water quench or rapidly cooled by other means.

7. Hydrostatic Test

7.1 Each pipe or tube shall be tested by the manufacturer to an internal hydrostatic pressure, not to exceed 1000 psi (6.89 MPa), that will produce a fiber stress, *S*, in the tube wall, calculated in accordance with the following equation:

$$P = 2St/D \quad (1)$$

where:

P = hydrostatic test pressure, psi (MPa),

S = allowable fiber stress of material in the condition furnished, as follows:

Alloy	S psi	S MPa
Nickel-molybdenum:		
UNS N10001	25 000	172
UNS N10665	27 500	190
UNS N10675	27 500	190
UNS N10629	27 500	190
UNS N10624	26 000	180
Nickel-molybdenum-chromium-iron:		
UNS N10242	26 500	182
Low carbon nickel-molybdenum-chromium:		
UNS N10276	25 000	172
UNS N06022	25 000	172
UNS N06455	25 000	172
Nickel-chromium-iron-molybdenum-copper:		
UNS N06007	22 000	152
UNS N06975	21 000	145
UNS N06985	22 500	155
UNS N06030	21 000	145
UNS N06255	21 000	145
UNS N06250	22 500	155
Nickel-iron-chromium-molybdenum:		
UNS N08320	18 500	127
UNS N08135	18 300	126
Nickel-chromium-molybdenum-iron:		
UNS N06002	23 000	159
UNS N06060	22 500	155
Nickel-iron-chromium-cobalt:		
UNS R30556	25 000	172
Nickel-chromium-tungsten-molybdenum:		
UNS N06230	27 500	190
Low carbon nickel-chromium-molybdenum:		
UNS N06058	27 500	190
UNS N06059	25 000	172
UNS N06200	25 000	172
Low carbon nickel-iron-chromium-molybdenum-copper:		
UNS N08031	22 500	155
UNS N08535	18 300	126
Low carbon nickel-chromium-molybdenum-tungsten:		
UNS N06686	25 000	172
Nickel-cobalt-chromium-silicon:		
UNS N12160	22 500	155
Chromium-nickel-iron-nitrogen:		
UNS R20033	27 000	186
Low carbon nickel-molybdenum-chromium-tantalum:		
UNS N06210	25 000	172

t = minimum wall thickness, in. (mm), equal to the specified average wall minus the permissible "minus" wall tolerance (Table 3) or the specified minimum wall thickness, and

D = outside diameter of the tube, in. (mm).

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TABLE 3 Permissible Variations in Outside Diameter and Wall Thickness (Average Wall)

Specified Outside Diameter	Wall Thickness, %					
	Outside Diameter		Average		Minimum Wall	
	+	−	+	−	+	−
	Inches					
0.500 to 5/8, incl	0.005	0.005	12.5	12.5	25.0	0
Over 5/8 to 1 1/2, incl	0.0075	0.0075	10.0	10.0	20.0	0
Over 1 1/2 to 3 1/2, incl	0.010	0.010	10.0	10.0	22.0	0
	Millimetres					
12.7 to 15.88, incl	0.13	0.13	12.5	12.5	25.0	0
Over 15.88 to 38.100, incl	0.190	0.190	10.0	10.0	20.0	0
Over 38.100 to 88.900, incl	0.254	0.254	10.0	10.0	22.0	0

7.2 Any pipe or tube showing leaks during the hydrostatic test shall be rejected.

8. Dimensions and Permissible Variations

8.1 *Outside Diameter and Wall Thickness*—The permissible variations in the outside diameter and wall thickness of pipe and tube shall not exceed those prescribed in Table 3.

8.2 *Length*—When pipe or tube is ordered cut-to-length, the length shall not be less than that specified, but a variation of + 1/8in. (3.2 mm) shall be permitted, except that for lengths over 30 ft (9.1 m), a variation of + 1/4in. (6.4 mm) shall be permitted.

8.3 *Straightness*— Material shall be reasonably straight and free of bends or kinks.

8.4 *Weight*—For calculation of mass or weight, the following densities shall be used:

Alloy	Density lb/in.^{3}	Density g/cm^3
Nickel-molybdenum:		
UNS N10001	0.334	9.24
UNS N10242	0.327	9.05
UNS N10665	0.333	9.22
UNS N10675	0.333	9.22
UNS N10629	0.333	9.22
UNS N10624	0.322	8.9
Low carbon nickel-molybdenum-chromium:		
UNS N10276	0.321	8.87
UNS N06022	0.314	8.69
UNS N06455	0.312	8.64
Nickel-chromium-iron-molybdenum-copper:		
UNS N06007	0.300	8.31
UNS N06975	0.295	8.17
UNS N06985	0.300	8.31
UNS N06030	0.297	8.22
UNS N06255	0.299	8.29
UNS N06250	0.307	8.58
Nickel-iron-chromium-molybdenum:		
UNS N08320	0.291	8.05
UNS N08135	0.292	8.10
Nickel-chromium-molybdenum-iron:		
UNS N06002	0.297	8.23
UNS N06060	0.315	8.71
Nickel-iron-chromium-cobalt:		
UNS R30556	0.297	8.23
Nickel-chromium-tungsten-molybdenum:		
UNS N06230	0.324	8.97
Low carbon nickel-chromium-molybdenum:		
UNS N06058	0.318	8.80
UNS N06059	0.311	8.6
UNS N06200	0.307	8.50
Low carbon nickel-iron-chromium-molybdenum-copper:		
UNS N08031	0.29	8.1
UNS N08535	0.291	8.07
Low carbon nickel-chromium-molybdenum-tungsten:		
UNS N06686	0.315	8.73
Nickel-cobalt-chromium-silicon:		
UNS N12160	0.292	8.08
Low carbon chromium-nickel-iron-nitrogen:		
UNS R20033	0.29	8.1
Low carbon nickel-molybdenum-chromium-tantalum:		
UNS N06210	0.316	8.76

9. Workmanship, Finish, and Appearance

9.1 The material shall be uniform in quality and condi-tion, smooth, and free of injurious imperfections.

10. Sampling

10.1 *Lots for Chemical Analysis and Mechanical Testing*:

10.1.1 A lot for chemical analysis shall consist of one heat.

10.1.2 A lot of pipe or tube for mechanical testing shall be defined as the material from one heat in the same condition and specified cross section and in no case more than 10 000 lb (4500 kg).

10.2 *Sampling of Chemical Analysis*:

10.2.1 A representative sample shall be taken from each lot during pouring or subsequent processing.

10.2.2 Product (check) analysis shall be wholly the responsibility of the purchaser.

10.3 *Sampling for Mechanical Testing*:

10.3.1 A representative sample shall be taken from each lot of finished material.

11. Number of Tests and Retests

11.1 *Chemical Analysis*—One test per lot.

11.2 *Tension Test*— One test per lot.

11.3 *Retests*—If the specimen used in the mechanical test of any lot fails to meet the specified requirements, two additional specimens shall be taken from different sample pieces and tested. The results of the tests on both of these specimens shall meet the specified requirements.

12. Specimen Preparation

12.1 Tension test specimens shall be taken from material after final heat treatment and tested in the direction of fabrication.

12.2 Whenever possible, all pipe and tube shall be tested in full tubular size. When testing in full tubular size is not possible, longitudinal strip specimens, or the largest possible round specimen prepared in accordance with Test Methods E 8, shall be used.

13. Test Methods

13.1 The chemical composition and mechanical properties of the material as enumerated in this specification shall be determined, in case of disagreement, in accordance with the following methods:

13.1.1 *Chemical Analysis*—Test Methods E 1473. For elements not covered by Test Methods E 1473, the referee method shall be as agreed upon between the manufacturer and the

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purchaser. The elements listed as "remainder" shall be determined arithmetically by difference.

13.1.2 *Tension Test*— Test Methods E 8.

13.1.3 *Determining Significant Places*—Practice E 29.

13.1.4 *Method of Sampling*—Practice E 55.

13.2 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded in accordance with the rounding method of Practice E 29.

Requirements	Rounded Unit for Observed or Calculated Value
Chemical composition and tolerances	nearest unit in the last right-hand place of figures of the specified limit
Tensile strength and yield strength	nearest 1000 psi (7 MPa)
Elongation	nearest 1 %

14. Inspection

14.1 Inspection of the material shall be in accordance with agreements between the manufacturer and the purchaser as part of the purchase contract.

15. Rejection and Rehearing

15.1 Material, tested by the purchaser, that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

16. Certification

16.1 When specified in the purchase order or contract, a manufacturer's certification shall be furnished to the purchaser stating that material has been manufactured, tested, and inspected in accordance with this specification, and that the test results on representative samples meet specification requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

17. Product Marking

17.1 Each piece of material ½ in. (12.7 mm) and over in diameter shall be marked with this specification number, alloy, heat number, name of the material, and size of the product.

17.2 Each bundle or shipping container shall be marked with the name of the material; specification number; alloy; class; condition; size; gross, tare, and net weight; consignor and consignee address; contract or order number; and such information as may be defined in the contract or order.

18. Keywords

18.1 seamless pipe; seamless tube; UNS N06002; UNS N06007; UNS N06022; UNS N06030; UNS N06058; UNS N06059; UNS N06060; UNS N06200; UNS N06210; UNS N06230; UNS N06250; UNS N06255; UNS N06455; UNS N06686; UNS N06975; UNS N06985; UNS N08031; UNS N08135; UNS N08320; UNS N08535; UNS N10001; UNS N10242; UNS N10276; UNS N10624; UNS N10629; UNS N10665; UNS N10675; UNS N12160; UNS R20033; UNS R30556

APPENDIXES

(Nonmandatory Information)

X1. HEAT TREATMENT

X1.1 Proper heat treatment during or subsequent to fabrication is necessary for optimum performance and themanufacturer shall be consulted for details.

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X2. PIPE SCHEDULES

X2.1 The schedules listed in Table X2.1 are regularly available. This table is published for information only.

TABLE X2.1 Pipe Schedules[A]

Nominal Pipe Size, in.	Outside Diameter	Nominal Wall Thickness		
		Schedule No. 10	Schedule No. 40	Schedule No. 80
		Inches		
¼	0.540	0.065	0.088	...
⅜	0.675	0.065	0.091	0.126
½	0.840	0.083	0.109	0.147
¾	1.050	0.083	0.113	0.154
1	1.315	0.109	0.133	0.179
1¼	1.660	0.109	0.140	0.191
1½	1.900	0.109	0.145	0.200
2	2.375	0.109	0.154	0.218
2½	2.875	0.120	0.203	0.276
3	3.500	0.120	0.216	0.300
		Millimetres		
¼	13.72	1.65	2.24	...
⅜	17.14	1.65	2.31	3.20
½	21.34	2.11	2.77	3.73
¾	26.67	2.11	2.87	3.91
1	33.40	2.77	3.38	4.55
1¼	42.16	2.77	3.56	4.85
1½	48.26	2.77	3.68	5.08
2	60.32	2.77	3.91	5.54
2½	73.02	3.05	5.16	7.04
3	88.90	3.05	5.49	7.62

[A] The pipe schedules shown conform with standards adopted by the American National Standards Institute.

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Standard Specification for Welded Nickel (UNS N02200/UNS N02201) and Nickel Copper Alloy (UNS N04400) Pipe[1]

This standard is issued under the fixed designation B 725; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers nickel (UNS N02200) and low carbon nickel (UNS N02201 and UNS N04400) in the form of welded and annealed or welded and stress relieved pipe intended for general corrosive service and for mechanical applications.

1.2 This specification covers outside diameter and nominal wall pipe in Schedules 5S, 10S, and 40S through 30-in. nominal pipe size shown in ANSI B36.19 (see Table 5). Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.3 The values stated in inch-pound units are to be regarded as the standard.

1.4 The following precautionary caveat pertains only to the test methods portion, Section 12, of this specification: *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 8 Test Methods of Tension Testing of Metallic Materials[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[3]

E 39 Test Methods for Chemical Analysis of Nickel[4]

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing[5]

E 571 Practice for Electromagnetic (Eddy-Current) Examination of Nickel and Nickel Alloy Tubular Products[5]

2.2 *ANSI Standards:*[6]

B 1.20.1 Pipe Threads

B 36.10 Welded and Seamless Wrought Steel Pipe

B 36.19 Stainless Steel Pipe

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Alloy name or UNS number,

3.1.2 ASTM designation and date of issue,

3.1.3 Condition (temper) (Table 2),

3.1.4 *Dimensions:*

3.1.4.1 Nominal pipe size or outside diameter and schedule number or nominal wall thickness (Table 5),

3.1.4.2 Length (specific or random),

3.1.5 *Quantity*—feet or metres, or number of pieces,

3.1.6 *Certification*—State if certification is required (Section 15),

3.1.7 *Samples for Product (Check) Analysis*—State whether samples for product (check) analysis should be furnished (9.2),

3.1.8 *Purchaser Inspection*—If the purchaser wishes to witness tests or inspection of material at the place of manufacture, the purchase order must so state indicating which tests or inspections are to be witnessed (Section 13),

3.1.9 *Nondestructive Tests (see 6.4)*—Specify either Test Category 1 or 2. If Test Category 1 is required, specify if either a hydrostatic, eddy-current or ultrasonic test is to apply. If Test Category 2 is required, specify if either an eddy-current or ultrasonic test is to apply. See Section S1.

3.1.10 Supplementary Requirements.

4. Materials and Manufacture

4.1 Pipe shall be made from flat-rolled alloy by an automatic welding process with no addition of filler metal. Subsequent to welding and prior to final heat treatment, the pipe shall be cold worked to assure that optimum corrosion resistance in the weld area and base metal will be developed during heat treatment.

4.2 Pipe shall be furnished with a scale free finish. When bright annealing is used, descaling is not necessary.

5. Chemical Composition

5.1 The material shall conform to the requirements as to chemical composition prescribed in Table 1.

5.2 If a product (check) analysis is performed by the purchaser, the material shall conform to the product (check) analysis variations in Table 1.

6. Mechanical Properties and Other Requirements

6.1 *Mechanical Properties*—The material shall conform to the requirements for mechanical properties prescribed in Table 2.

6.2 *Flattening Test Requirements*—Flattening test speci-

[1] This specification is under the jurisdiction of ASTM Committee B-2 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.07 on Refined Nickel and Cobalt, and Alloys Containing Nickel or Cobalt or Both as Principal Constituents.

Current edition approved Feb. 15, 1993. Published April 1993. Originally published as B 725 – 83. Last previous edition B 725 – 89.

[2] *Annual Book of ASTM Standards*, Vol 03.01.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 03.05.

[5] *Annual Book of ASTM Standards*, Vol 03.03.

[6] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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TABLE 1 Chemical Requirements

Element	Composition, %			Product (Check) Analysis Variations, under min or over max, of the Specified Limit of Element
	Nickel (UNS N02200)	Low-Carbon Nickel (UNS N02201)	Nickel-Copper (UNS N04400)	
Nickel, min	99.0	99.0	63.0	0.60
Copper, max	0.25	0.25	28.0–34.0	0.03
Iron, max	0.40	0.40	2.5	0.03
Manganese, max	0.35	0.35	2.0	0.03
Carbon, max	0.15	...	0.3	0.01
Carbon, max	...	0.02	...	0.005
Silicon, max	0.35	0.35	0.5	0.03
Sulfur, max	0.01	0.01	0.024	0.003

TABLE 2 Mechanical Properties of Pipe and Tube

Condition and Size	Tensile Strength, min, psi (MPa)			Yield Strength (0.2 % offset), min, psi (MPa)			Elongation in 2 in. or 50 mm (or 4*D*), min, %		
	Nickel	Low-Carbon Nickel	UNS N04400	Nickel	Low-Carbon Nickel	UNS N04400	Nickel	Low-Carbon Nickel	UNS N04400
Annealed									
5 in. (127 mm) and under outside diameter	55 000 (380)	50 000 (345)	70 000 (480)	15 000 (105)	12 000 (80)	28 000 (195)	35	35	35
Over 5 in. (127 mm) in outside diameter	55 000 (380)	50 000 (345)	70 000 (480)	12 000 (80)	10 000 (70)	25 000 (170)	40	40	35
Stress-relieved									
All sizes	65 000 (450)	60 000 (415)	85 000 (585)	40 000 (275)	30 000 (205)	55 000 (380)	15	15	15

TABLE 3 Permissible Variations in Outside Diameter

NPS Designator	Permissible Variations in Outside Diameter			
	Over		Under	
	in.	mm	in.	mm
⅛ to 1½, incl	1/64 (0.015)	0.4	1/32 (0.031)	0.8
Over 1½ to 4, incl	1/32 (0.031)	0.8	1/32 (0.031)	0.8
Over 4 to 8, incl	1/16 (0.062)	1.6	1/32 (0.031)	0.8
Over 8 to 12, incl	3/32 (0.093)	2.4	1/32 (0.031)	0.8
Over 18 to 26, incl	⅛ (0.125)	3.2	1/32 (0.031)	0.8
Over 26 to 34, incl	5/32 (0.156)	4.0	1/32 (0.031)	0.8
Over 34 to 48, incl	3/16 (0.187)	4.8	1/32 (0.031)	0.8

TABLE 4 Permissible Variations in Length[A]

Outside Diameter, in. (mm)	Cut Length, in. (mm)	
	Over	Under
Under 2 (50.8)	⅛ (3.18)	0
2 (50.8) and over	3/16 (4.75)	0

[A] These permissible variations in length apply to pipe before bending. They apply to cut lengths up to and including 24 ft (7.3 m). For lengths over 24 ft, an additional over-tolerance of ⅛ in. (3.18 mm) for each 10 ft (3.0 m) or fraction thereof shall be permissible up to a maximum additional over-tolerance of ½ in. (12.7 mm).

mens made in accordance with 12.3 shall show no cracks or breaks on the inside, outside, or end surfaces.

6.3 *Nondestructive Tests:*

6.3.1 Pipe shall be subjected to the nondestructive tests outlined in the following test categories.

6.3.1.1 *Category 1*—Hydrostatic, eddy-current, or ultrasonic test at the manufacturer's option unless the purchaser specifies in accordance with 3.1.9.

6.3.1.2 *Category 2*—Hydrostatic plus eddy-current or ultrasonic test at the manufacturer's option unless the purchaser specifies in accordance with 3.1.9.

6.3.1.3 The manufacturer shall have the option to use Test Category 1 or 2 if the purchaser does not specify the test category options in accordance with 3.1.9.

6.3.2 *Hydrostatic Test*—When tested in accordance with the requirements of 12.4, any pipe that leaks shall be rejected. Any leaking area may be cut out and the pipe retested.

6.3.3 *Acceptance and Rejection*—Pipe producing a signal equal to or greater than the calibration imperfection shall be subject to rejection.

6.3.3.1 Test signals produced by imperfections that cannot be identified or produced by cracks or crack-like imperfections shall result in rejection of the pipe subject to rework and retest. To be accepted, the pipe must pass the same electric test to which it was originally subjected provided that the dimensional requirements are met.

6.3.3.2 If the imperfection is judged as injurious, the pipe shall be rejected but may be reconditioned and retested providing the dimensional requirements are met. To be accepted, retested pipe shall meet the original electric test requirements.

6.3.3.3 If the imperfection is explored to the extent that it can be identified as noninjurious, the pipe may be accepted without further test, providing the imperfection does not encroach on the minimum wall thickness.

7. Dimensions and Permissible Variations

7.1 The outside diameter shall not exceed the permissible

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TABLE 5 Dimensions of Welded Pipe

NOTE 1—The following table is a partial reprint of Table 1 of ANSI B36.19.
NOTE 2—The decimal thicknesses listed for the respective pipe size represent their nominal wall dimensions.

Nominal Pipe Size, in.	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[A]		Schedule 10S[A]		Schedule 40S		Schedule 80S	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
⅛	0.405	10.29	...	...	0.049	1.245	0.068	1.727	0.095	2.41
¼	0.540	13.72	...	...	0.065	1.651	0.088	2.235	0.119	3.02
⅜	0.675	17.15		...	0.065	1.651	0.091	2.311	0.126	3.20
½	0.840	21.34	0.065	1.651	0.083	2.108	0.109	2.768	0.147	3.73
¾	1.050	26.67	0.065	1.651	0.083	2.108	0.113	2.870	0.154	3.91
1	1.315	33.40	0.065	1.651	0.109	2.768	0.133	3.378	0.179	4.55
1¼	1.660	42.16	0.065	1.651	0.109	2.768	0.140	3.556	0.191	4.85
1½	1.900	48.26	0.065	1.651	0.109	2.768	0.145	3.683	0.200	5.08
2	2.375	60.33	0.065	1.651	0.109	2.768	0.154	3.912	0.218	5.54
2½	2.875	73.03	0.083	2.108	0.120	3.048	0.203	5.156	0.276	7.01
3	3.500	88.90	0.083	2.108	0.120	3.048	0.216	5.486	0.300	7.62
3½	4.000	101.6	0.083	2.108	0.120	3.048	0.226	5.740	0.318	8.08
4	4.500	114.3	0.083	2.108	0.120	3.048	0.237	6.020	0.337	8.56
5	5.563	141.30	0.109	2.77	0.134	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109	2.77	0.148	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134	3.40	0.165	4.19	0.365	9.27	0.500[B]	12.70[B]
12	12.750	323.85	0.156	3.96	0.180	4.57	0.375[B]	9.52[B]	0.500[B]	12.70[B]
14	14.000	355.60	0.156	3.96	0.188[B]	4.78[B]	...	...	...	...
16	16.000	406.40	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
18	18.000	457.20	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
20	20.000	508.00	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
22	22.000	558.80	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
24	24.000	609.60	0.218	5.54	0.250	6.35	...	...	...	...
30	30.000	762.00	0.250	6.35	0.312	7.92	...	...	...	...

[A] Schedules 5S and 10S wall thicknesses do not permit threading in accordance with ANSI B1.20.1.
[B] These do not conform to ANSI B36.10.

variations prescribed in Table 3.

7.1.1 Pipe having a specified wall thickness that is 3 % or less of the outside diameter cannot be straightened properly without a certain amount of ovality resulting in the diameter. The limits to this ovality are stated in Footnote B of Table 3.

7.2 The wall thickness shall not vary from nominal by more than ± 12½ %.

7.3 *Straightness*—Material shall be reasonably straight and free of bends or kinks.

7.4 *Length*—Variations from the specified length shall not exceed the amounts prescribed in Table 4.

8. Workmanship, Finish, and Appearance

8.1 The material shall be uniform in quality and temper, smooth, commercially straight, and free of injurious imperfections.

9. Sampling

9.1 *Lots of Chemical Analysis and Mechanical Testing.*

TABLE 6 Fiber Stress Requirements for Hydrostatic Testing

Condition and Size	Nickel, psi (MPa)	Low Carbon Nickel, psi (MPa)
Annealed:		
5 in. (127 mm) outside diameter and under	10 000 (70)	8 000 (55)
Over 5 in. outside diameter	8 000 (55)	6 700 (45)
Stress relieved:		
All sizes	16 200 (110)	15 000 (105)

9.1.1 A lot for chemical analysis shall consist of one heat.

9.1.2 A lot for mechanical properties and flattening testing shall consist of all material from the same heat, nominal size (excepting length), and condition (temper).

9.2 *Test Material Selection.*

9.2.1 *Chemical Analysis*—Representative samples shall be taken during pouring or subsequent processing.

9.2.1.1 Product (check) analysis shall be wholly the responsibility of the purchaser.

9.2.2 *Mechanical Properties and Flattening Testing*—Samples of the material to provide test specimens shall be taken from such locations in each lot as to be representative of that lot.

10. Number of Tests

10.1 *Chemical Analysis*—One test per lot.
10.2 *Mechanical Properties*—One test per lot.
10.3 *Flattening*—One test per lot.
10.4 *Nondestructive*—Each piece in each lot.

11. Specimen Preparation

11.1 Tension test specimens shall be taken from material in the final condition (temper) and tested in the direction of fabrication.

11.1.1 Whenever possible, all pipe shall be tested in full-tubular size. When testing in full-tubular size is not possible, longitudinal strip specimens shall be used. In the event of disagreement when full-tubular testing is not possible, a longitudinal strip specimen with reduced gage length in accordance with Test Methods E 8 shall be used.

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12. Test Methods

12.1 The chemical composition, mechanical, and other properties of the material as enumerated in this specification shall be determined, in case of disagreement, in accordance with the following methods.

Test	ASTM Designation
Chemical Analysis	E 39
Tension	E 8
Rounding procedure	E 29

12.2 For purposes of determining compliance with the limits in this specification, an observed value or a calculated value shall be rounded in accordance with the rounding method of Practice E 29:

Test	Rounded Unit for Observed or Calculated Value
Chemical composition and tolerances (when expressed in decimals).	nearest unit in the last right-hand place of figures of the specified limit.
Tensile strength and yield strength.	nearest 1000 psi (6.9 MPa)
Elongation	nearest 1 %

12.3 *Flattening Test*—Pipe shall be capable of withstanding, without cracking, flattening under a load applied gradually at room temperature until the distance between the platens is five times the wall thickness. The weld shall be positioned 90 % from the direction of the applied flattening force.

12.4 *Hydrostatic Test*—Each pipe shall be tested at a pressure calculated by the following equation:

$$P = 2St/D$$

where:

P = hydrostatic test pressure, psi (or MPa),
t = specified wall thickness, in. (or mm),
D = specified outside diameter, in. (or mm), and
S = allowable fiber stress for material in the condition furnished, as follows:

	Nickel	Low Carbon Nickel	Nickel-Copper (Allowable Fiber Stress)
Annealed			
5 in. (127 mm) outside diameter and under	10 000 psi (70 MPa)	8000 psi (55 MPa)	17 500 psi (120 MPa)
Over 5 in. outside diameter	8000 psi (55 MPa)	6700 psi (45 MPa)	16 700 psi (115 MPa)
	Nickel	Low Carbon Nickel	Nickel-Copper (Allowable Fiber Stress)
Stress Relieved: All sizes	16 200 psi (110 MPa)	15 000 psi (105 MPa)	21 200 psi (145 MPa)

12.4.1 The test pressure shall be held for a minimum of 5s.

12.4.2 Visual examination shall be made when the pipe is under pressure. The full length of the pipe must be examined for leaks. If any pipe shows leaks during the hydrostatic test, it shall be rejected.

12.5 *Electric Test*—Each pipe shall be tested with an electric test in accordance with either Practice E 213 or E 571.

12.5.1 For eddy-current testing, the calibration pipe shall contain, at the option of the manufacturer, any one of the following discontinuities to establish a minimum sensitivity level for rejection. The discontinuity shall be placed in the weld if visible.

(a) *Drilled Hole*—A hole not larger than 0.031 in. (0.79 mm) in diameter shall be drilled radially and completely through the wall, care being taken to avoid distortion of the pipe while drilling.

(b) *Transverse Tangential Notch*—Using a round file or tool with a ¼-in. (6.4-mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. This notch shall have a depth not exceeding 12½ % of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

(c) *Longitudinal Notch*—A notch 0.031 in. (0.79 mm) or less in width shall be machined in a radial plan parallel to the pipe axis on the outside surface of the pipe, to have a depth not exceeding 12½ % of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

12.5.2 For ultrasonic testing, the longitudinal calibration reference notches shall be at the option of the manufacturer, any one of the three common notch shapes in accordance with Practice E 213. The depth of the notch shall not exceed 12½ % of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater. The notch shall be placed in the weld if visible.

13. Inspection

13.1 Inspection of the material shall be agreed upon between the purchaser and the supplier as part of the purchase contract.

14. Rejection and Rehearing

14.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

15. Certification

15.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

16. Product Marking

16.1 The name or brand of the manufacturer, the name of the material or UNS number from which the pipe is made, the letters ASTM, the specification number, condition (temper), heat number, test category for pipe outside diameters 1.5 in. (38.1 mm) and under, and the nominal size shall be stenciled legibly on each pipe ½ in. (12.7 mm) and over in outside diameter, provided the length is not under 3 ft (914 mm). The material marking shall be by any method that will not result in harmful contamination.

16.2 For pipe less than ½ in. (12.7 mm) in diameter and pipe under 3 ft (914 mm) in length, the information in accordance with 16.1 shall be either stenciled or marked on a tag securely attached to the bundle or box in which the pipe is shipped.

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SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order.

S1. Supplementary Requirements for Pipe Requiring Special Consideration

S1.1 The pipe may be furnished without cold working.

S1.2 The pipe may be furnished without a final heat treatment.

S1.3 Pipe over 0.125 in. (3.175 mm) wall thickness may be welded with the addition of matching filler metal.

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Designation: B 775 – 00

An American National Standard

Standard Specification for General Requirements for Nickel and Nickel Alloy Welded Pipe[1]

This standard is issued under the fixed designation B 775; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification contains various requirements that, with the exception of Section 5 and Section 10, are mandatory requirements to the following ASTM nickel and nickel alloy, longitudinally welded piping specifications:[2]

Title of Specification	ASTM Designation[2]
Welded UNS N08020, UNS N08024, and UNS N08026 Alloy Pipe	B 464
Welded Nickel-Iron-Chromium Alloy Pipe	B 514
Welded Nickel-Chromium-Iron-Alloy (UNS N06600) Pipe	B 517
Welded Nickel and Nickel-Cobalt Alloy Pipe	B 619
UNS N08904, UNS N08925, and UNS N08926 Welded Pipe	B 673
UNS N08366 and UNS N08367 Welded Pipe	B 675
Nickel-Alloy (UNS N06625 and N08825) Welded Pipe	B 705
Ni-Cr-Mo-Co-W-Fe-Si Alloy (UNS N06333) Welded Pipe	B 723
Welded Nickel (UNS N02200/UNS N02201) and Nickel Copper Alloy (UNS N04400) Pipe	B 725

1.2 One or more of the test requirements of Section 5 apply only if specifically stated in the product specification or in the purchase order.

1.3 In case of conflict between a requirement of the product specification and a requirement of this general specification, only the requirement of the product specification needs to be satisfied.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

B 880 Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys[2]

E 8 Test Methods for Tension Testing of Metallic Materials[3]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

E 39 Test Methods for Chemical Analysis of Nickel[5]

E 76 Test Methods for Chemical Analysis of Nickel Copper Alloys[5]

E 112 Test Methods for Determining the Average Grain Size[3]

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing[6]

E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys[6]

E 571 Practice for Electromagnetic (Eddy-Current) Examination of Nickel and Nickel Alloy Tubular Products[6]

E 1473 Test Methods for Chemical Analysis of Nickel, Cobalt, and High-Temperature Alloys[7]

2.2 *ANSI Standards:*[8]

B 1.20.1 Pipe Threads

B 36.10 Welded and Seamless Wrought Steel Pipe

B 36.19 Stainless Steel Pipe

3. Terminology

3.1 *Definitions:*

3.1.1 *average diameter*—the average of the maximum and minimum outside diameters, as determined at any one cross section of the pipe.

3.1.2 *nominal wall*—a specified wall thickness with a plus or minus tolerance from the specified thickness.

3.1.3 *welded pipe*—a round hollow produced by forming flat stock and joining the single longitudinal seam by welding, and produced to the particular dimensions commercially known as pipe sizes (NPS).

4. Chemical Composition

4.1 In case of disagreement, the chemical composition shall be determined in accordance with the following methods:

[1] This specification is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.07 on Refined Nickel and Cobalt and Their Alloys.

Current edition approved May 10, 2000. Published June 2000. Originally published as B 775 – 87. Last previous edition B 775 – 99.

[2] *Annual Book of ASTM Standards*, Vol 02.04.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 03.05.

[6] *Annual Book of ASTM Standards*, Vol 03.03.

[7] *Annual Book of ASTM Standards*, Vol 03.06.

[8] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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UNS No. Prefixes	ASTM Method
N02	E 39
N04	E 76
N06, N08	E 1473

4.2 The ladle analysis of the material shall conform to the chemical requirements prescribed by the individual product specification.

4.3 The product (check) analysis of the material shall meet the requirements for the ladle analysis within the tolerance limits prescribed in B 880.

5. Test Requirements

5.1 *Flattening Test*:

5.1.1 A length of pipe not less than three times the specified diameter or 4 in. (102 mm), whichever is longer, shall be flattened under a load applied gradually at room temperature until the distance between the platens is five times the wall thickness. The weld shall be positioned 90° from the direction of the applied flattening force.

5.1.2 The flattened specimen shall not exhibit cracks.

5.1.3 Superficial ruptures resulting from surface imperfections shall not be a cause for rejection.

5.2 *Pressure (Leak Test)*:

5.2.1 *Hydrostatic*— Each pipe shall be tested by the manufacturer to an internal hydrostatic pressure of 1000 psi (6.9 MPa) provided that the fiber stress, calculated from the following equation, does not exceed the allowable fiber stress for the material:

$$P = 2St/D \quad (1)$$

where:

P = hydrostatic test pressure, psi (MPa),
S = allowable fiber stress, for material in the condition (temper) furnished as specified in the product specification (S is calculated as the lower of ⅔ of the specified minimum 0.2 % offset yield strength or ¼ of the specified minimum ultimate strength for the material),
t = minimum wall thickness permitted, in. (mm), including minus tolerance, if any, and
D = nominal outside diameter of the pipe, in. (mm).

5.2.1.1 The test pressure must be held for a minimum of 5 s.

NOTE 1—Testing at a pressure greater than 1000 psi may be performed upon agreement between the purchaser and manufacturer provided that the allowable fiber stress is not exceeded.

5.2.2 *Pneumatic (Air Underwater Test)*—Each pipe shall be tested at a pressure of 150 psi (1.05 MPa). The test pressure shall be held for a minimum of 5 s. Visual examination is to be made when the material is submerged and under pressure. The full length of pipe must be examined for leaks.

5.2.3 If any pipe shows leaks during hydrostatic or pneumatic testing, it shall be rejected.

5.3 *Nondestructive Electric Test*:

5.3.1 *Eddy Current Testing*—Testing shall be conducted in accordance with Practices E 426 or E 571. The eddy current examination reference in this specification has the capability of detecting significant discontinuities, especially of the short, abrupt type.

5.3.1.1 Unless otherwise specified by the purchaser, the calibration standard shall contain, at the option of the manufacturer, any one of the following discontinuities to establish a minimum sensitivity level for rejection. The discontinuity shall be placed in the weld if visible.

5.3.1.2 *Drill Hole*—A hole not larger than 0.031 in. (0.79 mm) diameter shall be drilled radially and completely through the wall, care being taken to avoid distortion of the material while drilling.

5.3.1.3 *Transverse Tangential Notch*—Using a round file or tool with a ¼ in. (6 mm) diameter, a notch shall be filed or milled on the pipe outside diameter tangential to the surface and transverse to the longitudinal axis of the material. Said notch shall have a depth not exceeding 12.5 % of the specified wall thickness of the material, or 0.004 in. (0.10 mm), whichever is greater.

5.3.2 *Ultrasonic Testing*—Testing shall be conducted in accordance with Practice E 213. The ultrasonic examination referred to in this specification is intended to detect longitudinal discontinuities having a reflective area similar to or larger than the calibration reference notches specified in 5.3.2.1. The examination may not detect circumferentially oriented imperfections or short, deep defects.

5.3.2.1 For ultrasonic testing, longitudinal calibration notches shall be machined on the outside and inside diameter surfaces. The depth of the notches shall not exceed 12.5 % of the specified wall thickness or 0.004 in. (0.10 mm), whichever is greater. The notch shall be placed in the weld, if visible.

5.3.3 *Calibration Frequency*—The frequency of calibration checks shall be as follows:

5.3.3.1 At the beginning of each production run.

5.3.3.2 At least every four hours during testing.

5.3.3.3 At the end of each production run.

5.3.3.4 After any suspected equipment malfunction or work stoppage.

5.3.3.5 If, during any check, the equipment fails to detect the calibration defects, the instrument must be recalibrated and all material tested since the last satisfactory check shall be retested.

5.3.4 *Acceptance and Rejection*—Material producing a signal equal to or greater than the calibration defect shall be subject to rejection.

5.3.4.1 Test signals that are produced by imperfections that cannot be identified or that are produced by cracks or crack-like imperfections shall result in rejection of the pipe, subject to rework and retest.

5.3.4.2 If the imperfection is judged as not fit for use, the tube shall be rejected, but may be reconditioned and retested providing the wall thickness requirements are met. To be accepted, retested material shall meet the original electric test requirements.

5.3.4.3 If the imperfection is explored to the extent that it can be identified, and the pipe is determined to be fit for use, the material may be accepted without further testing providing the imperfection does not encroach on minimum wall thickness requirements.

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5.4 *Tension Test*— Tension testing shall be conducted in accordance with Test Methods E 8.

5.4.1 The material shall conform to the tensile properties prescribed in the individual product specification.

5.5 *Hardness Test*— Hardness testing shall be conducted in accordance with Test Methods E 18.

5.6 *Grain Size*—The measurement of average grain size may be carried out by the planimetric method, the comparison method, or the intercept method described in Test Methods E 112. In case of dispute, the "referee" method for determining average grain size shall be the intercept method.

5.7 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded in accordance with the rounding method of Practice E 29:

Requirements	Rounded Unit for Observed or Calculated Value
Chemical composition and tolerances	nearest unit in the last right-hand place of figures of the specified limit
Tensile strength and yield strength	nearest 1000 psi (7 MPa)
Elongation	nearest 1 %

6. Dimensions and Permissible Variations

6.1 Dimensions of pipe are shown in Table 1.

6.1.1 Permissible variations in outside diameter and wall thickness are shown in Table 2.

6.2 *Length*—When material is ordered as cut-to-length, the length shall conform to the permissible variations prescribed in Table 3. When material is ordered to random lengths, the lengths and variations shall be agreed upon between the manufacturer and purchaser.

6.3 *Straightness*— Material shall be reasonably straight and free of bends and kinks.

6.4 *Ends*—Ends shall be reasonably square and free from burrs.

TABLE 1 Dimensions of Pipe

NOTE 1—The following table is a reprint of Table 1 of ANSI B36.19.
NOTE 2—The decimal thicknesses listed for the respective pipe sizes represent their nominal wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
	in.	mm	Schedule 5S[A]		Schedule 10S[A]		Schedule 40S		Schedule 80S	
			in.	mm	in.	mm	in.	mm	in.	mm
⅛	0.405	10.29	...	...	0.049	1.24	0.068	1.73	0.095	2.41
¼	0.540	13.72	...	...	0.065	1.65	0.088	2.24	0.119	3.02
⅜	0.675	17.15	...	...	0.065	1.65	0.091	2.31	0.126	3.20
½	0.840	21.34	0.065	1.65	0.083	2.11	0.109	2.77	0.147	3.73
¾	1.050	26.67	0.065	1.65	0.083	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065	1.65	0.109	2.77	0.133	3.38	0.179	4.55
1¼	1.660	42.16	0.065	1.65	0.109	2.77	0.140	3.56	0.191	4.85
1½	1.900	48.26	0.065	1.65	0.109	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065	1.65	0.109	2.77	0.154	3.91	0.218	5.54
2½	2.875	73.03	0.083	2.11	0.120	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120	3.05	0.216	5.49	0.300	7.62
3½	4.000	101.60	0.083	2.11	0.120	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109	2.77	0.134	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109	2.77	0.148	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134	3.40	0.165	4.19	0.365	9.27	0.500[B]	12.70[B]
12	12.750	323.85	0.156	3.96	0.180	4.57	0.375[B]	9.52[B]	0.500[B]	12.70[B]
14	14.000	355.60	0.156	3.96	0.188[B]	4.78[B]	...	...	...	...
16	16.000	406.40	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
18	18.000	457.20	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
20	20.000	508.00	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
22	22.000	558.80	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
24	24.000	609.60	0.218	5.54	0.250	6.35	...	...	...	...
30	30.000	762.00	0.250	6.35	0.312	7.92	...	...	...	...

[A] Schedules 5S and 10S wall thicknesses do not permit threading in accordance with ANSI B1.20.1.
[B] These do not conform to ANSI B36.10.

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TABLE 2 Permissible Variations in Outside Diameter[A,B] and Wall Thickness[C] For Welded Pipe

NPS Designator	Permissible Variations in Outside Diameter			
	Over		Under	
	in.	mm	in.	mm
⅛ to 1½, incl	1/64 (0.015)	0.4	1/32 (0.031)	0.8
Over 1½ to 4, incl	1/32 (0.031)	0.8	1/32 (0.031)	0.8
Over 4 to 8, incl	1/16 (0.062)	1.6	1/32 (0.031)	0.8
Over 8 to 18, incl	3/32 (0.093)	2.4	1/32 (0.031)	0.8
Over 18 to 26, incl	⅛ (0.125)	3.2	1/32 (0.031)	0.8
Over 26 to 34, incl	5/32 (0.156)	4.0	1/32 (0.031)	0.8
Over 34 to 48, incl	3/16 (0.187)	4.8	1/32 (0.031)	0.8

[A] These permissible variations in outside diameter apply only to material as finished at the mill before subsequent swaging, expanding, bending, polishing, or other fabricating operations.

[B] Ovality is the difference between the maximum and the minimum outside diameter measured at any one cross section. There is no additional tolerance for ovality on material having a nominal wall thickness for more than 3 % of the outside diameter. On this material, the average of the maximum and the minimum outside diameter measurements will fall within the outside diameter tolerance shown in Table 2. An additional ovality allowance of twice the outside diameter tolerance spreads shown in Table 2, applied ±½, is allowed for material having a nominal wall thickness of 3 % or less of the nominal outside diameter.

[C] The wall thickness variation shall not exceed ±12.5 % of the nominal wall thickness.

TABLE 3 Permissible Variations in Cut Length[A]

Outside Diameter, in. (mm)	Length Tolerance, in. (mm)	
	Over	Under
Cold finished:		
all sizes	¼ (6.4)	0
Hot finished:		
all sizes	¼ (6.4)	0

[A] These permissible variations in length apply to pipe in straight lengths. They apply to cut lengths up to and including 24 ft (7.3 m). For lengths over 24 ft, an additional over-tolerance of ⅛ in. (3.2 mm) for each 10 ft (3.0 m) or fraction thereof shall be permitted up to a maximum additional over-tolerance of ½ in. (12.7 mm).

7. Workmanship, Finish, and Appearance

7.1 The material shall be uniform in quality and temper, smooth, and free from imperfections that would render it unfit for use.

8. Sampling

8.1 *Lot Definition*:

8.1.1 A lot for chemical analysis shall consist of one heat.

8.1.2 A lot for all other testing shall consist of all material from the same heat, nominal size (excepting length), and condition (temper). When final heat treatment is in a batch-type furnace, a lot shall include only those pipes of the same size and the same heat that are heat-treated in the same furnace charge. When heat treatment is in a continuous furnace, a lot shall include all pipe of the same size and heat, heat-treated in the same furnace at the same temperature, time at temperature, and furnace speed during one production run. At no time shall a lot consist of more than 20 000 lb (9070 kg).

8.1.2.1 Where material cannot be identified by heat, a lot shall consist of not more than 500 lb (227 kg) of material of the same alloy in the same condition (temper) and nominal size (excepting length).

NOTE 2—For tension, hardness and flattening test requirements, the term lot applies to all lengths prior to cutting.

8.2 *Test Material Selection*:

8.2.1 *Chemical Analysis*—Representative samples from each lot shall be taken during pouring or subsequent processing.

8.2.2 *Mechanical and Other Properties*—Samples of the material to provide test specimens for mechanical and other properties shall be taken from such locations in each lot as to be representative of that lot. Test specimens shall be taken from material in the final condition (temper).

9. Retests and Retreatment

9.1 *Retests*—If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional pipes of double the original number from the same group or lot, each of which shall conform to the requirements specified.

9.2 *Retreatment*— If the individual pipes or the pipes selected to represent any group or lot fail to conform to the test requirements, the individual pipes or the group or lot represented may be reheat treated and resubmitted for test. Not more than two reheat treatments shall be permitted.

10. Specimen Preparation

10.1 *Room Temperature Tensile Specimen*:

10.1.1 Material shall be tested in the direction of fabrication. Whenever possible, the pipe shall be tested in full cross section. When testing in full section is not possible, longitudinal strip specimens or the largest possible round section shall be used. In the event of disagreement when full section testing is not possible, a longitudinal strip specimen with reduced gage length as contained in Test Methods E 8 shall be used.

10.2 *Hardness Specimen*:

10.2.1 The hardness specimen shall be prepared in accordance with Test Methods E 18. The test shall be made on the inside diameter surface of a specimen cut from the end, or on the inside of the pipe near the end, at the option of the manufacturer.

10.3 *Grain Size*:

10.3.1 If required, the grain size specimen shall be a transverse sample representing full wall thickness.

11. Inspection

11.1 Witnessing of testing or inspection by the purchaser's representative shall be agreed upon by the purchaser and the manufacturer as part of the purchase contract.

12. Rejection and Rehearing

12.1 Material tested by the purchaser that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

13. Certification

13.1 When specified in the purchase contract, a manufacturer's certification shall be furnished to the purchaser stating that the material has been manufactured, tested and inspected in accordance with this specification, and that the test results on representative samples meet specification requirements. When specified in the purchase contract, a report of the test results shall be furnished.

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14. Product Marking

14.1 *Material Marking*:

14.1.1 The name or brand of the manufacturer, the name of the material or UNS number, the letters ASTM, the product specification number, heat number, class (if applicable) and nominal pipe size shall be legibly marked on each piece ½NPS and larger and lengths greater than 3 ft (914 mm). The material marking shall be by any method that will not result in harmful contamination.

14.1.2 For material smaller than ½ NPS, or lengths under 3 ft (914 mm), the information specified in 14.1.1 shall be legibly marked on each piece or marked on a tag securely attached to the bundle or box in which the material is shipped, at the option of the manufacturer.

15. Packaging and Package Marking

15.1 The following information shall be marked on the material or included on the package, or on a label or tag attached thereto: name of the material or UNS number, heat number, condition (temper), the letters ASTM, the product specification number, the nominal pipe size, gross, tare, and net weight, consignor and consignee addresses, contract or order number, and such other information as may be defined by the purchase contract.

16. Keywords

16.1 welded pipe

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Standard Specification for General Requirements for Nickel and Nickel Alloys Seamless Pipe and Tube[1]

This standard is issued under the fixed designation B 829; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification contains various requirements that, with the exception of Sections 5 and 10, are mandatory requirements to the following ASTM nickel and nickel alloy, seamless pipe and tube specifications:

Title of Specification	ASTM Designation[A]
Nickel Seamless Pipe and Tube	B 161
Seamless Nickel and Nickel Alloy, Condenser and Heat Exchanger Tubes	B 163
Nickel-Copper Alloy (UNS N04400) Seamless Pipe and Tube	B 165
Nickel-Chromium-Iron Alloys (UNS N06600, N06601, and N06690) Seamless Pipe and Tube	B 167
Nickel-Iron-Chromium Alloy Seamless Pipe and Tube	B 407
Nickel-Iron-Chromium-Molybdenum-Copper Alloy (UNS N08825 and N08221) Seamless Pipe and Tube	B 423
Nickel-Chromium-Molybdenum-Columbium Alloys (UNS N06625) Pipe and Tube	B 444
Nickel-Chromium-Iron-Columbium-Molybdenum-Tungsten Alloy (UNS N06102) Seamless Pipe and Tube	B 445
Nickel-Iron-Chromium-Silicon Alloys (UNS N08330 and UNS N08332) Seamless Pipe	B 535
Copper-Beryllium Alloy Forgings and Extrusion	B 570[B]
Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube	B 622
UNS N08028 Seamless Tubes	B 668
UNS N08904, UNS N08925 and UNS N08926 Seamless Pipe and Tube	B 677
Iron-Nickel-Chromium-Molybdenum Alloys (UNS N08366 and UNS N08367) Seamless Pipe and Tube	B 690
Ni-Cr-Mo-Co-W-Fe-Si Alloy (UNS N06333) Seamless Pipe and Tube	B 722
Seamless UNS N08020, UNS N08026, and UNS N08024 Nickel-Alloy Pipe and Tube	B 729

[A] *Annual Book of ASTM Standards*, Vol 02.01.
[B] *Annual Book of ASTM Standards*, Vol 02.04.

1.2 One or more of the test requirements of Section 5 apply only if specifically stated in the product specification or in the purchase order.

1.3 In case of conflict between a requirement of the product specification and a requirement of this general specification, only the requirement of the product specification needs to be satisfied.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The following safety hazards caveat pertains only to the test requirements portion, Section 5, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

B 880 Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys[2]
E 8 Test Methods for Tension Testing of Metallic Materials[3]
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[3]
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]
E 39 Methods for Chemical Analysis of Nickel[5]
E 76 Test Methods for Chemical Analysis of Nickel-Copper Alloys[5]
E 112 Test Methods for Determining the Average Grain Size[3]
E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing[6]
E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys[6]
E 571 Practice for Electromagnetic (Eddy-Current) Examination of Nickel and Nickel Alloy Tubular Products[6]
E 1473 Test Methods for Chemical Analysis of Nickel, Cobalt, and High-Temperature Alloys[7]

2.2 *ANSI Standards:*[8]

B 1.20.1 Pipe Threads
B 36.10 Welded and Seamless Wrought Steel Pipe
B 36.19 Stainless Steel Pipe

[1] This specification is under the jurisdiction of ASTM Committee B-2 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.07 on Refined Nickel and Cobalt and Their Alloys.

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[2] *Annual Book of ASTM Standards*, Vol 02.04.
[3] *Annual Book of ASTM Standards*, Vol 03.01.
[4] *Annual Book of ASTM Standards*, Vol 14.02.
[5] *Annual Book of ASTM Standards*, Vol 03.05.
[6] *Annual Book of ASTM Standards*, Vol 03.03.
[7] *Annual Book of ASTM Standards*, Vol 03.06.
[8] Available from American National Standards Institute, 11 West 42nd St., 13th Fl., New York, NY 10036.

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3. Terminology

3.1 *Definitions:*

3.1.1 *average diameter, n*—the average of the maximum and minimum outside diameters, as determined at any one cross section of the pipe or tube.

3.1.2 *nominal wall, n*—a specified wall thickness with a plus or minus tolerance from the specified thickness.

3.1.3 *seamless pipe, n*—a round hollow produced with a continuous periphery in all stages of manufacture, and produced to the particular dimensions commercially known as pipe sizes (NPS).

3.1.4 *seamless tube, n*—a tube produced with a continuous periphery in all stages of the operation.

3.1.5 *thin wall tube, n*—tube with specified wall thickness 3 % or less of the specified outside diameter.

4. Chemical Composition

4.1 In case of disagreement, the chemical composition shall be determined in accordance with the following methods.

UNS No. Prefixes	ASTM Method
N02	E 39
N04	E 76
N06, N08	E 1473

4.2 The ladle analysis of the material shall conform to the chemical requirements prescribed by the individual product specification.

4.3 The product (check) analysis of the material shall meet the requirements for the ladle analysis within the tolerance limits prescribed in B 880.

5. Test Requirements

5.1 *Flare Test*—The flare test shall consist of flaring a test specimen with an expanding tool having an included angle of 60° until the specified outside diameter has been increased by 30 %. The flared specimen shall not exhibit cracking through the wall.

5.2 *Hydrostatic Test*— Each pipe or tube shall be tested by the manufacturer to an internal hydrostatic pressure of 1000 psi (6.9 MPa) provided that the fiber stress, calculated from the following equation, does not exceed the allowable fiber stress for the material:

$$P = 2St/D \quad (1)$$

where:

P = hydrostatic test pressure, psi (MPa),

S = allowable fiber stress, for material in the condition (temper) furnished as specified in the product specification (S is calculated as the lower of ⅔ of the specified minimum 0.2 % offset yield strength or ¼ of the specified minimum ultimate strength for the material),

t = minimum wall thickness permitted, in. (mm), including minus tolerance, if any, and

D = nominal outside diameter of the pipe or tube, in. (mm).

5.2.1 The test pressure must be held for a minimum of 5 s.

NOTE 1—Testing at a pressure greater than 1000 psi may be performed upon agreement between purchaser and manufacturer provided that the allowable fiber stress is not exceeded.

5.2.2 If any pipe or tube shows leaks during hydrostatic testing, it shall be rejected.

5.3 *Nondestructive Electric Test*:

5.3.1 *Eddy Current Testing*—Testing shall be conducted in accordance with Practices E 426 or E 571. The eddy current examination reference in this specification has the capability of detecting significant discontinuities, especially of the short, abrupt type.

5.3.1.1 Unless otherwise specified by the purchaser, the calibration standard shall contain, at the option of the manufacturer, any one of the following discontinuities to establish a minimum sensitivity level for rejection.

5.3.1.2 *Drill Hole*—A hole not larger than 0.031 in. (0.79 mm) diameter shall be drilled radially and completely through the wall, care being taken to avoid distortion of the material while drilling.

5.3.1.3 *Transverse Tangential Notch*—Using a round file or tool with a ¼ in. (6 mm) diameter, a notch shall be filed or milled on the tube or pipe outside diameter tangential to the surface and transverse to the longitudinal axis of the material. Said notch shall have a depth not exceeding 12.5 % of the specified wall thickness of the material, or 0.004 in. (0.10 mm), whichever is greater.

5.3.2 *Ultrasonic Testing*—Testing shall be conducted in accordance with Practice E 213. The ultrasonic examination referred to in this specification is intended to detect longitudinal discontinuities having a reflective area similar to or larger than the calibration reference notches specified in 5.3.2.1. The examination may not detect circumferentially oriented imperfections or short, deep defects.

5.3.2.1 For ultrasonic testing, longitudinal calibration notches shall be machined on the outside and inside diameter surfaces. The depth of the notches shall not exceed 12.5 % of the specified wall thickness or 0.004 in. (0.10 mm), whichever is greater.

5.3.3 *Calibration Frequency*—The frequency of calibration checks shall be as follows:

5.3.3.1 At the beginning of each production run or lot.

5.3.3.2 At least every four hours during testing.

5.3.3.3 At the end of each production run or lot.

5.3.3.4 After any suspected equipment malfunction or work stoppage.

5.3.3.5 If, during any check, the equipment fails to detect the calibration defects, the instrument must be recalibrated and all material tested since the last satisfactory check shall be retested.

5.3.4 *Acceptance and Rejection*—Material producing a signal equal to or greater than the calibration defect shall be subject to rejection.

5.3.4.1 Test signals produced by imperfections that cannot be identified or produced by cracks or crack-like imperfections shall result in rejection of the pipe or tube, subject to rework and retest.

5.3.4.2 If the imperfection is judged as not fit for use, the tube shall be rejected, but may be reconditioned and retested providing the wall thickness requirements are met. To be accepted, retested material shall meet the original electric test requirements.

5.3.4.3 If the imperfection is explored to the extent that it

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can be identified, and the pipe or tube is determined to be fit for use, the material may be accepted without further testing, providing the imperfection does not encroach on minimum wall thickness requirements.

5.4 When specified by the purchaser, a nondestructive electric test, in accordance with Practices E 213, E 426, or E 571, may be used for seamless pipe or tube, instead of the hydrostatic test.

5.5 *Tension Test*— Tension testing shall be conducted in accordance with Test Methods E 8.

5.5.1 The material shall conform to the tensile properties prescribed in the individual product specification.

5.6 *Hardness Test*— Hardness testing shall be conducted in accordance with Test Methods E 18.

5.7 *Grain Size*—The measurement of average grain size may be carried out by the planimetric method, the comparison method, or the intercept method described in Test Methods E 112. In case of dispute, the "referee" method for determining average grain size shall be the intercept method.

5.8 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded in accordance with the rounding method of Practice E 29:

Requirements	Rounded Unit for Observed or Calculated Value
Chemical composition and tolerances	nearest unit in the last right-hand place of figures of the specified limit
Tensile strength and yield strength	nearest 1000 psi (7 MPa)
Elongation	nearest 1 %
Grain size	
0.0024 in. (0.060 mm) or larger	nearest multiple of 0.0002 in. (0.005 mm)
Less than 0.0024 in. (0.060 mm)	nearest multiple of 0.0001 in. (0.002 mm)

6. Dimensions and Permissible Variations

6.1 Dimensions of pipe are shown in Table 1.

6.1.1 Permissible variations in outside diameter and wall thickness are shown in Table 2, Table 3, and Table 4.

6.2 *Length*—When material is ordered as cut-to-length, the length shall conform to the permissible variations prescribed in Table 5. When material is ordered to random lengths, the lengths and variations shall be agreed upon between the manufacturer and purchaser.

6.3 *Straightness*— Material shall be reasonably straight and free of bends and kinks.

6.4 *Ends*—Ends shall be plain cut and deburred.

7. Workmanship, Finish, and Appearance

7.1 The material shall be uniform in quality and temper, smooth, and free from imperfections that would render it unfit for use.

8. Sampling

8.1 *Lot Definition*:

8.1.1 A lot for chemical analysis shall consist of one heat.

TABLE 1 Dimensions of Pipe

NOTE 1—The following table is a reprint of Table 1 of ANSI B36.19.
NOTE 2—The decimal thicknesses listed for the respective pipe sizes represent their nominal wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[A]		Schedule 10S[A]		Schedule 40S		Schedule 80S	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
⅛	0.405	10.29	...	...	0.049	1.24	0.068	1.73	0.095	2.41
¼	0.540	13.72	...	...	0.065	1.65	0.088	2.24	0.119	3.02
⅜	0.675	17.15	...	...	0.065	1.65	0.091	2.31	0.126	3.20
½	0.840	21.34	0.065	1.65	0.083	2.11	0.109	2.77	0.147	3.73
¾	1.050	26.67	0.065	1.65	0.083	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065	1.65	0.109	2.77	0.133	3.38	0.179	4.55
1¼	1.660	42.16	0.065	1.65	0.109	2.77	0.140	3.56	0.191	4.85
1½	1.900	48.26	0.065	1.65	0.109	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065	1.65	0.109	2.77	0.154	3.91	0.218	5.54
2½	2.875	73.03	0.083	2.11	0.120	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120	3.05	0.216	5.49	0.300	7.62
3½	4.000	101.60	0.083	2.11	0.120	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109	2.77	0.134	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109	2.77	0.148	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134	3.40	0.165	4.19	0.365	9.27	0.500[B]	12.70[B]
12	12.750	323.85	0.156	3.96	0.180	4.57	0.375[B]	9.52[B]	0.500[B]	12.70[B]
14	14.000	355.60	0.156	3.96	0.188[B]	4.78[B]	...	...	...	...
16	16.000	406.40	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
18	18.000	457.20	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
20	20.000	508.00	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
22	22.000	558.80	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
24	24.000	609.60	0.218	5.54	0.250	6.35	...	...	...	...
30	30.000	762.00	0.250	6.35	0.312	7.92	...	...	...	...

[A]Schedules 5S and 10S wall thicknesses do not permit threading in accordance with ANSI B1.20.1.
[B]These do not conform to ANSI B36.10.

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TABLE 2 Permissible Variations for Outside Diameter and Wall Thickness of Seamless Cold-Worked Pipe and Tube[A,B]

Nominal Outside Diameter, in. (mm)	Permissible Variations				Thickness of Specified Minimum Wall, %	
	Outside Diameter, in. (mm)		Thickness of Specified Nominal Wall, %		Plus	Minus
	Plus	Minus	Plus	Minus		
Over 0.400 (10) to 5/8 (16), excl	0.005 (0.13)	0.005 (0.13)	15.0	15.0	30	0
5/8 (16) to 1 1/2 (38), incl	0.0075 (0.19)	0.0075 (0.19)	10.0	10.0	22	0
Over 1 1/2 (38) to 3 (76), incl	0.010 (0.25)	0.010 (0.25)	10.0	10.0	22	0
Over 3 (76) to 4 1/2 (114), incl	0.015 (0.38)	0.015 (0.38)	10.0	10.0	22	0
Over 4 1/2 (114) to 6 (152), incl	0.020 (0.51)	0.020 (0.51)	12.5	12.5	28	0
Over 6 (152) to 6 5/8 (168), incl	0.025 (0.64)	0.025 (0.64)	12.5	12.5	28	0
Over 6 5/8 (168) to 8 5/8(219), incl	0.031 (0.79)	0.031 (0.79)	12.5	12.5	28	0

[A] *Ovality*—The permissible variations in this table apply to individual measurements, including out-of-roundness (ovality) except for the following:

For pipe and tube having a nominal wall thickness of 3 % or less of the nominal outside diameter, the mean outside diameter shall conform to the permissible variations of this table and individual measurements (including ovality) shall conform to the plus and minus values of the table, with the values increased by 0.5 % of the nominal outside diameter.

For pipe and tube over 4 1/2 in. (114 mm) in outside diameter with a nominal wall thickness greater than 3 % of the nominal outside diameter, the mean outside diameter shall conform to the permissible variations of this table and individual measurements shall not exceed twice the permissible variations of the table.

[B] *Eccentricity*—The permissible variations in this table apply to individual measurements including eccentricity.

TABLE 3 Permissible Variations for Outside Diameter and Wall Thickness of Hot-Finished Tube[A]

Nominal Outsider Diameter, in. (mm)	Permissible Variations					
	Outside Diameter or Inside Diameter, in. (mm)		% of Thickness of Specified Nominal Wall		% of Thickness of Specific Minimum Wall	
	+	−	+	−	+	−
3/4 (19) to 1 1/2(38), incl	0.015 (0.4)	0.031 (0.8)	12.5	12.5	28.5	0
Over 1 1/2(38.1) to 4 (102), incl	0.031 (0.8)	0.031 (0.8)	12.5	12.5	28.5	0
Over 4 (102) to 9 1/4(235), incl	0.062 (1.6)	0.031 (0.8)	12.5	12.5	28.5	0

[A] *Ovality*—Tube 5 in. (127 mm) and under in outside diameter the tolerance on the outside diameter applies for individual measurements and includes ovality. Tube over 5 in. (127 mm) in outside diameter the mean outside diameter shall conform to the permissible variations of this table and individual measurements shall not exceed twice the permissible variations of this table.

TABLE 4 Permissible Variations for Outside Diameter and Wall Thickness of Seamless Hot-Worked Pipe[A,B]

Nominal Outside Diameter, in. (mm)	Permissible Variations					
	Outside Diameter, in. (mm)		Thickness of Specified Nominal Wall, %		Thickness of Specified Minimal Wall, %	
	Plus	Minus	Plus	Minus	Plus	Minus
2 1/2 (64) to 4 1/2(114), incl	0.031 (0.79)	0.031 (0.79)	16.0	12.5	28.5	0
over 4 1/2 (114) to 6 1/2(165), incl	0.047 (1.2)	0.047 (1.2)	16.0	12.5	28.5	0
over 6 1/2 (165) to 9 1/4(235), incl	0.062 (1.6)	0.062 (1.6)	16.0	12.5	28.5	0

[A] *Ovality*—For pipe 5 in. (127 mm) and under in outside diameter, the tolerance on the outside diameter applies for individual measurements and includes ovality. For pipe over 5 in. (125 mm) in outside diameter, the mean outside diameter shall conform to the permissible variations of this table and individual measurements shall not exceed twice the permissible variations of this table.

[B] *Eccentricity*—The permissible variations in this table apply to individual measurements including eccentricity.

TABLE 5 Permissible Variations in Length[A]

Outside Diameter, in. (mm)	Cut Length, in. (mm)	
	Over	Under
Under 2 (50.8)	1/8 (3.2)	0
2 (50.8) and over	3/16 (4.8)	0

[A] These permissible variations in length apply to pipe or tube in straight lengths. They apply to cut lengths up to and including 24 ft (7.3 m). For lengths over 24 ft, an additional over-tolerance of 1/8 in. (3.2 mm) for each 10 ft (3 m) or fraction thereof shall be permissible up to a maximum additional over-tolerance of 1/2 in. (12.7 mm).

8.1.2 A lot for all other testing shall consist of all material from the same heat, nominal size (excepting length), and condition (temper). When final heat treatment is in a batch-type furnace, a lot shall include only those pipes or tubes of the same size and the same heat that are heat-treated in the same furnace charge. When heat treatment is in a continuous furnace, a lot shall include all pipes or tubes of the same size and heat, heat-treated in the same furnace at the same temperature, time at temperature, and furnace speed during one production run. At no time shall a lot consist of more than 20 000 lb (9100 kg).

8.1.2.1 Where material cannot be identified by heat, a lot shall consist of not more than 500 lb (227 kg) of material of the same alloy in the same condition (temper) and nominal size (excepting length).

NOTE 2—For tension, hardness, grain size, and flare test requirements, the term lot applies to all lengths prior to cutting.

8.2 *Test Material Selection*:

8.2.1 *Chemical Analysis*—Representative samples from each lot shall be taken during pouring or subsequent processing.

8.2.2 *Mechanical and Other Properties*—Samples of the material to provide test specimens for mechanical and other properties shall be taken from such locations in each lot as to be representative of that lot. Test specimens shall be taken from material in the final condition (temper).

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9. Retests and Retreatment

9.1 *Retests*—If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional tubes of double the original number from the same group or lot, each of which shall conform to the requirements specified.

9.2 *Retreatment*— If the individual pipes/tubes or the material selected to represent any lot fail to conform to the test requirements, the individual pipes/tubes or the lot represented may be reheat treated and resubmitted for test. Not more than two reheat treatments shall be permitted.

10. Specimen Preparation

10.1 *Room Temperature Tensile Specimen*:

10.1.1 Material shall be tested in the direction of fabrication. Whenever possible, the pipe or tube shall be tested in full cross section. When testing in full section is not possible, longitudinal strip specimens or the largest possible round section shall be used. In the event of disagreement when full section testing is not possible, a longitudinal strip specimen with reduced gage length as contained in Test Methods E 8 shall be used.

10.2 *Hardness Specimen*:

10.2.1 The hardness specimen shall be prepared in accordance with Test Methods E 18. The test shall be made on the inside diameter surface of a specimen cut from the end, or on the inside of the pipe near the end, at the option of the manufacturer.

10.3 *Grain Size*:

10.3.1 If required, the grain size specimen shall be a transverse sample representing full wall thickness.

11. Inspection

11.1 Witnessing of testing or inspection by the purchaser's representative shall be agreed upon by the purchaser and the manufacturer as part of the purchase contract.

12. Rejection and Rehearing

12.1 Material tested by the purchaser that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

13. Certification

13.1 When specified in the purchase contract, a manufacturer's certification shall be furnished to the purchaser stating that the material has been manufactured, tested and inspected in accordance with this specification, and that the test results on representative samples meet specification requirements. When specified in the purchase contract, a report of the test results shall be furnished.

14. Product Marking

14.1 *Material Marking*:

14.1.1 The name or brand of the manufacturer, the name of the material or UNS number, the letters ASTM, the product specification number, heat number, class (if applicable) and nominal size shall be legibly marked on each piece ¾ in. (19.0 mm) outside diameter and larger and lengths greater than 3 ft (914 mm). The material marking shall be by any method that will not result in harmful contamination.

14.1.2 For material smaller than ¾ in. (19.0 mm) outside diameter, or lengths under 3 ft (914 mm), the information specified in 14.1.1 shall be legibly marked on each piece or marked, at the option of the manufacturer, on a tag securely attached to the bundle or box in which the material is shipped.

15. Packaging and Package Marking

15.1 The following information shall be marked on the material or included on the package, or on a label or tag attached thereto: name of the material or UNS number, heat number, condition (temper), the letters ASTM, the product specification number, the nominal pipe size, gross, tare, and net weight, consignor and consignee addresses, contract or order number, and such other information as may be defined by the purchase contract.

16. Keywords

16.1 cold worked; hot finished; nickel; nickel alloys; seamless pipe; seamless tube

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Designation: D 380 – 94 (Reapproved 2000)

Standard Test Methods for Rubber Hose[1]

This standard is issued under the fixed designation D 380; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. These methods have been approved for use by agencies of the Department of Defense to replace Methods 7431, 7421, 10011, 10021, 10211, 10221, 10311, 10341, 10351, and 10361 of Federal Test Method Standard No. 601 and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 These test methods describe procedures for inspection and test of all types and constructions of rubber hose.[2]

1.2 In case of conflict between provisions of these test methods and those of detailed specifications or test methods for a particular hose, the latter shall take precedence.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension[3]

D 413 Test Methods for Rubber Property—Adhesion to Flexible Substrate[3]

D 471 Test Method for Rubber Property—Effect of Liquids[3]

D 572 Test Method for Rubber—Deterioration by Heat and Oxygen[3]

D 573 Test Method for Rubber—Deterioration in an Air Oven[3]

D 865 Test Method for Rubber—Deterioration by Heating in Air (Test Tube Enclosure)[3]

D 1149 Test Method for Rubber Deterioration—Surface Ozone Cracking in a Chamber[3]

D 1349 Practice for Rubber—Standard Temperatures for Testing[3]

D 1415 Test Method for Rubber Property—International Hardness[3]

D 2240 Test Method for Rubber Property—Durometer Hardness[3]

D 3183 Practice for Rubber—Preparation of Pieces for Test Purposes from Products[3]

D 3767 Practice for Rubber—Measurement of Dimensions[3]

D 4483 Practice for Determining Precision for Test Method Standards in the Rubber and Carbon Black Industries[3]

E 4 Practices for Force Verification of Testing Machines[4]

3. General Test Methods

3.1 Except as otherwise specified in these test methods for rubber hose, the following test methods, applicable in general to vulcanized rubber, shall be complied with as required and are hereby made a part of these test methods:

3.1.1 *General Physical Test Requirements*—Practice D 3183.

3.1.2 *Tension Test*— Test Method D 412.

3.1.3 *Aging Test*—Test Method D 572, Test Method D 573, and Test Method D 865.

3.1.4 *Adhesion Test*— Test Methods D 413.

3.1.5 *Immersion Test*— Test Method D 471.

3.1.6 *Hardness Test*— Test Method D 2240.

3.1.7 *Hardness Test*— Test Method D 1415.

4. Significance and Use

4.1 These test methods provide uniform methods for inspection and test of rubber hoses that can be referenced in hose specifications for various applications.

4.2 Uniform test methods make quality comparisons of hose easier and more meaningful, and are more economical particularly when the same rubber vulcanizates are used in different

[1] These test methods are under the jurisdiction of ASTM Committee D11 on Rubber and are the direct responsibility of Subcommittee D11.31 on Rubber Hose.

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[2] For specifications covering hose used in automotive, construction, and industrial equipment applications, reference should be made to SAE Standards for Coolant System Hoses (SAE J20e), Fuel and Oil Hoses (SAE J30b), Power Steering Pressure Hose—High Volumetric Expansion (SAE J188), Power Steering Return Hose (SAE 189), Power Steering Pressure Hose—Low Volumetric Expansion (SAE J191), Power Steering Pressure Hose—Wire Braid (SAE J190), Windshield Wiper Hose (SAE J50a), Emission Control Hose (SAE J1010), Windshield Washer Tubing (SAE J1037), Tests and Procedures for SAE 100R Series Hydraulic Hose and Hose Assemblies (SAE J343c), and for Tests and Procedures for High-Temperature Transmission Oil Hose, Lubricating Oil Hose, and Hose Assemblies (SAE J1019).

[3] *Annual Book of ASTM Standards*, Vol 09.01.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

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types, constructions, or sizes of hose.

5. Sampling

5.1 A sample of sufficient length for proper performance of the required tests shall be cut from the hose when possible without impairing its use and the pieces of hose from which samples have thus been cut shall be accepted by the purchaser as full length, provided the hose meets the specified requirements. The length of samples required depends on the tests which are required. The following will show the minimum length required for the various tests:

5.1.1 *Thickness of Tube, Cover, and Rubber Elements; Tensile Strength and Elongation (Original); Adhesion*:

Nominal Bore Diameter, mm (in.)	Sample Length, mm (in.)
below 19 (0.75)	900 (36)
19 to 31.5 (0.75 to 1.25)	750 (30)
over 31.5 (1.25)	600 (24)

5.1.2 *Volumetric Expansion*—For all sizes 450 mm (18 in.)

5.1.3 *Straight Burst*— For hose nominal 76 mm (3 in.) and smaller, 450 mm (18 in.); for hose over 76 mm in inside diameter 600 mm (24 in.) but not exceeding 900 mm (36 in.). Use 900 mm for all sizes of jacketed rubberlined fire hose.

NOTE 1—Volumetric samples can be used for burst tests when hose is nominal 76 mm (3 in.) inside diameter and smaller.

5.1.4 *Curved Burst*— For all bore diameters of hose, 900 mm (36 in.).

5.1.5 *Hold Test*—For hose 76 mm (3 in.) and smaller, 450 mm (18 in.); for hose over 76 mm in inside diameter, 600 mm (24 in.) but not exceeding 900 mm.

5.1.6 *Immersion Test—Volume Change and Strength Deterioration*:

Nominal Bore Diameter, mm (in.)	Sample Length, mm (in.)
below 19 (0.75)	450 (18)
19 to 31.5 (0.75 to 1.25)	300 (12)
over 31.5 (1.25)	150 (6)

5.1.7 *Low-Temperature Test*:

Nominal Bore Diameter, mm (in.)	Sample Length, mm (in.)
below 31.5 (1.25)	500 (20)
31.5 to 50 (1.25 to 2)	700 (28)
over 50 (2)	1 000 (40)

5.2 Where the construction of the hose does not permit the cutting of samples as described in 5.1 without impairment of use, as in wire inserted hose, dredging sleeves, etc., a separate length having the same specifications shall be provided, either as an additional length or as a prolongation built onto the hose. Wire shall be omitted from the prolongation or sample length unless the detailed physical tests include requirements that measure the effect of the wire or metal elements in the construction. Additional length taken for purpose of tests shall be paid for by the purchaser, provided they conform to the specified requirements.

5.3 The sampling of woven-jacketed rubber-lined hose shall be in accordance with detailed specifications for this material.

6. Measurement of Hose

6.1 *Length*—Determine the length by means of a steel tape or calibrated measuring device. It shall not include the length of fittings except when specifically so requested and recorded. In the case of woven-jacketed rubber-lined hose, or hose with a helical wire reinforcement, determine the length under a 70-kPa (10-psi) internal pressure.

6.2 *Outside Diameter and Reinforcement Diameter*— Measure the circumference with a flexible tape and determine the diameter by calculation. Use of a pi (π) tape graduated to read the diameter directly is acceptable. On diameters of 25 mm (1 in.) or less, caliper measurements are acceptable when at least two measurements are made approximately 90° apart and the measurements averaged. The measuring device shall be capable of measuring in increments of 0.25 mm (0.01 in.) or less. All diameter measurements shall be made at least 25 mm (1 in.) distance back from the ends of the hose.

6.3 *Inside Diameter*— On hose up to and including nominal inside diameter of 75 mm (3 in.) suitable expanding ball gages, telescoping gages, or cylindrical-plug gages shall be used.

6.3.1 The measuring devices shall have the following minimum precision:

Nominal Bore Diameter, mm (in.)	Plug Gages, mm (in.)	Calipers, mm (in.)	Scales, mm (in.)
25 (1) or less	0.25 (0.01)		
over 25 to 50 (1 to 2)	0.50 (0.02)		
over 50 to 75 (2 to 3)	0.75 (0.03)		
over 75 (3)		0.25 (0.01)	
150 (6) or more		0.50 (0.02)	0.50 (0.02)

6.3.1.1 Plug gates shall have the maximum increments in diameter as given above and a minimum step length of 9.5 mm (0.37 in.).

6.3.1.2 Ball gages and telescopic gages shall be capable of measuring increments of 0.50 mm (0.02 in.) or less.

6.3.2 On hose 150 mm (6 in.) or larger in nominal inside diameter, in addition to inside calipers, a graduated steel scale can be used. On hose 150 mm (6 in.) or larger the measuring device shall be capable of measuring 0.50 mm (0.02 in.) or less. With the exception of cylindrical plug gages, at least two measurements shall be made approximately 90° apart and these measurements averaged. For hose that has a visual inside diameter variation at the end of the hose, for example, the flared or necked down end on wire braid reinforced hose, measurements shall be made at least 25 mm (1 in.) distance back from the end of the hose.

6.4 *Wall Thickness*— Determine the wall thickness at least 12 mm from the end of the hose to avoid flare. Use a micrometer with a rounded anvil in contact with the inside of the hose. Contact surface of the anvil should be about 8 mm long. Support for the anvil should be smaller in diameter than the anvil to avoid inward flare. Care is needed to be sure that the anvil and the foot are square to the surface of the hose. Sufficient force shall be applied to obtain firm contact with, but not indent, hose surface.

6.4.1 The minimum wall thickness shall be the minimum measurement obtained from a series of measurements taken around the circumference of the hose but concentrated in the area visually suspected of being thin.

6.4.2 The maximum wall thickness shall be the maximum measurement obtained from a series of measurements taken around the circumference of the hose but concentrated in the area visually suspected of being thick.

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6.4.3 The average wall thickness shall be the average of at least four measurements taken equidistant around the circumference of the hose.

6.5 *Wall Concentricity*—The difference between the minimum and maximum wall thickness determined in 6.4.1 and 6.4.2.

7. Thickness of Tube, Cover or Other Rubber Elements

7.1 Determine the thickness of a rubber element from any type of hose in accordance with Method A of Practice D 3767.

7.2 Take the thickness of a rubber element adjoining a braid- or helical-wound reinforcing member of any material as the average between two measurements of thickness, one of which shall be obtained using the unbuffed specimen and the other using a specimen that is buffed just sufficiently to remove the braid or helical corrugations.

7.3 Take the thickness of a rubber element adjoining a seamless woven jacket of any material on a specimen that is buffed just sufficiently to remove the corrugations caused by the woven jacket. Where backing is used on a rubber element, remove the backing before measuring thickness.

7.4 Determine the thickness of a rubber element adjoining flexible metal convoluted lining at the valleys formed by the tops of the metal convolutions. Prepare the opposite side of the rubber element, adjacent to other reinforcing members, for thickness measurement as specified in the other paragraphs of this section, depending on the type of reinforcing member.

7.5 Determine the thickness of a rubber element adjoining reinforcing fabric woven prior to assembly in the hose on a specimen that is unbuffed.

8. Test Conditions

8.1 The temperature of the testing room shall be between 21 and 32°C (70 and 90°F). The samples to be tested shall be kept in this room for at least 30 min previous to the time of testing. In case of arbitration a test atmosphere of 50 ± 5 percent relative humidity at a temperature of 23 ± 2°C (73.4 ± 3.6°F) shall be used.

NOTE 2—These special test conditions shall be confined to tension and immersion testing only.

9. Number of Tests

9.1 When test value limits are established, test one specimen for each physical characteristic required in the detailed specifications for a particular hose, except in the immersion tests given in Sections 19-23 inclusive. If the results do not meet the specified requirements, prepare two additional specimens from the original sample and test. Should the results of either of these tests be below the specified requirements, consider the sample to have failed to meet the specifications.

9.2 If test value limits are not established, test at least three specimens and take the median.

10. Separation of Rubber Parts

10.1 Cut a sufficient length from the hose sample to provide longitudinal tension test specimens from hose 76 mm (3 in.) and under in nominal diameter and transverse test specimens on larger sizes. Separate the rubber parts to be tested from the balance of the hose. Perform the separation without the use of a solvent, if practicable, and without excessive stretching of the rubber. Make the separation a little at a time while the rubber is gripped near the point of separation. If it is necessary to use a solvent in the separating operation use commercial *iso*octane. If *iso*octane is used, place the rubber so as to permit free evaporation of the solvent from all parts of its surface, and allow it to rest at least 1 h before being tested.

TENSILE STRENGTH AND ELONGATION OF RUBBER

11. Procedure

11.1 Test in accordance with Test Method D 412. When specimen thickness is less than 1.5 mm (0.06 in.) after preparation a greater variation in test values can be anticipated. At times acceptable test specimens cannot be obtained or true values do not result from dumbbells prepared from the hose. In such cases substitution of sheet material in accordance with the section on Pieces of Practice D 3183 is recommended.

ADHESION TESTS

12. Test Specimens

12.1 From woven-jacketed rubber-lined hose, cut adhesion test specimens all transversely from the samples in rings 50 mm (2 in.) in width. Then open these rings and lay them out flat so as to give rectangular specimens of length equal to the full circumference of the hose. Accurately cut on each specimen a central strip of lining 38 mm (1.5 in.) in width, the cut extending through the lining but not entirely through the woven jacket. Separate these strips from the jacket at one end for a distance of about 38 mm.

12.2 From other types of hose, cut the adhesion test specimens transversely from the samples in rings 25 mm (1 in.) in width using a sharp tool that will leave clean edges. On hose 6.5 to 100 mm (0.25 to 4 in.), inclusive, in inside diameter test the specimens in ring form and refer to them as "ring specimens." For hose over 100 mm in inside diameter cut the rings through at the point where the outside ply of fabric ends, and open them to form strips that shall be referred to as "strip specimens."

12.3 Cut adhesion specimens from hose less than 6.5 mm in inside diameter longitudinally from the hose (Note 3). Since the width of these specimens will be less than 25 mm (1 in.), determine the adhesion on the contact width of the test specimen.

NOTE 3—Adhesion tests on hose smaller than 6.5 mm (0.25 in.) are not recommended, due to the size of the specimen available.

12.4 In hose constructions having braided wire reinforcing members, it is impractical to prepare adhesion test specimens.

12.5 On hose 19 mm (0.75 in.) to 100 mm (4 in.), inclusive, in inside diameter, having a woven wire filler reinforcement, prepare specimens for the adhesion test as follows: Cut the hose to form a longitudinal specimen 150 mm (6 in.) long and 50 mm (2 in.) wide. Flatten the specimen thus prepared and draw two parallel lines 25 mm (1 in.) apart along the tube and cover and cut through to the woven carcass. Separate from the jacket for a short distance the ends of the central portion between these two cuts. Determine adhesion in accordance

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with 13.2 for strip specimens.

13. Procedure

13.1 *Ring Specimens*— Test in accordance with the Static-Mass Method or Machine Method of Test Method D 413.

13.2 *Strip Specimens*— Test in accordance with the Static-Mass Method or Machine Method of Test Method D 413.

13.3 For hose with woven wire reinforcement having an inside diameter under 19 mm (0.75 in.), the hose may be tested for value of tube adhesion by use of the ball-vacuum method as follows: Lay sections of hose in a straight line on an inclined table. Pass a steel ball, 3.18 mm (0.125 in.) less in diameter than the nominal inside diameter of the hose, through the hose while the internal pressure is 60 ± 10 kPa (18± 3 in. Hg) below the external pressure.

13.4 *Report*:

13.4.1 The report shall include the following:

13.4.1.1 Value of the adhesions obtained by the Static-Mass Method in accordance with 13.1 and 13.2 as average millimetres per second (or inches per minute) of separation under a stated mass required to separate specimens at an average rate of 0.42 mm/s (or 1 in./min),

13.4.1.2 Value of the adhesions obtained by the Machine Method (see the Calculation section of Test Method D 413) in accordance with 13.1 and 13.2, and

13.4.1.3 Value of adhesion obtained in accordance with 13.3, as ball passing or not passing.

13.5 *Precision and Bias*—The precision and bias of the Static-Mass and Machine Methods are given in Test Method D 413. No statement is made about either the precision or bias of the ball method for measuring adhesion of hose lining since the results merely indicate whether there is conformance to the criteria specified in the procedure.

PRESSURE TESTS

14. Types of Tests

14.1 Hydrostatic tests of hose consist of subjecting the specimen to the action of internal water pressure under specified conditions to determine either the bursting strength of the hose or the effect of lower hydrostatic pressures in producing changes similar to those occurring in service. In the latter case, the test may be used as an inspection proof test with a minimum safe limit. Bursting strength is determined on short specimens cut from the full hose lengths, but in tests for service effects and for proof inspection, the full lengths are used as specimens. The specimens may be tested, as required, in straight, curved, or kinked positions, depending upon the stresses which are desired to be evaluated.

14.2 Aerostatic pressure tests of hose consist of subjecting the specimen to the action of internal air or nitrogen gas pressure under specified conditions to determine the integrity and leak resistance of the hose or hose assembly. Normally the hose or hose assembly is submerged under water and a constant stream of bubbles is an indication of leakage.

15. Application of Pressure

15.1 Apply hydrostatic pressure by means of a hand- or power-driven hydraulic pump or an accumulator system. Connect the hose to the waterline or pump and fill with water prior to application of pressure, allowing all air in the hose to escape through a petcock provided for the purpose. This is important as a safety measure because expansion of air compressed in the hose, when suddenly released by bursting or other failure, might result in serious accident. Then close the petcock and apply the pressure at a uniform rate of increase of approximately 7 MPa (1000 psi)/min except for hose with bursting strength specified above 14 MPa (2000 psi), in which case the pressure shall be applied at a rate of 70 MPa (10 000 psi)/min or as rapidly as pump capacity will permit. Measure the pressure with a calibrated gage.

NOTE 4—The specified rate of 7 MPa (1000 psi)/min requires too much time for small-diameter high-strength hose, such as hydraulic brake hose, wire-reinforced grease gun hose, etc. With 3.2-mm (0.125-in.) hydraulic brake hose, pressure increases at rates as high as 280 MPa (40 000 psi)/min are satisfactory.

15.2 Apply aerostatic pressure by connecting the hose or hose assembly to a source of air or nitrogen gas pressure. Submerge the hose and couplings entirely in water such that visual observations of the hose assembly is permitted. Apply the specified internal pressure, measured with a calibrated gage, and maintain for the specified period of time. Any evidence of leakage from the hose or couplings shall be reported. Initial appearance of bubbles may be an indication of air entrapped in the hose wall. Agitate the hose after 2 min to break the air bubbles from the hose surface. Following this a steady stream of bubbles from any location shall be considered failure to meet the test.

16. Bursting Tests

16.1 *Straight Bursting Test*—The specimen for the hydrostatic test for bursting strength shall be at least 450 mm (18 in.) in length for hose 76 mm (3 in.) and smaller in inside diameter, and at least 600 mm (24 in.) in length for larger hose. Shorter or longer lengths may be burst tested when circumstances dictate, for example, when a burst on a manufactured part is specified. The pressure shall be raised as specified in Section 15, until failure, and the pressure at which failure occurs shall be considered the bursting strength of the hose.

16.2 *Curved Bursting Test*—The curved bursting strength test for woven rubber-lined fire hose shall be made in accordance with 16.1, except that the hose shall be firmly secured at both ends to a suitable test frame which is curved to a radius of 690 mm (27 in.).

16.3 *Precision and Bias*:

16.3.1 This precision and bias section has been prepared in accordance with Practice D 4483. Refer to Practice D 4483 for terminology and other statistical calculation details.

16.3.2 The precision results in this precision and bias section give an estimate of the precision of this test method with the rubber materials used in the particular inter-laboratory program is described below. The precision parameters should not be used for acceptance/rejection testing of any group of materials without documentation that they are applicable to those particular materials and the specific testing protocols that include this test method.

16.3.2.1 A Type 1 (inter-laboratory) precision was evaluated in 1989. Both repeatability and reproducibility are short-term;

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a period of a few days separate replica to test results. A test result is the average value as specified by this method, obtained on two determinations or measurements of the property or parameter in question.

(1) Seven different types of hose were used in the inter-laboratory program. These were tested in varying numbers of laboratories as given in Table 1 on two different days.

(2) The results of the precision calculations for repeatability and reproducibility are given in Table 1 in ascending order of average hose burst pressure expressed in MPa.

(3) The precision of this test method may be expressed in the format of the following statements which use an appropriate value of *r, R* (*r*) or (*R*), to be used in decisions of test results. The appropriate value is that value of *r* or *R* associated with a mean value in the precision table closest to the main level under consideration at any given time, for any given hose in routine testing operations.

(4) Repeatability—The repeatability, *r*, of this test method has been established as the appropriate value tabulated in the precision table. Two single test results, obtained under normal test method procedures, that differ by more than this tabulated *r* (for any given level) must be considered as derived from different or non-identical sample populations.

(5) Reproducibility—The reproducibility, *R*, of this test method has been established as the appropriate value tabulated in the precision table. Two single test results obtained in two different laboratories, under normal test method procedures, that differ by more than the tabulated *R* (for any given level) must be considered to have come from different or non-identical sample populations.

(6) Repeatability and reproducibility expressed as a percentage of the mean level, (*r*) and (*R*), have equivalent application statements as above for *r* and *R*. For the (*r*) and (*R*) statements, the difference in the two single results is expressed as a percentage of the rhythmic mean of the two test results.

16.3.3 *Bias*—In test method terminology, bias is the difference between an average test value and the reference (or true) test property value. Reference values do not exist for this test method since the value (of the test property) is exclusively defined by the test method. Bias, therefore, cannot be determined.

TABLE 1 Precision for Hose Burst Strength[A]

Type Hose	No. of Laboratories[B]	Average Burst Pressure, MPa	Within Laboratories			Between Laboratories		
			Sr	*r*	*(r)*	*SR*	*R*	*(R)*
500	13	2.82	0.121	0.34	12.2	0.229	0.65	23.2
800	14	5.51	0.346	0.98	17.8	0.455	1.29	23.4
1600	13	15.2	0.558	1.58	10.4	1.21	3.42	22.5
2500	10	15.9	0.294	0.83	5.21	0.821	2.32	14.6
8000	9	75.7	1.53	4.32	5.71	2.67	7.58	10.05
14 000	11	134.4	3.51	9.92	7.38	4.08	11.54	8.59
20 000	10	179.8	5.74	16.2	9.01	12.1	34.2	19.01

Hose Pressure	No. of Laboratories	Average Burst Pressure, psi	Within Laboratory			Between Laboratories		
			Sr	*r*	*(r)*	*SR*	*R*	*(R)*
500	13	410	17.6	50	12.2	33	94	23.0
800	14	800	50	142	17.8	66	187	23.4
1600	13	2210	81	229	10.4	175	496	22.4
2500	10	2310	42	120	5.2	119	337	14.6
8000	9	10 980	222	627	5.7	388	1099	10.0
14 000	11	19 510	508	1440	7.4	592	1675	8.6
20 000	10	26 100	832	2356	9.0	1755	4967	19.0

[A] Symbols are defined as follows:

Sr = Within laboratory standard deviation.
r = Repeatability (in measurement units).
(r) = Repeatability (in percent).
SR = Between laboratory standard deviations.
R = Reproducibility (in measurement units).
(R) = Reproducibility (in percent).

[B] Number of laboratories participating in testing this type of hose.

17. Hydrostatic Pressure Tests

17.1 When tests for elongation, contraction, twist, warp, rise, and outside diametrical expansion are required, the hose shall be stretched out straight for inspection, and a pressure of 70 kPa (10 psi) applied. All original observations and measurements shall be taken at this pressure. Measurements shall be made using a graduated tape. The designated test pressure shall be applied at the rate specified in Section 15, without releasing the original pressure of 70 kPa (10 psi), and final measurements taken. The test pressure shall be applied for a minimum of 15 s prior to taking final measurements.

NOTE 5—The application of a pressure of 70 kPa (10 psi) prior to initial measurements is to assure that the hose is round, straight, and at manufactured length at the time of measurement. On very low pressure hose, such as ducting, this initial pressure might have a major effect on the attributes being measured. In such cases a lower initial pressure will provide a more valid evaluation of these attributes.

17.1.1 *Elongation and Contraction*—Measurements for the determination of elongation and contraction shall be based: *(1)* for hose, on distance between bench marks placed on hose; *(2)* for assemblies, on" free length," which is the distance between end connections on the hose. The results shall be reported as elongation if the final length is greater than the original length and as contraction if the final length is less than the original length. All results shall be reported to the nearest 1 %.

17.1.2 *Twist*—The amount of twist may be determined by noting, during the period the pressure is applied, the turns of the fitting at the free end of the hose. A crayon or pencil mark on the top surface of the hose adjacent to the closed coupling should be made so as to aid in determining the twist. Twist sometimes occurs quite rapidly. The amount of twist shall be reported to the nearest 45°. The direction of twist shall be reported as "right" or "left," a" right" twist being one in the direction that would tend to tighten the couplings.

17.1.3 *Warp*—Warping in hose tests is the deviation from a straight line drawn from fitting to fitting in a plane parallel to the surface on which the hose rests. The amount of warping is the maximum deviation of any portion of the hose from a straight line drawn from center to center of the fittings. The warp is measured as the distance from this line to the center line of the hose at the point of maximum deviation. A tightly stretched cord may be used to establish the straight line from center to center of the fittings. Results shall be reported to the nearest 5 mm or 0.25 in.

17.1.4 *Rise*—The amount the hose rises from the surface of the test table shall be considered as "rise" and recorded as such.

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Results shall be reported to the nearest 5 mm or 0.25 in.

17.1.5 *Outside Diameter Expansion—Change in Circumference*—While the hose is under the specified original pressure, make three crayon or pencil marks equally spaced along its length. Measure the circumference at each of these marks, using a suitable tape, and record the average of these values. After the specified test pressure has been applied for the required time, again make circumference measurements at the same three places on the hose and record the average for these three readings. Calculate the expansion, and report results to the nearest 1 %.

17.2 When tests for elongation and contraction are required on wire-braided reinforced hose, such hose shall be tested by applying a pressure equivalent to the maximum pressure to which the hose is to be used for 30 s, at which time the length shall be measured. A second reading between 20 and 30 s after the pressure has been released to zero shall then be designated as the original length and the change in length (contraction or elongation) calculated as a percentage of the original length.

17.3 *Proof Pressure Tests (except for woven-jacketed fire hose)*—When proof pressure tests to determine leakage of hose or couplings are required, the proof pressure shall be applied in accordance with Section 15, and held 1 min. The proof pressure shall not exceed 50 % of the specified minimum bursting strength.

17.4 *Kink Tests*—When kink tests are required, each length of hose selected shall be filled with water with the petcock open to allow all air to escape. The petcock shall then be closed and the hose shall be kinked 450 mm (18 in.) from the coupling by tying the coupling back against the hose so that there will be a sharp kink. The pressure shall then be raised as specified in Section 15, to the required pressure and immediately released.

17.5 *Hold Test*—When a hold test is specified instead of a bursting test, pressure shall be applied as specified in Section 15 until the required pressure is reached. The specimen shall withstand the specified pressure for a 10-min period without bursting, leaking, or developing other defects. Specimens that have been subjected to this test shall not be considered fit for service.

17.6 *Precision and Bias*—No statement is made about either the precision or bias of the proof pressure, kink, and hold tests since the results merely indicate whether there is conformance to the criteria specified in the procedure. Data are being collected to determine the precision and bias of the other hydrostatic pressure tests.

18. Volumetric Expansion Test

18.1 *Apparatus*—The test apparatus used shall consist essentially of the following: A suitable source for the required fluid pressures, pressure gages, piping, valves, fittings in which the hose assembly may be mounted in a vertical position for application of pressure under controlled conditions, and a graduated buret for measuring the volume of liquid corresponding to the expansion of the hose under pressure. All piping and connections shall be smooth bore without recesses or offsets, so that all air may be freely removed from the system before running each test. The valves shall be of such design as to open and close with minimum displacement of liquid.[5] The apparatus shall be capable of applying the pressure at a rate of increase of 3 ± mPa/s [25 000 ± 10 000 lbf/(in^2·min)]. A suitable apparatus is shown in Fig. 1.

18.2 *Calibration of Apparatus*—The apparatus shall be tested prior to use to determine its calibration correction factor. For this purpose, 6.3-mm (0.25-in.)-diameter Bundy steel tubing or its equivalent shall be used in place of the hose assembly. Calibration correction factors shall be established at specified expansion pressure, and these shall be subtracted from the expansion readings obtained on the test specimens. The maximum permissible calibration correction factor shall be 0.08 cm^3 at 10 MPa (1500 psi).

18.3 *Procedure*—Carefully thread the test specimen into position on the apparatus in such a way as to provide a leak-proof seal, taking care to avoid twisting and to maintain the hose in a vertical position without tension while under pressure. Fill the tank, *C*, Fig. 1, with alcohol or distilled water, taking care that it is free of air or dissolved gases. Then open valve *B* and turn crank *D* to the left to allow the maximum amount of liquid to flow into the master cylinder. Next open valves *E, F*, and *G*, allowing the liquid to run from tank *C* through buret *K* until no air bubbles are seen in the buret. Removal of air bubbles may be facilitated by moving the hose back and forth. Then close valves *B* and *F* and raise the pressure in the hose to proof pressure for not more than 10 s. After inspection for leaks at the connections, completely release the pressure in the hose by opening valve *F*, which shall then be closed before proceeding with the next step. Now adjust the liquid level in buret *K* to zero by means of valve *G*. Turn crank *D* to the right until gage *A* shows the desired expansion pressure. Seal this pressure in the hose by closing valve *E*, after which take the expansion immediately by opening valve *F* and allowing the liquid in the expanded hose to rise in the buret. As soon as the liquid level has become constant, close valve *F* and take the reading on buret *K*. This operation shall be repeated so that the final reading taken on buret *K* will be the total of three expansions. This reading, divided by three minus the calibration factor, shall be considered as the final volumetric expansion of the hose. If the pressure in the hose should inadvertently be raised just prior to the expansion reading to a value above that specified, no reading shall be taken, but instead, the pressure shall be completely released and the procedure repeated.

18.4 *Precision and Bias*—Data are being collected to determine the precision and bias of the volumetric expansion test.

IMMERSION TESTS FOR CHANGE IN VOLUME AND DETERIORATION OF HOSE USED FOR PETROLEUM PRODUCTS

19. Types of Tests

19.1 Immersion tests for evaluating the change in volume and deteriorating effects of petroleum products on rubber hose consist of subjecting suitable test specimens from the rubber portion having known physical properties to the action of

[5] Crane Glove Valve No. 222X, or equivalent, has been found satisfactory for this purpose.

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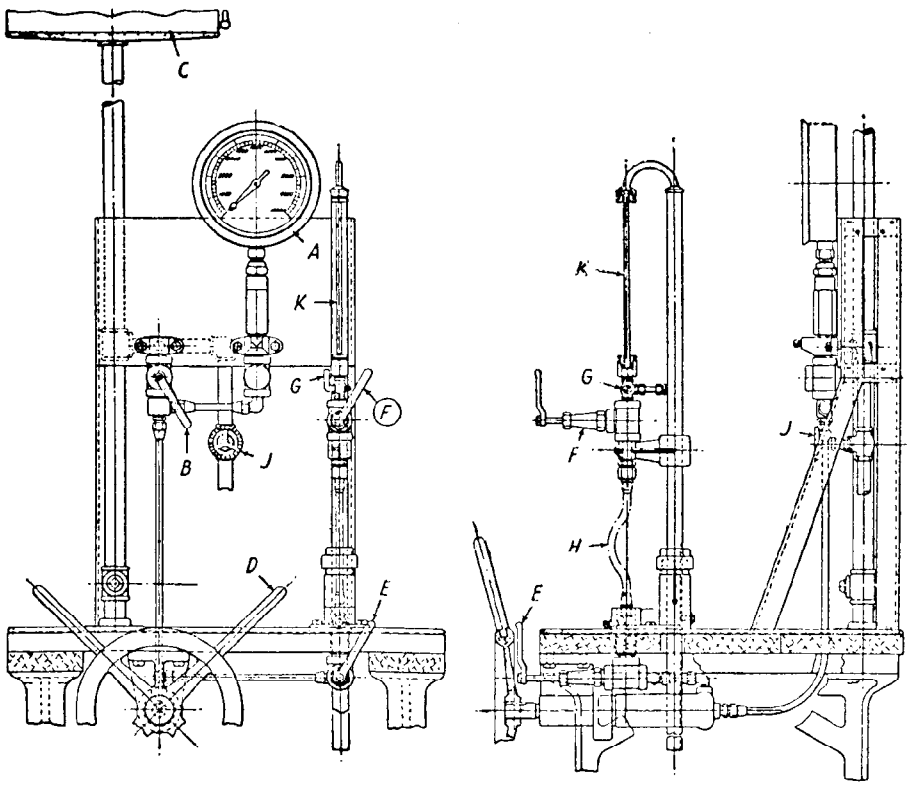

A—Pressure gage of 10 000-psi capacity.
B—Control valve from tank *C*.
C—Pressure-medium tank (vented on top).
D—Screw operated master cylinder.
E—Valve controlling line from master cylinder to hose.
F—Valve above hose.
G—Valve controlling flow into buret.
H—Hose in slack position.
J—Fluid line valve.
K—Buret graduated in 0.1 cm.[3]

FIG. 1 Apparatus for Expansion Test

selected test liquids by immersing the specimens completely in the liquid under controlled conditions for definite periods, after which the physical properties are again determined and the changes noted. Two types of test are covered, as follows:

19.1.1 *Change in Volume Test*—This type of test involves measurement of the change in volume of the rubber caused by the action of the liquid.

19.1.2 *Strength Deterioration Test*—This test measures changes in strength.

19.2 In any of the immersion tests, the choice of test method and test liquid depends upon the nature of the actual service and the petroleum product which is being used.

20. Test Liquids

20.1 Consider the reference fuels and oils described in the Standard Test Liquids section of Test Method D 471 as standard immersion test media for hose, and make the choice appropriate for the test from them unless other liquids are specifically required. In any case, report the liquid actually used with the test results.

21. Test Conditions

21.1 *Temperature*— Unless otherwise specified in the applicable specifications, the test temperatures shall be selected from the following, depending upon the anticipated service temperature:

Celsius Temperature	Fahrenheit Temperature
21 to 32	70 to 90
70 ± 2	158 ± 3.6
100 ± 2	12 ± 3.6
125 ± 2	257 ± 3.6
150 ± 2	302 ± 3.6

Generally when the test liquid is a fuel, for example, the temperature during the immersion period shall be 21 to 32°C (70 to 90°F). When the test liquid is an oil, any one of the three elevated temperatures may be used.

21.2 *Immersion Periods*—Immersion periods of 22 ± 0.25 h and 70 ± 0.7 h are recommended. Immersion tests shall be made in the absence of direct light.

22. Change in Volume Test

22.1 *Test Specimens*— The test specimens shall be rectangular rubber blocks, 50 by 25 mm (2 by 1 in.), having a thickness not over 1.6 mm (0.063 in.). They shall be cut from the hose and buffed on both faces only to the extent necessary to ensure smoothly buffed faces, except when the material is too thick, in which case the buffing shall be sufficient to reduce the specimens to 1.6 mm (0.063 in.). Three specimens shall be used for each test and the results averaged.

22.2 *Procedure*—Test in accordance with the Procedure for Change in Volume section of Test Method D 471.

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22.3 *Calculation*— Calculate the percentage change in volume in accordance with the Calculation section of Test Method D 471.

23. Strength Deterioration Test

23.1 *Test Specimens*— Six dumbbell-shaped test specimens, prepared as described in Test Methods D 412, except minimum specimen thickness of 0.80 mm (0.031 in.), shall be required. Both faces of dumbbell shall be buffed.

23.2 *Procedure*—Test three specimens for tensile strength and elongation in accordance with Test Methods D 412, except average the results to give the properties of the rubber before immersion. Follow the Properties After Evaporation of Test Liquid section of Test Method D 471 for immersion procedure on the remaining three dumbbells. Express the deterioration shown by the difference between the determinations before and after immersion as a percentage of the original property.

23.3 *Precision and Bias*—The precision and bias of the test for deterioration on fluid immersion are given in Test Method D 471.

LOW-TEMPERATURE TESTS

24. Types of Tests

24.1 Low-temperature tests are made on complete sections of hose as described in Section 25, or on the tube and cover, as described in Section 26.

25. Low-Temperature Test on Complete Hose

25.1 *Conditioning*— Condition the hose while laid out straight in a cold chamber at the specified temperature for a period of 72 h. The cold chamber shall be capable of maintaining within it a uniform atmosphere of cold, dry air or a mixture of air and carbon dioxide at specified temperature (Note 6) within a tolerance of± 2°C (±3.6°F).

NOTE 6—Temperatures of – 40 and – 55°C (–40 and – 67°F) are commonly used.

25.2 *Procedure*—After conditioning and without removal from the cold chamber, bend the nose around a mandrel having a diameter ten times the outside diameter of the hose; it shall not break or crack. Bending shall be completed within 5 s. The mandrel size shall be by 25-mm (1-in.) increments. Where ten times the hose outside diameter is not an even 25 mm (1 in.), the next larger mandrel shall be used. This test shall be applicable to hose having a maximum nominal inside diameter of 76 mm (3 in.).

25.3 To aid in determining whether or not the hose has failed the bend test, the hose, after the test, may be placed under a hydrostatic pressure equivalent to the hose proof pressure.

26. Low-Temperature Test on Tube and Cover

26.1 *Apparatus*:

26.1.1 *Cold Chamber*— The cold chamber in which the test specimens are exposed to the low temperature shall be of sufficient size to contain the flexing fixture when loaded with specimens, and so arranged as to permit the operation of the fixture to bend specimens without removal from the chamber. It shall be capable of maintaining within it a uniform atmosphere of cold, dry air or a mixture of air and carbon dioxide at specified temperatures (Note 7) within a tolerance of± 2°C (±3.6°F).

26.1.2 *Flexing Fixture*— The flexing fixture shall consist of two parallel plates each having a width of at least 50 mm (2 in.), so supported in guides that they may be rapidly moved from a position 63.5 mm (2.5 in.) apart until they are separated by a distance of 25 mm (1 in.). Suitable clamping bars or devices shall be provided for holding the ends of the specimens for a distance of 6.3 mm (0.25 in.) at the corresponding edge of each plate so that, when mounted, the specimens form similar bent loops between the plates. A satisfactory flexing fixture is shown in Fig. 2.

26.2 *Test Specimens*— Specimens of hose tube and cover shall be taken from hose in accordance with Section 10. They

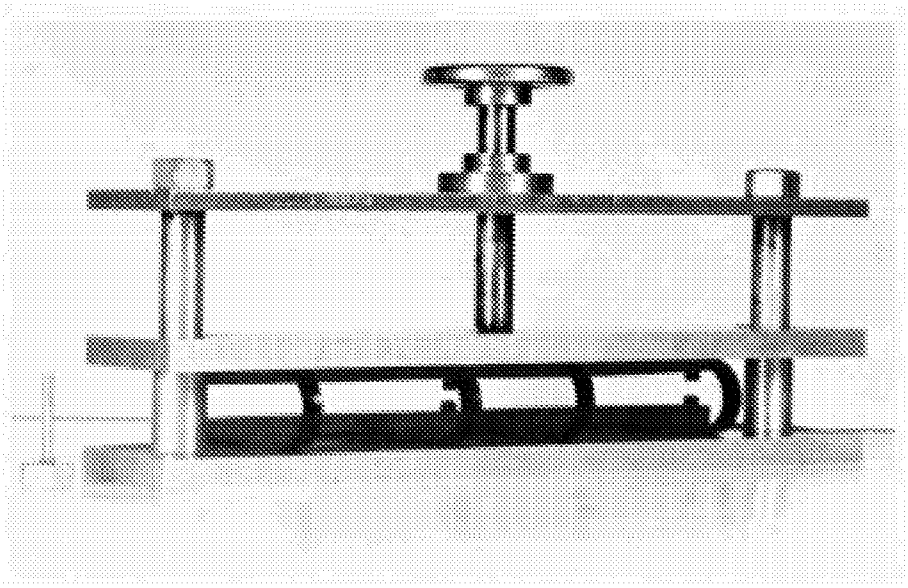

FIG. 2 Flexing Fixture for Low-Temperature Brittleness Test

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shall be buffed to a maximum thickness of 2.3 mm (0.09 in.), then cut to shape, using die C as specified in Test Method D 412. At least two specimens from each tube and cover shall be tested.

26.3 *Procedure*—Mount the test specimens in loop position between the plates of the flexing fixture, with the enlarged ends spaced at least 3.2 mm (0.125 in.) apart and held in the clamps for a distance of 6.3 mm (0.25 in.). With the plates in the open position separated 63.5 mm (2.5 in.), place the fixture containing the specimens in the cold chamber and expose for the specified period to cold, dry air or a mixture of air and carbon dioxide at the specified temperature. The standard exposure period shall be 5 h (Note 7). At the termination of the exposure period and while still in the cold chamber, move the plates of the flexing fixture as rapidly as possible from the 63.5-mm (2.5-in.) distance of separation to a position where they are 25 mm (1 in.) apart. Then examine the specimens for fracture or visible cracks.

NOTE 7—Formerly two periods were specified, 96 h for natural rubber compounds and 5 h for synthetic rubber compounds. It was found that 5 h is adequate for either class of compounds within the intent of this test method.

26.4 *Results*—When two specimens are tested and neither one fractures nor shows cracks after being tested, the compound shall be considered as having passed the brittleness test. If both specimens crack, the compound shall be considered to have failed. If only one specimen fractures or cracks, the result is inconclusive and two additional specimens shall be tested. If either one of these cracks, the compound shall then be considered to have failed.

26.5 *Report*—The report shall include the following:

26.5.1 Results of the test, expressed as "passed" or "failed,"

26.5.2 Temperature of the cold chamber,

26.5.3 Duration of the exposure period,

26.5.4 Identification of the material tested, including description of any special treatment prior to test, and

26.5.5 Date of manufacture of the material, if known, and date of test.

AGING TESTS OF RUBBER

27. Types of Tests

27.1 *Air-Heat Test*— Determine the change in tensile strength and elongation of rubber parts of hose due to aging at atmospheric pressure and elevated temperature as described in Test Method D 573 or Test Method D 865, as specified in the detail specification. Unless otherwise specified in the detail specification, age the specimen at a temperature of 70 ± 2°C (158 ± 3.6°F) or 100 ± 2°C (212 ± 3.6°F) for 166 ± 1 h.

27.2 *Ozone Test*—Determine if surface cracks appear after exposure to ozone.

27.2.1 *Apparatus*:

27.2.1.1 *Ozone Test Chamber*, in accordance with Test Method D 1149.

27.2.1.2 *Jig or Holder*, that permits elongation of specimen.

27.2.1.3 *Mandrels*.

27.2.1.4 *Tie Wire*.

27.2.1.5 *Plugs or Caps*.

27.2.1.6 Any apparatus placed in the test chamber shall be non-ozone absorbant material.

27.2.2 *Procedure*:

27.2.2.1 *Specimen Preparation*—For hose 25 mm (1 in.) in inside diameter or smaller, bend a specimen of hose of full circumference around the mandrel and tie ends together where they cross one another. The mandrel shall have a diameter eight times the nominal outside diameter of the hose. The specimen length shall be about 250 mm (10 in.) longer than the mandrel circumference. Seal the ends of the hose with plugs or caps in such a manner that the reinforcement and inner liner will not be exposed to ozone. This will allow for more uniform control of ozone concentration in the test chamber, since ozone will not be consumed by material not under test. For hose over 25 mm in inside diameter, transversely remove a 25-mm width of the hose cover. Lightly buff the under side of the specimen to remove any reinforcement impressions. Place the specimen in a jig or holder and elongate 12.5 %.

27.2.2.2 *Conditioning*— The specimen under relevant stress shall be conditioned 48 to 72 h in a substantially ozone-free atmosphere maintained at the standard laboratory temperature.

27.2.2.3 *Exposure*—Unless otherwise specified, the specimen shall be exposed to 50 ± 5 mPa partial pressure of ozone in the test chamber at 40 ± 2°C (104± 3.6°F) for 70 to 72 h.

27.2.2.4 *Examination*— After exposure and prior to removal of specimen from mandrel or holder, examine for surface cracks under 2× magnification. For hose on mandrel, ignore the area adjacent to the tie point. For specimen in holder, examine the unbuffed side and ignore areas adjacent to clamp points.

27.2.3 *Report*—The report shall include the following:

27.2.3.1 Ozone concentration,

27.2.3.2 Exposure time,

27.2.3.3 Ambient test chamber temperature, and

27.2.3.4 Specimen surface condition (cracks or no cracks).

27.3 *Precision and Bias*—The precision and bias of the air heat test are given in Test Method D 573 and Test Method D 865. No statement is made about either the precision or bias of the ozone test since the results merely indicate whether there is conformance to the criteria specified in the procedure.

TENSION TEST

28. Summary of Test Method

28.1 This tension test consists of subjecting the hose assembly to increasing tension load in a suitable testing machine until failure occurs, either by separation of the specimen from the end fittings or by failure of the hose structure.

28.2 *Apparatus*:

28.2.1 *Tension Testing Machine*, conforming to the requirements of Practice E 4, and provided with an indicating device to give the total pull in newtons (pounds) at the conclusion of the test.

28.2.2 *Hose Assembly*, attached to the test machine by suitable fixtures so that the hose and fittings shall have a straight center line corresponding to the direction of the machine pull.

28.3 *Procedure*—Apply a steady tension load at a speed such that the moving head of the testing machine travels at the rate of 25± 3 mm (1.0 ± 0.1 in.)/min until failure. Record the

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total load at the time of failure and note the type of failure.

28.4 *Precision and Bias*—Data are being collected to determine the precision and bias of the tension test.

29. Inspection

29.1 Make all tests and inspection at the place of manufacture prior to shipment, unless otherwise specified. The manufacturer shall afford the purchaser, inspector, or representative of the purchaser reasonable facilities to test and inspect the hose without charge.

29.2 The purchaser may make the tests and inspection to govern the acceptance or rejection of the material in his own laboratory or elsewhere. Make such tests and inspection at the expense of the purchaser not later than 60 days after receipt of the material.

30. Retests and Rejection

30.1 Any material that fails in one or more tests may be resampled and retested at the expense of the manufacturer. For this purpose select two additional samples from the hose. Failure of either of the retested samples shall be cause for final rejection.

30.2 Rejected material shall be disposed of as directed by the manufacturer and at his expense.

31. Keywords

31.1 rubber hose

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ASTM D 471 should be used instead of TT-S-735A, which was cancelled on 11 September 1998.

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Designation: D 471 – 98$^{\epsilon 1}$

Standard Test Method for Rubber Property—Effect of Liquids[1]

This standard is issued under the fixed designation D 471; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

ϵ^1 NOTE—Table 3 was editorially updated in September 1999.

1. Scope

1.1 This test method covers the required procedures to evaluate the comparative ability of rubber and rubber-like compositions to withstand the effect of liquids. It is designed for testing: (*1*) specimens of vulcanized rubber cut from standard sheets (see Practice D 3182), (*2*) specimens cut from fabric coated with vulcanized rubber (see Test Method D 751), or (*3*) finished articles of commerce (see Practice D 3183). This test method is not applicable to the testing of cellular rubbers, porous compositions, and compressed sheet packing, except as described in 11.2.2.

1.2 ASTM Oils No. 2 and No. 3, formerly used in this test method as standard test liquids, are no longer commercially available and in 1993 were replaced with IRM 902 and IRM 903, respectively (see Appendix X1 for details).

1.3 This test method includes the following:

Change in Mass (after immersion)	Section 10
Change in Volume (after immersion)	Section 11
Dimensional-Change Method for Water-Insoluble Liquids and Mixed Liquids	Section 12
Change in Mass with Liquid on One Surface Only	Section 13
Determining Mass of Soluble Matter Extracted by the Liquid	Section 14
Change in Tensile Strength, Elongation and Hardness (after immersion)	Section 15
Change in Breaking Resistance, Burst Strength, Tear Strength and Adhesion for Coated Fabrics	Section 16
Calculation (of test results)	Section 17

1.4 The values stated in SI units are to be regarded as the standard. The values in parentheses are for information only.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 92 Test Method for Flash and Fire Points by Cleveland Open Cup[2]

D 97 Test Method for Pour Point of Petroleum Products[2]

D 287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)[2]

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers— Tension[3]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[2]

D 611 Test Methods for Aniline Point and Mixed Aniline Point of Petroleum Products and Hydrocarbon Solvents[2]

D 751 Test Methods for Coated Fabrics[4]

D 975 Specification for Diesel Fuel Oils[2]

D 1217 Test Method for Density and Relative Density (Specific Gravity) of Liquids by Bingham Pycnometer[2]

D 1415 Test Method for Rubber Property—International Hardness[3]

D 1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)[2]

D 1747 Test Method for Refractive Index of Viscous Materials[2]

D 2008 Test Method for Ultraviolet Absorbance and Absorptivity of Petroleum Products[2]

D 2140 Test Method for Carbon-Type Composition of Insulating Oils of Petroleum Origin[5]

D 2240 Test Method for Rubber Property—Durometer Hardness[3]

D 2699 Test Method for Research Octane Number of Spark-Ignition Engine Fuel[6]

D 3182 Practice for Rubber—Materials, Equipment, and Procedures for Mixing Standard Compounds and Preparing Standard Vulcanized Sheets[3]

D 3183 Practice for Rubber—Preparation of Pieces for Test Purposes from Products[3]

D 4483 Practice for Determining Precision for Test Method Standards in the Rubber and Carbon Black Industries[3]

[1] This test method is under the jurisdiction of ASTM Committee D-11 on Rubber and is the direct responsibility of Subcommittee D11.15 on Degradation Tests.

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[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 09.01.

[4] *Annual Book of ASTM Standards*, Vol 09.02.

[5] *Annual Book of ASTM Standards*, Vol 10.03.

[6] *Annual Book of ASTM Standards*, Vol 05.05.

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D 4485 Specification for Performance Engine Oils[7]
D 4678 Practice for Rubber– Preparation, Testing, Acceptance, Documentation, and Use of Reference Materials[3]
D 5900 Specifications for Physical and Chemical Properties of Industry Reference Materials (IRM)[3]
E 145 Specification for Gravity-Convection and Forced-Ventilation Ovens[8]

2.2 *SAE Standards:*[9]
J 300 Engine Oil Viscosity Classification

3. Summary of Test Method

3.1 This test method provides procedures for exposing test specimens to the influence of liquids under definite conditions of temperature and time. The resulting deterioration is determined by measuring the changes in physical properties, such as stress/strain properties, hardness, and changes in mass, volume, and dimension, before and after immersion in the test liquid.

3.2 The precision statement in Section 19 is based on an interlaboratory test program run in 1981, using six different rubbers with ASTM Reference Fuels B, C, D[10] and ASTM Oils No. 1 and No. 3.

3.3 The precision statement in Appendix X2 is based on an interlaboratory test program conducted in 1993 to establish replacements for ASTM Oils No. 2 and No. 3. Because of the limited number of participating laboratories, only repeatability could be evaluated, and it was necessary to use pooled values of four No. 2 type oils (No. 2 plus three candidate replacement oils) and four No. 3 type oils (No. 3 plus three candidate replacement oils). Twelve rubbers were tested in this program.

4. Significance and Use

4.1 Certain rubber articles, for example, seals, gaskets, hoses, diaphragms, and sleeves, may be exposed to oils, greases, fuels, and other fluids during service. The exposure may be continuous or intermittent and may occur over wide temperature ranges.

4.2 Properties of rubber articles deteriorate during exposure to these liquids, affecting the performance of the rubber part, which can result in partial failure.

4.3 This test method attempts to simulate service conditions through controlled accelerated testing, but may not give any direct correlation with actual part performance, since service conditions vary too widely. It yields comparative data on which to base judgment as to expected service quality.

4.4 This test method is suitable for specification compliance testing, quality control, referee purposes, and research and development work.

5. Test Conditions

5.1 *Temperature and Immersion Periods*—Unless otherwise specified the test temperature and immersion period shall be as indicated in Table 1, depending upon the anticipated service conditions:

5.1.1 When the temperature of the testing room is other than the standard 23 ± 2°C (73 ± 4°F) the temperature of test shall be reported.

TABLE 1 Test Temperatures and Immersion Periods

Temperature in °C (°F)		Immersion Period, h
−75 ± 2 (−103 ± 4)	85 ± 2 (185 ± 4)	22
−55 ± 2 (−67 ± 4)	100 ± 2 (212 ± 4)	46
−40 ± 2 (−40 ± 4)	125 ± 2 (257 ± 4)	70
−25 ± 2 (−13 ± 4)	150 ± 2 (302 ± 4)	166
−10 ± 2 (14 ± 4)	175 ± 2 (347 ± 4)	670
0 ± 2 (32 ± 4)	200 ± 2 (392 ± 4)	1006
23 ± 2 (73 ± 4)	225 ± 2 (437 ± 4)	2998
50 ± 2 (122 ± 4)	250 ± 2 (482 ± 4)	4990
70 ± 2 (158 ± 4)		

5.1.2 The choice of the immersion period will depend upon the nature of the vulcanizate, the test temperature, and the liquid to be used. To obtain information on the rate of deterioration it is necessary to make determinations after several immersion periods. The tolerance for any immersion period shall be ±15 min or ±1 % of the immersion period, whichever is greater.

5.2 *Illumination*— Immersion tests shall be made in the absence of direct light.

6. Standard Test Liquids

6.1 For test purposes, it is usually desirable to use the liquid that will come into contact with the vulcanizate in service. For comparative tests with liquids of unknown or doubtful composition, samples of liquid from the same container or shipment shall be used. Many commercial products, particularly those of petroleum origin, are subject to sufficient variation that it is not practical to use them for test liquids. It is then advisable to use a standard test liquid, such as described in 6.1.1 and 6.1.2, covering the range of properties that may be encountered in the particular service.

6.1.1 *ASTM and IRM Oils*—The test shall be conducted in one of the petroleum-base ASTM or IRM oils (Note 1) specified in Table 2 that has its aniline point nearest that of the oil with which the vulcanizate is expected to come in contact in service except as indicated in 6.1.3.

NOTE 1—The aniline point of a petroleum oil appears to characterize the swelling action of that oil on rubber vulcanizates. In general, the lower the aniline point, the more severe the swelling action by the oil. The oils specified in Table 2 cover a range of aniline points commonly found in lubricating oils.

6.1.2 *ASTM Reference Fuels*—When gasolines or diesel fuels are to be encountered in service, the test shall be conducted in one of the ASTM reference fuels (Note 2) specified in Table 3, except as indicated in 6.1.3.

NOTE 2—The ASTM reference fuels in Table 3 have been selected to provide the maximum and minimum swelling effects produced by commercial gasolines. Reference Fuel A has a mild action on rubber vulcanizates and produces results of the same order as low swelling gasolines of the highly paraffinic, straight run type. Reference Fuels B, C, and D simulate the swelling behavior of the majority of commercial gasolines, with Reference Fuel C producing the highest swelling which is typical of highly aromatic premium grades of automotive gasoline.

[7] *Annual Book of ASTM Standards*, Vol 05.02.
[8] *Annual Book of ASTM Standards*, Vol 14.02.
[9] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Drive, Warrendale, PA 15096.
[10] Reference Fuels A, B, C, D, and E are available from Phillips Petroleum Co., Customer Service Center, P.O. Box 968, Borger, TX 79007: Phone: 1 (800) 858-4327; FAX: 1 (806) 275-3771.

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TABLE 2 Specifications and Typical Properties of ASTM and IRM Reference Oils

Property	ASTM Oil No. 1	ASTM Oil No. 5	IRM 902	IRM 903	ASTM Method
Specified Properties:					
Aniline Point, °C (°F)	124 ± 1 (255 ± 2)	115 ± 1 (239± 2)	93 ± 3 (199 ± 5)	70± 1 (158 ± 2)	D 611
Kinematic Viscosity (mm^2/s [cSt])					
38°C (100°F)	...	...	...	31.9–34.1	D 445
99°C (210°F)	18.7–21.0	10.8–11.9	19.2–21.5	...	D 445
Gravity, API, 16°C (60°F)	...	...	19.0–21.0	21.0–23.0	D 287
Viscosity-Gravity Constant	...	...	0.860–0.870	0.875–0.885	D 2140
Flash Point COC, °C (°F)	243 (469) min	243 (469) min	240 (464) min	163 (325) min	D 92
Naphthenics, C_N(%)	...	...	35 min	40 min	D 2140
Paraffinics, C_P(%)	...	...	50 max	45 max	D 2140
Typical Properties:					
Pour Point, °C (°F)	...	−15 (5)	−12 (10)	−31 (−24)	D 97
ASTM Color	...	*L* 1.0	*L* 2.5	*L* 0.5	D 1500
Refractive Index	...	1.4808	1.5105	1.5026	D 1747
UV Absorbance, 260 nm	...	...	4.0	2.2	D 2008
Aromatics, C_A(%)	...	4	12	14	D 2140

TABLE 3 ASTM Reference Fuels

Fuel Type	Composition, Volume %
Reference Fuel A	Isooctane[A], 100
Reference Fuel B	Isooctane[A], 70; Toluene[A], 30
Reference Fuel C	Isooctane[A], 50; Toluene[A], 50
Reference Fuel D	Isooctane[A], 60; Toluene[A], 40
Reference Fuel E	Toluene[A], 100
Reference Fuel F	Diesel Fuel, Grade No. 2[B], 100
Reference Fuel G	Fuel D, 85; anhydrous denatured ethanol[C], 15
Reference Fuel H	Fuel C, 85; anhydrous denatured ethanol[C], 15
Reference Fuel I	Fuel C, 85; anhydrous methanol, 15
Reference Fuel K	Fuel C, 15; anhydrous methanol, 85

[A] Motor Fuels, Section 1, Test Method D 2699

[B] Specification D 975.

[C] Anhydrous ethanol denatured with unleaded gasoline (CDA formula No. 20), available from Archer-Daniels-Midland, P.O. Box 1470, Decatur, IL 62525.

TABLE 4 ASTM Service Liquids

Liquid	Composition
Service Liquid 101[A]	di-2 ethyl hexyl sebacate, 99.5 mass %; phenothiazine, 0.5 mass %
Service Liquid 102[B]	ASTM Oil No. 1, 95 mass %; hydrocarbon compound additive[C], 5 mass % (29.5–33.5 mass % sulfur, 1.5–2.0 mass% phosphorus, 0.7 mass % nitrogen)
Service Liquid 103[D]	tri-*n*-butyl phosphate, 100 mass %
Service Liquid 104[E]	ethylene glycol[F], 50 volume %; distilled water, 50 volume %
Service Liquid 105[G]	ASTM Reference Oil TMC 1006
Service Liquid 106[H]	ARM 200 (Aerospace Reference Material 200)

[A] Service liquid 101 is intended to simulate the swelling action of synthetic diester-type lubricating oils.

[B] Service liquid 102 approximates the swelling behavior of hydraulic oils.

[C] This hydrocarbon oil additive is available as Anglamol 99 from Lubrizol Corp., 29400 Lakeland Blvd., Wickliffe, OH 44092. Properties are as follows: Kinematic viscosity (mm^2/s [cSt]) at 99°C (210°F) – 9.70 ± 0.52 (Test Method D 445); Flash point COC °C (°F) – 45 (113) min (Test Method D 92); Density at 16°C (61°F) – 1.065 ± 0.015 (Test Method D 1217).

[D] Service liquid 103 simulates phosphate ester-type aircraft hydraulic oils.

[E] Service liquid 104 approximates the swelling behavior of automotive engine coolant.

[F] Ethylene glycol, reagent grade, shall be used.

[G] Service Liquid 105 is an API SJ/ILSAC GF-2 SAE 5W-30 reference engine oil meeting the requirements of ASTM D 4485 and SAE J 300. It is available from ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh, PA 15206–4489. Phone (412) 365–1000, Fax (412) 365–1047.

[H] Service Liquid 106 is intended to eventually replace Service Liquid 101 which is no longer readily available for purchase as a mixture. ARM 200 is available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

Reference Fuel F (diesel fuel) swells rubber vulcanizates to a lesser extent than Reference Fuel B. Reference Fuels G, H, and I are fuel-alcohol blends (gasohol), which have a stronger swelling action than the corresponding fuel alone, where blends with methanol are more severe than blends with ethanol. Reference Fuel K, a methanol-rich blend, has a substantially weaker swelling action than that of the fuel used to prepare the blend. Reference Fuels I and K are also referred to as M15 and M85, respectively.

6.1.3 *Service Liquids*— Some commercial oils, fuels and other service liquids (see Table 4) are either non-petroleum or are compounded from special petroleum hydrocarbon fractions or mixtures of petroleum hydrocarbon fractions and other ingredients resulting in materials having properties beyond the range of the reference fluids listed in Table 2 and Table 3. Immersion tests of rubber vulcanizates that are to come into contact with such fluids should be made in the actual service liquid.

6.1.4 *Water*—Since the purity of water varies throughout the world, all water immersion tests are to be conducted in distilled or deionized water.

7. Preparation of Specimen

7.1 Except as otherwise specified in the applicable specifications, specimens shall be prepared in accordance with the requirements of Practices D 3182 and D 3183.

8. Apparatus

8.1 *For non-volatile liquids, a glass test tube*, having an outside diameter of 38 mm (1.5 in.) and an overall length of 300 mm (12 in.) fitted loosely with a stopper (see 8.2.1) shall be used.[11] Glass beads shall be used in the liquid as a bumper and to separate the specimens.

8.2 *For volatile liquids*, the test tube described in 8.1 shall be tightly fitted with a stopper (see 8.2.1) and a reflux condenser. An air-cooled reflux condenser shall be used for ASTM Oils No. 1[12,13] and No. 5 and for IRM 902[12,13] and

[11] Test tubes available under Part No. LGB24 and LGB24C (case of 30) from Edwin H. Benz Co. Inc., 73T Maplehurst Ave., Providence, RI 02908 or under Part No. LG226 from Precision Scientific, 2777 Washington Blvd., Bellwood, IL 60104, have been found suitable for this purpose.

[12] Information about ASTM Oil No. 1 is included in Research Report RR: D11-1004 and information about IRM 902 and IRM 903 in Research Report RR: D11-1069. Both reports are available from ASTM Headquarters.

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IRM 903[12],[13] at test temperatures of 125°C (257°F) or more. This condenser shall be a glass tube, approximately 500 mm (20 in.) or longer, in length and 15 mm (0.6 in.) in outside diameter, tightly fitted to the immersion tube by means of a stopper (see 8.2.1). The bottom of the condenser tube shall project about 12 mm (0.47 in.) below the stopper. A suitable (watercooled) reflux condenser shall be used for water or other low-boiling liquids. Glass beads shall be used as in 8.1.

8.2.1 The stopper shall not contaminate the test liquid. When in doubt, cover the stopper with aluminum foil.

8.3 *Maintaining Test Temperatures*—The apparatus and method chosen to maintain the specified temperature during immersion testing varies with test conditions, requirements, and circumstances. Water baths, appropriate temperature transfer oil baths, hot air ovens Note 3, or aging blocks[14] may be used.

NOTE 3—When hot air ovens are used, it should be noted that contamination with volatile components of the immersion liquid may occur. This can affect test results, when the same ovens are subsequently used for hot air aging.

8.3.1 The preferred method for above room temperatures is the use of aging blocks, since they have the widest temperature capability.

8.3.2 *Ovens*—Type IIB ovens specified in Test Method E 145 are satisfactory for use through 70°C. For higher temperatures, Type IIA ovens are necessary.

8.3.2.1 The interior size shall be as follows or of an equivalent volume:

Interior size of air oven:	
min	300 by 300 by 300 mm (12 by 12 by 12 in.)
max	900 by 900 by 1200 mm (36 by 36 by 48 in.)

8.3.2.2 Provision shall be made for placing immersion test tubes in the oven without touching each other or the sides of the aging chamber and allowing proper air circulation around them.

8.3.2.3 The heating medium for the aging chamber shall be air circulated within it at atmospheric pressure.

8.3.2.4 The source of heat is optional but shall be located in the air supply outside of the aging chamber proper.

8.3.2.5 A recording thermometer located in the upper central portion of the chamber near the center of the aging specimens shall be provided to record the actual aging temperature.

8.3.2.6 Automatic temperature control by means of thermostatic regulation shall be used.

8.3.2.7 The following special precautions shall be taken in order that accurate, uniform heating is obtained in all parts of the aging chamber:

8.3.2.8 The heated air shall be thoroughly circulated in the oven by means of mechanical agitation. When a motor-driven fan is used, the air must not come in contact with the fan motor brush discharge because of danger of ozone formation.

8.3.2.9 Baffles shall be used as required to prevent local overheating and dead spots.

8.3.2.10 The thermostatic control device shall be so located as to give accurate temperature control of the heating medium. The preferred location is adjacent to the recording thermometer.

8.3.2.11 An actual check shall be made by means of maximum reading thermometers placed in various parts of the oven to verify the uniformity of the heating.

9. Test Specimens—Change in Mass or Volume

9.1 The standard specimen shall be rectangular, having dimensions of 25 by 50 by 2.0 ± 0.1 mm (1 by 2 by 0.08 ± 0.004 in.). Specimens from commercial articles shall be the thickness of the material as received when they are less than 2 mm (0.08 in.); otherwise they should be reduced to a thickness of 2.0 ± 0.1 mm (0.08 ± 0.004 in.). Data obtained on test specimens having different original thicknesses are not comparable.

10. Procedure for Change in Mass

10.1 Test three specimens of a single composition. Calculate the test results of the three specimens (see 17.1, Eq 1) and average the results. Weigh each specimen in air to the nearest 1 mg, record the mass as M_1, and immerse in the test tube (see 8.1) containing 100 cm^3 of the test liquid (see 10.1.1). Separate each test specimen from any adjacent test specimen and the walls of the test tube by approximately 6 mm (0.25 in.), for example, by perforated glass beads[15] as shown in Fig. 1. The

[13] ASTM Oil No. 1, IRM 902 and IRM 903 may be ordered from Penreco, 4426 East Washington Blvd., Los Angeles, CA 90023-4476. ASTM Oils No. 1, No. 5, IRM 902, and IRM 903 are distributed by R. E. Carroll, Inc., P.O. Box 5806, Trenton, NJ 08638-0806.

[14] Aging blocks, available under Model No. LGB9 (9 cavities) and LGB28 (28 cavities) from Edwin H. Benz Co., Inc., 73T Maplehurst Ave., Providence, RI 02908, have been found suitable for this purpose.

[15] Hollow perforated glass beads, available under Catalog No. 11-311C from Fisher Scientific Co., 711T Forbes Ave., Pittsburgh, PA 15219, have been found suitable for this purpose.

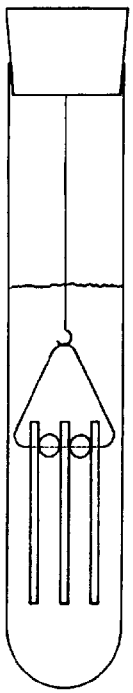

FIG. 1 Method of Separation

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materials used to suspend and separate the specimens shall not affect the test liquid or the rubber.

10.1.1 Test liquids shall not be reused.

10.1.1.1 For non-volatile liquids, condition the test tube assembly at the specified temperature within the limits given in 5.1 for the specified length of time. A check of the actual temperature of the test liquid contained in the test tube should be made to ensure that the liquid is within the test temperature specified.

10.1.1.2 For volatile liquids, fit the test tube assembly with a reflux condenser (see 8.2) and condition at the specified temperature within the limits given in 5.1 for the specified length of time. A check of the actual temperature of the test liquid contained in the test tube should be made to ensure that the test liquid is within the test temperature specified.

10.2 After the immersion test has proceeded for the required length of time, remove the test specimens. If the immersion has been at elevated temperature, cool the test specimens to room temperature by transferring them to a cool clean portion of the test liquid for 30 to 60 min. Then dip the specimens quickly in acetone at room temperature, blot lightly with filter paper free of lint and foreign material, place them immediately in a tared, stoppered weighing bottle, and determine the mass after test, M_2, of each specimen to the nearest 1 mg. After weighing, again immerse the test specimen in the same test liquid (see 11.2.1) if data are desired on the progressive changes that occur with increasing time of immersion. It is important that each manipulation take place promptly with the least possible lapse of time. When utilizing liquids that tend to volatilize at room temperature, no more than 30 s should elapse between removal from the test liquid and stoppering the weighing bottle.

10.3 Relatively viscous oils may be difficult to remove from the specimens with a quick acetone dip and blotting or even more vigorous wiping when the specimens are cooled in the test liquid after immersion; this can yield erroneous test results. Since these oils do not readily volatilize, specimens may be cooled by suspending them for about 30 min in air at room temperature shielded from draft, after removal from the immersion liquid at the test temperature. This will allow the majority of the oil to drip off the surface of the specimen. Then proceed with the acetone dip and blotting as described in 10.2. Report when this alternate method of specimen cooling is used.

11. Procedure for Change in Volume

11.1 *Water Displacement Method for Water-Insoluble Liquids and Mixed Liquids*—Test three specimens, calculate the test results for each specimen (see 17.2, Eq 2), and average the results. Obtain the mass M_1 of each specimen (see 11.2.2) in air, to the nearest 1 mg, and then obtain the mass M_2 of each specimen immersed in distilled water at room temperature. Quickly dip each specimen in alcohol (methanol or ethanol) to remove water (see 11.2.3), blot dry with filter paper free of lint and foreign material, and place in the immersion apparatus described in 8.1 or 8.2. Add 100 cm^3 of liquid (see 10.1.1) to the test tube and complete the immersion test as described in 10.1.1.1 or 10.1.1.2. At the end of the required immersion period, remove each specimen from the test tube. Cool the specimens to room temperature by transferring them to a cool, clean portion of the test liquid for 30 to 60 min, then dip quickly in acetone at room temperature, blot lightly with filter paper free of lint or foreign material, place in a tared, stoppered weighing bottle, weigh, and record the mass as M_3. Remove each specimen from the bottle, weigh in distilled water, and record the mass as M_4 in immediate consecutive order to determine the water displacement after immersion (see 11.2.2 and Note 4). When data on progressive changes with increasing time of immersion are desired, dip each specimen after weighing in alcohol (methanol or ethanol) to remove water (see 11.2.3), blot dry with filter paper free of lint and foreign material, and again immerse in the same test liquid (see 11.2.1). It is important that each manipulation following removal of the test specimen from the test medium take place promptly with the least possible lapse in time. When utilizing liquids that tend to volatilize at room temperature, no more than 30 s should elapse between removal from the test liquid and stoppering the weighing bottle, and no more than an additional 30 s between removal from the weighing bottle and immersion in water.

11.2 Relatively viscous oils may be difficult to remove from the specimens with a quick acetone dip and blotting or even more vigorous wiping when specimens are cooled in the test liquid after immersion; this can yield erroneous test results. Refer to 10.3 for an alternate method of specimen cooling.

11.2.1 Report if fresh test liquid is used, which can be a requirement for certain test methods or specifications.

11.2.2 It is important that all air bubbles clinging to the test specimen be removed before weighing in distilled water. If, in the course of weighing, air bubbles appear on the surface of the specimen, or the computed volume changes 0.5 % in 5 min, the specimen is too porous to permit volume determination in this manner. In that case, the initial volume of the specimen, if the latter is a simple geometrical solid, can be determined from the overall dimensions by employing an appropriate mensuration formula, and the same procedure followed in determining the volume after the immersion test; or, if volume increase occurs principally in the thickness dimension, a simple change in thickness may be substituted for change in volume. If, in the course of weighing the test specimen floats, AISI No. 316 stainless steel can be used as ballast to immerse the test specimen in the test liquid. In those cases where ballast is needed to submerge the specimen, the following procedure may be used.

11.2.2.1 Weigh the test specimen with ballast in water,

11.2.2.2 Weigh the ballast alone in water, and

11.2.2.3 Determine the difference between the weighings, and proceed with the calculations.

11.2.3 The acetone dip before and after immersion shall be omitted when water is employed as the test medium.

NOTE 4—A jolly balance, adequately shielded from air currents, may be used for making these determinations. When utilizing liquids that tend to volatilize at room temperature, no more than 30 s should elapse between removal from the test liquid and completion of the weighing operation.

11.3 *Displacement Method for Water-Soluble Liquids and Mixed Liquids (Other Than Water)*—For immersion liquids that are readily miscible with water or react with it, the water displacement method as described in 11.1 may not be suitable. For such liquids that are not too viscous or volatile at room

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temperature, weighings for M_2 and M_4 may be made in the immersion liquid instead of water with weighing for M_4 made in a fresh portion of the immersion liquid. These values are then used in calculating volume change using Eq 2 in 17.2. If this is not practicable, the water displacement method shall be used, except that the final weighing for M_4 is omitted and change in volume is calculated according to Eq 3 in 17.2. This formula may be only approximate if the immersion liquid is a mixture, because the density of the absorbed liquid may differ from that of the bulk. Also the density of any matter extracted from the rubber may differ from that of the immersion liquid.

12. Dimensional-Change Method for Water-Insoluble Liquids and Mixed Liquids

12.1 *Dimensional Change Method*—Measure the original length and width of three test specimens used in 11.1 to the nearest 0.5 mm (0.02 in.) using an average of three measurements in each direction recording the dimensions as L_0 and W_0, respectively. Measure the thickness of each test piece using a dial micrometer as described in 6.3 of Test Methods D 412, and record as T_0. Place specimens in the immersion apparatus described in 8.1 and 8.2. Add 100 cm^3 of liquid (see 10.1.1) to the test tube and complete the immersion test as described in 10.1.1.1 or 10.1.1.2. At the end of the required immersion period, remove each specimen from the test tube and bring to room temperature by transferring them to a cool clean portion of the test liquid for 30 to 60 min. Dip the specimens quickly in acetone at room temperature, blot lightly with filter paper free of lint and foreign material, and promptly remeasure as described above, recording the immersed length, width, and thickness as L, W, and T, respectively. If the immersion liquid tends to volatilize at room temperature, the measurements should be completed within 30 s after removing the test specimens from the liquid at room temperature. Calculate test results according to Eq 4 in 17.3 and report the average of three specimens.

13. Procedure for Change in Mass with Liquid on One Surface Only

13.1 *Scope*—This test method provides a procedure for exposing thin sheet materials (rubber-coated fabrics, diaphragms, etc.) that are in contact with the immersion liquid on only one surface under definite conditions of time and temperature.

13.2 *Test Specimen*— A disk 60 mm (2.4 in.) in diameter and thickness of thin sheet or rubber-coated fabric being tested.

13.3 *Apparatus*—The essential features are illustrated in Fig. 2 and consist of a base plate, *A*, an open-ended cylindrical chamber, *B*, which is held tightly against the test specimen, *C*, by wing nuts, *D*, mounted on bolts, *E*. During the test, the opening in the top of the chamber is tightly closed by a suitable plug, *F*.

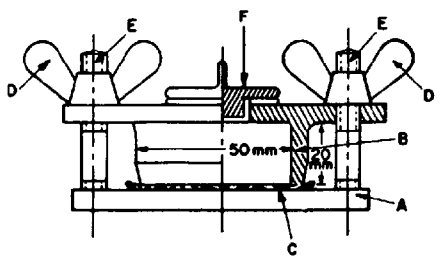

FIG. 2 Surface Immersion Apparatus

13.4 *Procedure*—Weigh the test specimen in air to the nearest 1 mg, record as M_1, and place in the apparatus as indicated in Fig. 2. Fill the chamber of the apparatus with the test liquid to a depth of 15 mm (0.6 in.), replace plug *F* and complete the test at the specified conditions as described in 5.1 and 5.2. At the end of the required immersion period, bring the apparatus to standard room temperature, remove the test liquid, and release the test specimen. Remove any excess liquid from the surface by wiping or blotting with filter paper free of lint and foreign material and place the specimen immediately in a tared, stoppered weighing bottle. Determine the mass of the specimen to the nearest 1 mg and record as M_2. When the immersion liquid tends to volatilize at room temperature, no more than 30 s should elapse between removal of the test specimen from the liquid and stoppering the weighing bottle. Use Eq 5 in 17.4 to calculate test results. If more than one specimen of the same composition is tested, report the result as the average.

14. Procedure for Determining Mass of Soluble Matter Extracted by the Liquid

14.1 This test method is applicable for immersions in volatile-type immersion liquids, such as ASTM reference fuels (see 6.1.2). Conduct the immersions as described in 10.1, 10.1.1.1, and 10.1.1.2. Test three specimens of a single composition, and report the result as the average. The extracted matter can be determined either by the difference in mass of the specimen before and after immersion or by evaporating the test liquid and weighing the non-volatile residue (Note 5). The mass is determined in air to the nearest 1 mg.

NOTE 5—Both methods are subject to error. Results obtained by the mass difference of specimens before and after immersion can be affected by possible oxidation of the material during immersion. Results obtained by evaporating the test liquid may be affected by partial loss of volatile extracted material during drying. The method of choice will depend on the material under test and the test conditions. For example, the evaporation method would be preferred if further testing is to be done on the extracted matter.

14.2 *Mass-Difference Method*—At the end of the required immersion period, remove the test specimens from the test tube and dry to a constant mass at a temperature of approximately 40°C (104°F) and an absolute pressure of 20 kPa (150 mm Hg). Record the original mass of the test specimen before immersion as M_1, the mass after immersion as M_2, and express the change in mass as a percentage of the original mass, using Eq 6 in 17.5. Report the results as the average if more than one specimen of the same composition is tested.

14.3 *Evaporation Method*—Transfer the liquid from the test tube in which the three test specimens have been immersed to a suitable vessel, wash the specimens in the test tube three times with 25 cm^3 of fresh liquid and transfer the liquid to the same vessel. Evaporate the liquid and dry the residue to a constant mass under an absolute pressure of 20 kPa (150 mm Hg) and a temperature of approximately 40°C (104°F). Record the sum of the original mass of three specimens before

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immersion as ΣM_1, the mass of the dried residue as M_3, and express M_3 as a percentage of ΣM_1, using Eq 7 in 17.5.

15. Changes in Tensile Strength, Elongation, and Hardness

15.1 *Original Properties*—The original tensile strength, ultimate elongation (Test Methods D 412, Die C) and hardness (Test Methods D 1415 or D 2240) shall be determined, using three specimens cut from the sheet or article adjacent to those that are to be immersed in the liquid. Report results in accordance with the appropriate test method.

15.2 *Immediate Deteriorated Properties*—For determining the tensile strength, ultimate elongation, and hardness, prepare three test specimens from flat vulcanized sheets 2.0± 0.1 mm (0.08 ± 0.004 in.) in thickness (see 9.1) using Die C of Test Methods D 412. Measure the thickness of each test specimen, place the specimens in the test tube described in 8.1, and add 150 cm^3 of liquid (see 10.1.1) to the test tube. Complete the immersion period in accordance with 10.1.1.1 or 10.1.1.2. At the end of the required immersion period, remove the specimens from the test tubes and cool immediately to room temperature in a fresh sample of the same liquid for 30 to 60 min. Then quickly dip each sample in acetone and blot lightly with filter paper that is free of lint and foreign material and immediately apply bench marks.

15.2.1 Determine the tensile strength and ultimate elongation in accordance with Test Methods D 412, using the original unimmersed thickness or cross-sectional area (see 17.6, Eq 8). Determine the hardness of each immersed specimen in accordance with Test Methods D 1415 or D 2240. The time interval between removal from the cool liquid and testing shall be not less than 2 nor more than 3 min.

15.2.2 It may be desirable to calculate the tensile strength based on the swollen cross-sectional area. In that case Eq 9 in 17.6 shall be used. Report when this method of calculation is employed.

15.3 Relatively viscous oils may be difficult to remove from the specimens with a quick acetone dip and blotting or even more vigorous wiping when specimens are cooled in the test liquid after immersion; this can yield erroneous test results. Refer to 10.3 for an alternate method of specimen cooling.

15.4 *Properties After Evaporation of Test Liquid*—This test method is applicable for immersions in volatile-type immersion liquids, such as ASTM reference fuels (see 6.1.2). For determining the tensile strength, ultimate elongation, and hardness of specimens after evaporation of the immersion liquid, immerse the specimens in the test liquid in accordance with 15.2. At the end of the required immersion time, remove the specimens and, if necessary, cool them to room temperature in a fresh sample of the same liquid for 30 to 60 min.

15.4.1 For room temperature drying, suspend the specimens for 4 ± 0.25 h in air at ambient conditions shielded from drafts. After the drying period apply bench marks and determine tensile strength and ultimate elongation in accordance with Test Methods D 412 using the original thickness or cross-sectional area of the untreated specimens (see 17.6, Eq 8) and hardness according to Test Methods D 1415 or D 2240.

15.4.2 For determining properties after complete evaporation of the test liquid, suspend specimens after the 4-h airdrying cycle at room temperature for 20 h ± 15 min at 70 ± 2°C (158 ± 4°F) in a circulating-air oven. After the heat drying cycle, remove the specimens from the oven, allow them to cool to room temperature and measure the required physical properties as described in 15.4.1. Report when the heat drying procedure is used.

15.5 The tensile strength and ultimate elongation after immersion and evaporation also can be expressed as percent change from the original values, using Eq 10 in 17.6, and hardness in unit change from the original value, according to Eq 11 in 17.6.

16. Changes in Breaking Resistance, Burst Strength, Tear Strength, and Adhesion for Coated Fabrics

16.1 *Original Properties*—The original properties for breaking resistance, burst strength, tear strength, and adhesion shall be determined in accordance with Test Method D 751, using the specified number of specimens cut from the coated fabric adjacent to those that are to be immersed in the liquid, or, if necessary, from other pieces of coated fabric that were produced from the same lot(s) of materials under the same conditions.

16.2 *Immediate Deteriorated Properties*—For determining breaking resistance, burst strength, tear strength, and adhesion, prepare the number of specimens specified for each parameter in Test Method D 751. Place the specimens in the test tube described in 8.1 and add 150 cm^3 of liquid (see 10.1.1) to the test tube. Complete the immersion test in accordance with 10.1.1.1 or 10.1.1.2. At the end of the required immersion period, remove the specimens from the test tubes, and cool immediately to room temperature in a fresh sample of the same liquid for 30 to 60 min. Then quickly dip each specimen in acetone and blot lightly with filter paper that is free of lint or foreign material. Measure the required physical properties in accordance with Test Method D 751 (see 17.7). The time interval between removal from the cool liquid and testing shall be not less than 2 min nor more than 3 min.

16.3 Relatively viscous oils may be difficult to remove from the specimens with a quick acetone dip and blotting or even more vigorous wiping when specimens are cooled in the test liquid after immersion; this can yield erroneous test results. Refer to 10.3 for an alternate method of specimen cooling.

16.4 *Properties After Evaporation of Volatile Test Liquid*—For determining breaking resistance, burst strength, tear strength, and adhesion of specimens after evaporation of a volatile immersion liquid, such as ASTM reference fuels (see 6.1.2), immerse the specimens in the test liquid in accordance with 15.2. At the end of the required immersion time, remove the specimens, suspend them for 2 h ± 5 min at ambient conditions shielded from draft and then place them in a circulating-air oven at a temperature of 70 ± 2°C (158 ± 4°F) for a period of 2 h ± 5 min. At the end of the drying period, remove the specimens from the oven, allow them to cool to room temperature and measure the required physical properties in accordance with Test Method D 751 (see 17.7). The time interval between removal from the oven and testing shall be not less than 1 h nor more than 2 h.

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16.5 If desired, report results after immersion and evaporation in percent change from the original property values, as described in 15.5.

17. Calculation

17.1 Calculate the percent change in mass as follows (Section 10):

$$\Delta M, \% = \frac{(M_2 - M_1)}{M_1} \cdot 100 \quad (1)$$

where:
ΔM = change in mass, %,
M_1 = initial mass of specimen in air, g, and
M_2 = mass of specimen in air after immersion, g.

17.2 Calculate the percent change in volume as follows (Section 11):

$$\Delta V, \% = \frac{(M_3 - M_4) - (M_1 - M_2)}{(M_1 - M_2)} \cdot 100 \quad (2)$$

$$\Delta V, \% = \frac{(M_3 - M_1)}{d(M_1 - M_2)} \cdot 100 \quad (3)$$

where:
ΔV = change in volume, %,
M_1 = initial mass of specimen in air, g,
M_2 = initial mass of specimen in water, g,
M_3 = mass of specimen in air after immersion, g,
M_4 = mass of specimen in water after immersion, g, and
d = density of immersion liquid at standard laboratory room temperature, Mg/m^3.

17.3 Calculate the percent change in dimensions as follows (Section 12):

$$\Delta L, \% = \frac{(L - L_0)}{L_0} \cdot 100 \quad (4)$$

where:
ΔL = change in length, %,
L_0 = initial length of specimen, mm, and
L = length of specimen after immersion, mm.

Calculate the percent change in width, ΔW, and thickness, ΔT, accordingly.

17.4 Calculate the change in mass for single surface exposure as follows (Section 13):

$$\Delta M_A, \text{ kg/m}^2 = \frac{(M_2 - M_1)}{A} \cdot 1000 \quad (5)$$

where:
ΔM_A = change in mass per unit surface area, kg/m^2,
M_1 = initial mass of specimen in air, g,
M_2 = mass of specimen in air after exposure to the test liquid, g, and
A = area of the specimen in actual contact with the test liquid, mm^2.

17.5 Calculate percent extracted soluble matter as follows (Section 14):

$$M_E, \% = \frac{(M_1 - M_2)}{M_1} \cdot 100 \quad (6)$$

$$M_E, \% = \frac{M_3}{\Sigma M_1} \cdot 100 \quad (7)$$

where:
M_E = extracted soluble matter, %,
M_1 = initial mass of specimen in air, g,
M_2 = mass of specimen in air after immersion and drying, g,
ΣM_1 = sum of the initial mass of three specimens in air, g, and
M_3 = mass of the residue in air after evaporating and drying the immersion liquid of three specimens, g.

17.6 Calculate tensile strength of the specimens both on immediate deteriorated properties and properties after evaporation of the test liquid as described in the Calculation section of Test Methods D 412.

17.6.1 Based on the original unstretched cross-sectional area:

$$TS_o = \frac{F}{A} \quad (8)$$

17.6.2 Based on the swollen unstretched cross-sectional area:

$$TS_s = \frac{F}{A\left(1 + \frac{\Delta V}{100}\right)^{2/3}} \quad (9)$$

17.6.3 To express tensile strength and ultimate elongation after immersion as a percentage change from the original properties, use the following formula:

$$\Delta P, \% = \frac{P_i - P_o}{P_o} \cdot 100 \quad (10)$$

17.6.4 Calculate hardness change after immersion in hardness units:

$$\Delta H = H_i - H_o \quad (11)$$

where:
TS_o = tensile stress based on original unstretched cross-sectional area,
TS_s = tensile stress based on swollen unstretched cross-sectional area,
F = observed force,
A = original unstretched cross-sectional area of the test specimen before immersion,
ΔV = volume swell after immersion, %,
ΔP = change in property (tensile strength and ultimate elongation) after immersion, %,
P_o = original property before immersion,
P_i = property after immersion,
ΔH = hardness change after immersion, units,
H_o = original hardness before immersion, units, and
H_i = hardness after immersion, units.

17.7 Calculate breaking resistance, burst strength, tear strength, and adhesion both on the immediate deteriorated properties and properties after evaporation of volatile test liquid as described in Test Method D 751. If desired, results may also be expressed in percentage change after immersion as detailed in 17.6.3.

18. Report

18.1 State that the test was conducted in accordance with Test Method D 471 and report the following:

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18.1.1 Description of the sample and its origin,

18.1.2 Date and temperature of testing room (see 5.1),

18.1.3 Duration, temperature, and date of vulcanization of test specimens,

18.1.4 Dates of the various periods of exposure,

18.1.5 Immersion liquid used,

18.1.6 Temperature of exposure,

18.1.7 Exposure period,

18.1.8 All observed and recorded data, to include the type of properties being reported,

18.1.9 Results calculated in accordance with Section 17,

18.1.10 Statement of condition of exposed specimens from visual and manual examination,

18.1.11 Report which test method was used for determination of hardness, and

18.1.12 Any deviations from standard test methods.

19. Precision and Bias [16]

19.1 This precision and bias section deals with property changes in tensile strength, ultimate elongation, hardness, and volume after immersion in test liquids and has been prepared in accordance with Practice D 4483. Refer to this practice for terminology and other statistical calculation details.

19.2 The precision results in this precision and bias section give an estimate of the precision of this test method with the materials used in the particular interlaboratory test program as described in the following paragraphs. The precision parameters should not be used for acceptance or rejection testing of any group of materials without documentation that the parameters are applicable to the particular group of materials and the specific testing protocols of the test method.

19.3 A Type 1 interlaboratory test program was evaluated in 1981 using six different vulcanized rubber compounds (materials). These compounds were prepared in one laboratory and test specimens were distributed to nine participating laboratories. Each laboratory prepared and purchased from approved sources, the liquids and fuels, or both, used for testing. A test result (as used for these calculations) is the average of three individual test specimen values. Each laboratory conducted tests (that is, obtained one test result) on each of two days. Both repeatability and reproducibility are therefore short term; a period of a few days separates test results.

[16] Details and supporting data of the precision evaluation program are available in a research report from ASTM Headquarters. Request RR: D11-1069.

19.4 The results of the precision evaluation are given in Table 5 and Table 6 for each of the six rubbers or materials for immersion tests in (*1*) Reference Fuels B, C and D, for 70 h at 23 ± 2°C (73 ± 4°F), and (*2*) ASTM Oil No. 2 and ASTM Oil No. 3 for 70 h at 150 ± 2°C (302 ± 4°F).

19.5 The precision is given in terms of *Sr, r, SR*, and *R* for four measured physical properties: (*1*) percent change in tensile strength, (*2*) percent change in ultimate elongation (that is, percent change in percent elongation), (*3*) hardness change in hardness units, and (*4*) percent change in volume of the test specimen. No values are given for (*r*) and (*R*), the normal precision parameters used to express relative precision because numerous average values for properties (*1*), (*2*), and (*4*) are near zero, thus resulting in extremely large (*r*) and (*R*) values. These large values are essentially meaningless for precision comparisons when average values are near zero.

19.6 The precision of the test method may be expressed in the following statements that use an appropriate value of *r* and *R*. The appropriate value is that value of *r* or *R*, associated with a mean level in the tables closest to the mean level under consideration for any immersion liquid or rubber, for any test result for a similar material in routine testing operations.

19.7 *Repeatability*— The repeatability, *r*, of this test method has been established as the appropriate value tabulated in Table 5 and Table 6. Two single test results, obtained under normal test method procedures, that differ by more than this tabulated *r* (for any given level) must be considered as derived from different or nonidentical sample populations.

19.8 *Reproducibility*— The reproducibility, *R*, of this test method has been established as the appropriate value tabulated in Table 4 through Table 6. Two single test results obtained in two different laboratories, under normal test method procedures, that differ by more than the tabulated *R* (for any given value) must be considered to have come from different or nonidentical sample populations.

19.9 *Bias*—In test terminology, bias is the difference between an average test value and the reference (or true) value. Reference values do not exist for this test method since the value (of the test property) is exclusively defined by the test method. Bias, therefore, cannot be determined.

20. Keywords

20.1 elevated temperature; fluid immersion; liquid immersion; reference fuel; rubber articles; rubber products; service liquid

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TABLE 5 Type 1 Precision Data[A]

Rubber	Change in Tensile Strength, %					Change in Elongation,%					Change in Hardness, Units				
	Within-Lab			Between-Lab		Within-Lab			Between-Lab		Within-Lab			Between-Lab	
	Mean	*Sr*	*r*	*SR*	*R*	Mean	*Sr*	*r*	*SR*	*R*	Mean	*Sr*	*r*	*SR*	*R*
ASTM Reference Fuel B:															
CR	−48.0	3.12	8.8	3.26	9.2	−43.7	4.55	12.9	5.36	15.2	−16.0	0.76	2.1	1.87	5.3
FKM	−7.9	1.94	5.5	3.55	10.0	−0.1	3.25	9.2	3.58	10.1	−2.3	0.90	2.6	1.68	4.8
FVMQ	−30.6	4.17	11.8	6.08	17.2	−27.1	2.47	7.0	7.05	19.9	−9.6	1.12	3.2	2.16	8.1
NBR-1	−63.6	2.90	8.2	4.27	12.1	−50.3	3.44	9.7	7.24	20.5	−9.8	0.87	2.5	1.32	3.7
NBR-2	−11.8	2.59	7.3	3.75	10.6	−16.3	2.41	6.8	4.55	12.9	−12.7	1.15	3.3	1.73	4.9
CO	−8.6	3.35	9.5	5.23	14.8	−26.0	4.19	11.9	3.04	8.6	−12.4	1.00	2.8	1.68	4.8
Pooled Values	...	3.07	8.7	4.47	12.6	...	3.52	10.0	5.38	15.2	...	0.98	2.8	1.76	5.0
ASTM Reference Fuel C:															
CR	−57.4	2.70	7.6	3.49	9.9	−54.2	3.51	9.9	5.47	15.5	−17.7	1.58	4.5	3.36	9.5
FKM	−11.1	3.32	9.4	6.34	17.9	−0.6	2.29	6.5	6.55	18.5	−2.8	0.80	2.3	1.64	4.3
FVMQ	−30.9	2.74	7.8	7.20	20.4	−28.4	4.01	11.3	6.83	19.4	−9.7	1.76	5.0	2.87	8.1
NBR-1	−68.9	2.77	7.8	4.17	11.8	−58.1	5.27	14.9	5.53	15.7	−10.7	1.33	3.8	1.22	3.5
NBR-2	−14.8	3.78	10.7	5.15	14.6	−21.0	2.87	8.1	6.30	17.8	−18.3	1.12	3.2	2.95	8.3
CO	−18.0	3.24	9.2	3.38	9.6	−33.9	4.52	12.8	2.64	7.5	−17.3	1.18	3.3	1.85	5.2
Pooled Values	...	3.10	8.8	5.16	14.6	...	3.89	11.0	5.73	16.2	...	1.35	3.8	2.43	6.9
ASTM Reference Fuel D:															
CR	−54.8	2.69	7.6	2.36	6.6	−50.9	1.83	5.2	3.62	10.2	−16.9	0.60	1.7	2.57	7.3
FKM	−9.2	2.26	6.4	6.00	17.0	−0.2	2.83	8.0	6.83	19.3	−1.9	0.85	2.4	2.46	6.9
FVMQ	−33.2	3.45	9.8	5.90	16.7	−28.5	3.44	9.7	7.13	20.2	−9.6	1.39	3.9	2.48	7.0
NBR-1	−67.4	2.01	5.7	4.00	11.3	−55.8	2.35	6.7	5.05	14.3	−10.9	1.06	3.0	0.98	2.8
NBR-2	−12.4	3.05	8.6	2.56	7.2	−18.3	1.78	5.0	6.21	17.6	−15.1	0.79	2.2	3.39	9.6
CO	−14.6	3.02	8.5	3.36	9.5	−30.0	3.08	8.7	3.31	9.4	−15.3	1.17	3.3	3.41	9.7
Pooled Values	...	2.81	7.9	4.29	12.1	...	2.63	7.4	5.63	15.9	...	1.02	2.9	2.67	7.6
ASTM Oil No. 1:															
CR	−15.4	2.78	7.9	5.01	14.2	−31.3	1.94	5.5	5.20	14.7	−8.6	1.39	3.9	2.80	7.9
FKM	−6.1	5.25	14.8	6.11	17.3	−9.3	4.38	12.4	5.74	16.2	−2.8	1.84	5.2	3.34	9.4
FVMQ	−4.3	5.93	16.8	9.48	26.8	−11.9	4.89	13.8	4.34	12.3	−2.4	1.54	4.4	3.20	9.0
NBR-1	−18.9	3.55	10.0	6.38	18.1	−12.5	5.07	14.3	10.49	29.7	−4.0	1.09	3.1	2.74	7.8
NBR-2	−7.7	3.38	9.6	9.67	27.4	−70.7	3.67	10.4	7.17	20.3	17.2	1.32	3.7	2.08	5.9
CO	20.2	4.81	13.6	7.25	20.5	−48.5	3.72	10.5	4.17	11.8	8.6	0.67	1.9	3.24	9.2
Pooled Values	...	4.43	12.5	7.52	21.3	...	4.06	11.5	6.55	18.5	...	1.36	3.8	3.11	8.8
ASTM Oil No. 3:															
CR	−42.5	3.43	9.7	4.19	11.9	−42.0	2.64	7.5	4.41	12.5	−19.1	1.27	3.6	4.46	12.6
FKM	−11.3	4.27	12.1	17.20	48.7	−2.4	4.58	12.9	7.95	22.5	−2.9	1.15	3.3	3.67	10.4
FVMQ	−18.2	2.84	8.0	10.65	30.1	−17.9	5.28	14.9	6.83	19.3	−1.9	1.25	3.5	1.74	4.9
NBR-1	−37.2	5.32	15.1	12.82	36.6	−19.5	6.12	17.3	12.19	34.5	−12.7	1.44	4.1	4.67	13.2
NBR-2	−27.0	5.67	16.0	14.64	41.4	−69.7	3.80	17.3	5.72	16.2	10.6	1.39	3.9	2.22	8.3
CO	21.7	6.50	18.4	10.29	29.1	−39.7	5.42	10.7	4.40	12.4	3.3	0.97	2.8	2.73	7.7
Pooled Values	...	4.85	13.7	12.33	34.9	...	4.76	13.5	7.55	21.4	...	1.25	3.5	3.61	10.2

[A] *Sr* = repeatability standard deviation, in measurement units, *r* = repeatability = 2.83 × *Sr*, *SR* = reproducibility standard deviation, in measurement units, and *R* = reproducibility = 2.83 × *SR*.

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TABLE 6 Precision Data[A]

Rubber	Change in Volume, %				
	Within-Laboratory			Between-Laboratories	
	Mean	*Sr*	*r*	*SR*	*R*
ASTM Reference Fuel B:					
CR	66.2	0.94	2.7	5.40	15.3
FKM	1.5	0.36	1.0	0.34	1.0
FVMQ	5.1	0.48	1.4	0.92	2.8
NBR-1	46.9	0.38	1.1	3.96	11.2
NBR-2	12.0	0.73	2.1	0.63	1.8
CO	15.6	0.39	1.0	1.27	3.6
Pooled Values	...	0.60	1.7	2.95	8.4
ASTM Reference Fuel C:					
CR	108.9	1.04	2.9	4.99	14.1
FKM	2.6	0.46	1.3	0.32	0.9
FVMQ	17.8	0.53	1.5	1.61	4.5
NBR-1	76.8	0.59	1.7	3.47	9.8
NBR-2	22.6	0.69	2.0	0.77	2.2
CO	25.3	0.51	1.4	0.59	1.7
Pooled Values	...	0.64	1.8	2.60	7.4
ASTM Reference Fuel D:					
CR	90.6	1.52	4.3	3.15	8.9
FKM	2.3	0.33	0.9	0.56	1.6
FVMQ	15.9	0.92	2.6	3.05	8.6
NBR-1	62.2	1.23	3.5	2.10	5.9
NBR-2	18.1	1.38	3.9	1.55	4.4
CO	20.4	0.89	2.5	1.25	3.5
Pooled Values	...	1.11	3.1	2.26	6.4
ASTM Oil No. 1:					
CR	15.8	0.50	1.4	0.61	1.7
FKM	1.2	0.29	0.8	1.12	3.2
FVMQ	0.6	0.57	1.6	1.05	3.0
NBR-1	3.4	0.69	1.9	1.88	5.3
NBR-2	−11.2	0.45	1.3	0.47	1.3
CO	−5.2	0.42	1.2	0.64	1.8
Pooled Values	...	0.50	1.4	1.67	4.7
ASTM Oil No. 3:					
CR	75.6	1.03	2.9	1.84	5.2
FKM	3.1	1.47	4.2	1.97	5.6
FVMQ	2.8	0.61	1.7	3.75	2.4
NBR-1	31.4	0.18	1.5	4.21	11.9
NBR-2	−2.1	0.14	2.5	0.67	1.9
CO	4.2	0.24	0.7	0.77	2.2
Pooled Values	...	0.88	2.5	2.70	7.6

[A] *Sr* = repeatability standard deviation, in measurement units, *r* = repeatability = 2.83 × *Sr*, *SR* = reproducibility standard deviation, in measurement units, and *R* = reproducibility = 2.83 × *SR*.

APPENDIXES

(Nonmandatory Information)

X1. REPLACEMENT OF ASTM OILS NO. 2 AND NO. 3 WITH IRM 902 AND IRM 903

X1.1 ASTM Oils No. 2 and No. 3 became subject to cancer hazard warning label requirements under the OSHA Hazard Communication Standard, published November 25, 1983. This contributed to the discontinuation of commercial production in 1990.

X1.2 ASTM Subcommittee D11.15 on Degradation Testing began a program in 1985–1986 to establish replacements for these oils, with the objective to match the action on vulcanized rubbers as closely as possible, while eliminating the need for cancer hazard labeling (negative modified Ames Test). An interlaboratory test program (ITP) was organized in 1993 with six candidate oils as No. 2 and No. 3 replacements from three different suppliers, using twelve different types of vulcanized rubbers. As a result of this ITP, two oils from Calumet Lubricants Company were selected as best (but not equivalent) matches for the ASTM oils, and confirmed independently by ASTM Subcommittee D11.15 and the SAE Committee on Automotive Rubber Specifications (SAE-CARS). Calumet No. 2, the replacement for No. 2 oil, provided a closer match than Calumet No. 3, the replacement for No. 3 oil. The two oils were established as industry reference materials, IRM 902 (Calumet No. 2, replacement for ASTM Oil No. 2) and IRM 903 (Calumet No. 3, replacement for ASTM Oil No. 3).

X1.2.1 Details of the ITP are described in Research Report

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RR: D11-1069, which can be obtained from ASTM headquarters. A precision statement on volume swells generated in this test program is given in Appendix X2.

X1.3 Since the inventory of ASTM Oils No. 2 and No. 3 was depleted by the end of 1993, Committee D-11 published Emergency Standard ES 27 in 1994 to address the replacement with IRM 902 and IRM 903.

X2. PRECISION AND BIAS—TEST PROGRAM FOR THE REPLACEMENT OF ASTM OILS NO. 2 AND NO. 3

X2.1 This precision statement was prepared using data from the comprehensive ITP evaluation program conducted in 1993 to establish replacement oils for ASTM Oils No. 2 and No. 3. Because of the limited number of laboratories (three), only within-laboratory variation or repeatability could be evaluated. Some terminology used in this appendix is contained in Practice D 4483. Refer to Practice D 4483 for background details.

X2.2 In the evaluation program twelve compounds were tested in groups of four; each group of four was tested by three laboratories. There are only three duplicates (one duplicate set of tests in each laboratory) for an estimate of within-laboratory variation for any combination of rubber and oil. This is an inadequate number of degrees of freedom (DF) for such an estimate. However, a reasonable assumption may be made that for any given rubber, the true test variation with each of the four oils is equivalent. On this basis for any candidate set of the four oils, the three DF estimates of test standard deviation for each of the four oils may be pooled to obtain a twelve DF estimate of test standard deviation. The within-laboratory precision of this appendix is based on such pooled values.

X2.3 The precision results are given in Table X2.1 for percent volume swell. This is the only property that was evaluated for precision, since it shows the highest sensitivity to variation.

X2.4 Table X2.1 lists the repeatability standard deviation, *Sr*; the repeatability, *r*, in units of % volume swell, the relative repeatability, (*r*), which is a percent of a percent for volume swell measurements, and for completeness, the coefficient of variation, CV, in %. The mean volume swell values range from near zero to about 160 %. The precision parameters also display a wide range. Regression and graphical analysis reveals that (*1*) there is a direct (positive slope) log-log relationship for *Sr* versus mean volume swell, and (*2*) an inverse (negative slope) relationship between the relative repeatability (*r*) and mean volume swell. These relationships apply to both sets of data and to the combined data sets.

X2.5 The results of Table X2.1 may be applied to within-laboratory data comparisons using either IRM 902 or IRM 903 for any commercial or proprietary compound by selecting the Table X2.1 rubber closest to the commercial compound and selecting the level of volume swell value in Table X2.1 closest to the measured volume swell of the commercial rubber.

TABLE X2.1 Precision Data for Within-Laboratory Variation

NOTE 1—*Sr* = repeatability standard deviation, *r* = repeatability = 2.83 × *Sr*, (*r*) = repeatability on relative basis (percent of percent), and *CV* = coefficient of variation, % = (*Sr*/Mean) × 100.

Rubber	Change in Volume, % (Pooled Values)				
	Mean	*Sr*	*r*	(*r*)	*CV*
ASTM Oil No. 2 Types:[A]					
ACM	1.3	0.57	1.60	119.0	42.2
AEM	27.8	0.82	2.33	8.4	3.0
CR	36.0	1.63	4.61	12.8	4.5
ECO	3.9	0.58	1.65	42.7	15.1
EPDM	120.2	2.17	6.14	5.1	1.8
EVM	34.1	0.60	1.68	4.9	1.8
FKM	0.7	0.20	0.57	76.5	27.0
FVMQ	0.4	0.31	0.87	198.0	70.0
HNBR	9.4	0.30	0.85	9.1	0.3
NBR	7.6	0.35	0.99	13.1	4.6
TPV	48.4	1.98	5.62	11.6	4.1
VMQ	10.4	1.36	3.84	37.0	13.1
ASTM Oil No. 3 Types:[B]					
ACM	8.3	1.31	3.71	44.6	15.8
AEM	50.3	0.71	2.01	4.0	1.4
CR	68.1	1.15	3.26	4.8	1.7
ECO	7.1	1.22	3.48	48.5	17.1
EPDM	161.5	5.19	14.70	9.1	3.2
EVM	58.7	1.04	2.94	5.0	1.8
FKM	1.6	0.34	0.95	59.1	20.9
FVMQ	2.0	0.43	1.21	59.5	21.0
HNBR	15.9	0.46	1.29	8.1	2.9
NBR	14.8	0.72	2.05	13.8	4.9
TPV	79.5	1.92	5.43	6.8	2.4
VMQ	43.4	2.30	6.52	15.0	5.3

[A] Pooled results for No. 2 oil plus three candidate replacements.
[B] Pooled results for No. 3 oil plus three candidate replacements.

X2.5.1 Two test results of the commercial rubber that differ by more than the tabulated *r* or (*r*) values as selected by the above process, must be considered to have come from different sample populations (that is, be significantly different).

X2.5.2 Alternatively normal testing operations should produce values for duplicate test results that are within the *r* and (*r*) intervals as selected by the above process.

X2.6 Bias reference values do not exist for this type of testing, since the value of the test property is defined exclusively by the test method. Bias, therefore, cannot be determined.

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Designation: D 1600 – 99

An American National Standard

Standard Terminology for Abbreviated Terms Relating to Plastics[1]

This standard is issued under the fixed designation D 1600; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 The purpose of this terminology is to provide uniform contractions of terms relating to plastics. Abbreviated terminology has evolved through widespread common usage. This compilation has been prepared to avoid both the occurrence of more than one abbreviated term for a given plastics term and multiple meanings for abbreviated terms.

1.2 The scope of these abbreviated terms includes plastics terms pertaining to composition and relating to type or kind according to mode of preparation or principle distinguishing characteristics. Also included are abbreviated terms for terms relating to copolymers, blends and alloys of plastics, and additives such as plasticizers, fillers, etc.

NOTE 1—A code relating to the composition of rubbers is given in Practice D 1418.

1.3 No attempt is made here to systematize formally a shorthand terminology for polymers. Terminology, including nomenclature, codes, symbols, and formula designations for use in scientific literature in the field of natural and synthetic polymers, are being studied and standardized by the International Union of Pure and Applied Chemistry.[2]

1.4 These abbreviated terms are by no means all-inclusive of plastics terminology. They represent, in general, those terms that have come into established use. Since it is recognized that abbreviated terms serve no useful purpose unless they are generally accepted and used, no attempt has been made to establish a rigorous code for devising standard abbreviated terms. This would result in awkward departures from established usage of existing and accepted abbreviated terms and lead to cumbersome combinations in the future, which would not be likely to receive widespread acceptance. The abbreviated terms now in use have grown naturally out of the need for convenient, readily comprehended shorthand for long chemical names. This process can be expected to continue along the natural lines of least resistance and will serve as a basis for further standardization as the need arises. A general guide for the preparation of abbreviated terms appears desirable, however, to facilitate more organized and uniform standardization in the future. An appendix is attached, which suggests a uniform way to prepare abbreviated terms.

1.5 Note that the uppercase letter F should be used to designate phosphate and that other elements may also be designated F.

1.6 An abbreviated term (FR) and code numbers are provided to identify classes of materials used as flame retardants added to plastics. The system is provided for use in situations where marking of plastics products is desired.

NOTE 2—Many of the abbreviated terms, codes, numbers, and symbols in ISO 1043 parts 1 through 3 and in ISO/DIS 1043-4 are the same as the corresponding item in ASTM D 1600. D 1600 includes a number of abbreviated terms that are not in ISO 1043.

2. Referenced Documents

2.1 *ASTM Standards:*

D 883 Terminology Relating to Plastics[3]

D 1418 Practice for Rubber and Rubber Latices—Nomenclature[4]

D 1972 Practice for Generic Marking of Plastics Products[3]

2.2 *ISO Standards:*

ISO 472:1988 Plastics—Vocabulary[5]

ISO 1043-1:1996 Plastics—Symbols—Part 1: Basic Polymers and Their Special Characteristics[5]

ISO 1043-2:1988 Plastics—Symbols—Part 2: Fillers and Reinforcing Materials[5]

ISO 1043-3:1988 Plastics—Symbols—Part 3: Plasticizers[5]

ISO/DIS 1043-4:1996 Plastics—Symbols and Abbreviated Terms—Part 4: Flame Retardants[5]

ISO 11469:1992 Plastics—Generic Identification and Marking of Plastics Products[5]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of general terms, see Terminology D 883.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *flame retardant, FR, n*—a substance that markedly retards the propagation of a flame. (See ISO 472.)

[1] This terminology is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.92 on Terminology.

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[2] "Report on Nomenclature in the Field of Macromolecules," *Journal of Polymer Science*, Vol VIII, 1952, pp. 257–277.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 09.01.

[5] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

***A Summary of Changes section appears at the end of this standard.**

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3.2.1.1 *Discussion*—Flame retardants may be incorporated in plastics as additives (external flame retardant) or as chemical groups in the base polymer by use of reactive intermediates in the polymerization process (internal flame retardant). The code numbers in this standard are restricted to external flame retardants.

4. Terms and Abbreviated Terms

4.1 *Plastics and Resins:*[6]

Term	Abbreviated Term
Acrylonitrile/butadiene plastics	AB
Acrylonitrile-butadiene-acrylate plastics	ABA
Acrylonitrile-butadiene-styrene plastics	ABS
Acrylonitrile-chlorinated polyethylene-styrene plastics	ACPES
Acrylonitrile-ethylene-styrene plastics	AES
Acrylonitrile-methyl acrylate-acrylonitrile-butadiene rubber	AMAB
Acrylonitrile-methyl methacrylate plastics	AMMA
Acrylonitrile-styrene-acrylate plastics	ASA
Acrylonitrile/ethylene-propylene-diene/styrene	AEPDMS
Aromatic polyester	ARP
Carboxymethyl cellulose	CMC
Casein	CS
Caseine-formaldehyde resin	CSF
Cellulose acetate	CA
Cellulose acetate-butyrate	CAB
Cellulose acetate propionate	CAP
Cellulose formaldehyde	CEF
Cellulose nitrate	CN
Cellulose plastics, general	CE
Cellulose propionate	CP
Cellulose triacetate	CTA
Chlorinated poly(vinyl chloride)	CPVC
Chlorinated polyethylene	CPE
Cresol-formaldehyde resin	CF
Epoxy, epoxide	EP
Ethyl cellulose	EC
Ethylene-chlorotrifluoroethylene copolymer	E-CTFE
Ethylene-ethyl acrylate plastics	EEA
Ethylene-methacrylic acid plastics	EMA
Ethylene-propylene polymer	EPM
Ethylene-propylene-diene plastics	EPD
Ethylene-tetrafluoroethylene copolymer	ETFE
Ethylene-vinyl acetate plastics	EVA
Ethylene-vinyl alcohol copolymer	EVOH
Fluorocarbon perfluoromethoxy	MPA
Furan formaldehyde resin	FF
High density polyethylene plastics	HDPE
High impact-resistant polystyrene	HIPS
Impact resistant polystyrene	IPS
Linear low density polyethylene plastics	LLDPE
Linear medium density polyethylene plastics	LMDPE
Liquid crystal polymer	LCP
Low density polyethylene plastics	LDPE
Medium density polyethylene plastics	MDPE
Melamine-formaldehyde resin	MF
Melamine/phenol-formaldehyde resin	MPF
Methacrylate-butadiene-styrene plastics	MBS
Methyl cellulose	MC
Methyl methacrylate-acrylonitrile-butadiene-styrene resin	MMABS
Nylon (see also polyamide)	PA
Perfluoro(alkoxy alkane)	PFA
Perfluoro(ethylene-propylene) copolymer	FEP
Perfluoromethoxy resin	MFA
Phenol-formaldehyde resin	PF
Phenol-furfural resin	PFF
Poly(acrylic acid)	PAA
Poly(allyl diglycol carbonate)	PADC
Poly(aryl ether ketone)	PAEK
Poly(butyl acrylate)	PBA
Poly(butylene terephthalate)	PBT
Poly(cyclohexylenedimethylene cyclohexandicarboxylate), glycoland acid comonomer	PCCE
Poly(cyclohexylenedimethylene terephthalate)	PCT
Poly(cyclohexylenedimethylene terephthalate), acid comonomer	PCTA
Poly(cyclohexylenedimethylene terephthalate), glycol	PCTG
Poly(diallyl phthalate)	PDAP
Poly(ester urethane)	PAUR
Poly(ether block amide)	PEBA
Poly(ether sulfone)	PES
Poly(ether urethane)	PEUR
Poly(ethylene oxide)	PEOX
Poly(ethylene terephthalate)	PET[6]
Poly(ethylene terephthalate) glycol comonomer	PETG
Poly(methyl methacrylate)	PMMA
Poly(methyl methacrylimide)	PMMI
Poly(methyl-α-chloroacrylate)	PMCA
Poly(phenyl sulfone)	PPSU
Poly(phenylene ether) (or Poly(phenylene oxide), a deprecated term)	PPE
Poly(phenylene sulfide)	PPS
Poly(phenylene sulfone)	PPSU
Poly(propylene oxide)	PPOX
Poly(vinyl acetate)	PVAC
Poly(vinyl alcohol)	PVOH
Poly(vinyl butyral)	PVB
Poly(vinyl carbazole)	PVK
Poly(vinyl chloride)	PVC
Poly(vinyl chloride-acetate)	PVCA
Poly(vinyl fluoride)	PVF
Poly(vinyl formal)	PVFM
Poly(vinyl pyrrolidone)	PVP
Poly(vinylidene chloride)	PVDC
Poly(vinylidene fluoride)	PVDF
Poly(ε-caprolactone)	PCL
Poly-4-methylpentene-1	PMP
Poly-α-methylstyrene	PMS
Poly-p-oxybenzoate	POB
Polyacrylonitrile	PAN
Polyamide (nylon)	PA
Polyamide 11	PA11
Polyamide 12	PA12
Polyamide 1212	PA1212
Polyamide 46	PA46
Polyamide 6	PA6
Polyamide 610	PA610
Polyamide 612	PA612
Polyamide 66	PA66
Polyamide 69	PA69
Polyamide-imide	PAI
Polyarylate	PAR
Polyaryl amide	PARA
Polyarylether	PAE
Polyarylsulfone	PASU
Polybutadiene-acrylonitrile	PBAN
Polybutadiene-styrene	PBS
Polybutene-1	PB
Polycarbonate	PC
Polychlorotrifluoroethylene	PCTFE
Polyester alkyd (or polyacrylate)	PAK
Polyetheretherketone	PEEK
Polyetheretherketoneketone	PEEKK
Polyetherketonetherketoneketone	PEKEKK

[6] To prevent any confusion with or misuse of the registered trademark, PET® Milk, the guidelines of 8.1 shall be followed.

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Term	Abbreviated Term
Polyetherketoneketone	PEKK
Polyetherimide	PEI
Polyetherketone	PEK
Polyethylene	PE
Poly(ethylene naphthalate)	PEN
Polyhydroxy butyrate	PHB
Polyimide	PI
Polyimidesulfone	PISU
Polyisobutylene	PIB
Polyisocyanurate	PIR
Polyketone	PK
Polymethacrylimide	PMI
Polyoxymethylene, polyacetal	POM
Polyphthalamide	PPA
Polypropylene	PP
Polystyrene	PS
Polysulfone	PSU
Polytetrafluoroethylene	PTFE
Polyurethane	PUR
Saturated polyester plastic	SP
Silicone plastics	SI
Styrene-α-methylstyrene plastic	SMS
Styrene-acrylonitrile plastic	SAN
Styrene-butadiene plastic	SB
Styrene-butadiene-styrene block copolymer	SBS
Styrene-ethylene/butylene-styrene block copolymer	SEBS
Styrene-ethylene/propylene-styrene block copolymer	SEPS
Styrene-isoprene-styrene block copolymer	SIS
Styrene-maleic anhydride plastics	S/MA
Styrene-rubber plastics	SRP
Thermoplastic elastomer	TPE
Thermoplastic elastomer, ether-ester	TEEE
Thermoplastic elastomer, fully crosslinked elastomer alloy	FCEA
Thermoplastic elastomer, highly crosslinked thermoplastic vulcanizate	HCTPV
Thermoplastic elastomer, olefinic	TEO
Thermoplastic elastomer, polyether block amide	PEBA
Thermoplastic elastomer, styrenic	TES
Thermoplastic elastomer styrenic, saturated	TESS
Thermoplastic elastomer styrenic, unsaturated	TESU
Thermoplastic polyester	TPES
Thermoplastic polyester:	
Copolyester [poly(aryl terephthalate)]	ARP
Polyarylate [poly(aryl terephthalate)]—liquid crystal polymer	PAT
Thermoplastic polyurethane	TPU
Thermoplastic polyurethane, reinforced	RTPU
Thermoset polyurethane	TSPU
Ultra-high molecular weight polyethylene	UHMWPE
Unsaturated polyester	UP
Urea-formaldehyde resin	UF
Vinyl chloride-ethylene resin	VCE
Vinyl chloride-ethylene-methyl acrylate resin	VCEMA
Vinyl chloride-ethylene-vinyl acetate resin	VCEVAC
Vinyl chloride-methyl acrylate resin	VCMA
Vinyl chloride-methyl methacrylate resin	VCMMA
Vinyl chloride-octyl acrylate resin	VCOA
Vinyl chloride-vinyl acetate resin	VCVAC
Vinyl chloride-vinylidene chloride resin	VCVDC
Vinylidene fluoride	VDF

4.2 *Blends and Alloys of Plastics*:

Term	Abbreviated Term
Acrylonitrile-butadiene-acrylate plastics + poly(methyl methacrylate)	ABA+PMMA
Acrylonitrile-butadiene-acrylate plastics+poly(vinyl chloride)	ABA+PVC
Acrylonitrile-butadiene-acrylate plastics+polycarbonate	ABA+PC
Acrylonitrile-butadiene-styrene plastics+poly(vinyl chloride)	ABS+PVC
Acrylonitrile-butadiene-styrene plastics+polyphenylene sulfone	ABS+PPSU
Acrylonitrile-butadiene-styrene plastics+polytetrafluoroethylene	ABS+PTFE
Acrylonitrile-butadiene-styrene plastics+styrene maleic anhydride	ABS+SMA
Acrylonitrile-butadiene-styrene plastics+thermoplastic polyurethane	ABS+TPU
Acrylonitrile-butadiene-styrene plastics+polyamide	ABS+PA
Acrylonitrile-butadiene-styrene plastics+polycarbonate	ABS+PC
Acrylonitrile-styrene-acrylate plastics+poly(methyl methacrylate)	ASA+PMMA
Acrylonitrile-styrene-acrylate plastics+polycarbonate	ASA+PC
Fully crosslinked elastomeric alloy	FCEA
Poly(butylene terephthalate)+poly(ethylene terephthalate)	PBT+PET[6] Abbreviated
Poly(butylene terephthalate)+rubber	PBT+RBR
Poly(ethylene naphthalate)	PEN
Poly(ethylene terephthalate)+poly(methyl methacrylate)	PET[6] +PMMA
Poly(ethylene terephthalate)+poly(phenylene sulfone)	PET[6]+PPSU
Poly(ethylene terephthalate)+rubber	PET[6]+RBR
Poly(phenylene ether)+impact resistant polystyrene	PPE+IPS
Poly(phenylene sulfide)+polytetrafluoroethylene	PPS+PTFE
Poly(vinyl chloride)+chlorinated polyethylene	PVC+CPE
Poly(vinyl chloride)+nitrile-butadiene rubber	PVC+NBR
Poly(vinyl chloride)+poly(methyl methacrylate)	PVC+PMMA
Poly(vinyl chloride) plastics+polyurethane	PVC+PUR
Polyamide (amorphous) blend	PA +
Polyamide plastics+ethylene-methacrylic acid (ionomer)	PA+EMA
Polyamide+poly(phenylene ether)	PA+PPE
Polyamide+polyethylene	PA+PE
Polyamide+rubber	PA+RBR
Polyamide+styrene-acrylonitrile plastics	PA+SAN
Polycarbonate+poly(butylene terephthalate)	PC+PBT
Polycarbonate+poly(ethylene terephthalate)	PC+PET[6]
Polycarbonate+polyethylene	PC+PE
Polycarbonate+styrene-maleic anhydride	PC+SMA
Polycarbonate+thermoplastic polyurethane	PC+TPU
Polyoxymethylene+polytetrafluoroethylene	POM+PTFE
Polyoxymethylene+rubber	POM+RBR
Polyurethane+polyisocyanate	PUR+PIR
Styrene-maleic anhydride plastics+impact resistant polystyrene	SMA+IPS
Thermoplastic elastomer-chlorinated ethylene alloy	TECEA

4.3 *Plastic and Resin Additives*:

Term	Abbreviated Term
Alkylsulfonic acid ester	ASE
Benzyl butyl phthalate	BBP
Benzyl octyl adipate (benzyl 2-ethylhexyl adipate)	BOA
Benzyl octyl phthalate (benzyl 2-ethylhexyl phthalate)	BOP
Di-n-octyl phthalate	DNOP
Dibutylphthalate	DBP
Dibutyl sebacate	DBS
Dicapryl phthalate	DCP
Dicylohexyl phthalate	DCHP
Didecyl phthalate	DDP
Diethyl phthalate	DEP
Diheptyl phthalate	DHP
Dihexyl phthalate	DHXP
Diisobutyl phthalate	DIBP
Diisodecyl adipate	DIDA
Diisodecyl phthalate	DIDP
Diisoheptyl phthalate	DIHP
Diisohexyl phthalate	DIHXP
Diisononyl adipate	DINA
Diisononyl phthalate	DINP
Diisooctyl adipate	DIOA
Diisooctyl phthalate	DIOP
Diisopentyl phthalate	DIPP
Diisotridecyl phthalate	DITDP
Dimethyl phthalate	DMP
Dinonyl phthalate	DNP
Dioctyl adipate	DOA
Dioctyl azelate	DOZ
Dioctyl isophthalate (di-2-ethylhexyl isophthalate)	DOIP

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Term	Abbreviated Term
Dioctyl phthalate	DOP
Dioctyl sebacate	DOS
Dioctyl terephthalate (di-2-ethylhexyl terephthalate)	DOTP
Diphenyl octyl phosphate	DPOF
Diphenyl cresyl phosphate	DPCF
Diphenyl 2-ethylhexyl phosphate	DPOF
Diundecyl phthalate	DUP
Epoxidized linseed oil	ELO
Epoxidized soya bean oil	ESO
Heptyl nonyl undecyl adipate	HNUA
Heptyl nonyl undecyl phthalate	HNUP
Hexyl octyl decyl adipate	HXODA
Hexyl octyl decyl phthalate	HXODP
n-Octyl decyl trimellitate	ODTM
Nonyl undecyl adipate	NUA
Nonyl undecyl phthalate	NUP
Octyl decyl adipate	ODA
Octyl decyl phthalate	ODP
Tetraoctyl pyromellitate (tetra-2-ethylhexyl pyromellitate)	TOPM
Trichloroethyl phosphate	TCEF
Tricresyl phosphate (or tritolyl phosphate)	TCF
Triheptyl trimellitate	THTM
Triisooctyl trimellitate	TIOTM
Trioctyl phosphate	TOF
Trioctyl trimellitate (tri-2-ethylhexyl trimellitate)	TOTM
Triphenyl phosphate	TPP
Trixylyl phosphate	TXF

4.4 *Monomers*:

Term	Abbreviated Term
Allyl diglycol carbonate	ADC
Chlorotrifluoroethylene	CTFE
Diallyl chlorendate (diallyl ester of 1,4,5,6,7,7-hexa chlorobicyclo-(2,2,1)-5-heptene-2,3 -dicarboxylic acid)	DAC
Diallyl fumarate	DAF
Diallyl isophthalate	DAIP
Diallyl maleate	DAM
Diallyl phthalate (diallyl orthophthalate)	DAP
Methyl methacrylate	MMA
Tetrafluoroethylene	TFE
Triallyl cyanurate	TAC

4.5 *Miscellaneous Plastics Terms*:

Term	Abbreviated Term
General purpose	GP
Single stage	SS

NOTE 3—When listing one or more components, the order preferably should be in decreasing amount by mass. There are situations, however, where long standing usage indicates that this recommendation should not be followed. An example is ETFE.

5. Full List by Term and Abbreviated Term

Term	Abbreviated Term
Acrylonitrile-butadiene-acrylate plastics+poly(methyl methacrylate)	ABA+PMMA
Acrylonitrile-butadiene-acrylate plastics+poly(vinyl chloride)	ABA+PVC
Acrylonitrile-butadiene-acrylate plastics+polycarbonate	ABA+PC
Acrylonitrile-butadiene-acrylate plastics	ABA
Acrylonitrile-butadiene-styrene plastics+poly(vinyl chloride)	ABS+PVC
Acrylonitrile-butadiene-styrene plastics+polyphenylene sulfone	ABS+PPSU
Acrylonitrile-butadiene-styrene plastics+polytetrafluoro-ethylene	ABS+PTFE
Acrylonitrile-butadiene-styrene plastics+styrene maleic anhydride	ABS+SMA
Acrylonitrile-butadiene-styrene plastics+thermoplastic polyurethane	ABS+TPU
Acrylonitrile/butadiene plastics	AB
Acrylonitrile-butadiene-styrene plastics+polyamide	ABS+PA
Acrylonitrile-butadiene-styrene plastics+polycarbonate	ABS+PC
Acrylonitrile-chlorinated polyethylene-styrene plastics	ACPES
Acrylonitrile-ethylene-styrene plastics	AES
Acrylonitrile-methyl acrylate-acrylonitrile-butadiene rubber	AMAB
Acrylonitrile-methyl methacrylate plastics	AMMA
Acrylonitrile-styrene-acrylate plastics+poly(methyl methacrylate)	ASA+PMMA
Acrylonitrile-styrene-acrylate plastics+poly(vinyl chloride)	ASA+PVC
Acrylonitrile-styrene-acrylate plastics	ASA
Acrylonitrile-styrene-acrylate plastics+polycarbonate	ASA+PC
Acrylonitrile/ethylene-propylene-diene/styrene plastics	AEPDMS
Alkylsulfonic acid ester	ASE
Allyl diglycol carbonate	ADC
Aromatic polyester	ARP
Benzyl butyl phthalate	BBP
Benzyl octyl adipate (benzyl 2-ethylhexyl adipate)	BOA
Benzyl octyl phthalate (benzyl 2-ethylhexyl phthalate)	BOP
Carboxymethyl cellulose	CMC
Casein	CS
Caseine-formaldehyde resin	CSF
Cellulose acetate	CA
Cellulose acetate-butyrate	CAB
Cellulose acetate-propionate	CAP
Cellulose formaldehyde	CEF
Cellulose nitrate	CN
Cellulose plastics, general	CE
Cellulose propionate	CP
Cellulose triacetate	CTA
Chlorinated poly(vinyl chloride)	CPVC
Chlorinated polyethylene	CPE
Chlorotrifluoroethylene	CTFE
Cresol-formaldehyde resin	CF
Di-n-octyl phthalate	DNOP
Diallyl chlorendate (diallyl ester of 1,4,5,6,7,7-hexachloro-bicyclo-(2,2,1)-5-heptene-2,3-dicarboxylic acid)	DAC
Diallyl fumarate	DAF
Diallyl isophthalate	DAIP
Diallyl maleate	DAM
Diallyl phthalate (diallyl orthophthalate)	DAP
Dibutyl phthalate	DBP
Dibutyl sebacate	DBS
Dicapryl phthalate	DCP
Dicyclohexyl phthalate	DCHP
Didecyl phthalate	DDP
Diethyl phthalate	DEP
Diheptyl phthalate	DHP
Dihexyl phthalate	DHXP
Diisobutyl phthalate	DIBP
Diisodecyl adipate	DIDA
Diisodecyl phthalate	DIDP
Diisoheptyl phthalate	DIHP
Diisohexyl phthalate	DIHXP
Diisononyl adipate	DINA
Diisononyl phthalate	DINP
Diisooctyl adipate	DIOA
Diisooctyl phthalate	DIOP
Diisopentyl phthalate	DIPP
Diisotridecyl phthalate	DITDP
Dimethyl phthalate	DMP
Dinonyl phthalate	DNP
Dioctyl adipate	DOA
Dioctyl azelate	DOZ
Dioctyl isophthalate (di-2-ethylhexyl isophthalate)	DOIP
Dioctyl phthalate	DOP
Dioctyl sebacate	DOS

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Term	Abbreviated Term
Dioctyl terephthalate (di-2-ethylhexyl terephthalate)	DOTP
Diphenyl 2-ethylhexyl phosphate	DPOF
Diphenyl cresyl phosphate	DPCF
Diphenyl octyl phosphate	DPOF
Diundecyl phthalate	DUP
Epoxidized linseed oil	ELO
Epoxidized soya bean oil	ESO
Epoxy, epoxide	EP
Ethyl cellulose	EC
Ethylene-chlorotrifluoroethylene copolymer	E-CTFE
Ethylene-ethyl acrylate plastics	EEA
Ethylene-methacrylic acid plastics	EMA
Ethylene-propylene polymer	EPM
Ethylene-propylene-diene plastics	EPD
Ethylene-tetrafluoroethylene copolymer	ETFE
Ethylene-vinyl acetate plastics	EVA
Ethlene-vinyl alcohol copolymer	EVOH
Fluorocarbon perfluoromethoxy	MPA
Fully crosslinked elastomeric alloy	FCEA
Furan-formaldehyde resin	FF
General purpose	GP
Heptyl nonyl undecyl adipate	HNUA
Heptyl nonyl undecyl phthalate	HNUP
Hexyl octyl decyl adipate	HXODA
Hexyl octyl decyl phthalate	HXODP
High density polyethylene plastics	HDPE
High impact-resistant polystyrene	HIPS
Impact resistant polystyrene	IPS
Linear low density polyethylene plastics	LLDPE
Linear medium density polyethylene plastics	LMDPE
Liquid crystal polymer	LCP
Low density polyethylene plastics	LDPE
Medium density polyethylene plastics	MDPE
Melamine-formaldehyde resin	MF
Melamine/phenol-formaldehyde resin	MPF
Methacrylate-butadiene-styrene plastics	MBS
Methyl cellulose	MC
Methyl methacrylate	MMA
Methyl methacrylate-acrylonitrile-butadiene-styrene resin	MMABS
n-Octyl decyl trimellitate	ODTM
Nonyl undecyl adipate	NUA
Nonyl undecyl phthalate	NUP
Nylon (See also *polyamide*)	PA
Octyl decyl adipate	ODA
Octyl decyl phthalate	ODP
Perfluoro(alkoxy alkane)	PFA
Perfluoro(ethylene-propylene) copolymer	FEP
Perfluoromethoxy resin	MFA
Phenol-formaldehyde resin	PF
Phenol-furfural resin	PFF
Poly(acrylic acid)	PAA
Poly(allyl diglycol carbonate)	PADC
Poly(aryl ether ketone)	PAEK
Poly(butyl acrylate)	PBA
Poly(butylene terephthalate)	PBT
Poly(butylene terephthalate)+poly(ethylene terephthalate)	PBT+PET[6]
Poly(butylene terephthalate)+poly(phenylene ether)	PBT+PPE
Poly(butylene terephthalate)+rubber	PBT+RBR
Poly(cyclohexylenedimethylene cyclohexandicarboxylate), glycol and acid comonomer	PCCE
Poly(cyclohexylenedimethylene terephthalate)	PCT
Poly(cyclohexylenedimethylene terephthalate), acid comonomer	PCTA
Poly(cyclohexylenedimethylene terephthalate), glycol	PCTG
Poly(diallyl phthalate)	PDAP
Poly(ester urethane)	PAUR
Poly(ether block amide)	PEBA
Poly(ether sulfone)	PES
Poly(ether urethane)	PEUR
Poly(ethylene naphthalate)	PEN
Poly(ethylene oxide)	PEOX
Poly(ethylene terephthalate)	PET[6]
Poly(ethylene terephthalate)+poly(methyl methacrylate)	PET[6] +PMMA
Poly(ethylene terephthalate)+poly(phenylene sulfone)	PET[6]+PPSU
	PET[6]+RBR
Poly(ethylene terephthalate), glycol comonomer	PETG
Poly(methyl methacrylate)	PMMA
Poly(methyl methacrylimide)	PMMI
Poly(methyl-α-chloroacrylate)	PMCA
Poly(phenyl sulfone)	PPSU
Poly(phenylene ether) (or poly(phenylene oxide), a deprecated term)	PPE
Poly(phenylene ether)+impact resistant polystyrene	PPE+IPS
Poly(phenylene sulfide)	PPS
Poly(phenylene sulfide)+polytetrafluoroethylene	PPS+PTFE
Poly(phenylene sulfone)	PPSU
Poly(propylene oxide)	PPOX
Poly(vinyl acetate)	PVAC
Poly(vinyl alcohol)	PVOH
Poly(vinyl butyral)	PVB
Poly(vinyl carbazole)	PVK
Poly(vinyl chloride)	PVC
Poly(vinyl chloride)+chlorinated polyethylene	PVC+CPE
Poly(vinyl chloride)+nitrile-butadiene rubber	PVC+NBR
Poly(vinyl chloride)+poly(methyl methacrylate)	PVC+PMMA
Poly(vinyl chloride) plastics+polyurethane	PVC+PUR
Poly(vinyl chloride-acetate)	PVCA
Poly(vinyl fluoride)	PVF
Poly(vinyl formal)	PVFM
Poly(vinyl pyrrolidone)	PVP
Poly(vinylidene chloride)	PVDC
Poly(vinylidene fluoride)	PVDF
Poly(ε-caprolactone)	PCL
Poly-4-methyl pentene-1	PMP
Poly-α-methylstyrene	PMS
Poly-p-oxybenzoate	POB
Polyacrylonitrile	PAN
Polyamide (amorphous) blend	PA +
Polyamide (nylon)	PA
Polyamide 11	PA11
Polyamide 12	PA12
Polyamide 1212	PA1212
Polyamide 46	PA46
Polyamide 6	PA6
Polyamide 610	PA610
Polyamide 612	PA612
Polyamide 66	PA66
Polyamide 69	PA69
Polyamide plastics+ethylene-methacrylic acid (ionomer)	PA+EMA
Polyamide+poly(phenylene ether)	PA+PPE
Polyamide+polyethylene	PA+PE
Polyamide+rubber	PA+RBR
Polyamide+styrene-acrylonitrile plastics	PA+SAN
Polyamide-imide	PAI
Polyarylate	PAR
Polyaryl amide	PARA
Polyarylether	PAE
Polyarylsulfone	PASU
Polybutadiene-acrylonitrile	PBAN
Polybutadiene-styrene	PBS
Polybutene-1	PB
Polycarbonate	PC
Polycarbonate+poly(butylene terephthalate)	PC+PBT
Polycarbonate+poly(ethylene terephthalate)	PC+PC+PET[6]
Polycarbonate+polyethylene	PC+PE
Polycarbonate+styrene-maleic anhydride	PC+SMA
Polycarbonate+thermoplastic polyurethane	PC+TPU
Polychlorotrifluoroethylene	PCTFE
Polyester alkyd (or polyacrylate)	PAK
Polyester, thermoplastic; polyarylate [poly(aryl terephthalate)]—liquid crystal polymer	PAT
Polyetheretherketone	PEEK

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Term	Abbreviated Term
Polyetheretherketoneketone	PEEKK
Polyetherketonetherketoneketone	PEKEKK
Polyetherketoneketone	PEKK
Polyetherizmide	PEI
Polyetherketone	PEK
Polyethylene	PE
Polyhydroxy butyrate	PHB
Polyhydroxy butyrate-polyhydroxy valerate	PHBV
Polyimide	PI
Polyimidesulfone	PISU
Polyisobutylene	PIB
Polyisocyanurate	PIR
Polyketone	PK
Polymethacrylimide	PMI
Polyoxymethylene+polytetrafluoroethylene	POM+PTFE
Polyoxymethylene+rubber	POM+RBR
Polyoxymethylene, polyacetal	POM
Polyphthalamide	PPA
Polypropylene	PP
Polystyrene	PS
Polysulfone	PSU
Polytetrafluoroethylene	PTFE
Polyurethane	PUR
Polyurethane+polyisocyanate	PUR+PIR
Saturated polyester plastic	SP
See TCF	TTP
Silicone plastics	SI
Single stage	SS
Styrene-α-methylstyrene plastic	SMS
Styrene-acrylonitrile plastic	SAN
Styrene-butadiene plastics	SB
Styrene-butadiene-styrene block copolymer	SBS
Styrene-ethylene/butylene-styrene block copolymer	SEBS
Styrene-ethylene/propylene-styrene block copolymer	SEPS
Styrene-isoprene-styrene block copolymer	SIS
Styrene-maleic anhydride plastics+impact resistant polystyrene	SMA+IPS
Styrene-maleic anhydride plastics	S/MA
Styrene-rubber plastics	SRP
Tetrafluoroethylene	TFE
Tetraoctyl pyromellitate (tetra-2-ethylhexyl pyromellitate)	TOPM
Thermoplastic elastomer	TPE
Thermoplastic elastomer, ether-ester	TEEE
Thermoplastic elastomer, fully crosslinked elastomer alloy	FCEA
Thermoplastic elastomer, highly crosslinked thermoplastic vulcanizate	HCTPV
Thermoplastic elastomer, olefinic	TEO
Thermoplastic elastomer, polyether block amide	PEBA
Thermoplastic elastomer, styrenic	TES
Thermoplastic elastomer styrenic, saturated	TESS
Thermoplastic elastomer styrenic, unsaturated	TESU
Thermoplastic elastomer-chlorinated ethylene alloy	TECEA
Thermoplastic polyester	TPES
Thermoplastic polyester:	
Copolyester [poly(aryl terephthalate)]	ARP
Polyarylate [poly(aryl terephthalate)]—liquid crystal polymer	PAT
Thermoplastic polyurethane	TPU
Thermoplastic polyurethane, reinforced	RTPU
Thermoset polyurethane	TSPU
Triallyl cyanurate	TAC
Trichlorethyl phosphate	TCEF
Tricresyl phosphate (or tritolyl phosphate)	TCF
Triheptyl trimellitate	THTM
Triisooctyl trimellitate	TIOTM
Trioctyl phosphate	TOF
Trioctyl trimellitate (tri-2-ethylhexyl trimellitate)	TOTM
Triphenyl phosphate	TPP
Trixylyl phosphate	TXF
Ultra-high molecular weight polyethylene	UHMWPE
Unsaturated polyester	UP
Urea-formaldehyde resin	UF
Vinyl chloride-ethylene resin	VCE
Vinyl chloride-ethylene-methyl acrylate resin	VCEMA
Vinyl chloride-ethylene-vinyl acetate resin	VCEVAC
Vinyl chloride-methyl acrylate resin	VCMA
Vinyl chloride-methyl methacrylate resin	VCMMA
Vinyl chloride-octyl acrylate resin	VCOA
Vinyl chloride-vinyl acetate resin	VCVAC
Vinyl chloride-vinylidene chloride resin	VCVDC
Vinylidene fluoride	VDF

6. Full List by Abbreviated Term

Abbreviated Term	Term
AB	Acrylonitrile/butadiene plastics
ABA	Acrylonitrile-butadiene-acrylate plastics
ABA+PC	Acrylonitrile-butadiene-acrylate+polycarbonate
ABA+PMMA	Acrylonitrile-butadiene-acrylate+poly(methyl methacrylate)
ABA+PVC	Acrylonitrile-butadiene-acrylate+poly(vinyl chloride)
ABS	Acrylonitrile-butadiene-styrene plastics
ABS+PA	Acrylonitrile-butadiene-styrene plastics+polyamide
ABS+PC	Acrylonitrile-butadiene-styrene plastics+polycarbonate
ABS+PPSU	Acrylonitrile-butadiene-styrene+polyphenylene sulfone
ABS+PTFE	Acrylonitrile-butadiene-styrene+polytetrafluoroethylene
ABS+PVC	Acrylonitrile-butadiene-styrene+poly(vinyl chloride)
ABS+SMA	Acrylonitrile-butadiene-styrene+styrene maleic anhydride
ABS+TPU	Acrylonitrile-butadiene-styrene+thermoplastic polyurethane
ACPES	Acrylonitrile-chlorinated polyethylene-styrene plastics
ADC	Allyl diglycol carbonate
AEPDMS	Acrylonitrile/ethylene-propylene-diene/styrene plastics
AES	Acrylonitrile-ethylene-styrene plastics
AMMA	Acrylonitrile-methyl methacrylate plastics
ARP	Aromatic polyester
AHP	Thermoplastic polyester, (polyaryl terephthalate)
ASA	Acrylonitrile-styrene-acrylate plastics
ASA+PC	Acrylonitrile-styrene-acrylate plastics+polycarbonate
ASA+PMMA	Acrylonitrile-styrene-acrylate+poly(methyl methacrylate)
ASA+PVC	Acrylonitrile-styrene-acrylate+poly(vinyl chloride)
ASE	Alkylsulfonic acid ester
BBP	Benzyl butyl phthalate
BOA	Benzyl octyl adipate (benzyl 2-ethylhexyl adipate)
BOP	Benzyl octyl phthalate (benzyl 2-ethylhexyl phthalate)
CA	Cellulose acetate
CAB	Cellulose acetate-butyrate
CAP	Cellulose acetate-propionate
CE	Cellulose plastics, general
CEF	Cellulose formaldehyde
CF	Cresol-formaldehyde resin
CMC	Carboxymethyl cellulose
CN	Cellulose nitrate
CP	Cellulose propionate
CPE	Chlorinated polyethylene
CPVC	Chlorinated poly(vinyl chloride)
CS	Casein
CSF	Caseine-formaldehyde resin
CTA	Cellulose triacetate
CTFE	Chlorotrifluoroethylene
DAC	Diallyl chlorendate (diallyl ester of 1,4,5,6,7,7-hexachlorobicyclo-(2,2,1)-5-heptene-2,3-dicarboxylic acid)
DAF	Diallyl fumarate
DAIP	Diallyl isophthalate
DAM	Diallyl maleate
DAP	Diallyl phthalate (diallyl orthophthalate)
DBP	Dibutyl phthalate
DBS	Dibutyl sebacate
DCHP	Dicyclohexyl phthalate
DCP	Dicapryl phthalate
DDP	Didecyl phthalate
DEP	Diethyl phthalate
DHP	Diheptyl phthalate
DHXP	Dihexyl phthalate
DIBP	Diisobutyl phthalate
DIDA	Diisodecyl adipate
DIDP	Diisodecyl phthalate

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Abbreviated Term	Term
DIHP	Diisoheptyl phthalate
DIHXP	Diisohexyl phthalate
DINA	Diisononyl adipate
DINP	Diisononyl phthalate
DIOA	Diisooctyl adipate
DIOP	Diisooctyl phthalate
DIPP	Diisopentyl phthalate
DITDP	Diisotridecyl phthalate
DNOP	Di-n-octyl phthalate
DNP	Dinonyl phthalate
DOA	Dioctyl adipate (di-2-ethylhexyl adipate)
DOIP	Dioctyl isophthalate (di-2-ethylhexyl isophthalate)
DOP	Dioctyl phthalate (di-2-ethylhexyl phthalate)
DOS	Dioctyl sebacate (di-2-ethylhexyl sebacate)
DOTP	Dioctyl terephthalate (di-2-ethylhexyl terephthalate)
DOZ	Dioctyl azelate (di-2-ethylhexyl azelate)
DPCF	Diphenyl cresyl phosphate
DPOF	Diphenyl 2-ethylhexyl phosphate
DPOF	Diphenyl octyl phosphate
DUP	Diundecyl phthalate
EC	Ethyl cellulose
E-CTFE	Ethylene-chlorotrifluoroethylene copolymer
EEA	Ethylene-ethyl acrylate plastics
ELO	Epoxidized linseed oil
EMA	Ethylene-methacrylic acid plastics
EP	Epoxy, epoxide
EPD	Ethylene-propylene-diene plastics
EPM	Ethylene-propylene polymer
ESO	Epoxidized soya bean oil
ETFE	Ethylene-tetrafluoroethylene copolymer
EVA	Ethylene-vinyl acetate plastics
EVOH	Ethylene-vinyl alcohol copolymer
FCEA	Thermoplastic elastomer, fully crosslinked elastomer alloy
FEP	Perfluoro(ethylene-propylene) copolymer
FF	Furan-formaldehyde resin
GP	General purpose
HCTPV	Thermoplastic elastomer, highly crosslinked thermoplastic vulcanizate
HDPE	High-density polyethylene plastics
HIPS	High impact-resistant polystyrene
HNUA	Heptyl nonyl undecyl adipate
HNUP	Heptyl nonyl undecyl phthalate
HXODA	Hexyl octyl decyl adipate
HXODP	Hexyl octyl decyl phthalate
IPS	Impact-resistant polystyrene
LCP	Liquid crystal polymer
LDPE	Low density polyethylene plastics
LLDPE	Linear low density polyethylene plastics
LMDPE	Linear medium density polyethylene plastics
MBS	Methacrylate-butadiene-styrene plastics
MC	Methyl cellulose
MDPE	Medium density polyethylene plastics
MF	Melamine-formaldehyde resin
MFA	Perfluoromethoxy resin
MMA	Methyl methacrylate
MMABS	Methyl methacrylate-acrylonitrile-butadiene-styrene resin
MPA	Fluorocarbon perfluoromethoxy
MPF	Melamine/phenol-formaldehyde resin
NUA	Nonyl undecyl adipate
NUP	Nonyl undecyl phthalate
ODA	Octyl decyl adipate
ODP	Octyl decyl phthalate
ODTM	*n*-Octyl decyl trimellitate
PA	Polyamide (nylon)
PA	Nylon (see also polyamide)
PA11	Polyamide 11
PA12	Polyamide 12
PA1212	Polyamide 1212
PA46	Polyamide 46
PA6	Polyamide 6
PA610	Polyamide 610
PA612	Polyamide 612
PA66	Polyamide 66
PA69	Polyamide 69
PA+	Polyamide (amorphous) blend
PA+EMA	Polyamide plastics+ethylene-methacrylic acid (ionomer)
PA+PE	Polyamide+polyethylene
PA+PPE	Polyamide+poly(phenylene ether)
PA+RBR	Polyamide+rubber
PA+SAN	Polyamide+styrene-acrylonitrile
PAA	Poly(acrylic acid)
PADC	Poly(allyl diglycol carbonate)
PAE	Polyarylether ketone)
PAI	Polyamide-imide
PAK	Polyester alkyd (or polyacrylate)
PAN	Polyacrylonitrile
PAR	Polyarylate
PARA	Polyaryl amide
PASU	Polyarylsulfone
PAT	Polyester, thermoplastic; polyarylate [poly(aryl terephthalate)]
PAUR	Poly(ester urethane)
PB	Polybutene-1
PBA	Poly(butyl acrylate)
PBAN	Polybutadiene-acrylonitrile
PBS	Polybutadiene-styrene
PBT	Poly(butylene terephthalate)
PBT+PET[6]	Poly(butylene terephthalate)+poly(ethylene terephthalate)
PBT+PPE	Poly(butylene terephthalate)+poly(phenylene ether)
PBT+RBR	Poly(butylene terephthalate)+rubber
PC	Polycarbonate
PC+PBT	Polycarbonate+poly(butylene terephthalate)
PC+PE	Polycarbonate+polyethylene
PC+PET[6]	Polycarbonate+poly(ethylene terephthalate)
PC+SMA	Polycarbonate+styrene-maleic anhydride
PC+TPU	Polycarbonate+thermoplastic polyurethane
PCCE	Poly(cyclohexylenedimethylene cyclohexandicarboxylate), glycol and acid comonomer
PCL	Poly(ε-caprolactone)
PCT	Poly(cyclohexylenedimethylene terephthalate)
PCTA	Poly(cyclohexylenedimethylene terephthalate), cid comonomer
PCTFE	Polychlorotrifluoroethylene
PCTG	Poly(cyclohexylenedimethylene terephthalate), glycol
PDAP	Poly(diallyl phthalate)
PE	Polyethylene
PEBA	Thermoplastic elastomer, polyether block amide
PEBA	Poly(ether block amide)
PEEK	Polyetheretherketone
PEEKK	Polyetheretherketoneketone
PEI	Polyetherimide
PEK	Polyetherketone
PEKEKK	Polyetherketonetherketoneketone
PEKK	Polyetherketoneketone
PEN	Poly(ethylene naphthalate)
PEOX	Poly(ethylene oxide)
PES	Poly(ether sulfone)
PET[6]	Poly(ethylene terephthalate)
PET[6]+PMMA	Poly(ethylene terephthalate)+poly(methyl methacrylate)
PET[6]+PPSU	Poly(ethylene terephthalate)+poly(phenylene sulfone)
PET[6]+RBR	Poly(ethylene terephthalate)+rubber
PETG	Poly(ethylene terephthalate) glycol comonomer
PEUR	Poly(ether urethane)
PF	Phenol-formaldehyde resin
PFA	Perfluoro(alkoxy alkane)
PFF	Phenol-furfural resin
PHB	Polyhydroxy butyrate
PHBV	Polyhydroxy butyrate-polyhydroxy valerate
PI	Polyimide
PIB	Polyisobutylene
PIR	Polyisocyanurate
PISU	Polyimidesulfone
PK	Polyketone

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Abbreviated Term	Term
PMCA	Poly(methyl-α-chloroacrylate)
PMI	Polymethacrylimide
PMMA	Poly(methyl methacrylate)
PMMI	Poly(methyl methacrylimide)
PMP	Poly-4-methylpentene-1
PMS	Poly-α-methylstyrene
POB	Poly-p-oxybenzoate
POM	Polyoxymethylene, polyacetal
POM+PTFE	Polyoxymethylene+polytetrafluoroethylene
POM+RBR	Polyoxymethylene+rubber
PP	Polypropylene
PPA	Polyphthalamide
PPE	Poly(phenylene ether) (or poly(phenylene oxide), a deprecated term)
PPE+IPS	Poly(phenylene ether)+impact-resistant polystyrene
PPOX	Poly(propylene oxide)
PPS	Poly(phenylene sulfide)
PPSU	Poly(phenyl sulfone)
PPS+PTFE	Poly(phenylene sulfide)+polytetrafluoroethylene
PS	Polystyrene
PSU	Polysulfone
PTFE	Polytetrafluorethylene
PUR	Polyurethane
PUR+PIR	Polyurethane+polyisocyanate
PVAC	Poly(vinyl acetate)
PVOH	Poly(vinyl alcohol)
PVB	Poly(vinyl butyral)
PVC	Poly(vinyl chloride)
PVC+CPE	Poly(vinyl chloride)+chlorinated polyethylene
PVC+NBR	Poly(vinyl chloride)+nitrile-butadiene rubber
PVC+PMMA	Poly(vinyl chloride)+poly(methyl methacrylate)
PVC+PUR	Poly(vinyl chloride) plastics+polyurethane
PVCA	Poly(vinyl chloride-acetate)
PVDC	Poly(vinylidene chloride)
PVDF	Poly(vinylidene fluoride)
PVF	Poly(vinyl fluoride)
PVFM	Poly(vinyl formal)
PVK	Poly(vinyl carbazole)
PVP	Poly(vinyl pyrrolidone)
RTPU	Thermoplastic polyurethane, reinforced
S/MA	Styrene-maleic anhydride plastics
SAN	Styrene-acrylonitrile plastic
SB	Styrene-butadiene plastics
SBS	Styrene-butadiene-styrene block copolymer
SEBS	Styrene-ethylene/butylene-styrene block copolymer
SEPS	Styrene-ethylene/propylene-styrene block copolymer
SI	Silicone plastics
SIS	Styrene-isoprene-styrene block copolymer
SMA+IPS	Styrene-maleic anhydride+impact-resistant polystyrene
SMS	Styrene-α-methylstyrene plastic
SP	Saturated polyester plastic
SRP	Styrene-rubber plastics
SS	Single stage
TAC	Triallyl cyanurate
TCEF	Trichloroethyl phosphate
TCF	Tricresyl phosphate (or tritolyl phosphate)
TECEA	Thermoplastic elastomer-chlorinated ethylene alloy
TEEE	Thermoplastic elastomer, ether-ester
TEO	Thermoplastic elastomer, olefinic
TES	Thermoplastic elastomer, styrenic
TESS	Thermoplastic elastomer styrenic, saturated
TESU	Thermoplastic elastomer styrenic, unsaturated
TFE	Tetrafluoroethylene
THTM	Triheptyl trimellitate
TIOTM	Triisooctyl trimellitate
TOF	Trioctyl phosphate
TOPM	Tetraoctyl pyromellitate (tetra-2-ethylhexyl pyromellitate)
TOTM	Trioctyl trimellitate (tri-2-ethylhexyl trimellitate)
TPE	Thermoplastic elastomer
TPES	Thermoplastic polyester
TPP	Triphenyl phosphate
TPU	Thermoplastic polyurethane
TSPU	Thermoset polyurethane
TXF	Trixylyl phosphate
UF	Urea-formaldehyde resin
UHMWPE	Ultra-high molecular weight polyethylene
UP	Unsaturated polyester
VCE	Vinyl chloride-ethylene resin
VCEMA	Vinyl chloride-ethylene-methyl acrylate resin
VCEVAC	Vinyl chloride-ethylene-vinyl acetate resin
VCMA	Vinyl chloride-methyl acrylate resin
VCMMA	Vinyl chloride-methyl methacrylate resin
VCOA	Vinyl chloride-octyl acrylate resin
VCVAC	Vinyl chloride-vinyl acetate resin
VCVDC	Vinyl chloride-vinylidene chloride resin
VDF	Vinylidene fluoride

7. Code Numbers for Identifying Flame Retardant Compounds

7.1 The code numbers are grouped according to the chemical composition of the flame retardant.

7.1.1 *Halogenated Compounds*:

7.1.1.1 In compounds containing both aliphatic/alicyclic and aromatic groups, the group containing the halogen determines the code to be used.

Code	Compound
10	aliphatic/alicyclic chlorinated compounds
11	aliphatic/alicyclic chlorinated compounds in combination with antimony compounds
12	aromatic chlorinated compounds
13	aromatic chlorinated compounds in combination with antimony compounds
14	aliphatic/alicyclic brominated compounds
15	aliphatic/alicyclic brominated compounds in combination with antimony compounds
16	aromatic brominated compounds (excluding brominated diphenylether and biphenyls)
17	aromatic brominated compounds (excluding brominated diphenylether and biphenyls) in combination with antimony compounds
18	polybrominated diphenylether
19	polybrominated diphenylether in combination with antimony compounds
20	polybrominated biphenyls
21	polybrominated biphenyls in combination with antimony compounds
22 to 24	not allocated
25	aliphatic fluorinated compounds
26 to 29	not allocated

7.2 *Nitrogen Compounds*:

Code	Compound
30	nitrogen compounds (including but not limited to melamine, melamine cyanurate, urea)
31 to 39	not allocated

7.3 *Organic Phosphorus Compounds*:

Code	Compound
40	halogen free organic phosphorous compounds
41	chlorinated organic phosphorus compounds
42	brominated organic phosphorus compounds
43 to 49	not allocated

7.4 *Inorganic Phosphorus Compounds*:

Code	Compound
50	ammonium orthophosphates
51	ammonium polyphosphates
52	red phosphorus
53 to 59	not allocated

7.5 *Metallic Oxides, Hydroxides, and Salts*:

Code	Compound

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60	aluminum hydroxide
61	magnesium hydroxide
62	antimony (III)-oxide
63	alkali antimonate
64	magnesium/calcium carbonate-hydrate
65 to 69	not allocated

7.6 *Boron and Zinc Compounds*:

Code	Compound
70	inorganic boron compounds (excluding zinc borate)
71	organic boron compounds
72	zinc borate
73	inorganic zinc compounds (excluding zinc borate)
74	not allocated

7.7 *Silica Compounds*:

Code	Compound
75	inorganic silica compounds
76	organic silica compounds
77 to 79	not allocated

7.8 *Miscellaneous Compounds*:

Code	Compound
80	graphite
81 to 89	not allocated
90 to 99	not allocated

8. Use of Abbreviated Terms

8.1 When abbreviated terms are used in publications or other written matter, their first occurrence in the text should be enclosed in parentheses and preceded by the written word or words being abbreviated. Subsequent references to such words in the article can then be made using the abbreviated term. For example, if one wishes to use PET[6] as the acronym for poly(ethylene terephthalate), wording such as the following would be acceptable: "Poly(ethylene terephthalate) (PET[6]) is a crystalline plastic. PET[6] offers many advantages in such articles as soft drink bottles."

8.2 Additional information on use of abbreviated terms, symbols and codes for flame retardants is included in Guide D 1972.

9. Keywords

9.1 abbreviated terms; code numbers; flame retardants; monomers; plastic blends and alloys; plastics; plasticizers; terminology symbols

APPENDIX

(Nonmandatory Information)

X1. A SUGGESTED SYSTEM FOR PREPARING ABBREVIATED TERMS FOR PLASTICS AND RELATED TERMS[6]

NOTE X1.1—The use of the following guide in establishing abbreviated terms for plastics and related terms will promote uniform and systematic standardization.[7]

X1.1 Use upper case letters for the main components in the order in which they occur in the plastics term for which an abbreviated term is being established, for example:

Poly(vinyl chloride) = PVC

X1.2 Use generic terms for family designations, for example:

nylon for polyamide plastics

X1.3 Use figures and letters to distinguish among plastics prepared from various condensation units in a homologous series, for example:

Poly(hexamethylene sebacamide) = PA 610 where, with aliphatic components, the first number(s) refers to the number of carbon atoms in the diamine and the second number(s) refers to the number of carbon atoms in the diacid. It is the convention not to use any separator, such as a comma, dash, or virgule (solidus,/) between the numbers. In these systems there is no confusion when the separator is not used. With alicyclic or aromatic diamines or diacids, a letter acronym is usually used. For example:

meta−phenylene diamine = MPD

terephthalic acid = T

isophthalic acid = I

X1.4 The components in copolymers are separated by hyphens "-" in the term, but usually no separation is required in the abbreviated term. In cases where use of the hyphen may cause confusion, it is acceptable to use a virgule, "/", as the separator. The virgule also is correctly termed a solidus and often, incorrectly, referred to as a "slash" or "diagonal."

X1.5 The components in blends of polymers are separated by a plus sign, "+", in both the term and the abbreviated term.

X1.6 A more elaborate system for developing abbreviated terms for plastics and related materials has been standardized by ISO in ISO 1043.

[7] Based in part on Proposals under Consideration by the Division of Plastics and High Polymers, IUPAC.

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SUMMARY OF CHANGES

Committee D-20 has identified the location of selected changes to this terminology since the last issue that may impact the use of this terminology.

D 1600 – 97:
(*1*) The scope was expanded with a new part to provide for inclusion of symbols and codes for flame retardant additives in plastics.
(*2*) An ISO equivalence statement was added to the scope.
(*3*) In Section 2, the list of referenced documents was expanded as needed to conform to the other changes.
(*4*) A definition for "flame retardant" from ISO 472 was included in Section 2.
(*5*) Section 7 was renumbered to Section 8, retitled, and additional information was added to provide reference to the standard that provides instructions for marking plastics products so that the new code numbers can be implemented.
(*6*) A new Section 7 was added to add codes numbers for different classes of flame retardants.
(*7*) Keywords were added in a new Section 9.
D 1600 – 98:
(*1*) Poly(ethylene naphthalate) (PEN) and perfluoromethoxy resin (MFA) were added.
D 1600 – 99:
(*1*) Added PCL.
(*2*) E-CTFE, FCEA, HCTPV, MPA, PPSU, and VDF added editorially.

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Designation: D 2000 – 01

Approved by
Society of Automotive Engineers
SAE Recommended Practice J200

Standard Classification System for Rubber Products in Automotive Applications[1]

This standard is issued under the fixed designation D 2000; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This classification system tabulates the properties of vulcanized rubber materials (natural rubber, reclaimed rubber, synthetic rubbers, alone or in combination) that are intended for, but not limited to, use in rubber products for automotive applications.

NOTE 1—This classification system may serve many of the needs of other industries in much the same manner as SAE numbered steels. It must be remembered, however, that this system is subject to revision when required by automotive needs. It is recommended that the latest revision always be used.

1.2 This classification system is based on the premise that the properties of all rubber products can be arranged into characteristic material designations. These designations are determined by *types,* based on resistance to heat aging, and *classes,* based on resistance to swelling in oil. Basic levels are thus established which, together with values describing additional requirements, permit complete description of the quality of all elastomeric materials.

1.3 In all cases where the provisions of this classification system would conflict with those of the detailed specifications for a particular product, the latter shall take precedence.

NOTE 2—When the rubber product is to be used for purposes where the requirements are too specific to be completely prescribed by this classification system, it is necessary for the purchaser to consult the supplier in advance, to establish the appropriate properties, test methods, and specification test limits.

1.4 The values stated in SI units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 395 Test Methods for Rubber Property—Compression Set[2]

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension[2]

D 429 Test Methods for Rubber Property—Adhesion to Rigid Substrates[2]

D 430 Test Methods for Rubber Deterioration—Dynamic Fatigue[2]

D 471 Test Method for Rubber Property—Effect of Liquids[2]

D 573 Test Method for Rubber—Deterioration in an Air Oven[2]

D 575 Test Methods for Rubber Properties in Compression[2]

D 624 Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers[2]

D 865 Test Method for Rubber—Deterioration by Heating in Air (Test Tube Enclosure)[2]

D 925 Test Methods for Rubber Property—Staining of Surfaces (Contact, Migration, and Diffusion)[2]

D 945 Test Methods for Rubber Properties in Compression or Shear (Mechanical Oscillograph)[2]

D 1053 Test Methods for Rubber Property—Stiffening at Low Temperatures: Flexible Polymers and Coated Fabrics[2]

D 1171 Test Method for Rubber Deterioration—Surface Ozone Cracking Outdoors or Chamber (Triangular Specimens)[2]

D 1329 Test Method for Evaluating Rubber Property—Retraction at Lower Temperatures (TR Test)[2]

D 1349 Practice for Rubber—Standard Temperatures for Testing[2]

D 1418 Practice for Rubber and Rubber Latices—Nomenclature[2]

D 2137 Test Methods for Rubber Property—Brittleness Point of Flexible Polymers and Coated Fabrics[2]

D 2240 Test Method for Rubber Property—Durometer Hardness[2]

D 3183 Practice for Rubber—Preparation of Pieces for Test Purposes from Products[2]

D 5964 Practice for Rubber—IRM 902 and IRM 903 Replacement Oils for ASTM No. 2 and ASTM No. 3 Oils[2]

3. Purpose

3.1 The purpose of this classification system is to provide guidance to the engineer in the selection of practical, commercially available rubber materials, and further to provide a method for specifying these materials by the use of a simple

[1] This classification system is under the jurisdiction of ASTM Committee D11 on Rubber and is the direct responsibility of Subcommittee D11.30 on Classification of Rubber Compounds .

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[2] *Annual Book of ASTM Standards,* Vol 09.01.

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"line call-out" designation.

3.2 This classification system was developed to permit the addition of descriptive values for future rubber materials without complete reorganization of the classification system and to facilitate the incorporation of future new test methods to keep pace with changing industry requirements.

4. Type and Class

4.1 The prefix letter "M" shall be used to indicate that the classification system is based on SI units.

NOTE 3—Call outs not prefixed by the letter M refer to an earlier classification system based on inch-pound units. This was published in editions up to 1980.

4.2 Rubber materials shall be designated on the basis of *type* (heat resistance) and *class* (oil resistance). Type and class are indicated by letter designations as shown in Table 1 and Table 2 and illustrated in 9.1.

4.3 *Type* is based on changes in tensile strength of not more than ±30 %, elongation of not more than – 50 %, and hardness of not more than ±15 points after heat aging for 70 h at an appropriate temperature. The temperatures at which these materials shall be tested for determining type are listed in Table 1.

4.4 *Class* is based on the resistance of the material to swelling in ASTM Oil No. 3 after 70-h immersion at a temperature determined from Table 1, except that a maximum temperature of 150°C (the upper limit of oil stability) shall be used. Limits of swelling for each class are shown in Table 2.

4.4.1 ASTM No. 2 and No. 3 Oils have been replaced by IRM 902 and 903 Oils, respectively, under Practice D 5964. These Oils are similar but not identical to ASTM No. 2 and No. 3 Oils.

4.4.2 Substitutability of IRM 902 and 903 Oils for ASTM No. 2 and No. 3 Oils has not been established, as their swelling characteristics are different and may affect compound classification.

NOTE 4—The selection of type based on heat resistance is understood to be indicative of the inherent heat resistance that can be normally expected from commercial compositions. Likewise, choice of class is based on the range of volume swell normally expected from such commercial compositions as established by type. *The fact that a type and class of material is listed in Table 6, under Basic Requirements, indicates that materials that meet these requirements for heat and oil resistance are commercially available.*

4.5 The letter designations shall always be followed by a three-digit number to specify the hardness and the tensile strength—for example, 505. The first digit indicates durometer hardness, Type A, for example, 5 for 50 ± 5, 6 for 60 ± 5. The next two digits indicate the minimum tensile strength—for example, 05 for 5 MPa, 14 for 14 MPa. *Correlation of*

TABLE 1 Basic Requirements for Establishing Type by Temperature

Type	Test Temperature, °C
A	70
B	100
C	125
D	150
E	175
F	200
G	225
H	250
J	275
K	300

TABLE 2 Basic Requirements for Establishing Class by Volume Swell

Class	Volume Swell, max, %
A	no requirement
B	140
C	120
D	100
E	80
F	60
G	40
H	30
J	20
K	10

TABLE 3 Meaning of Suffix Letters

Suffix Letter	Test Required
A	Heat Resistance
B	Compression Set
C	Ozone or Weather Resistance
D	Compression-Deflection Resistance
EA	Fluid Resistance (Aqueous)
EF	Fluid Resistance (Fuels)
EO	Fluid Resistance (Oils and Lubricants)
F	Low-Temperature Resistance
G	Tear Resistance
H	Flex Resistance
J	Abrasion Resistance
K	Adhesion
M	Flammability Resistance
N	Impact Resistance
P	Staining Resistance
R	Resilience
Z	Any special requirement, which shall be specified in detail

TABLE 4 Suffix Numbers to Indicate Temperature of Test

Applicable Suffix Requirements	Second Suffix Number	Test Temperature, °C[A]
A, B, C, EA, EF, EO, G,	11	275
K	10	250
	9	225
	8	200
	7	175
	6	150
	5	125
	4	100
	3	70
	2	38
	1	23
	0	[B]
F	1	23
	2	0
	3	–10
	4	–18
	5	–25
	6	–35
	7	–40
	8	–50
	9	–55
	10	–65
	11	–75
	12	–80

[A] These test temperatures are based on Practice D 1349.
[B] Ambient temperature in the case of outdoor testing.

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available materials for desired hardness and tensile strength is obtained through the elongation values in Table 6. See 7.2.

5. Grade Numbers, Suffix Letters, and Number

5.1 *Grade Numbers*—Since the basic requirements do not always describe sufficiently all the necessary qualities, provision is made for deviation or adding requirements through a system of prefix grade numbers. Grade No. 1 indicates that only the basic requirements are compulsory, and no suffix requirements are permitted. Grades other than No. 1 are used for expressing deviation or additional requirements and are listed as "Available Suffix Grade Numbers" in the last column under Basic Requirements in Table 6. A grade number is written as a material prefix number preceding the letters for type and class (see 9.1). Grade No. 1 is always an available suffix grade number, and thus is not referenced in the last column of each basic requirement table.

5.2 *Suffix Letters*—The suffix letters that may be used, together with their meaning, appear in Table 3.

5.3 *Suffix Numbers*—Each suffix letter should preferably be followed by two suffix numbers (see Note 6 in 8.1). *The first suffix number always indicates the test method;* time of test is part of the method and is taken from the listings in Table 5. *The second suffix number, if used, always indicates the temperature of test* and is taken from Table 4. Where three-digit numbers are required, they are separated by a dash—for example: –10; B4–10; F1–11.

6. Composition and Manufacture

6.1 This classification system is predicated upon materials furnished under a specification based thereon being manufactured from natural rubber, reclaimed rubber, synthetic rubber, alone or in combination, together with added compounding ingredients of such nature and quantity as to produce vulcanizates that comply with the specified requirements. All materials and workmanship shall be in accordance with good commercial practice, and the resulting product shall be free of porous areas, weak sections, bubbles, foreign matter, or other defects affecting serviceability.

6.2 *Color*—With the exception of FC, FE, FK, and GE materials, the values in the material tables are based on black compounds and comparable values may not be available in color.

7. Basic Requirements

7.1 The basic requirements for physical properties specified in Table 6[3] are based on values obtained from standard laboratory test specimens prepared and tested in accordance with the applicable ASTM test methods. *Test results from specimens prepared from finished products may not duplicate values obtained from standard test specimens.*

NOTE 5—When standard test specimens are cut from finished parts in accordance with Practice D 3183, a deviation to the extent of 10 % (on tensile strength and elongation values only) is permissible when agreed upon by the purchaser and the supplier. This deviation is permissible *only* because of the recognized effects of knitting, grain, and buffing on the material when test specimens are prepared from finished parts and tested for tensile strength and elongation. When differences due to the method of processing or to the difficulty in obtaining suitable test specimens from the finished part arise, the purchaser and the supplier may agree on acceptable deviations. This can be done by comparing results of standard test specimens with those obtained on actual parts.

7.2 The available materials are listed in the appropriate material section of the table, giving each hardness and tensile strength with its appropriate elongation value. Also, there is a repetition of the values for the basic heat and oil aging requirements for the material resulting from the assignment of type and class. In addition, values for compression set, normally a basic requirement to ensure proper vulcanization, are specified.

8. Suffix Requirements

8.1 Suffix requirements shall be specified *only as needed* to define qualities necessary to meet service requirements. These suffix requirements are set forth for the various grade numbers. Suffix letters and suffix numbers describing these suffix requirements may be used singly or in combination, *but not all suffix values available for a given material need be specified.*

NOTE 6—Examples of the use of suffix letters and numbers would be A14 and EO34. Suffix A (Table 3) stands for heat resistance, Suffix 1 (Table 5) specifies that the test be run in accordance with Test Method D 573 for 70 h, and Suffix A (Table 4) indicates the temperature of test as 100°C. Similarly, Suffix EO34 indicates resistance in ASTM Oil No. 3 in accordance with Test Method D 471 for 70 h at 100°C.[4]

8.2 Basic requirements are always in effect, unless superseded by specific suffix requirements in the "line call-out."

[3] Tensile values are shown as pounds per square inch in Table 6 for information only.

[4] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

TABLE 5 ASTM Test Methods

Basic Requirements and First Suffix No. / Requirement or Suffix Letter	Basic	1	2	3	4	5	6	7	8	9
Tensile Strength, Elongation	D 412, die C	...	...	...	...	...	...	...	...	...
Durometer Hardness, Type A	D 2240	...	...	...	...	...	...	...	...	...
Suffix A, Heat Resistance	...	D 573, 70 h	D 865, 70 h	D 865, 168 h	D 573, 168 h	D 573, 1000 h	D 865, 1000 h	...	...	...

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TABLE 5 *Continued*

Basic Requirements and First Suffix No. / Requirement or Suffix Letter	Basic	1	2	3	4	5	6	7	8	9
Suffix B, Compression Set, Standard Test Specimen Cut from a Slab	...	D 395, 22 h, Method B, solid	D 395, 70 h, Method B, solid	D 395, 22 h, Method B, plied	D 395, 70 h, Method B, plied	D 395, 1000 h, Method B, solid	D 395, 1000 h, Method B, plied	...	...	...
Suffix C, Ozone or Weather Resistance	...	D 1171, ozone[A] exposure, Method A	D 1171,[B] weather	D 1171, ozone[C] exposure, Method B	...	...	...	...	...	...
Suffix D, Compression-Deflection Resistance	...	D 575, Method A	D 575, Method B	...	...	...	...	...	...	...
Suffix EO, Oil Resistance	...	D 471, ASTM Oil No. 1,[D] 70 h	D 471, ASTM Oil No. 2[D], 70 h	D 471, ASTM Oil No. 3[D], 70 h	D 471, ASTM Oil No. 1, 168 h	D 471, ASTM Oil No. 2, 168 h	D 471, ASTM Oil No. 3, 168 h	D 471, Service Liquid No. 101, 70 h	D 471, Oil as specifically designated in Table 6, 70 h	
Suffix EF, Fluid Resistance	...	D 471, Reference Fuel A, 70 h	D 471, Reference Fuel B, 70 h	D 471, Reference Fuel C, 70 h	D 471, Reference Fuel D, 70 h	D 471, Volume Percent Reference Fuel D Plus 15 Volume Percent Denatured Ethanol, 70 h	...	...	...	...
Suffix EA, Aqueous Fluid Resistance	...	D 471, Distilled Water, 70 h[E]	D 471, Equal Parts by Volume Distilled Water-Reagent Grade Ethylene Glycol, 70 h[F]	...	...	...	...	...	...	...
Suffix F, Low-Temperature Resistance	...	D 2137, Method A, 9.3.2, 3 min	D 1053, 5 min, T_2, T_5, T_{10}, T_{50}, or T_{100}	D 2137, Method A 9.3.2, 22 h	D 1329, 38.1 mm die, 50 % elongation, *retraction* 10 % min	D 1329, 38.1 mm die, 50 % elongation, *retraction* 50 % min				...
Suffix G, Tear Resistance	...	D 624, die B	D 624, die C	...	...	...	...	...	...	...
Suffix H, Flex Resistance	...	D 430, Method A	D 430, Method B	D 430, Method C	...	...	...	...	...	...
Suffix J, Abrasion Resistance	...	[G]	...	...	...	...	...	...	...	...
Suffix K, Adhesion	...	D 429, Method A	D 429, Method B	Bond made after vulcanization	...	...	...	...	...	...
Suffix M, Flammability Resistance[G]	...	...	...	...	...	...	...	...	...	...
Suffix N, Impact Resistance[G]	...	...	...	...	...	...	...	...	...	...
Suffix P, Staining Resistance	...	D 925, Method A	D 925, Method B Control Panel	...	...	...	...	...	...	...
Suffix R, Resilience	...	D 945	...	...	...	...	...	...	...	...
Suffix Z, Special Requirement[G]	...	...	...	...	...	...	...	...	...	...

[A] Use ozone chamber exposure method of Test Method D 1171, Method A.

[B] Test Method D 1171, Weather Test, is 6 weeks duration. Test area and time of year to be agreed upon by the purchaser and the manufacturer

[C] Use ozone chamber exposure method of Test Method D 1171, Method B.

[D] ASTM No. 2 and No. 3 Oils are no longer commercially available. They have been replaced by IRM 902 and 903 Oils, respectively. See 4.4.1. ASTM Oil No. 1, IRM 902 and IRM 903 may be ordered from Penreco, 4426 East Washington Blvd., Los Angeles, CA 90023-4476. They are also distributed by R. E. Carroll, Inc., P.O. Box 5806, Trenton, NJ 08638-0806.

[E] Distilled water shall be used. Volume increase by water displacement method, except alcohol dip omitted. When determining changes in tensile strength, elongation, and hardness, test tube to be ¾full after specimens are immersed. Determination to be made after 30 min. Cool in distilled water, acetone dip to be omitted.

[F] Equal parts by volume of distilled water and reagent grade ethylene glycol. Volume increase by displacement method, except alcohol dip omitted, When determining changes in tensile strength, elongation, and hardness, test tube to be ¾ full after specimens are immersed. Determination to be made after 30 min. Cool in distilled water, acetone dip to be omitted.

[G] Test method to be specified.

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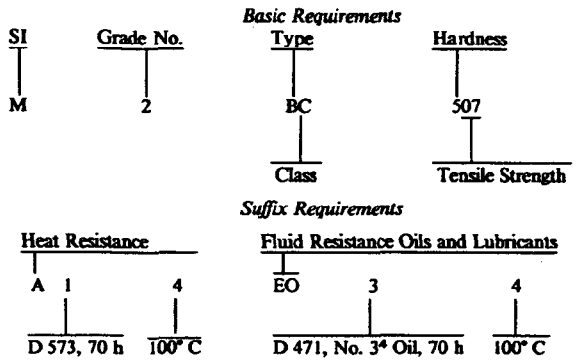
9. Line Call-Outs

9.1 A "line call-out," *which is a specification,* shall contain: the documents names, the prefix letter M, the grade number, the material designation (type and class), and the hardness and tensile strength, followed by the appropriate suffix requirements. Following is an example of a "line call-out" or specification:

ASTM D 2000 M2BC 507 A14EO34



In this example, basic requirements for heat resistance and fluid resistance are superseded by suffix requirements. However, the basic requirement of 80 % for compression set, which is not included as a suffix requirement, is not superseded and therefore shall be met as specified in Table 6.

10. Test Methods

10.1 The applicable test methods are listed in Table 5.

11. Sampling and Inspection

11.1 A lot, unless otherwise specified, shall consist of all products of the same material submitted for inspection at the same time.

11.2 When proof of conformance with a specification based on this classification system is required, the supplier shall, upon request of the purchaser at the time of ordering, furnish a sufficient number of samples to permit the performance of the required tests. Test specimens shall be prepared as prescribed in 7.1. The samples shall be warranted to have equivalent cure and to be from the same run or batch of compound used in the lot.

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TABLE 6 Basic and Supplementary (Suffix) Requirements for Classification of Elastomeric Materials

AA MATERIALS

Basic Requirements						
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 70°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 70C	Compression Set, Test Methods D 395, Solid, max, %, 22 h at 70°C	Available Suffix Grade Numbers
	MPa	psi					
30	7	1015	400				2, 4
30	10	1450	400				2, 4
30	14	2031	400				2, 4
40	7	1015	400				2, 4
40	10	1450	400				2, 4
40	14	2031	400				2, 4
40	17	2466	500				2, 4
40	21	3046	600				2, 4
50	3	435	250				2
50	6	870	250				2
50	7	1015	400				2, 3
50	8	1160	400				2, 3
50	10	1450	400				2, 3, 4, 5
50	14	2031	400				2, 3, 4, 5
50	17	2466	400				2, 3, 4, 5
50	21	3046	500				2, 3, 4, 5
60	3	435	250				2
60	6	870	250				2
60	7	1015	300	Change in tensile strength, ±30 %			2, 3
60	8	1160	300				2, 3
60	10	1450	350	Change in ultimate elongation, – 50 % max	No Requirement	Compression set, 50 % max	2, 3, 4, 5
60	14	2031	400				2, 3, 4, 5
60	17	2466	400	Change in durometer hardness, ±15 points			2, 3, 4, 5
60	21	3046	400				2, 3, 4, 5
60	24	3481	500				2, 3, 4, 5
70	3	435	150				2
70	6	870	150				2
70	7	1015	200				2, 3
70	8	1160	200				2, 3
70	10	1450	250				2, 3, 4, 5
70	14	2031	300				2, 3, 4, 5
70	17	2466	300				2, 3, 4, 5
70	21	3046	350				2, 3, 4, 5
80	3	435	100				2
80	7	1015	100				2
80	10	1450	150				2
80	14	2031	200				2
80	17	2466	200				2
90	3	435	75				2
90	7	1015	100				2
90	10	1450	125				2

[A]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

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TABLE 6 *Continued*

AA MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A13	Heat resistance, Test Method D 573, 70 h at 70°C:								
	Change in hardness, max, points		±15		+10	+10			
	Change in tensile strength, max, %		±30		−25	−25			
	Change in ultimate elongation, max, %		−50		−25	−25			
B13	Compression set, Test Methods D 395, Method B, max, %, 22 h at 70°C			25	25	25			
B33	Compression set, Test Methods D 395, Method B, max, %, 22 h at 70°C			50	50	50			
C12	Resistance to ozone, Test Method D 1171, quality retention rating, min, %		85	†	85	†			
C20	Resistance to outdoor aging, Test Method D 1171, quality retention rating, min, %		85	85	85	85			
EA14	Water resistance, Test Method D 471, 70 h at 100°C, volume change, max, %		10	10	10	10			
F17	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at − 40°C		pass	pass	pass	pass			
G21	Tear resistance, Test Method D 624, Die C:								
	under 7.0 MPa tensile strength, min. kN/m			22	22	22			
	over 7.0 MPa tensile strength, min, kN/m			26	26	26			
K11	Adhesion, Test Methods D 429, min:								
	Method A, min, MPa		1.4	2.8	1.4	2.8			
K21	Adhesion, Test Method D 429, Method B, min, MPa		7	7	7	9			
P2	Staining resistance, Test Methods D 925, Method B, control panel		pass	pass	pass	pass			
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.								

[A] Basic properties only—no suffix requirements for Grade No. 1.

† The requirement is applicable, and materials are available having these characteristics, but values have not yet been established.

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TABLE 6 *Continued*

AK MATERIALS

Basic Requirements

Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 70°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 70°C	Compression Set, Test Methods D 395, Solid, max, %, 22 h at 70°C	Available Suffix Grade Numbers
	MPa	psi					
40	3	435	400	Change in tensile strength,			2
50	3	435	400	±30 %			2
60	5	725	300	Change in ultimate elonga-	Volume change,	Compression set,	2
70	7	1015	250	tion, – 50 % max	+ 10 % max	50 % max	2
80	7	1015	150	Change in durometer hard-			3
90	7	1015	100	ness, ±15 points			3

[A]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1

AK MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A14	Heat resistance, Test Method D 573, 70 h at 100°C:								
	Change in durometer hardness, max, points		+15	+15					
	Change in tensile strength, max, %		–15	–15					
	Change in ultimate elongation, max, %		–40	–40					
B33	Compression set, Test Methods D 395, Method B, 22 h at 70°C max, %		50	50					
EO14	Fluid resistance, Test Method D 471, Oil No. 1, 70 h at 100°C:								
	Change in tensile strength, max. %		†	†					
	Change in ultimate elongation, max. %		†	†					
	Change in durometer hardness, max, points		†	†					
	Change in volume, max, %		–3 to +5	–3 to +5					
EO34	Fluid resistance, Test Method D 471, Oil No. 3, 70 h at 100°C:								
	Change in durometer hardness, points		–5 to +10	–5 to +10					
	Change in tensile strength, max. %		–30	–30					
	Change in ultimate elongation, max, %		–50	–50					
	Change in volume, max, %		†	†					
F17	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at – 40°C		pass						
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.								

[A]Basic properties only, no suffix requirements for Grade No. 1.

† The requirement is applicable, and materials are available having these characteristics, but values have not yet been established.

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TABLE 6 *Continued*

BA MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 100°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 100°C	Compression Set, Test Methods D 395, Solid, max, %, 22 h at 70°C	Available Suffix Grade Numbers
	MPa	psi					
20[B]	6	870	400				3
30	7	1015	400				2
30	10	1450	400				2, 3, 4, 5
30	14	2031	400				2, 3, 4, 5
40	3	435	300				2, 8
40	7	1015	300				2, 8
40	10	1450	400				2, 3, 4, 5, 6
40	14	2031	400				2, 3, 4, 5
50	7	1015	300				2, 8
50	10	1450	400				2, 3, 4, 5, 6
50	14	2031	400				2, 3, 4, 5
50	17	2466	400				2, 3, 4, 5
60	3	435	250	Change in tensile strength, ±30 %	No requirement	Compression set, 50 % max	8
60	6	870	250				8
60	7	1015	300	Change in ultimate elongation, – 50 % max			2, 8
60	10	1450	350				2, 3, 4, 5, 6
60	14	2031	400	Change in durometer hardness, ±15 points			2, 3, 4, 5, 6
60	17	2466	400				2, 3, 4, 5, 6
70	3	435	150				8
70	6	870	150				8
70	7	1015	200				2, 8
70	8	1160	200				8
70	10	1450	250				2, 3, 4, 5, 6
70	14	2031	300				2, 3, 4, 5
70	17	2466	300				2, 3, 4, 5
80	7	1015	100				2, 7
80	10	1450	150				2, 4
80	14	2031	200				2, 4
90	3	435	75				7
90	7	1015	100				2, 7
90	10	1450	125				2, 4

[A] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.
[B] Materials would typically be 20 to 25 durometer based upon current capability.

BA MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A14	Heat resistance, Test Method D 573, 70 h at 100°C:								
	Change in hardness, max, points			+10	+10				
	Change in tensile strength, max, %			–25	–25				
	Change in ultimate elongation, max, %			–25	–25				
B13	Compression set, Test Methods D 395, Method B, max, %, 22 h at 70°C			25			25		25
C12	Resistance to ozone, Test Method D 1171, quality retention rating, min, %		100	100	100	100	100	100	100
F17	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at – 40°C		pass	pass	pass	pass			
F19	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at – 55°C			pass		pass			
K11	Adhesion, Test Methods D 429, min:								
	Method A, min, MPa			1.4	1.4	1.4	1.4		
K21	Adhesion, Test Methods D 429, min:								
	Method B, min, kN/m			7	7	7			
K31	Adhesion, bond made after vulcanization			[B]	[B]	[B]			
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.								

[A] Basic properties only—no suffix requirements for Grade No. 1.
[B] Suffix K31 indicates that the material shall be free of surface conditions and compound constituents that are or may become deleterious to cement adhesion.

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TABLE 6 *Continued*

BC MATERIALS

Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 100°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 100°C	Compression Set, Test Methods D 395, Solid, max, %, 22 h at 100°C	Available Suffix Grade Numbers
	MPa	psi					
				Basic Requirements			
30	3	435	300				2, 5
30	7	1015	400				2, 5
30	10	1450	500				2, 5
30	14	2031	500				2
40	3	435	300				2
40	7	1015	400				2, 5
40	10	1450	500				2, 5
40	14	2031	500				2, 5
40	17	2466	500				2
50	3	435	300				2, 5
50	7	1015	300				2, 5
50	10	1450	350				2, 5, 6
50	14	2031	400				2, 5, 6
50	17	2466	450				2, 6
50	21	3046	500				2, 6
50	24	3481	500				2, 6
60	3	435	300	Change in tensile strength, ±30 %			3, 5
60	7	1015	300	Change in ultimate elongation, – 50 % max			3, 5
60	10	1450	350		Volume change, + 120 % max	Compression set, 80 % max	3, 5, 6
60	14	2031	350	Change in durometer hardness, ±15 points			3, 6
60	17	2466	400				3, 6
60	21	3046	400	3, 6			
60	24	3481	400				3, 6
70	3	435	200				3, 5
70	7	1015	200				3, 5
70	10	1450	250				3, 5, 6
70	14	2031	300				3, 5, 6
70	17	2466	300				3, 6
70	21	3046	300				3, 6
80	3	435	100				4
80	7	1015	100				4
80	10	1450	100				4
80	14	2031	150				4
90	3	435	50				4
90	7	1015	100				4
90	10	1450	150				4
90	14	2031	150				4

[A] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

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TABLE 6 *Continued*

BC MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A14	Heat resistance, Test Method D 573, 70 h at 100°C:								
	Change in hardness, max points		+15	+15	+15	+15	+15		
	Change in tensile strength, max, %		−15	−15	−15	−15	−15		
	Change in ultimate elongation, max, %		−40	−40	−40	−40	−40		
B14	Compression set, Test Methods D 395, Method B, 22 h at 100°C, max, %		35	35	35	35	35		
C12	Resistance to ozone, Test Method D 1171		100	100	100	100	100		
C20	Resistance to outdoor aging, Test Method D 1171, quality retention rating, min, %		†	†	†	†	†		
EO14	Fluid resistance, Test Method D 471, No. 1 Oil, 70 h at 100°C:								
	Change in hardness, points		±10	±10	±10	±10	±10		
	Change in tensile strength, max, %		−30	−30	−30	−30	−30		
	Change in ultimate elongation, max, %		−30	−30	−30	−30	−30		
	Change in volume, %		−10 to +15	−10 to +15	−10 to +15	−10 to +15	−10 to +15		
EO34	Fluid resistance, Test Method D 471, No. 3 Oil,[B] 70 h at 100°C:								
	Change in tensile strength, max, %		−70	−60	−45	−60	−60		
	Change in ultimate elongation, max, %		−55	−50	−30	−60	−50		
	Change in volume, %		+120	+100	+80	+100	+100		
F17	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −40°C		pass	pass	pass		pass		
F19	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −55°C					pass			
G21	Tear resistance, Test Method D 624, Die C:								
	Under 7.0 MPa tensile load, min, kN/m		22	22	22				
	7.0 to 10 MPa tensile load, min, kN/m		26	26	26				
	10 MPa tensile load and over, min, kN/m		26	26	26	26	26		
K11	Adhesion, Test Methods D 429, min:								
	Method A, min, MPa		1.4	1.4	1.4	1.4	2.8		
P2	Staining resistance, Test Methods D 925, Method B, control panel, nonstaining		†	†	†				
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.								

[A] Basic properties only—no suffix requirements for Grade No. 1.

† The requirement is applicable, and materials are available having these characteristics, but values have not yet been established.

[B] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

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TABLE 6 *Continued*

BE MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 100°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 100°C	Compression Set, Test Methods D 395, Solid, max, %, 22 h at 100°C	Available Suffix Grade Numbers
	MPa	psi					
40	3	435	500			40	2
40	7	1015	500			40	2
50	3	435	350			40	2
50	6	870	350			40	2
50	7	1015	400			40	2
50	10	1450	400			40	2, 3
50	14	2031	400			40	2
60	3	435	300			40	2
60	6	870	300			40	2
60	7	1015	350			40	2
60	10	1450	350	Change in tensile strength, ±30 %		40	2, 3
60	14	2031	350			40	2
70	3	435	200	Change in ultimate elongation, – 50 % max	Volume change, +80 % max	50	2
70	6	870	200	Change in durometer hardness, ±15 points		50	2
70	7	1015	200			50	2
70	10	1450	250			50	2, 3
70	14	2031	250			50	2
70	17	2466	250			50	2
80	7	1015	100			50	2
80	10	1450	100			50	2
80	14	2031	150			50	2
80	17	2466	150			50	2
90	7	1015	100			50	2
90	10	1450	100			50	2
90	14	2931	150			50	2

[A] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

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TABLE 6 *Continued*

BE MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A14	Heat resistance, Test Method D 573, 70 h at 100°C:								
	Change in hardness, max, points		+15	+15					
	Change in tensile strength, max, %		−15	−15					
	Change in ultimate elongation, max, %		−40	−40					
B14	Compression set, Test Methods D 395, Method B, max, %, 22 h at 100°C		25	25					
C12	Resistance to ozone, Test Method D 1171, quality retention rating, min, %		100	100					
C20	Resistance to outdoor aging, Test Method D 1171		†	†					
EO14	Fluid resistance, Test Method D 471, No. 1 Oil, 70 h at 100°C:								
	Change in hardness, points		±10	±10					
	Change in tensile strength, max, %		−30	−30					
	Change in ultimate elongation, max, %		−30	−30					
	Change in volume, %		−10 to +15	−10 to +15					
EO34	Fluid resistance, Test Method D 471, No. 3 Oil,[B] 70 h at 100°C:								
	Change in tensile strength, max, %		−50	−50					
	Change in ultimate elongation, max, %		−40	−40					
F17	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −40°C		pass						
F19	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −55°C			pass					
G21	Tear resistance, Test Method D 624, Die C:								
	10 MPa tensile load and over, min, kN/m			26					
K11	Adhesion, Test Methods D 429, Method A, min, MPa			1.4					
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.								

[A] Basic properties only—no suffix requirements for Grade No. 1.

† The requirement is applicable, and materials are available having those characteristics, but values have not yet been established.

[B] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

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TABLE 6 *Continued*

BF MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 100°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 100°C	Compression Set, Test Methods D 395, Solid, max, %, 22 h at 100°C	Available Suffix Grade Numbers
	MPa	psi					
60	3	435	200				2
60	6	870	200				2
60	7	1015	250				2
60	8	1160	250				2
60	10	1450	300				2
60	14	2031	350				2
60	17	2466	350				2
70	3	435	150	Change in tensile strength, ±30 %			2
70	6	870	150	Change in ultimate elongation, −50 % max	Volume change, +60 % max	Compression set, 50 % max	2
70	7	1015	200	Change in durometer hardness, ±15 points			2
70	8	1160	200				2
70	10	1450	250				2
70	14	2031	250				2
70	17	2466	300				2
80	3	435	100				2
80	7	1015	100				2
80	10	1450	125				2
80	14	2031	125				2

[A] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

BF MATERIALS

Suffix Requirements		Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
B14	Compression set, Test Methods D 395, Method B, max, %, 22 h at 100°C		25						
B34	Compression set, Test Methods D 395, Method B, max, %, 22 h at 100°C		25						
EO14	Fluid resistance, Test Method D 471, No. 1 Oil, 70 h at 100°C:								
	Change in hardness, points		±10						
	Change in tensile strength, max, %		−25						
	Change in ultimate elongation, max, %		−45						
	Change in volume, %		−10 to +10						
EO34	Fluid resistance, Test Method D 471, No. 3 Oil, 70 h at 100°C:								
	Change in hardness, max, points		−20						
	Change in tensile strength, max, %		−45						
	Change in ultimate elongation, max, %		−45						
	Change in volume, %		0 to +60						
F19	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −55°C		pass						
K11	Adhesion, Test Methods D 429, Method A, MPa		[B]						
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods								

[A] Basic properties only—no suffix requirements for Grade No. 1.

[B] Materials are available that can be bonded to metal during vulcanization. Because of the wide variety of compounds in use, combined with manifold end-use requirements, no values are shown. Test Methods D 429 and requirements should be agreed upon by the supplier and user.

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TABLE 6 *Continued*

BG MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 100°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 100°C	Compression Set, Test Methods D 395, Solid, max, %, 22 h at 100°C	Available Suffix Grade Numbers
	MPa	psi					
40	7	1015	450				2, 5
40	10	1450	450				2, 5
50	3	435	300				2, 5
50	6	870	300				2
50	7	1015	350				2, 5
50	8	1160	350				2
50	10	1450	300				2, 3, 4, 5
50	14	2031	350				2, 3, 4, 5
50	21	3046	400				3, 4
60	3	435	200				2, 5
60	6	870	200				2
60	7	1015	250				2, 5
60	8	1160	250				2
60	10	1450	300				2, 5
60	14	2031	300				2, 3, 4, 5
60	17	2466	350				2
60	21	3046	350	Change in tensile strength, ±30 %			3, 4
60	28	4061	400	Change in ultimate elongation, −50 % max	Volume change, +40 % max	Compression set, 50 % max	3, 4
70	3	435	150	Change in durometer hardness, ±15 points			2, 5
70	6	870	150				2
70	7	1015	200				2, 5
70	8	1160	200				2
70	10	1450	250				2, 5
70	14	2031	250				2, 3, 4, 5
70	17	2466	300				2, 3
70	21	3046	350				3, 4
70	28	4061	400				3, 4
80	3	435	100				6, 7
80	7	1015	100				6, 7
80	10	1450	125				6, 7
80	14	2031	125				3, 4, 6, 7
80	21	3046	300				3, 4
80	28	4061	350				3, 4
90	3	435	50				6, 7
90	7	1015	100				6, 7
90	10	1450	100				6, 7

[A] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

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TABLE 6 *Continued*

BG MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A14	Heat resistance, Test Method D 573, 70 h at 100°C:								
	Change in hardness, max, points				±5	+15	+15		
	Change in tensile strength, max, %				±15	−20	−20		
	Change in ultimate elongation, max, %				−15	−40	−40		
B14	Compression set, Test Methods D 395, Method B, max, %, 22 h at 100°C		25	50	50	25	25	25	
B34	Compression set, Test Methods D 395, Method B, max, %, 22 h at 100°C		25			25	25		
C12	Resistance to ozone, Test Method D 1171, quality retention rating, min, %			†	†				
C20	Resistance to outdoor aging, Test Method D 1171			†	†				
EA14	Water resistance, Test Method D 471, 70 h at 100°C:								
	Change in hardness, points		±10					±10	
	Change in volume, %		±15					±15	
EF11	Fluid resistance, Test Method D 471, Reference Fuel A, 70 h at 23°C:								
	Change in hardness, points		±10					±10	
	Change in tensile strength, max, %		−25					−25	
	Change in ultimate elongation, max, %		−25					−25	
	Change in volume, %		−5 to +10					−5 to +10	
EF21	Fluid resistance, Test Method D 471, Reference Fuel B, 70 h at 23°C:								
	Change in hardness, points		0 to −30					0 to −30	
	Change in tensile strength, max, %		−60					−60	
	Change in ultimate elongation, max, %		−60					−60	
	Change in volume, %		0 to +40					0 to +40	
EO14	Fluid resistance, Test Method D 471, No. 1 Oil, 70 h at 100°C:								
	Change in hardness, max, points		−5 to +10	−7 to +5	−7 to +5	−5 to +15	−5 to +15	−5 to +5	
	Change in tensile strength, max, %		−25	−20	−20	−25	−25	−25	
	Change in ultimate elongation, max, %		−45	−40	−40	−45	−45	−45	
	Change in volume, %		−10 to +5	−5 to +10	−5 to +5	−10 to +5	−10 to +5	−10 to +5	
EO34	Fluid resistance, Test Method D 471, No. 3 Oil, 70 h at 100°C:								
	Change in hardness, points		−10 to +5	−10 to +5	−10 to +5	0 to −15	0 to −20	−10 to +5	
	Change in tensile strength, max, %		−45	−35	−35	−45	−45	−45	
	Change in ultimate elongation, max, %		−45	−40	−40	−45	−45	−45	
	Change in volume, %		0 to +25	+16 to +35	0 to +6	0 to +35	0 to +35	0 to +25	
F16	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −35°C							pass	
F17	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −40°C		pass				pass		
F19	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −55°C			pass	pass	pass			
K11	*Adhesion, Test Methods D 429, Method A, MPa*		*B*	*B*	*B*	*B*	*B*	*B*	
P2	Staining resistance, Test Methods D 925, Method B, control panel			pass	pass				
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.								

[A] Basic properties only—no suffix requirements for Grade No. 1.

[B] Materials are available that can be bonded to metal during vulcanization. Because of the wide variety of compounds in use, combined with manifold end-use requirements, no values are shown. Test Methods D 429 and requirements should be agreed upon by the supplier and user.

† The requirement is applicable, and materials are available having these characteristics, but values have not yet been established. These values should be determined between the end user and producer.

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TABLE 6 *Continued*

BK MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 100°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 100°C	Compression Set, Test Methods D 395, Solid, max, %, 22 h at 100°C	Available Suffix Grade Numbers
	MPa	psi					
60	3	435	200				4
60	6	870	200				4
60	7	1015	250				4
60	8	1160	250				4
60	10	1450	300				4
60	14	2031	350				4
60	17	2466	350				4
70	3	435	150				4
70	6	870	150	Change in tensile strength, ±30 %			4
70	7	1015	200		Volume change, + 10 % max	Compression set, 50 % max	4
70	8	1160	200	Change in ultimate elongation, − 50 % max			4
70	10	1450	250				4
70	14	2031	250	Change in durometer hardness, ±15 points			4
70	17	2466	300				4
80	3	435	100				4
80	7	1015	100				4
80	10	1450	125				4
80	14	2031	125				4
90	3	435	50				4
90	7	1015	100				4
90	10	1450	100				4

[A] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

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TABLE 6 *Continued*

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
									BK MATERIALS
A24	Heat resistance, Test Method D 865, 70 h at 100°C:								
	Change in hardness, points				±10				
	Change in tensile strength, max, %				−20				
	Change in ultimate elongation, max, %				−30				
B14	Compression set, Test Methods D 395, Method B, max, %, 22 h at 100°C				25				
B34	Compression set, Test Methods D 395, Method B, max, %, 22 h at 100°C				25				
EF11	Fluid resistance, Test Method D 471, Reference Fuel A, 70 h at 23°C:								
	Change in hardness, points				±5				
	Change in tensile strength, max, %				−20				
	Change in ultimate elongation, max, %				−20				
	Change in volume, %				±5				
EF21	Fluid resistance, Test Method D 471, Reference Fuel B, 70 h at 23°C:								
	Change in hardness, max, points				0 to −20				
	Change in tensile strength, max, %				−50				
	Change in ultimate elongation, max, %				−50				
	Change in volume, %				0 to +25				
EO14	Fluid resistance, Test Method D 471, No. 1 Oil, 70 h at 100°C:								
	Change in hardness, points				±5				
	Change in tensile strength, max, %				−20				
	Change in ultimate elongation, max, %				−20				
	Change in volume, %				−10 to 0				
EO34	Fluid resistance, Test Method D 471, No. 3 Oil, 70 h at 100°C:								
	Change in hardness, points				−10 to +5				
	Change in tensile strength, max, %				−20				
	Change in ultimate elongation, max, %				−30				
	Change in volume, %				0 to +5				
K11	Adhesion, Test Methods D 429, Method A, MPa				[B]				
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.								

[A] Basic properties only—no suffix requirements for Grade No. 1.

[B] Materials are available that can be bonded to metal during vulcanization. Because of the wide variety of compounds in use, combined with manifold end-use requirements, no values are shown. Test Methods D 429 and requirements should be agreed upon by the supplier and user.

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TABLE 6 *Continued*

CA MATERIALS

Basic Requirements

Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 125°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 150°C	Compression Set, Test Methods D 395, Solid, max, %, 22 h at 100°C	Available Suffix Grade Numbers
	MPa	psi					
30	7	1015	500				2
30	10	1450	500				2
40	7	1015	400				2
40	10	1450	400				2
40	14	2031	400				2
50	7	1015	300				3
50	10	1450	300				4
50	14	2031	350				4
50	17	2466	350	Change in tensile strength, ± 30 %			4
60	7	1015	250	Change in ultimate elongation, – 50 % max			3
60	10	1450	250		No requirements	Compression set, 60 % max	4
60	14	2031	250	Change in durometer hardness, ±15 points			4
70	7	1015	200				3
70	10	1450	200				4, 5
70	14	2031	200				4, 5
80	7	1015	150				6
80	10	1450	150				7, 8
80	14	2031	150				7, 8
90	7	1015	100				6
90	10	1450	100				7, 8

[A]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

CA MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A25	Heat resistance, Test Method D 865, 70 h at 125°C:								
	Change in hardness, max, points		+10	+10	+10	+10	+10	+10	+10
	Change in tensile strength, max, %		–20	–20	–20	–20	–20	–20	–20
	Change in ultimate elongation, max, %		–40	–40	–40	–40	–50	–40	–40
B44	Compression set, Test Methods D 395, Method B, 70 h at 100°C, plied specimen, max, %		35	50					
B35	Compression set, Test Methods D 395, Method B, 22 h at 125°C, plied specimen, max, %		70	70	70	50	70	70	50
C32	Resistance to ozone, Test Method D 1171, exposure Method B		pass	pass	pass	pass	pass	pass	pass
EA14	Water resistance, Test Method D 471, 70 h at 100°C, volume change, %		±5	±5	±5	±5	±5	±5	±5
F17	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at –40°C		pass	pass	pass	pass	pass	pass	pass
F18	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at –50°C		pass	pass	pass	pass		pass	
F19	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at –55°C				pass				
G11	Tear resistance, Test Method D 624, Die B, min, kN/m		17	26	26	26	26	26	26
G21	Tear resistance, Test Method D 624, Die C, min, kN/m		17	26	26	26	26	26	26
K11	Adhesion, Test Methods D 429, Method A, min, MPa			1.4	2.8	2.8	1.4	2.8	2.8
P2	Staining resistance, Test Methods D 925, Method B, control panel		pass	pass	pass	pass	pass	pass	pass
R11	Resilience in compression, Test Methods D 945, min, %		70	50	60				
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.								

[A]Basic properties only—no suffix requirements for Grade No. 1.

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TABLE 6 *Continued*

CE MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 125°C	*Oil Immersion, Test* Method D 471, No. 3 Oil,[A] 70 h at 125°C	*Compression Set, Test* Methods D 395, Solid, max, %, 22 h at 70°C	Available Suffix Grade Numbers
	MPa	psi					
50	14	2031	400				2, 3
60	10	1450	350				2, 3
60	14	2031	400				2, 3
60	17	2466	400	Change in tensile strength, ±30 %			2, 3
70	7	1015	200	Change in ultimate elongation, –50 % max	Volume change, +80 % max	Compression set, 80 % max	2, 3
70	10	1450	250				2, 3
70	14	2031	300	Change in durometer hardness,± 15 points			2, 3
70	17	2466	300				2, 3
80	7	1015	200				2, 3
80	10	1450	250				2, 3
80	14	2031	250				2, 3

[A]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

CE MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A16	Heat resistance, Test Method D 573, 70 h at 150°C:								
	Change in hardness, points		±20						
	Change in tensile strength, %		±30						
	Change in ultimate elongation, max, %		–60						
B15	Compression set, Test Methods D 395, Method B, max, %, 22 h at 125°C		60	80					
C12	Resistance to ozone, Test Method D 1171, quality retention rating, min, %		†	†					
C20	Resistance to outdoor aging, Test Method D 1171		†	†					
F19	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at –55°C		pass	pass					
P2	Staining resistance, Test Methods D 925, Method B, control panel		pass	pass					
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.								

[A]Basic properties only—no suffix requirements for Grade No. 1.

† The requirement is applicable, and materials are available having these characteristics, but values have not yet been established.

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TABLE 6 *Continued*

CH MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 865, 70 h at 125°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 125°C	Compression Set, Test Methods D 395, Solid, max, %, 22 h at 100°C	Available Suffix Grade Numbers
	MPa	psi					
60	3	435	200				2, 3
60	6	870	200	2, 3			
60	7	1015	250	2, 3			
60	8	1160	250	2, 3			
60	10	1450	300	2, 3, 5, 6			
60	14	2031	350	2, 3			
60	17	2466	350	2, 3			
70	3	435	150	2, 3			
70	6	870	150	Change in tensile strength,			2, 3
70	7	1015	200	±30 %			2, 3
70	8	1160	200	Change in ultimate	Volume change,	Compression set,	2, 3
70	10	1450	250	elongation, −50 % max	+30 % max	50 % max	2, 3
70	14	2031	250	Change in durometer			2, 3, 5, 6
70	17	2466	300	hardness, ± 15 points			2, 3
80	3	435	100	3, 4			
80	7	1015	100	3, 4			
80	10	1450	125	3, 4			
80	14	2031	125	3, 4, 5, 6			
90	3	435	50	3, 4			
90	7	1015	100	3, 4			
90	10	1450	100		3, 4, 5, 6		

[A]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

CH MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A25	Heat resistance, Test Method D 865, 70 h 125°C:								
	Change in hardness, points		0 to +15	0 to +15	0 to +15	0 to +10	0 to +10		
	Change in tensile strength, max, %		−25	−25	−25	−10	−20		
	Change in ultimate elongation, max, %		−50	−50	−50	−40	−30		
B14	Compression set, Test Methods D 395, Method B, max, %, 22 h at 100°C		25	25	25	30	25		
B34	Compression set, Test Methods D 395, Method B, max, %, 22 h at 100°C		25	25		30	25		
C12	Resistance to ozone retention rating, Test Method D 1171					100	100		
C20	Resistance to outdoor aging, Test Method D 1171					†	†		
EF31	Fluid resistance, Test Method D 471, Reference Fuel C, 70 h at 23°C:								
	Change in hardness, points		0 to −30		0 to −30	0 to −20	0 to −20		
	Change in tensile strength, max, %		−60		−60	−50	−50		
	Change in ultimate elongation, max, %		−60		−60	−60	−50		
	Change in volume, %		0 to +50		0 to +50	0 to +40	0 to +40		

[A]Basic properties only—no suffix requirements for Grade No. 1

† The requirement is applicable, and materials are available having these characteristics, but values have not yet been established.

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TABLE 6 *Continued*

CH MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
EO15	Fluid resistance, Test Method D 471, No. 1 Oil, 70 h at 125°C:								
	Change in hardness, points		0 to +10		0 to +10				
	Change in tensile strength, max, %		−20		−20				
	Change in ultimate elongation, max, %		−35		−35				
	Change in volume, %		−15 to +5		−15 to +5				
EO16	Fluid resistance, Test Method D 471, No. 1 Oil, 70 h at 150°C:								
	Change in hardness, points			0 to +10					
	Change in tensile strength, max, %			−20					
	Change in ultimate elongation, max, %			−40					
	Change in volume, %			−15 to +5					
EO35	Fluid resistance, Test Method D 471, No. 3 Oil,[B] 70 h at 125°C:								
	Change in hardness, points		±10		±10				
	Change in tensile strength, max, %		−15		−15				
	Change in ultimate elongation, max, %		−30		−30				
	Change in volume, %		0 to +25		0 to +25				
EO36	Fluid resistance, Test Method D 471, No. 3 Oil,[B] 70 h at 150°C:								
	Change in hardness, points			±10		−5 to +10	−5 to +10		
	Change in tensile strength, max, %			−35		−10	−15		
	Change in ultimate elongation, max, %			−35		−50	−40		
	Change in volume, %			0 to +25		0 to +10	0 to +15		
F14	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −18°C					pass			
F16	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −35°C				pass				
F17	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −40°C		pass				pass		
K11	Adhesion, Test Methods D 429, Method A, MPa		*c*	*c*	*c*	*c*			
Z	(Special requirements) Any requirements shall be specified in detail, including test methods.								

[A] Basic properties only—no suffix requirements for Grade No. 1

[B] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

[C] Materials are available that can be bonded to metal during vulcanization. Because of the wide variety of compounds in use, combined with manifold end-use requirements, no values are shown. Test Methods D 429 and requirements should be agreed upon by the supplier and user.

† The requirement is applicable, and materials are available having these characteristics, but values have not yet been established.

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TABLE 6 *Continued*

DA MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 150°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 150°C	Compression Set, Test Methods D 395, Plied, max, %, 22 h at 150°C	Available Suffix Grade Numbers
	MPa	psi					
50	7	1015	300				2
50	10	1450	300				2
50	14	2031	350				2
60	7	1015	250				2,3
60	10	1450	250	Change in tensile strength, ±30 %		Compression set, 50 % max	2,3
60	14	2031	300	Change in ultimate elongation, – 50 % max	No Requirement		2,3
70	7	1015	200	Change in durometer hardness, ±15 points			2,3
70	10	1450	200				2,3
70	14	2031	200				2,3
80	7	1015	150				2,3
80	10	1450	150				2,3
80	14	2031	150				2,3

[A]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

DA MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A26	Heat resistance, Test Methods D 865, 70 h at 150°C:								
	Change in hardness, max, points		+10	+10					
	Change in tensile strength, max, %		–20	–20					
	Change in ultimate elongation, max, %		–20	–20					
B36	Compression set, Test Methods D 395, Method B, 22 h at 150°C, plied, max, %		40	25					
C32	Resistance to ozone, Test Method D 1171, Exposure, Method B		pass	pass					
EA14	Water resistance, Test Method D 471, 70 h at 100°C, volume change, %		±5	±5					
F19	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at –55°C		pass	pass					
G11	Tear resistance, Test Method D 624, Die B, min, kN/m		17	17					
G21	Tear resistance, Test Method D 624, Die C, min, kN/m		17	17					
K11	Adhesion, Test Methods D 429, Method A, min, MPa			1.4					
P2	Staining resistance, Test Methods D 925, Method B, control panel		pass	pass					
R11	Resilience in compression, Test Methods D 945, min, %		60	60					
Z	(Special requirements) Any special requirement shall be specified in detail, including test methods.								

[A]Basic properties only—no suffix requirements for Grade No. 1

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TABLE 6 *Continued*

DE MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 150°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 150°C	Compression Set, Test Methods D 395, Method B, Solid, max, %, 22 h at 125°C	Available Suffix Grade Numbers
	MPa	psi					
60	10	1450	350				2
60	14	2031	400				2,3
60	17	2466	400				2,3,4
70	7	1015	200	Change in durometer hardness, ±15 points			2
70	10	1450	250				5
70	14	2031	300	Change in tensile strength, ±30 %	Volume change, +80 % max	Compression set, +80 % max	6
70	17	2466	300				
80	7	1015	200	Change in ultimate elongation, −50 % max			
80	10	1450	200				2
80	14	2031	250				
90	10	1450	150				
90	14	2031	150				5

[A] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

DE MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
A16	Heat resistance, Test Method D 573, 70 h at 150°C:		15	15	15		15
	Change in hardness, points		30	30	30		30
	Change in tensile strength, %		−30	−30	−30		−30
	Change in ultimate elongation, max, %						
B15	Compression set, Test Methods D 395, Method B, 22 h at 125°C, max, %		55	35	25	35	30
C12	Resistance to ozone, Test Method D 1171		[B]	[B]	[B]	[B]	[B]
EO36	Fluid resistance, Test Method D 471, No. 3 Oil, 70 h at 150°C:						
	Volume change, max, %		+70	+70		+60	
F16	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −35°C		pass			pass	
F17	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −40°C			pass	pass		pass
Z	(Special Requirements) Any special requirement shall be specified in detail, including test methods.						

[A] Basic properties only—no-suffix requirements for Grade No. 1.
[B] The requirement is applicable, and materials are available having these characteristics, but values have not yet been established.

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TABLE 6 *Continued*

DF MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 865, 70 h at 150°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 150°C	Compression Set, Test Methods D 395, Solid, max, %, 22 h at 150°C	Available Suffix Grade Numbers
	MPa	psi					
40	6	870	225			80	2
50	7	1015	225			80	2
60	8	1160	175	Change in tensile strength, ±30 %		80	2
70	6	870	100	Change in ultimate elongation, −50 % max	Volume change, + 60 % max	90	5
70	8	1160	150	Change in durometer hardness,± 15 points		80	2
80	6	870	100			90	5
80	8	1160	150			80	3
90	7	1015	125			85	4

[A]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

DF MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A26	Heat resistance, Test Method D 865, 70 h at 150°C:								
	Change in hardness, max, points		+10	+10	+10	+10			
	Change in tensile strength, max, %		−25	−25	−25	−25			
	Change in ultimate elongation, max, %		−30	−30	−30	−30			
B16	Compression set, Test Methods D 395, Method B, max, %, 22 h at 150°C		50	60	75	80			
B36	Compression set, Test Methods D 395, Method B, max, %, 22 h at 150°C		75	80	85				
C12	Resistance to ozone, Test Method D 1171, quality retention rating, min, %		†	†	†	†			
C20	Resistance to weather aging, Test Method D 1171		†	†	†	†			
EO16	Fluid resistance, Test Method D 471, No. 1 Oil, 70 h at 150°C:								
	Change in hardness, points		−8 to +15	−8 to +10	−8 to +10	−8 to +10			
	Change in tensile strength, max, %		−20	−20	−20	−30			
	Change in ultimate elongation, max, %		−30	−30	−30	−50			
	Change in volume, %		−5 to +10	−5 to +10	−5 to +10	−5 to +10			
EO36	Fluid resistance, Test Method D 471, No. 3 Oil, 70 h at 150°C:								
	Change in hardness, max, points		−30	−30	−30	−30			
	Change in tensile strength, max, %		−60	−60	−60	−60			
	Change in ultimate elongation, max, %		−40	−30	−30	−50			
	Change in volume, %		+50	+50	+50	+50			
F14	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −18°C			pass	pass	pass			
F15	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −25°C		pass						
K11	Adhesion, Test Methods D 429, Method A, min, MPa		1.4	1.4	1.4	1.4			
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.								

[A]Basic properties only—no suffix requirements for Grade No. 1.

† The requirement is applicable, and materials are available having these characteristics, but values have not yet been established.

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TABLE 6 *Continued*

DH MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 865, 70 h at 150°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 150°C	Compression Set, Test Methods D 395, Solid, max, %, 22 h at 150°C	Available Suffix Grade Numbers
	MPa	psi					
40	7	1015	300			60	2
50	8	1160	250			60	2
60	8	1160	200			60	2
60	9	1450	200	Change in tensile strength, ±30 %		60	2
60	14	2031	250			40	4
70	6	870	100	Change in ultimate elongation, −50 % max	Volume change, +30 % max	75	5
70	8	1160	200			60	3
70	10	1450	200	Change in durometer hardness, ±15 points		60	3
70	16	2321	250			40	4
80	6	870	100			75	5
80	8	1160	175			60	3
80	10	1450	175			60	3
80	20	2900	150			40	4
90	10	1450	100			60	3
90	20	2900	100			45	

[A] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

DH MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A26	Heat resistance, Test Method D 865, 70 h at 150°C:								
	Change in hardness, max, points		+10	+10	+10	+10			
	Change in tensile strength, max, %		−25	−25	−15	−25			
	Change in ultimate elongation, max, %		−30	−30	−25	−30			
B16	Compression set, Test Methods D 395, Method B, max, %, 22 h at 150°C		30	30		60			
B36	Compression set, Test Methods D 395, Method B, max, %, 22 h at 150°C		50	50	35				
C12	Resistance to ozone, Test Method D 1171, quality retention rating, min, %		†	†	†	†			
C20	Resistance to outdoor aging, Test Method D 1171		†	†	†	†			
EO16	Fluid resistance, Test Method D 471, No. 1 Oil, 70 h at 150°C:								
	Change in hardness, points		−5 to +10	−5 to +10	−5 to +10	−5 to +10			
	Change in tensile strength, max, %		−20	−20	−20	−20			
	Change in ultimate elongation, max, %		−30	−30	−30	−40			
	Change in volume, %		±5	±5	−10 to +5	±5			
EO36	Fluid resistance, Test Method D 471, No. 3 Oil, 70 h at 150°C:								
	Change in hardness, max, points		−15	−15	−15	−15			
	Change in tensile strength, max, %		−40	−30	−40	−40			
	Change in ultimate elongation, max, %		−40	−30	−30	−40			
	Change in volume, %		+25	+25	+25	+25			
F13	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at − 10°C			pass		pass			
F14	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at − 18°C		pass						
F17	Low-temperature resistance, Test Method D 2137, Method A, 9.3.2, nonbrittle after 3 min at −40°C				pass				
K11	Adhesion, Test Methods D 429, Method A, bonded during vulcanization, min, MPa		1.4	1.4		1.4			
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.								

[A] Basic properties only—no suffix requirements for Grade No. 1.

† The requirement is applicable, and materials are available having these characteristics, but values have not yet been established.

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TABLE 6 *Continued*

EE MATERIALS

Basic Requirements						
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 865, 70 h at 175°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 150°C	Compression Set, Test Methods D 395, Method B, Solid, max, %, 22 h at 150°C	Available Suffix Grade Numbers
	MPa	psi					
50	8	1160	400				3
50	10	1450	500				3
50	12	1740	500				
50	14	2031	500				
60	6	870	200				4
60	8	1160	300				3,4,5
60	12	1740	300				3
60	14	2031	400	Change in durometer hardness, ±15 points			3
70	8	1160	200	Change in tensile strength, ±30 %	Volume change, +80 % max	Compression set, 75 % max	3,4,5
70	10	1450	200				4
70	12	1740	300	Change in ultimate elongation, –50 % max			3
80	10	1450	200				4
80	12	1740	200				3,4
80	14	2031	200				3,4,5
80	16	2320	200				3
90	6	870	100				4
90	10	1450	100				3
90	14	2031	100				

[A]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

EE MATERIALS

	Suffix Requirements	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A47	Heat resistance, Test Method D 573, 168 h at 175°C:								
	Change in hardness, max, points	Basic requirements only		+10	+20	+10			
	Change in tensile strength, max, %	Basic requirements only		–30	–30	–30			
	Change in ultimate elongation, max, %	Basic requirements only		–50	–65	–50			
B46	Compression set, Test Methods D 395, Method B, plied, 70 h at 150°C, max, %	Basic requirements only		50	75	50			
B37	Compression set, Test Methods D 395, Method B, plied, 22 h at 175°C, max, %	Basic requirements only		50	75	50			
EO16	Fluid resistance, Test Method D 471, No. 1 Oil, 70 h at 150°C:								
	Change in hardness, max, points	Basic requirements only		–10 to +5	–10 to +5	–10 to +5			
	Change in tensile strength, max, %	Basic requirements only		–25	–25	–25			
	Change in ultimate elongation, max, %	Basic requirements only		–35	–35	–35			
	Change in volume, %	Basic requirements only		±15	±10	±10			
EO36	Fluid resistance, Test Method D 471, No. 3 Oil,[A] 70 h at 150°C:								
	Change in tensile strength, max, %	Basic requirements only		–60	–50	–50			
	Change in ultimate elongation, max, %	Basic requirements only		–55	–50	–50			
	Change in volume, max, %	Basic requirements only		+70	+60	+50			
EA14	Water resistance, Test Method D 471, 70 h at 100°C:								
	Change in volume, max, %	Basic requirements only		+15	+15	+15			
F17	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at – 40°C	Basic requirements only		pass	pass	pass			
G21	Tear resistance, Test Method D 624, Die C, min, kN/M	Basic requirements only		20	20				

[A]Change in Hardness values are omitted because the round robin data did not support them statistically.

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TABLE 6 *Continued*

EH MATERIALS

Basic Requirements

Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, ASTM D 865, 70 h at 175°C	Oil Immersion, ASTM D 471, No. 3 Oil,[A] 70 h at 150°C	Compression Set, ASTM D 395, Solid, max, %, 22 h at 150°C	Available Suffix Grade Numbers
	MPa	psi					
40	7	1015	250			75	3
50	8	1160	175			75	3
60	6	870	100	Change in durometer		75	3
60	9	1306	150	hardness,± 15 points Change in tensile strength, ±30 %	Volume change, ±30 %	75	3
70	6	870	100	Change in ultimate elonga-		75	3
70	9	1306	125	tion, –50 % max		75	3
80	7	1015	100			75	3

[A]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM 903 oil. See 4.4.1.

EH MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A27	Heat resistance, Test Method D 865, 70 h at 175°C:								
	Change in hardness, max, points			+10					
	Change in tensile strength, max, %			–30					
	Change in ultimate elongation, max, %			–40					
B17	Compression set, ASTM D 395, Method B, 22 h at 175°C, solid max, %			60					
B37	Compression set, ASTM D 395, Method B, 22 h at 175°C, plied, max, %			60					
E016	Fluid resistance, ASTM D 471, No. 1 Oil, 70 h at 150°C:								
	Change in hardness, points			±5					
	Change in tensile strength, max, %			–20					
	Change in ultimate elongation, max, %			–30					
	Change in volume, %			±5					
EO36	Fluid resistance, ASTM D 471, No.3 Oil,[B] 70 h at 150°C:								
	Change in hardness, points			–20					
	Change in tensile strength, max, %			–40					
	Change in ultimate elongation, max, %			–30					
	Change in volume, %			+25					
F14	Low-temperature resistance, ASTM D 2137, Method A, Pass, °C			pass					
F25	Low-temperature resistance, ASTM D 1053, T100, Pass,° C			pass					
K11	Adhesion, ASTM D 429, Method A, min, MPa			1.4					
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.								

[A]Basic properties only—no suffix requirements for Grade No. 1

[B]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM 903 oil. See 4.4.1.

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TABLE 6 *Continued*

EK MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, ASTM D 573, 70 h at 150°C	Oil Immersion, ASTM D 471, No. 3 Oil,[A] 70 h at 150°C	Compression Set, ASTM D 395, Solid, max, %, 22 h at 150°C	Available Suffix Grade Numbers
	MPa	psi					
50	9	1305	125	Change in durometer hardness, ±15 points	Volume change, ±10 % max	60	2
70	10	1450	125	Change in tensile strength, ±30 %		60	2
80	10	1450	100	Change in ulitmate elongation, −50 % max		60	2

[A]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM 903 oil. See 4.4.1.

EK MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A17	Heat resistance, ASTM D 573, 70 h at 175°C:								
	Change in hardness, points		±10						
	Change in tensile strength, %		−25						
	Change in ultimate elongation, max, %		−20 to +30						
A18	Heat aging resistance, ASTM D 573, 70 h at 200°C:								
	Change in hardness, points		−15 to +10						
	Change in tensile strength, max, %		−60						
	Change in ultimate elongation, %		−10 to +40						
B17	Compression set, ASTM D 395, Method B, solid, 22 h at 175°C, max, %		60						
B26	Compression set, ASTM D 395, Method B, solid, 70 h at 150°C, max %		50						
C32	Resistance to ozone, ASTM D 1171, Method B		pass						
EA14	Fluid resistance to ASTM D 471, water, 70 g at 100°C								
	Change in hardness, points		−5 to +10						
	Change in volume		0 to +20						
EF31	Fluid resistance, ASTM D 471, Reference Fuel C, 70 h at room temperature								
	Change in hardness, points		−20 to +5						
	Change in tensile strength, max, %		−50						
	Change in ultimate elongation, max, %		−50						
	Change in volume, max, %		+40						
EO16	Fluid resistance, ASTM D 471, No. 1 Oil, 70 h at 150°C:								
	Change in hardness, points		−10 to +5						
	Change in tensile strength, max, %		−10						
	Change in ultimate elongation, max, %		−20						
	Change in volume, max %		+10						
E036	Fluid resistance, ASTM D 471, No. 3 Oil,[B] 70 h at 150°C:								
	Change in hardness, points		−15 to 0						
	Change in tensile strength, max, %		−20						
	Change in ultimate elongation, max, %		−20						
	Change in volume, max, %		+10						
F19	Low-temperature resistance, ASTM D 2137, Method A, 9.3.2, nonbrittle after 3 min at −55°C		pass						
F49	Low-temperature resistance, ASTM D 1329, after 10 min at −55°C, 10 % retraction, min		pass						

[A]Basic properties only—no suffix requirements for Grade No. 1.

[B]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM 903 oil. See 4.4.1.

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TABLE 6 *Continued*

FC MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 200°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 150°C	Compression Set, Test Methods D 395, Plied, max, %, 22 h at 175°C	Available Suffix Grade Numbers
	MPa	psi					
30	3	435	350			60	2
30	5	725	400			60	2
40	7	1015	400	Change in tensile strength, ±30 %		60	3
50	7	1015	400	Change in ultimate elongation, – 50 % max	Volume change, +120 % max	60	3
50	8	1160	500			80	4
60	7	1015	300	Change in durometer hardness, ±15 points		60	3
60	8	1160	400			80	4
70	7	1015	200			60	3

[A]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

FC MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A19	Heat resistance, Test Method D 573, 70 h at 225°C:								
	Change in hardness, max, points		+10	+10	+15				
	Change in tensile strength, max, %		–40	–40	–50				
	Change in ultimate elongation, max, %		–40	–40	–50				
B37	Compression set, Test Methods D 395, Method B, max, %, 22 h at 175°C		40	45	60				
C12	Resistance to ozone, Test Method D 1171, quality retention rating, min, %		†	†	†				
C20	Resistance to outdoor aging, Test Method D 1171		†	†	†				
EA14	Water resistance, Test Method D 471, 70 h at 100°C:								
	Change in hardness, points		±5	±5	±5				
	Change in volume, %		±5	±5	±5				
EO16	Fluid resistance, Test Method D 471, No. 1 Oil, 70 h at 150°C:								
	Change in hardness, points		0 to –10	0 to –15	0 to –15				
	Change in tensile strength, max, %		–50	–50	–50				
	Change in ultimate elongation, max, %		–30	–50	–50				
	Change in volume, %		0 to +20	0 to +20	0 to +20				
F1-11	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at – 75°C		pass	pass	pass				
G11	Tear resistance, Test Method D 624, Die B:								
	Under 7.0 MPa load, min, kN/m		5						
	7.0 to 10.5 MPa load, min, kN/m			17	26				
Z	(Special requirements) Any special requirement shall be specified in detail, including test methods.								

[A]*Basic properties only—no suffix requirements for Grade No. 1.*

† The requirement is applicable, and materials are available having these characteristics, but values have not yet been established.

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TABLE 6 *Continued*

FE MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 200°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 150°C	Compression Set, Test Methods D 395, Solid, max, %, 22 h at 175°C	Available Suffix Grade Numbers
	MPa	psi					
30	3	435	400	Change in tensile strength, ±30 %	Volume change, +80 % max	60	2
30	7	1015	500	Change in ultimate elongation, −50 % max		60	5
40	8	1160	500	Change in durometer hardness, ±15 points		60	3
50	8	1160	500			80	4

[A]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

FE MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5
A19	Heat resistance, Test Method D 573, 70 h at 225°C:					
	Change in hardness, max, points		+10	+10	+15	±10
	Change in tensile strength, max, %		−60	−40	−40	−50
	Change in ultimate elongation, max, %		−60	−60	−60	−50
B37	Compression set, Test Methods D 395, Method B, max, %, 22 h at 175°C		45	50	65	35
C12	Resistance to ozone, Test Method D 1171, quality retention rating, min, %		†	†	†	
C20	Resistance to outdoor aging, Test Method D 1171		†	†	†	
EA14	Water resistance, Test Method D 471, 70 h at 100°C:					
	Change in hardness, points		±5	±5	±5	±5
	Change in volume, %		±5	±5	±5	±5
EO16	Fluid resistance, Test Method D 471, No. 1 Oil, 70 h at 150°C:					
	Change in hardness, points		0 to −10	0 to −10	0 to −10	0 to −10
	Change in tensile strength, max, %		−50	−50	−50	−40
	Change in ultimate elongation, max, %		−50	−50	−50	−40
	Change in volume, %		0 to +20	0 to +20	0 to +20	0 to +20
EO36	Fluid resistance, Test Method D 471 No. 3 Oil, 70 h at 150°C:					
	Change in hardness, max, points			†	−40	
	Change in volume, %			+ 80	+80	+65
F19	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −55°C		pass	pass	pass	
G11	Tear resistance, Test Method D 624, Die B:					
	Under 7.0 MPa load, min, kN/m		9			
	7.0 to 10.5 MPa load, min, kN/m			22	26	25
K11	Adhesion, Test Methods D 429, Method A		†	†	†	
K21	Adhesion, Test Methods D 429, Method B		†	†	†	
K31	Bond after vulcanization		*B*	*B*	*B*	*B*
P2	Staining resistance, Test Methods D 925, Method B, control panel		pass	pass	pass	
Z	(Special requirements) Any special requirement shall be specified in detail, including test methods.					

[A]Basic properties only—no suffix requirements for Grade No. 1.

[B]Suffix K31 indicates that the materials shall be free of surface conditions and compound constituents that are or may become deleterious to cement adhesion.

† The requirement is applicable, and materials are available having these characteristics, but values have not yet been established.

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TABLE 6 *Continued*

FK MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 200°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 150°C	Compression Set, Test Methods D 395, Plied, max, %, 22 h at 175°C	Available Suffix Grade Numbers
	MPa	psi					
60	6	870	150	Change in tensile strength, ±30 % Change in ultimate elongation, −50 % max Change in durometer hardness, ±15 points	Volume change, +10 % max	50	2

[A]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

FK MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A19	Heat resistance, Test Method D 573, 70 h at 225°C:								
	Change in hardness, max, points		+15						
	Change in tensile strength, max, %		−45						
	Change in ultimate elongation, max, %		−45						
C12	Resistance to ozone, Test Method D 1171, quality retention rating, min, %		†						
C20	Resistance to outdoor aging, Test Method D 1171		†						
EF31	Fluid resistance, Test Method D 471, Reference Fuel C, 70 h at 23°C:								
	Change in hardness, points		0 to − 15						
	Change in tensile strength, max, %		−60						
	Change in ultimate elongation, max, %		−50						
	Change in volume, %		0 to +25						
EO36	Fluid resistance, Test Method D 471, No. 3 Oil,[B] 70 h at 150°C:								
	Change in hardness, points		0 to −10						
	Change in tensile strength, max, %		−35						
	Change in ultimate elongation, max, %		−30						
	Change in volume, %		0 to +10						
F19	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at −55°C		pass						
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.								

[A]Basic properties only—no suffix requirements for Grade No. 1.
† The requirement is applicable, and materials are available having these characteristics, but values have not yet been established.
[B]ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

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TABLE 6 *Continued*

GE MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 225°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 150°C	Compression Set, Test Methods D 395, Plied, max, %, 22 h at 175°C	Available Suffix Grade Numbers
	MPa	psi					
30	3	435	300			50	2
30	5	725	400			50	2
30	6	870	400			50	8
40	3	435	200			50	2
40	5	725	300			50	2
40	6	870	300			50	8
50	3	435	200			50	3
50	5	725	250	Change in tensile strength, ±30 %		70	4, 5
50	6	870	250			50	5
50	8	1160	400	Change in ultimate elongation, −50 % max	Volume change, +80 % max	60	9
60	3	435	100	Change in durometer hardness, ± 15 points		50	3
60	5	725	200			70	4, 5
60	6	870	200			50	5
70	3	435	60			50	6
70	5	725	150			50	7
70	6	870	150			50	5
80	3	435	50			50	6
80	5	725	150			50	7
80	6	870	100			50	5

[A] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

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TABLE 6 *Continued*

GE MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8	Grade 9
A19	Heat resistance, Test Method D 573, 70 h at 225°C:									
	Change in hardness, max, points		+10	+10	+10	+10	+10	+10	+10	+10
	Change in tensile strength, max, %		–25	–25	–30	–25	–25	–25	–25	–30
	Change in ultimate elongation, max, %		–30	–30	–30	–30	–30	–30	–25	–30
B37	Compression set, Test Methods D 395, Method B, max, %, 22 h at 175°C		25	30	50	25	30	30	25	40
C12	Resistance to ozone, Test Method D 1171, quality retention rating, min, %		†	†	†	†	†	†	†	†
C20	Resistance to outdoor aging, Test Method D 1171		†	†	†	†	†	†	†	†
EA14	Water resistance, Test Method D 471, 70 h at 100°C:									
	Change in hardness, points		±5	±5	±5	±5	±5	±5	±5	±5
	Change in volume, %		±5	±5	±5	±5	±5	±5	±5	±5
EO16	Fluid resistance, Test Method D 471, No. 1 Oil, 70 h at 150°C:									
	Change in hardness, points		0 to –10	0 to –15	0 to –15	0 to –15	0 to –15	0 to –15	0 to –10	0 to –10
	Change in tensile strength, max, %		–30	–20	–20	–20	–20	–20	–30	–30
	Change in ultimate elongation, max, %		–30	–20	–20	–20	–20	–20	–20	–30
	Change in volume, %		0 to +15	0 to +10	0 to +15	0 to +10	0 to +10	0 to +15	0 to +15	0 to +10
EO36	Fluid Resistance, Test Method D 471, No. 3 Oil,[B] 70 h at 150°C:									
	Change in hardness, max, points			–30	–35	–30	–40	–40	†	–30
	Change in volume, %		+60	+60	+60	+60	+60	+60	+60	+60
F19	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at –55°C		pass	pass	pass	pass	pass	pass	pass	pass
G11	Tear resistance, Test Method D 624, Die B:									
	Under 7.0 MPa load, min, kN/m		5	6	9	9	5	9	9	
	7.0 to 10.5 MPa load, min, kN/m									25
K11	Adhesion, Test Method D 429, Methods A		†	†	†	†	†	†	†	†
K21	Adhesion, Test Method D 429, Methods B		†	†	†	†	†	†	†	†
K31	Bond after vulcanization		c	c	c	c	c	c	c	c
P2	Staining resistance, Test Methods D 925, Method B, control panel		pass	pass	pass	pass	pass	pass	pass	pass
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.									

[A] Basic properties only—no suffix requirements for Grade No. 1.

[B] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

† The requirement is applicable, and materials are available having these characteristics, but values have not yet been established.

[C] Suffix K31 indicates that the materials shall be free of surface conditions and compound constitutents that are or may become deleterious to cement adhesion.

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TABLE 6 *Continued*

HK MATERIALS

Basic Requirements							
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 250°C	Oil Immersion, Test Method D 471, No. 3 Oil,[A] 70 h at 150°C	Compression Set, Test Methods D 395, Plied, max, %, 22 h at 175°C	Available Suffix Grade Numbers
	MPa	psi					
60	7	1015	200				2, 4, 6
60	10	1450	200				2, 4, 6
60	14	2031	200				2, 4, 6
70	7	1015	175	Change in durometer hardness, ±15 points Change in tensile strength, ±30 % Change in ultimate elongation, −50 % max	Volume change, +10 % max	Compression set, 35 % max	2, 4, 6
70	10	1450	175				2, 4, 6
70	14	2031	175				2, 4, 6
80	7	1015	150				2, 4, 6
80	10	1450	150				2, 4, 6
80	14	2031	150				2, 4, 6
90	7	1015	100				3, 5, 7
90	10	1450	100				3, 5, 7
90	14	2031	100				3, 5, 7

[A] ASTM Oil No. 3 is no longer commercially available. It has been replaced by IRM903 oil. See 4.4.1.

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TABLE 6 *Continued*

HK MATERIALS

	Suffix Requirements	Grade 1[A]	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
A1-10	Heat resistance, Test Method D 573, 70 h at 250°C:								
	Change in hardness, max, points		+10	+10			+10	+10	
	Change in tensile strength, max, %		–25	–25			–25	–25	
	Change in ultimate elongation, max, %		–25	–25			–25	–25	
A1-11	Heat resistance, Test Method D 573, 70 h at 275°C:								
	Change in hardness, max, points				+10	+10	–5 to +10	–5 to +10	
	Change in tensile strength, max, %				–40	–40	–40	–40	
	Change in ultimate elongation, max, %				–20	–20	–20	–20	
B31	Compression set, Test Methods D 395, Method B, 22 h at 23°C						15	20	
B37	Compression, set, Test Methods D 395, Method B, max, %, 22 h at 175°C		50	30					
B38	Compression set, Test Methods D 395, Method B, max, %, 22 h at 200°C		50	50	50	50	15	20	
C12	Resistance to ozone, Test Method D 1171, quality retention rating, min, %		no cracks	no cracks	no cracks	no cracks	no cracks	no cracks	
C20	Resistance to outdoor aging, Test Method D 1171		no cracks	no cracks	no cracks	no cracks	no cracks	no cracks	
EF31	Fluid resistance, Test Method D 471, Reference Fuel C, 70 h at 23°C:								
	Change in hardness, points		±5	±5	±5	±5	±5	±5	
	Change in tensile strength, max, %		–25	–25	–25	–25	–25	–25	
	Change in ultimate elongation, max, %		–20	–20	–20	–20	–20	–20	
	Change in volume, %		0 to +10	0 to +10	0 to +10	0 to +10	0 to +10	0 to +10	
EO78	Fluid resistance, Test Method D 471, Service Liquid[B] No. 101, 70 h at 200°C:								
	Change in hardness, points		–15 to +5	–15 to +5	–15 to +5	–15 to +5			
	Change in tensile strength, max, %		–40	–40	–40	–40			
	Change in ultimate elongation, max, %		–20	–20	–20	–20			
	Change in volume, %		0 to +15	0 to +15	0 to +15	0 to +15			
EO88	Fluid resistance, Test Method D 471 SAE Fluid No. 2, Blend 7700[C] 70 h at 200°C:								
	Change in hardness, points						–15 to +5	–15 to +5	
	Change in tensile strength, max, %						–40	–40	
	Change in ultimate elongation, max, %						–20	–20	
	Change in volume, %						+25	+25	
F15	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at –25°C		pass			pass	pass		
F17	Low-temperature resistance, Test Methods D 2137, Method A, 9.3.2, nonbrittle after 3 min at –40°C				pass				
Z	(Special requirements) Any special requirements shall be specified in detail, including test methods.								

[A] Basic properties only—no suffix requirements for Grade No. 1.
[B] Service Liquid No. 101– di-2 ethyl hexyl sebacate, 99.5 mass %; phenothiazine, 0.5 mass %
[C] SAE Fluid No. 2, Blend 7700 is available from AKZO Nobel Chemicals, Inc. 5 Livingstone Avenue, Debbs Ferry, NY 10522, 1-800-666-1200.

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TABLE 6 *Continued*

KK MATERIALS[A]						
Basic Requirements						
Durometer Hardness, ±5 Points	Tensile Strength, min		Ultimate Elongation, min, %	Heat Aged, Test Method D 573, 70 h at 300°C	Oil Immersion, Test Method D 471, IRM 903 Oil, 70 h at 150°C	Compression Set, Test Methods D 395, Method B, Plied max, %, 22 h at 200°C
	MPa	psi				
80	11	1595	125	Change in durometer hardness, ±15 points Change in tensile strength, ±30% Change in ultimate elongation, -50% max	Volume change, (+ 10 % max)	Compression set, 25 % max

[A]Supporting data are available from ASTM headquarters. Request RR: D11–1090.

ANNEX

(Mandatory Information)

A1. Statement of Understanding between SAE CARS and ASTM D11.30

A1.1 The SAE Committee on Automotive Rubber Specifications, (CARS), and the ASTM D11.30 committee affirm that we will work together to maintain the SAE J200 and ASTM D 2000 specification systems. It is our goal to keep the tables in these two documents equivalent. As such, the SAE CARS will be the gatekeeper of any changes and additions to the tables in these specification systems. They will consider, as necessary, the expansion of current tables or the addition of new tables based on new rubber materials that will better serve both the rubber industry and their customers. SAE CARS may ask for assistance from ASTM D11.30 to provide the necessary laboratories for performing the required interlaboratory testing. In the unlikely event that SAE CARS declines to make any additions or changes to the tables, then ASTM D11.30 may choose to proceed with making those changes or additions if they deem them as additive for the rubber industry.

APPENDIX

(Nonmandatory Information)

X1. TYPE AND CLASS OF POLYMER USAGE

X1.1 This appendix is intended to assist the users of Classification System D 2000-SAE J200 and is not to be considered as part of the system. Table X1.1 lists the Classification System D 2000-SAE J200 material designations (type and class) and the type of polymer most often used in meeting the material requirements (type and class). This table is not intended to be limiting; other polymers may be used to meet the same specification.

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TABLE X1.1 Polymers Most Often Used in Meeting Material Requirements

Classification System D2000-SAE J200 Material Designation (Type and Class)	Type of Polymer Most Often Used[A]
AA	Natural rubber, reclaimed rubber, SBR, butyl, EP polybutadiene, polyisoprene
AK	Polysulfides
BA	Ethylene propylene, high-temperature SBR and butyl compounds
BC	Chloroprene polymers (neoprene), cm
BE	Chloroprene polymers (neoprene), cm
BF	NBR polymers
BG	NBR polymers, urethanes
BK	NBR
CA	Ethylene propylene
CE	Chlorosulfonated polyethylene (Hypalon), cm
CH	NBR polymers, epichlorohydrin polymers
DA	Ethylene propylene polymers
DE	CM, CSM
DF	Polyacrylic (butyl-acrylate type)
DH	Polyacrylic polymers, HNBR
EE	AEM
EH	ACM
EK	FZ
FC	Silicones (high strength)
FE	Silicones
FK	Fluorinated silicones
GE	Silicones
HK	Fluorinated elastomers (Viton, Fluorel, etc.)
KK	Perfluoroelastomers

[A] Refer to Practice D 1418.

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Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR)[1]

This standard is issued under the fixed designation D 2282; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers acrylonitrile-butadienestyrene (ABS) pipe produced by single extrusion or simultaneous multiple coextrusion, in standard thermoplastic pipe dimension ratios and pressure rated for water (see Appendix). Included are criteria for classifying ABS plastic pipe materials and ABS plastic pipe, a system of nomenclature for ABS plastic pipe, and requirements and test methods for materials, workmanship, dimensions, sustained pressure, burst pressure, and extrusion quality. Methods of marking are also given.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 1—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious saftey hazards should a system fail for any reason.

1.3 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

1.5 The following safety hazards caveat pertains only to the test method portion, Section 7, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics for Testing[2]

D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure[3]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D 2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials[3]

D 3965 Specification for Rigid Acrylonitrile-Butadiene-Styrene (ABS) Compounds for Pipe and Fittings[4]

F 412 Terminology Relating to Plastic Piping Systems[3]

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[5]

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[6]

2.4 *NSF Standard:*

Standard No. 14 for Plastic Piping Components and Related Materials[5]

3. Terminology

3.1 General—Definitions are in accordance with Terminology F 412. Abbreviations are in accordance with Terminology D 1600, unless otherwise indicated. The abbreviation for acrylonitrile-butadiene-styrene plastic is ABS.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *acrylonitrile-butadiene-styrene (ABS) pipe and fitting plastics*—plastics containing polymers or blends of polymers, or both, in which the minimum butadiene content is 6 %, the minimum acrylonitrile content is 15 %, the minimum styrene or substituted styrene content, or both, is 15 %, and the

[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.61 on Water.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] Available from the National Sanitation Foundation, P.O. Box 1468, Ann Arbor, MI 48106.

[6] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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maximum content of all other monomers is not more than 5 %, and lubricants, stabilizers, and colorants.

3.2.2 *hydrostatic design stress*—the estimated maximum tensile stress the material is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur. This stress is circumferential when internal hydrostatic water pressure is applied.

3.2.3 *pressure rating (PR)*—the estimated maximum water pressure the pipe is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur.

3.2.4 *relation between standard dimension ratio, hydrostatic design stress, and pressure rating*—the following expression is used in this specification to relate standard dimension ratio, hydrostatic design stress, and pressure rating:

$$2S/P = R - 1 \text{ or } 2S/P = (D_O/t) - 1$$

where:

S = hydrostatic design stress, psi (or MPa),
P = pressure rating, psi (or MPa),
D_O = average outside diameter, in. (or mm),
t = minimum wall thickness, in. (or mm), and
R = standard thermoplastic pipe dimension ratio (D_O/t for ABS pipe), also known as SDR.

3.2.5 *standard thermoplastic pipe dimension ratio (SDR)*—the ratio of pipe diameter to wall thickness. For ABS pipe it is calculated by dividing the average outside diameter of the pipe in millimetres or in inches by the minimum wall thickness in millimetres or in inches. If the wall thickness calculated by this formula is less than 0.060 in. (1.52 mm), it shall be arbitrarily increased to 0.060 in. (1.52 mm). SDR values shall be rounded to the nearest 0.5.

3.2.6 *standard thermoplastic pipe materials designation code*—the pipe materials designation code shall consist of the abbreviation ABS for the type of plastic, followed by the ASTM type and grade (see Table X1.2), and the hydrostatic design stress in units of 100 psi with any decimal figures dropped. When the design stress code contains less than two figures, a cipher is used before the number. Thus a complete material code consists of three letters and four figures for ABS plastic pipe materials (see 4.3).

4. Materials

4.1 *General*—Acrylonitrile-butadiene-styrene plastics used to make pipe meeting the requirements of this specification are categorized by means of two criteria namely (*1*) short-term strength tests and (2) long-term strength tests.

4.2 *Basic Materials*—This specification covers ABS pipe made from three ABS plastics as defined in Specification D 3965, in which the requirements are based on short-term tests. These are ABS Classes 42222, 20643, and 30444.

4.3 *Hydrostatic Design Stress*—This specification covers ABS pipe made from ABS plastics as defined by four hydrostatic design stresses developed on the basis of long-term tests (Appendix X1.2).

4.4 *Compound*—The ABS plastic extrusion compound shall meet the requirements of ABS Classes 42222, 20643, or 30444 as described in Specification D 3965. For pipe produced by simultaneous multiple coextrusion, all layers shall be of the same formulation.

4.5 *Rework Material*—The manufacturers shall use only their own clean rework pipe material and the pipe produced shall meet all the requirements of this specification.

5. Pipe Classification

5.1 *General*—This specification covers ABS pipe produced by single extrusion or simultaneous multiple coextrusion from three ABS plastic pipe materials in four standard dimension ratios and six water pressure ratings for nonthreaded pipe. Pipe produced by simultaneous multiple coextrusion shall be classified as "CoeX."

5.2 *Standard Thermoplastic Pipe Dimension Ratios (SDR)*—This specification covers ABS pipe in four standard dimension ratios, namely, 13.5, 17, 21, and 26. These are referred to as SDR13.5, SDR17, SDR21, and SDR26, respectively. The pressure rating is uniform for all nominal pipe sizes for a given ABS pipe material and SDR (see Table X1.1, Appendix).

6. Requirements

6.1 *Workmanship*——The pipe shall be homogeneous throughout and free of visible cracks, holes, foreign inclusions, or other defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

6.2 *Dimensions and Tolerances*:

6.2.1 *Outside Diameters*—The outside diameters and tolerances shall be as shown in Table 1 when measured in accordance with 7.4 and 7.4.1.

6.2.2 *Wall Thickness*—The wall thicknesses and tolerances shall be as shown in Table 2 when measured in accordance with 7.4 and 7.4.2.

6.2.3 *Thickness of Outer Layer*—For pipe produced by simultaneous multiple extrusion, that is, pipe containing two or more concentric layers, the outer layer shall be at least 0.020 in. (0.50 mm) thick.

TABLE 1 Outside Diameters and Tolerances for ABS Plastic Pipe, in.

Nominal Pipe Size	Outside Diameter	Tolerances		
		Average	For Max and Min (Out-of-Roundness)	
			SDR26 SDR21	SDR17 SDR13.5
⅛	0.405	±0.004	±0.015	±0.008
¼	0.540	±0.004	±0.015	±0.008
⅜	0.675	±0.004	±0.015	±0.008
½	0.840	±0.004	±0.015	±0.008
¾	1.050	±0.004	±0.015	±0.010
1	1.315	±0.005	±0.015	±0.010
1¼	1.660	±0.005	±0.015	±0.012
1½	1.900	±0.006	±0.030	±0.012
2	2.375	±0.006	±0.030	±0.012
2½	2.875	±0.007	±0.030	±0.015
3	3.500	±0.008	±0.030	±0.015
3½	4.000	±0.008	±0.030	±0.015
4	4.500	±0.009	±0.050	±0.015
5	5.563	±0.010	±0.050	±0.030
6	6.625	±0.011	±0.050	±0.035
8	8.625	±0.015	±0.075	±0.045
10	10.750	±0.015	±0.075	±0.050
12	12.750	±0.015	±0.075	±0.060

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TABLE 2 Wall Thicknesses and Tolerances for ABS Plastic Pipe

Nominal Pipe Size, in.	Wall Thickness[A], in.							
	SDR26		SDR21		SDR17		SDR13.5	
	Min	Tolerance	Min	Tolerance	Min	Tolerance	Min	Tolerance
⅛	...	...	...	...	...	...	0.060	+0.020
¼	...	...	...	...	...	...	0.060	+0.020
⅜	...	...	...	...	...	...	0.060	+0.020
½	...	...	...	...	0.060	+0.020	0.062	+0.020
¾	...	...	0.060	+0.020	0.062	+0.020	0.078	+0.020
1	0.060	+0.020	0.063	+0.020	0.077	+0.020	0.097	+0.020
1¼	0.064	+0.020	0.079	+0.020	0.098	+0.020	0.123	+0.020
1½	0.073	+0.020	0.090	+0.020	0.112	+0.020	0.141	+0.020
2	0.091	+0.020	0.113	+0.020	0.140	+0.020	0.176	+0.021
2½	0.110	+0.020	0.137	+0.020	0.169	+0.020	0.231	+0.026
3	0.135	+0.020	0.167	+0.020	0.206	+0.025	0.259	+0.031
3½	0.154	+0.020	0.190	+0.023	0.235	+0.028	0.296	+0.036
4	0.173	+0.021	0.214	+0.026	0.265	+0.032	0.333	+0.040
5	0.214	+0.027	0.265	+0.032	0.327	+0.039	0.412	+0.049
6	0.255	+0.031	0.316	+0.038	0.390	+0.047	0.491	+0.059
8	0.332	+0.040	0.410	+0.049	...	...	...	...
10	0.413	+0.050	0.511	+0.061	...	...	...	...
12	0.490	+0.059	0.606	+0.073	...	...	...	...

[A] The minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement.

6.2.4 *Wall Thickness Range*—The wall thickness range shall be within 12 % when measured in accordance with 7.4 and 7.4.3.

6.3 *Bond*—For pipe produced by simultaneous multiple coextrusion, the bond between the layers shall be strong and uniform, it shall not be possible to separate any two layers with a probe or point of a knife blade so that the layers separate cleanly at any point, nor shall separation of bond occur, between layers, during testing performed under the requirements of this specification.

6.4 *Sustained Pressure*—The pipe shall not fail, balloon, burst, or weep as defined in Test Method D 1598 at the test pressures given in Table 3 when tested in accordance with 7.5.

6.5 *Burst Pressure*—The minimum burst pressures for ABS plastic pipe shall be as given in Table 4, when determined in accordance with 7.6.

7. Test Methods

7.1 *Conditioning*—Condition the test specimens at 73 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618 for those tests where conditioning is required.

TABLE 3 Sustained Pressure Test Conditions for Water at 73°F (23°C) for ABS Plastic Pipe

Standard Dimension Ratio	Pressure[A] Required for Test					
	ABS1316		ABS2112		ABS1208, ABS1210	
	psi	MPa	psi	MPa	psi	MPa
13.5	510	3.52	430	2.96	340	2.34
17	400	2.76	340	2.34	270	1.86
21	320	2.21	270	1.86	220	1.52
26	260	1.79	220	1.52	170	1.17

[A] The fiber stresses used to derive these test pressures are as follows:

ABS1316	3200 psi (22.1 MPa)
ABS2112	2700 psi (18.6 MPa)
ABS1208, ABS1210	2140 psi (14.8 MPa)

Some minor adjustments have been made to keep the test pressures uniform to simplify testing.

TABLE 4 Burst Pressure Requirements for Water at 73°F (23°C) for ABS Plastic Pipe

Standard Dimension Ratio	Min Burst Pressure[A]							
	ABS2112		ABS1316		ABS1210		ABS1208	
	psi	MPa	psi	MPa	psi	MPa	psi	MPa
13.5	1050	7.24	960	6.62	830	5.72	530	3.65
17	830	5.72	750	5.17	660	4.55	420	2.90
21	660	4.55	600	4.14	530	3.65	330	2.28
26	530	3.65	480	3.31	420	2.90	260	1.79

[A] The fiber stresses used to derive these test pressures are as follows:

ABS2112	6600 psi (45.5 MPa)
ABS1316	6000 psi (41.4 MPa)
ABS1210	5240 psi (36.2 MPa)
ABS1208	3300 psi (22.8 MPa)

Some minor adjustments have been made to keep the test pressures uniform to simplify testing.

7.2 *Test Conditions*—Conduct the tests in the Standard Laboratory Atmosphere of 23 ± 2°C and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

7.3 *Sampling*—The selection of the sample or samples of pipe shall be as agreed upon by the purchaser and the seller. In case of no prior agreement, any sample selected by the testing laboratory shall be deemed adequate.

7.3.1 *Test Specimens*—Not less than 50 % of the test specimens required for any pressure test shall have at least a part of the marking in their central sections. The central section is that portion of pipe which is at least one pipe diameter away from an end closure.

7.4 *Dimensions and Tolerances*—Use any length of pipe to determine the dimensions. Measure in accordance with Test Method D 2122.

7.4.1 *Outside Diameter*—Measure the outside diameter of the pipe in accordance with Test Method D 2122. The average

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outside diameter is the arithmetic average of the maximum and minimum diameters at any cross section on the length of the pipe. The tolerances for out-of-roundness shall apply only on pipe before shipment.

7.4.2 *Wall Thickness*—Make micrometre measurements of the wall thickness in accordance with Test Method D 2122 to determine the maximum and minimum values. Measure the wall thickness at both ends of the pipe to the nearest 0.001 in. (0.02 mm).

7.4.3 *Wall Thickness Range*—Measure in such a manner that the maximum, *A*, and the minimum, *B*, wall thicknesses of each cross section measured are obtained. Calculate the wall thickness range, *E*, in percent, for each cross section as follows:

$$E = [(A - B)/A] \times 100$$

The wall thickness range shall not exceed 12 % for any cross section measured.

7.5 *Sustained Pressure Test*—Select the test specimens at random. Test individually with water at the internal pressures given in Table 3, six specimens of pipe, each specimen at least ten times the nominal diameter in length, but not less than 10 in. (250 mm) or more than 3 ft (920 mm) between end closures and bearing the permanent marking on the pipe. Maintain the specimens at the pressure indicated for a period of 1000 h. Hold the pressure as closely as possible, but within ±10 psi (±70 kPa). Condition the specimens at the test temperature of 73°F (23°C) to within ±3.6°F (±2°C). Maintain the test temperature at 73 ± 3.6°F (23 ± 2°C). Test in accordance with Test Method D 1598, except maintain the pressure at the values given in Table 3 for 1000 h. Failure of two of the six specimens tested shall constitute failure in the test. Failure of one of the six specimens tested is cause for retest of six additional specimens. Failure of one of the six specimens tested in retest shall constitute failure in the test. Evidence of failure of the pipe shall be as defined in Test Method D 1598.

7.6 *Burst Pressure*—Determine the minimum burst pressure with at least five specimens in accordance with Test Method D 1599. The time of testing each specimen shall be between 60 and 70 s.

8. Retest and Rejection

8.1 If the results of any test(s) do not meet the requirements of this specification, the test(s) shall be conducted again only by agreement between the purchaser and the seller. Under such agreement, minimum requirements shall not be lowered, changed, or modified, nor shall specification limits be changed. If upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

9. Marking

9.1 *Quality of Marking*—The marking shall be applied to the pipe in such a manner that it remains legible (easily read) after installation and inspection.

9.2 Marking on the pipe shall include the following, spaced at intervals of not more than 5 ft:

9.2.1 Nominal pipe size (for example, 2 in.).

9.2.2 Type of plastic pipe material in accordance with the designation code given in 3.2.6 (for example, ABS1210).

9.2.3 Standard thermoplastic pipe dimension ratio in accordance with the designation code given in 5.2 (for example, SDR17), or the pressure rating in pounds per square inch for water at 73°F (23°C) shown as the number followed by psi (for example, 125 psi), except that when intended for pressure application the pressure rating shall be shown (for example, 125 psi). When the indicated pressure rating is lower than that calculated in accordance with 3.2.5 (see Appendix), the SDR shall also be included in the marking code.

9.2.4 This designation "ASTM D 2282," with which the pipe complies.

9.2.5 Manufacturer's name (or trade mark) and code.

9.2.6 Pipe intended for the transport of potable water shall also include the seal or mark of the laboratory making the evaluation for this purpose, spaced at intervals specified by the laboratory. Pipe produced by simultaneous multiple coextrusion shall be marked "CoeX" in accordance with 5.1.

10. Quality Assurance

10.1 When the product is marked with this designation, D 2282, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

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SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply *only* to Federal/Military procurement, not domestic sales or transfers.

S1. *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless the purchaser disapproves. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE S1—In U.S. Federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this document.

POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for product to be used to convey or to be in contact with potable water.

S3. Products intended for contact with potable water shall be evaluated, tested and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

APPENDIX

(Nonmandatory Information)

X1. SOURCE OF HYDROSTATIC DESIGN STRESSES

X1.1 The hydrostatic design stresses recommended by the Plastics Pipe Institute are used to pressure rate ABS plastic pipe. These hydrostatic design stresses are 800 psi (5.5 MPa), 1000 psi (6.9 MPa), 1250 psi (8.6 MPa), and 1600 psi (11.0 MPa) for water at 73°F (23°C). These hydrostatic design stresses apply only to pipe meeting all the requirements of this specification.

X1.2 Four ABS pipe materials are included based on the requirements of Specification D 3965 and the PPI-recommended hydrostatic design stresses as follows:

X1.2.1 Type 1, Grade 2, with a hydrostatic design stress of 800 psi (5.5 MPa) for water at 23°C, designated as ABS1208.

X1.2.2 Type 1, Grade 2, with a hydrostatic design stress of 1000 psi (6.9 MPa) for water at 23°C, designated as ABS1210.

X1.2.3 Type 1, Grade 3, with a hydrostatic design stress of 1600 psi (11.0 MPa) for water at 23°C, designated as ABS1316.

X1.2.4 Type 2, Grade 1, with a hydrostatic design stress of 1250 psi (8.6 MPa) for water at 23°C, designated as ABS2112.

X1.3 Information regarding the criteria used in developing these hydrostatic design stresses may be obtained from the Plastics Pipe Institute, a division of The Society of the Plastics Industry, 355 Lexington Ave., New York, NY 10017 (Note X1.1). These hydrostatic design stresses may not be suitable for materials that show a wide departure from a straight-line plot of log stress versus log time to failure. All the data available to date on ABS pipe materials made in the United States exhibit a straight-line plot under these plotting conditions.

NOTE X1.1—Refer also to Test Method D 2837.

X1.4 The pipe is rated for use with water at 23°C at the maximum internal pressures shown in Table X1.1 (see also Table X1.2). Lower pressure ratings than those calculated in accordance with 6.5 may be recommended, at the option of the pipe manufacturer, in which case the SDR shall be included in

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TABLE X1.1 Standard Thermoplastic Pipe Dimension Ratios (SDR) and Water Pressure Ratings (PR) at 73°F (23°C) for Nonthreaded[A] ABS Plastic Pipe

SDR	ABS 1316		ABS 2112		ABS 1210		ABS 1208	
	Pressure Rating[B]							
psi	MPa	psi	MPa	psi	MPa	psi	MPa	
13.5	250	1.72	200	1.38	160	1.10	125	0.86
17	200	1.38	160	1.10	125	0.86	100	0.69
21	160	1.10	125	0.86	100	0.69	80	0.55
26	125	0.86	100	0.69	80	0.55	...	...

Pressure Rating		Standard Dimension Ratio			
psi	MPa				
250	1.72	13.5	...	...	...
200	1.38	17	13.5	...	...
160	1.10	21	17	13.5	...
125	0.86	26	21	17	13.5
100	0.69	...	26	21	17
80	0.55	...	...	26	21

[A]These pressure ratings do not apply for threaded pipe.
[B]See 3.2.6 and 4.3 for code designation.

TABLE X1.2 Type and Grade Designations

Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Material Designation
2	0	2	1	1	Type 1, Grade 1
4	2	2	2	2	Type 1, Grade 2
2	0	6	4	3	Type 1, Grade 3
3	0	4	4	4	Type 2, Grade 1

the marking. Experience of the industry indicates that ABS plastic pipe meeting the requirements of this specification gives satisfactory service under normal conditions for a long period at these pressure ratings. The sustained pressure requirements (6.4) are related to these ratings through the slopes of the strength-time plots of these materials in pipe form.

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Designation: D 2310 – 01

An American National Standard

Standard Classification for Machine-Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[1]

This standard is issued under the fixed designation D 2310; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This classification covers machine-made "fiberglass" (glass-fiber-reinforced thermosetting-resin) pressure pipe. Methods of classification, requirements, test methods and the method of marking are included. Both glass-fiber-reinforced thermosetting-resin pipe (RTRP) and glass-fiber-reinforced polymer mortar pipe (RPMP) are fiberglass pipes.

NOTE 1—For the purposes of this standard, polymer does not include natural polymers.

1.2 This classification is based on the method of manufacture, the type of materials used in construction, and the test performance of the product type. It is not based on dimensions or raw material specifications.

1.3 Two methods of classifying long-term strength are included: (*1*) based on cyclic loads for use in those liquid-handling applications where the effects of pumping by duplex or triplex pumps or other cyclic pressure loads dictate the performance requirements of the piping, and (*2*) based on the steady (static) loads such as would be required for gas service applications.

1.4 The values stated in inch-pound units are to regarded as the standard. The values in parentheses are provided for information only.

1.5 The following precautionary caveat pertains only to the test method portion, Section 7, of this classification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 2—There is no similar or equivalent ISO standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 883 Terminology Relating to Plastics[2]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber Reinforced Thermosetting Resin) Pipe and Fittings[3]

D 3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

3. Terminology

3.1 General—Definitions are in accordance with Terminology D 883 or F 412 and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:* Description of Terms Specific to This Standard:

3.2.1 *fiberglass pipe, n*—a tubular product containing glass fiber reinforcements embedded in or surrounded by cured thermosetting resin; the composite structure may contain aggregate, granular, or platelet fillers, thixotropic agents, pigments, or dyes; thermoplastic or thermosetting liners or coatings may be included.

3.2.2 *reinforced thermosetting resin pipe (RTRP), n*—a fiberglass pipe without aggregate.

3.2.3 *reinforced polymer mortar pipe (RPMP), n*—a fiberglass pipe with aggregate.

3.2.4 *centrifugal casting, n*— a manufacturing process used to produce tubular goods by applying resin and reinforcement to the inside of a mold that is rotated and heated, subsequently polymerizing the resin system. The outside diameter of the finished pipe is fixed by the inside diameter of the mold tube. The inside diameter of the pipe is determined by the amount of material introduced into the mold.

3.2.5 *filament winding, n*—a process used to manufacture tubular goods by winding continuous fibrous glass strand roving or roving tape onto the outside of a mandrel in a predetermined pattern under controlled tension; the roving may be saturated with liquid resin or preimpregnated with partially cured resin; subsequent polymerization of the resin system may require application of heat; the inside diameter of the finished pipe is fixed by the mandrel outside diameter; the outside

[1] This classification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.23 on Reinforced Plastic Piping Systems and Chemical Equipment.

Current edition approved June 10, 2001. Published August 2001. Originally published as D 2310 – 64 T. Last previous edition D 2310 – 97.

[2] *Annual Book of ASTM Standards*, Vols 08.01 and 08.04.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

***A Summary of Changes section appears at the end of this standard.**

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diameter of the finished pipe is determined by the amount of material that is wound onto the mandrel.

3.2.6 *liner, n*—the inner portion of the wall, at least 0.005 in. (0.13 mm) in thickness when determined in accordance with Practice D 3567, that does not contribute to the strength in the determination of the hydrostatic design basis.

3.2.7 *pressure laminating, n*—a process to manufacture tubular goods in which reinforcement is impregnated with a thermosetting resin, and the resin partially cured to form a prepreg; it is subsequently laminated around a mandrel and cured under heat and pressure to form the pipe; the pipe is then removed from the mandrel and postcured. The inside diameter of the finished pipe is fixed by the mandrel outside diameter; the outside diameter of the finished pipe is determined by the amount of material that is wound onto the mandrel.

3.2.8 *aggregate, n*—a siliceous sand conforming to the requirements of Specification C 33, except that the requirements for gradation shall not apply.

4. Basis of Classification

4.1 *General*—This classification covers machine-made fiberglass pipe defined by method of manufacturing (type), raw materials in body (grade), liner material (class), and long-term cyclic pressure strength or long-term static pressure strength, whichever is applicable. It covers the following types, grades, and classes of machine-made fiberglass pipe:

NOTE 3—All possible pressure strength combinations of types, grades, and classes may not be commercially available.

4.1.1 *Types:*—Type I
Filament-wound pipe
Type II—Centrifugally cast pipe
Type III—Pressure-laminated pipe

4.1.2 *Grades:*—Grade 1
Glass-fiber-reinforced epoxy resin pipe (RTRP epoxy)
Grade 2—Glass-fiber-reinforced polyester resin pipe (RTRP polyester)
Grade 3—Glass-fiber-reinforced phenolic resin pipe (RTRP phenolic)
Grade 7—Glass-fiber-reinforced furan resin pipe (RTRP furan)
Grade 8—Glass-fiber-reinforced epoxy resin mortar pipe (RPMP epoxy)
Grade 9—Glass-fiber-reinforced polyester resin mortar pipe (RPMP polyester)

4.1.3 *Classes:*—Class A
No liner
Class B—Polyester resin liner (nonreinforced)
Class C—Epoxy resin liner (nonreinforced)
Class D—Phenolic resin liner (nonreinforced)
Class E—Polyester resin liner (reinforced)
Class F—Epoxy resin liner (reinforced)
Class G—Phenolic resin liner (reinforced)
Class H—Thermoplastic resin liner (specify)
Class I—Furan resin liner (reinforced)

4.1.4 *Pressure Strength*—Two methods of classifying the pressure strength of the pipe are incorporated in this document; one or both may be used. Pipe meeting this classification shall be identified by one or both of the hydrostatic design bases shown in Table 1.

4.1.5 *Designation Requirements*—The pipe materials designation code shall consist of the abbreviation RTRP or RPMP, followed by type and grade in arabic numerals, class by a

TABLE 1 General Designation Requirements[A] for Machine-Made Fiberglass Pipe

Designation Order	Property	Cell Limits								
1	Type	1 filament-wound	2 centrifugally cast	3 pressure-laminated						
2	Grade	1 glass-fiber-reinforced epoxy resin (RTRP)	2 glass-fiber-reinforced polyester resin (RTRP)	3 glass-fiber-reinforced phenolic resin (RTRP)				7 glass-fiber-reinforced furan resin (RTRP)	8 glass-fiber-reinforced epoxy resin (RPMP)	9 glass-fiber-reinforced polyester resin mortar (RPMP)
3	Class	A no liner	B polyester resin liner (nonreinforced)	C epoxy resin liner (nonreinforced)	D phenolic resin liner (nonreinforced)	E polyester resin liner (reinforced)	F epoxy resin liner (reinforced)	G phenolic resin liner (reinforced)	H thermoplastic resin liner (specify)	I furan resin liner (reinforced)
		Hoop Stress—Hydrostatic Design Basis[B]								
		A	B	C	D	E	F	G	H	
4	Cyclic psi (MPa)	2500 (17.2)	3150 (21.7)	4000 (27.5)	5000 (34.4)	6300 (43.4)	8000 (55.1)	10 000 (68.9)	12 500 (86.1)	
or		Q	R	S	T	U	W	X	Y	Z
4	Static psi (MPa)	5000 (34.4)	6300 (43.4)	8000 (51.5)	10 000 (68.9)	12 500 (86.1)	16 000 (110.0)	20 000 (137.0)	25 000 (172.0)	31 500 (217.0)

[A] The cell-type format provides the means of identification and specification of piping materials. This cell-type format, however, is subject to misapplication since unobtainable property combinations can be selected if the user is not familiar with commercially available products. The manufacturer should be consulted.
[B] Refer to Practice D 2992 to obtain classification of the values.

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capital letter, and the long-term strength by a second capital letter. Table 1 presents a summary of the designation requirements. Thus a complete material code shall consist of RTRP or RPMP . . . two numerals, and two letters.

4.1.5.1 *Examples*:

(*1*) RTRP-11AE for filament-wound glass-fiber-reinforced epoxy resin pipe, unlined, with a 6300 psi (43.4 MPa) (cyclic) hydrostatic design basis, or

(*2*) RTRP-11AT for filament-wound glass-fiber-reinforced epoxy resin pipe, unlined, with a 10 000 psi (68.9 MPa) (static) hydrostatic design basis, or

(*3*) both, if the pipe is to be dual rated.

NOTE 4—Although *Form and Style for ASTM Standards* requires that the type classification be roman numerals, it is recognized that few companies have stencil-cutting equipment for this style of type, and it is, therefore, acceptable to mark the product type in arabic numerals. Precedence for this change has been made in other ASTM standards.

5. Materials

5.1 *General*—The resins, reinforcements, and other materials, when combined as a composite structure, shall produce a pipe that shall meet the performance requirements of this classification.

6. Requirements

6.1 *Properties*:

6.1.1 *Hydrostatic Design Basis*—The hydrostatic design basis for products meeting this classification is derived from the long-term pressure strength, as determined at ambient temperature in accordance with 7.1 or 7.2. Standard categories for the hydrostatic design basis are shown in Table 1. A hydrostatic design basis as shown in Table 1 shall be determined for each type, grade, and class of product manufactured. Changes in materials or manufacturing processes will necessitate a screening evaluation as described in Practice D 2992.

6.1.2 *Pressure Rating*—The hydrostatic design stress for products meeting this classification is obtained by multiplying the applicable hydrostatic design basis (from Table 1) by a service (design) factor equal to or less than 1.0.

NOTE 5—Information regarding selection of service (design) factors and pressure rating is provided in Practice D 2992 and the individual product standards.

7. Test Methods

7.1 *Cyclic Pressure Strength*—Determine the cyclic pressure strength in accordance with Procedure A of Practice D 2992.

7.2 *Static Pressure Strength*—Determine the static pressure strength in accordance with Procedure B of Practice D 2992.

8. Marking

8.1 Marking on the pipe shall include the following items, spaced at intervals of not more than 15 ft (4.5 m):

8.1.1 Nominal pipe size (example: 2 in.),

8.1.2 Type of fiberglass pipe, in accordance with the designation code given in 4.1.5,

8.1.3 ASTM pipe product specification with which the pipe complies, and

8.1.4 Manufacturer's name (or trademark).

8.2 All markings shall be such that they will remain legible under normal handling and installation practices.

9. Keywords

9.1 centrifugal casting; fiberglass pipe; filament winding; hydrostatic design basis; machine-made fiberglass pressure pipe; pipe; pressure laminating; pressure strength; reinforced polymer mortar pipe (RPMP); reinforced thermosetting-resin pipe (RTRP)

SUMMARY OF CHANGES

Committee D-20 has identified the location of selected changes to this classification since the last issue D 2310–97 that may impact the use of this classification.

(*1*) Changed acronym, RPMP, definition from reinforced *plastic* mortar pipe to reinforced *polymer* mortar pipe.

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Designation: D 2464 – 99

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Standard Specification for Threaded Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80[1]

This standard is issued under the fixed designation D 2464; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers poly(vinyl chloride) (PVC) threaded Schedule 80 pipe fittings. Included are requirements for materials, workmanship, dimensions, and burst pressure.

NOTE 1—Threaded CPVC plastic pipe fittings, Schedule 80, which were formerly included in this standard, are now covered by Specification F 437.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 2—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious saftey hazards should a system fail for any reason.

1.3 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only.

1.5 The following safety hazards caveat pertains only to the test method portion, Section 7, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics for Testing[2]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[2]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D 2749 Symbols for Dimensions of Plastic Pipe Fittings[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 437 Specification for Threaded Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80[3]

F 1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings[3]

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[4]

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[4]

2.4 *NSF Standard:*

Standard No. 14 for Plastic Piping Components and Related Materials[5]

Standard No. 61 for Drinking Water Systems Components—Health Effects[5]

3. Terminology

3.1 General—Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated. The abbreviation for poly(vinyl chloride) plastic is PVC.

4. Classification

4.1 *General*—This specification covers threaded Schedule 80 PVC pipe fittings, made from four PVC plastic compounds and intended for use with threaded Iron Pipe Size (IPS) outside-diameter plastic pipe.

4.1.1 Fittings covered by this specification are normally molded. In-line fittings, such as couplings, unions, bushings,

[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.10 on Fittings.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[5] Available from the National Sanitation Foundation, P.O. Box 1468, Ann Arbor, MI 48106.

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caps, nipples, etc., shall be molded or machined from extruded stock.

4.1.2 Fittings fabricated by back welding or butt fusion are not included in this specification.

5. Materials and Manufacture

5.1 This specification covers PVC pipe fittings made from five PVC plastics as classified in Specification D 1784. These are PVC 12454-B, 12454-C, 13354-C, 11443-B, and 14333-D.

NOTE 3—Mechanical strength, heat resistance, flammability, and chemical resistance requirements are covered in Specification D 1784.

5.2 *Rework Material*—The manufacturers shall use only their own clean rework fitting material and the fittings produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances*:

6.1.1 The dimensions and tolerances of the fittings shall be as shown in Table 1 and Table 2 when measured in accordance with Test Method D 2122. Minimum dimensions have zero negative tolerances. Bushings shall have thread lengths applicable to the corresponding sizes. Counterbore is optional, is not shown in Table 1, and is not included in the center-to-end or end-to-end dimensions.

6.1.2 The maximum angular variation of any opening shall be not more than ½° off the true centerline axis.

6.1.3 *Fittings Not Illustrated*—All fittings, whether illustrated in Table 1 and Table 2 or not, shall have wall thicknesses and thread dimensions conforming to 6.1 and 6.2.

6.2 *Threads*—For all fittings having taper pipe threads, threads shall conform to Specification F 1498 and be gaged in accordance with 8.4.

6.3 *Burst Pressure*:

6.3.1 The burst strength of the fittings shall be not less than that calculated for the size and wall thickness of the pipe with which it is to be used, when calculated from the following equation:

$$S = P(D_O t)/2t \quad (1)$$

where:

S = hoop stress, psi (or MPa),
P = internal pressure, psi (or MPa),
D_O = average outside diameter, in. (or mm), and
t = minimum wall thickness, in. (or mm).

Fittings tested in accordance with 8.4 shall withstand the minimum burst pressure shown in Table 3.

6.3.2 Pressures shown are minimum burst pressures and do not imply rated working pressures. The burst pressure shall be used only as an indication of quality.

7. Workmanship, Finish, and Appearance

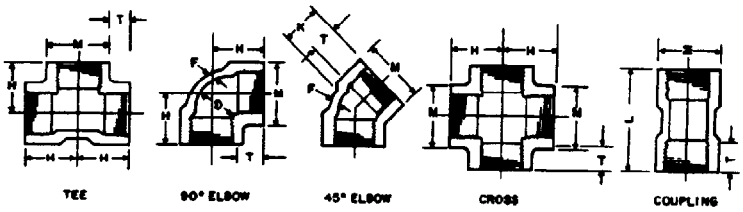
7.1 The fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 *Conditioning*—Condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of 73 ± 3.6 °F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

TABLE 1 Dimensions of 90° Ells, Tees, Crosses, 45° Elbows and Couplings (Straight Sizes), in. (mm)[A]



Nominal Pipe Size	Center to Thread End, 90° Elbows, Tees, Crosses,[B] *H*, min	Length of Thread, *T*, min	Center to Thread End, 45° Elbow,[B] *K*, min	Inside Diameter of Fitting, *D*, min	Nominal Wall Thickness, *F*, min	Outside Diameter of Band, *M*, min	Thread End to Thread End of Coupling, *L*, min
1/8	0.688 (17.48)	0.38 (9.65)	0.625 (15.88)	0.171 (4.34)	0.108 (2.74)	0.645 (16.40)	0.813 (20.65)
1/4	0.812 (20.63)	0.50 (12.70)	0.688 (17.48)	0.258 (6.55)	0.135 (3.43)	0.840 (21.30)	1.063 (27.00)
3/8	0.938 (23.83)	0.50 (12.70)	0.750 (19.05)	0.379 (9.63)	0.144 (3.66)	1.000 (25.40)	1.063 (27.00)
1/2	1.125 (28.58)	0.64 (16.26)	0.750 (19.05)	0.502 (12.75)	0.198 (5.03)	1.280 (32.50)	1.344 (34.14)
3/4	1.250 (31.75)	0.65 (16.51)	1.000 (25.40)	0.698 (17.73)	0.207 (5.26)	1.500 (38.10)	1.500 (38.10)
1	1.500 (38.10)	0.81 (20.57)	1.125 (28.58)	0.911 (23.14)	0.225 (5.72)	1.810 (45.97)	1.688 (42.88)
1 1/4	1.750 (44.45)	0.85 (21.59)	1.313 (33.35)	1.227 (31.17)	0.261 (6.63)	2.200 (55.88)	1.750 (44.45)
1 1/2	1.938 (49.23)	0.85 (21.54)	1.438 (36.53)	1.446 (36.73)	0.270 (6.86)	2.500 (63.50)	2.000 (50.80)
2	2.250 (57.15)	0.90 (22.86)	1.625 (41.28)	1.881 (47.78)	0.297 (7.54)	3.000 (76.20)	2.063 (52.40)
2 1/2	2.688 (68.28)	1.21 (30.73)	1.938 (49.23)	2.250 (57.15)	0.315 (8.00)	3.580 (90.42)	2.625 (66.68)
3	3.063 (77.80)	1.30 (33.02)	2.125 (53.48)	2.820 (71.65)	0.405 (10.29)	4.300 (104.22)	2.750 (69.85)
4	3.625 (92.08)	1.38 (35.05)	2.625 (66.68)	3.737 (94.92)	0.450 (11.43)	5.430 (137.92)	3.000 (76.20)
6	5.125 (130.18)	1.50 (38.10)	3.250 (82.55)	5.646 (143.41)	0.504 (12.80)	7.625 (193.68)	3.250 (82.55)

[A]The sketches and designs of fittings shown are illustrative only.
[B]This dimension locates the end of the fitting.

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TABLE 2 Dimensions of Plugs and Caps, in.[A]

Nominal Pipe Size	Length of Male Thread, *S*, min	Length of Female Thread, *T*, min	Width of Flats,[B] *Q*, min	Nominal Wall Thickness, *F*, min	Height of Head, *R*, min	Cap Height, *W*, min	Outside Diameter of Band, *M*, min
1/8	0.31 (7.87)	0.38 (9.65)	0.469 (11.19)	0.108 (2.74)	0.188 (4.76)	0.625 (15.88)	0.645 (16.38)
1/4	0.44 (11.18)	0.50 (12.70)	0.625 (15.88)	0.135 (3.43)	0.188 (4.76)	0.688 (17.48)	0.840 (21.34)
3/8	0.44 (11.18)	0.50 (12.70)	0.750 (14.05)	0.144 (3.66)	0.188 (4.76)	0.688 (17.48)	1.000 (25.40)
1/2	0.53 (13.45)	0.64 (16.26)	0.938 (23.83)	0.198 (5.03)	0.188 (4.76)	0.875 (22.23)	1.280 (32.51)
3/4	0.55 (13.97)	0.65 (16.51)	1.125 (28.58)	0.207 (5.26)	0.219 (5.56)	1.000 (25.40)	1.450 (36.80)
1	0.68 (17.27)	0.81 (20.57)	1.375 (34.93)	0.225 (5.72)	0.219 (5.56)	1.188 (30.18)	1.810 (45.97)
1 1/4	0.71 (18.03)	0.85 (21.59)	1.750 (44.45)	0.261 (6.63)	0.281 (7.14)	1.250 (31.75)	2.200 (55.88)
1 1/2	0.72 (18.29)	0.85 (21.59)	1.875 (47.63)	0.270 (6.86)	0.313 (7.95)	1.250 (31.75)	2.450 (62.23)
2	0.76 (19.30)	0.90 (22.86)	1.875 (47.63)	0.297 (7.54)	0.313 (7.45)	1.375 (34.93)	3.000 (76.20)
2 1/2	1.14 (28.96)	1.21 (30.73)	1.875 (47.63)	0.369 (9.37)	0.375 (9.53)	1.625 (41.28)	3.560 (90.42)
3	1.20 (30.48)	1.30 (33.02)	2.000 (50.80)	0.405 (10.29)	0.375 (9.53)	1.750 (44.45)	4.250 (107.90)
4	1.30 (33.02)	1.38 (35.05)	2.000 (50.80)	0.450 (11.43)	0.375 (9.53)	2.000 (50.80)	5.350 (134.62)
6	1.44 (36.58)	1.50 (38.10)	2.000 (50.80)	0.504 (12.80)	0.500 (12.70)	2.125 (53.98)	7.625 (193.00)

[A]The sketches and designs of fittings shown are illustrative only.
[B]At the manufacturer's option the head of the plug shall be hexagonal, octagonal, square, or round.

TABLE 3 Burst Pressure Requirements for Water at 73°F (23°C) for PVC Threaded Pipe Fittings, Schedule 80

Nominal Size, in.	Minimum Burst Strength[A]			
	Classes 12454, 13354,-C and 11443		Class 14333	
	psi	MPa	psi	MPa
1/4	3620	(24.96)	2830	(19.51)
3/8	2940	(20.27)	2300	(15.86)
1/2	2720	(18.75)	2120	(14.62)
3/4	2200	(15.17)	1720	(11.86)
1	2020	(13.93)	1580	(10.89)
1 1/4	1660	(11.44)	1300	(8.96)
1 1/2	1510	(10.41)	1180	(8.14)
2	1290	(8.89)	1010	(6.96)
2 1/2	1360	(8.38)	1060	(7.31)
3	1200	(8.27)	940	(6.48)
4	1040	(7.17)	810	(5.51)
6	890	(6.19)	700	(4.83)

[A]This table was calculated for Schedule 80 pipe using the ISO formula and the stress levels for materials as follows:

	psi	MPa
Classes 11443, 13354, -C and 12454	6400	44.1
Class 14333	5000	34.5

8.3 *Sampling*—A sufficient quantity of fittings as agreed upon between the seller and the purchaser shall be selected at random from each lot or shipment and tested to determine that the basic design is in conformance with this specification.

NOTE 4—For individual orders or specifications where supplemental tests are required, only those tests and numbers of tests specifically agreed upon between purchaser and supplier need be conducted.

8.4 *Burst Pressure*—Determine the minimum burst pressure with at least five specimens in accordance with Test Method D 1599. Join the fittings to the pipe sufficiently strong and in such a manner that no failures shall occur in the assembly at a pressure less than the pressure requirement given in Table 3. The time of testing each assembly shall be between 60 and 70 s.

9. Retest and Rejection

9.1 If the results of any test(s) do not meet the requirements of this specification, the test(s) shall be conducted again only by agreement between the purchaser and seller. Under such agreement, minimum requirements shall not be lowered, changed or modified, nor shall specification limits be changed. If upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

10. Product Marking

10.1 *Quality of Marking*—The marking shall be applied to the fittings in such a manner that they remain legible under normal handling and installation practices.

10.2 *Content of Marking*:

10.2.1 Fittings shall be marked with the following:

10.2.1.1 Manufacturer's name or trademark,

10.2.1.2 Material designation PVC I for PVC 12454-B, PVC 12 for PVC 12454-C, PVC 13 for PVC 13354-C and 11443-B, PVC II for PVC 14333-D,

10.2.1.3 The seal or mark of the laboratory making the evaluation for potable water contact.

10.2.1.4 Size, and

10.2.1.5 This designation, D 2464, with which this fitting complies.

10.3 Where the size of the fittings does not allow complete marking, omit identification marking in the following sequence: size, material designation, D 2464, manufacturer's name or trademark.

10.4 Markings or symbols shall be molded, hot-stamped, or

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applied to fittings by any other suitable method, such as printing.

10.5 Where recessed marking is used, care shall be taken to see that in no case marking causes cracks or reduces the wall thickness below the minimum specified.

11. Quality Assurance

11.1 When the product is marked with this designation, D 2464, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

The following requirements apply only to federal/military procurement, not domestic sales or transfers.

S1. *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for performance of the inspection and test requirements specified herein, unless the purchaser disapproves. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE S1.1—In U.S. federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD 129 for military agencies.

NOTE S2.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this specification.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for product to be used to convey or to be in contact with potable water.

S3. *Potable Water Requirement*—Products intended for contact with potable water shall be evaluated, tested and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

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Designation: D 2466 – 01

An American National Standard

Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40[1]

This standard is issued under the fixed designation D 2466; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers poly(vinyl chloride) (PVC) Schedule 40 pipe fittings. Included are requirements for materials, workmanship, dimensions, and burst pressure.

NOTE 1—Socket-type CPVC plastic pipe fittings, Schedule 40, which were formerly included in this standard, are now covered by Specification F 438.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 2—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious saftey hazards should a system fail for any reason.

1.3 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only.

1.5 The following safety hazards caveat pertains only to the test method portion, Section 7, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics for Testing[2]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[2]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 438 Specification for Socket-Type Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40[3]

F 1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings[3]

2.2 *NSF Standards:*

Standard No. 14 for Plastic Piping Components and Related Materials[4]

Standard No. 61 for Drinking Water Systems Components—Health Effects[4]

3. Terminology

3.1 General—Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated. The abbreviation for poly(vinyl chloride) plastic is PVC.

4. Classification

4.1 *General*—This specification covers Schedule 40 PVC pipe fittings, made from four PVC plastic compounds and intended for use with Iron Pipe Size (IPS) outside-diameter plastic pipe.

4.1.1 Fittings covered by this specification are normally molded. In-line fittings, such as couplings, unions, bushings, caps, nipples, etc., shall be molded or machined from extruded stock.

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[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.10 on Fittings.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] Available from the National Sanitation Foundation, P.O. Box 1468, Ann Arbor, MI 48106.

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4.1.2 Fittings fabricated by welding are not included in this specification.

5. Materials

5.1 This specification covers PVC pipe fittings made from five PVC plastics as classified in Specification D 1784. These are PVC 12454-B, 12454-C, 13354-C, 11443-B, and 14333-D.

5.2 *Compound*—The PVC plastic compound shall meet the requirements of PVC 12454-B, 12454-C, 11443-B, or 14333-D, as described in Specification D 1784.

NOTE 3—Mechanical strength, heat resistance, flammability, and chemical resistance requirements are covered in Specification D 1784.

5.3 *Rework Material*—The manufacturers shall use only their own clean rework fitting material and the fittings produced shall meet all the requirements of this specification.

6. Requirements

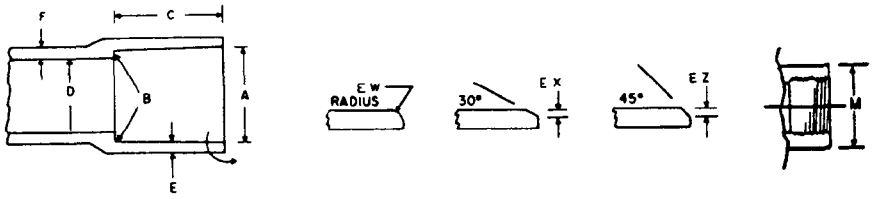
6.1 *Dimensions and Tolerances*:

6.1.1 Fitting sockets inside diameters (waterways), minimum wall thicknesses, and dimensions shall be as shown in Table 1, Table 2, and Table 3 when measured in accordance with Test Method D 2122.

6.1.2 When multistep reducer bushings are cored out, the inner socket shall be reinforced from the outer wall by a minimum of three ribs extending from the top of the inner socket to the deepest extremity of the coring. The transition from D to DJ (Table 3) shall be straight, tapered as shown, or radiused. A positive taper in the same direction of the taper in the socket on the outside diameter of the bushing is optional.

6.1.3 The maximum angular variation of any opening shall be not more than ½° off the true centerline axis.

TABLE 1 Tapered Sockets for PVC Pipe Fittings, Schedule 40, in.[A]



Nominal Pipe Size	A Socket Entrance Diameter			B Socket Bottom Diameter			C[B] Socket Length, min	D[C] Inside Diameter, min	Wall Thickness, min		Min Outside Diameter of Hub, M	Entrance, min	
	Diameter	Tolerance on Diameter	Max Out-of-Round	Diameter	Tolerance on Diameter	Max Out-of-Round			E	F		EW	EX, EZ
⅛	0.417	±0.004	0.016 (0.41)	0.401	±0.004	0.016 (0.41)	0.500	0.225	0.068	0.085	0.526	1/64	1/64
¼	0.552	±0.004	0.016 (0.41)	0.536	±0.004	0.016 (0.41)	0.500	0.320	0.088	0.110	0.672	1/64	1/64
⅜	0.687	±0.004	0.016 (0.41)	0.671	±0.004	0.016 (0.41)	0.594	0.449	0.091	0.114	0.821	1/32	1/32
½	0.848	±0.004	0.016 (0.41)	0.836	±0.004	0.016 (0.41)	0.688	0.578	0.109	0.136	0.998	1/32	1/32
¾	1.058	±0.004	0.020 (0.51)	1.046	±0.004	0.020 (0.51)	0.719	0.740	0.113	0.141	1.221	1/32	1/32
1	1.325	±0.005	0.020 (0.51)	1.310	±0.005	0.020 (0.51)	0.875	0.990	0.133	0.166	1.504	1/16	1/16
1¼	1.670	±0.005	0.024 (0.61)	1.655	±0.005	0.024 (0.61)	0.938	1.335	0.140	0.175	1.871	1/16	1/16
1½	1.912	±0.006	0.024 (0.61)	1.894	±0.006	0.024 (0.61)	1.094	1.564	0.145	0.181	2.127	1/16	1/16
2	2.387	±0.006	0.024 (0.61)	2.369	±0.006	0.024 (0.61)	1.156	2.021	0.154	0.193	2.634	1/16	1/16
2½	2.889	±0.007	0.030 (0.76)	2.868	±0.007	0.030 (0.76)	1.750	2.414	0.203	0.254	3.170	3/32	⅛
3	3.516	±0.008	0.030 (0.76)	3.492	±0.008	0.030 (0.76)	1.875	3.008	0.216	0.270	3.841	3/32	⅛
3½	4.016	±0.008	0.030 (0.76)	3.992	±0.008	0.030 (0.76)	2.000	3.486	0.226	0.283	4.374	3/32	⅛
4	4.518	±0.009	0.030 (0.76)	4.491	±0.009	0.030 (0.76)	2.000	3.961	0.237	0.296	4.907	3/32	⅛
5	5.583	±0.010	0.060 (1.52)	5.553	±0.010	0.060 (1.52)	3.000	4.975	0.258	0.323	6.039	3/32	⅛
6	6.647	±0.011	0.060 (1.52)	6.614	±0.011	0.060 (1.52)	3.000	5.986	0.280	0.350	7.203	⅛	3/16
8	8.655	±0.015	0.090 (2.29)	8.610	±0.015	0.090 (2.29)	4.000	7.888	0.322	0.403	9.320	⅛	3/16
10	10.780	±0.015	0.100 (3.05)	10.735	±0.015	0.100 (3.05)	5.000	9.917	0.365	0.456	11.614	⅛	3/16
12	12.780	±0.015	0.120 (3.81)	12.735	±0.015	0.120 (3.81)	6.000	11.825	0.406	0.508	13.786	⅛	3/16

[A] The sketches and designs of fittings are illustrative only.
[B] Socket depth, measured from socket entrance face to socket bottom face.
[C] See 6.1.5.

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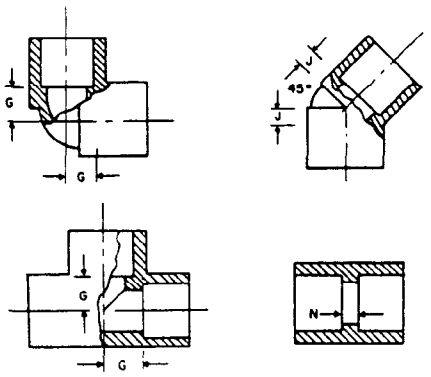
TABLE 2 Minimum Dimension from Center to End of Sockets (Laying Length) for Couplings, Tees, 90° and 45° Elbows, PVC Socket-Type Pipe Fittings, Schedule 40, in.[A]



Nominal Pipe Size	G, min	J, min	N, min
⅛	¼	⅛	1/16
¼	5/16	5/32	1/16
⅜	⅜	3/16	3/32
½	½	¼	3/32
¾	9/16	5/16	3/32
1	11/16	5/16	3/32
1¼	⅞	⅜	3/32
1½	1	7/16	3/32
2	1¼	⅝	3/32
2½	1½	11/16	3/16
3	1 13/16	¾	3/16
3½	2⅛	1	3/16
4	2 5/16	1	3/16
5	3	1⅜	3/16
6	3½	1¾	¼
8	4½	2	¼
10	5 13/16	2 9/16	¼
12	6 15/16	3 1/16	¼

[A] The sketches and designs of fittings are illustrative only.

6.1.4 The minimum wall thickness of fittings shall be 125 % of the minimum wall thickness of the corresponding size of Schedule 40 pipe for which they are designed to be used, except that for the socket, the wall thickness shall be at least equal to the minimum wall thickness of the corresponding size of Schedule 40 pipe. For any threaded fitting the minimum wall thickness of the threaded portion shall be at least equal to the thickness of material under the thread root of threaded Schedule 80 pipe of the same size.

6.1.5 The minimum inside diameter of the fittings shall be not less than the minimum specified inside diameter of the corresponding size of Schedule 40 pipe. Any fitting having a male thread shall have an internal diameter not larger than Schedule 80 pipe of the same size.

6.1.6 Minimum dimensions have zero negative tolerance. Tolerances on other dimensions are shown in Table 1 and Table 3.

6.2 *Threads*—For all fittings having taper pipe threads, threads shall conform to Specification F 1498 and be gaged in accordance with 8.4.

6.3 *Burst Pressure*:

6.3.1 The minimum burst strength of the fittings shall be not less than that calculated for the size and wall thickness of the pipe with which it is to be used, when calculated from the following equation:

$$S = P\,(D_O - t)/2t \quad (1)$$

where:

S = hoop stress, psi (or MPa),
P = internal pressure, psi (or MPa),
D_O = average outside diameter, in. (or mm), and
t = minimum wall thickness, in. (or mm).

Fittings tested in accordance with 8.5 shall withstand the minimum burst pressure shown in Table 4.

6.3.2 Pressures shown are minimum burst pressures and do not imply rated working pressures. The burst pressure shall be used only as an indication of quality.

7. Workmanship, Finish, and Appearance

7.1 The fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 *Conditioning*—Condition the test specimens at 73 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of 73 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Sampling*—A sufficient quantity of fittings as agreed upon between the seller and the purchaser shall be selected at random from each lot or shipment and tested to determine that the basic design is in conformance with this specification.

NOTE 4—For individual orders or specifications, only those tests and numbers of tests specifically agreed upon between the purchaser and the seller need be conducted.

8.4 *Threads*—All taper pipe threads shall be gaged in accordance with Specification F 1498.

8.5 *Burst Pressure*—Determine the minimum burst pressure in accordance with Test Method D 1599. The pressure shall be applied at a uniform rate such that the minimum allowable burst pressure is attained in 60 or 70 s.

NOTE 5—The time-to-failure may exceed 70 s.

8.5.1 *Apparatus*—Fittings shall be tested while held in a test jig constructed in such a manner as to seal the socket by means of O-rings, or gaskets but not to reinforce or support the fittings, except where contact is necessary because of the shape of the fitting to keep the fitting in the test jig. Such contact shall be held to the minimum. The socket plug portion of the test fixture must extend one third to two thirds of the socket depth. Failure of any part of the test apparatus does not constitute failure of the fittings.

9. Retest and Rejection

9.1 If the results of any test(s) do not meet the requirements of this specification, the tests(s) shall be conducted again only by agreement between the purchaser and seller. Under such

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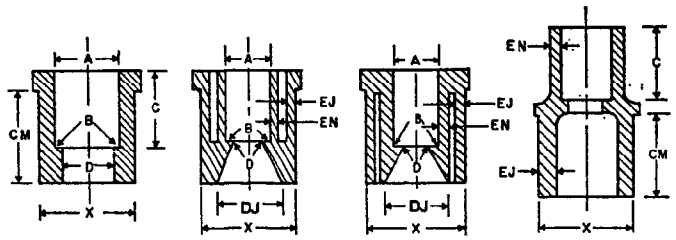
TABLE 3 Dimensions of Reducer Bushings, PVC Socket-Type Pipe Fittings, Schedule 40,[A,B] in.



Nominal Size	*X*, Outside Diameter	Tolerance on Outside Diameter	Maximum Out-of-Roundness (max, minus min.)
¼ by ⅛	0.540	±0.004 (0.10)	0.016 (0.41)
⅜ by ¼, ⅛	0.675	±0.004 (0.10)	0.016 (0.41)
½ by ⅜, ¼	0.840	±0.004 (0.10)	0.016 (0.41)
¾ by ½, ⅜, ¼	1.050	±0.004 (0.10)	0.020 (0.51)
1 by ½, ¾	1.315	±0.005 (0.13)	0.020 (0.51)
1¼ by ½, ¾, 1	1.660	±0.005 (0.13)	0.024 (0.61)
1½ by ½, ¾, 1, 1¼	1.900	±0.006 (0.15)	0.024 (0.61)
2 by ½, ¾, 1, 1¼, 1½	2.375	±0.006 (0.15)	0.024 (0.61)
2½ by 2	2.875	±0.007 (0.18)	0.030 (0.76)
3 by 2½, 2	3.500	±0.008 (0.20)	0.030 (0.76)
3½ by 2½, 2	4.000	±0.008 (0.20)	0.030 (0.76)
4 by 3½, 3, 2½, 2	4.500	±0.009 (0.23)	0.030 (0.76)
5 by 4	5.563	±0.010 (0.25)	0.060 (1.52)
6 by 5	6.625	±0.011 (0.28)	0.070 (1.78)
8 by 6	8.625	±0.015 (0.38)	0.090 (2.29)
10 by 6	10.750	±0.015 (0.38)	0.100 (3.05)
10 by 8	10.750	±0.015 (0.38)	0.100 (3.05)
12 by 6	12.750	±0.015 (0.38)	0.100 (3.05)
12 by 8	12.750	±0.015 (0.38)	0.100 (3.05)
12 by 10	12.750	±0.015 (0.38)	0.100 (3.05)

[A] The sketches and designs of fittings are illustrative only.
[B] Dimensions not shown in Table 1.

TABLE 4 Burst Pressure Requirements for Water at 73°F (23°C) for PVC Socket-Type Pipe Fittings, Schedule 40

Nominal Size, in.	Min Burst Strength,[A]			
	Classes 12454, 13354-C, and 11443		Class 14333	
	psi	(MPa)	psi	(MPa)
⅛	2580	(17.79)	2020	(13.93)
¼	2490	(17.17)	1950	(13.44)
⅜	1990	(13.72)	1560	(10.76)
½	1910	(13.17)	1490	(10.27)
¾	1540	(10.62)	1210	(8.34)
1	1440	(9.93)	1130	(7.79)
1¼	1180	(8.14)	920	(6.34)
1½	1060	(7.31)	830	(5.72)
2	890	(6.14)	690	(4.76)
2½	970	(6.69)	760	(5.24)
3	840	(5.79)	660	(4.55)
3½	770	(5.31)	600	(4.14)
4	710	(4.90)	560	(3.86)
5	620	(4.27)	490	(3.38)
6	560	(3.86)	440	(3.03)
8	500	(3.45)	390	(2.69)
10	450	3.10	...	...
12	420	2.90	...	...

[A] This table was calculated for Schedule 40 pipe using the formula and the stress levels for materials as follows:

	psi	MPa
Classes 11443, 13354-C, and 12454	6400	44.1
Class 1433	5000	34.5

agreement, minimum requirements shall not be lowered, changed, or modified, nor shall specification limits be changed.

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If upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

10. Marking

10.1 Fittings shall be marked with the following:

10.1.1 Manufacturer's name or trademark,

10.1.2 Material designation PVC I for PVC 12454-B, PVC 12 for PVC 12454-C, PVC 13 for PVC 13354-C and 11443-B, and PVC II for PVC 14333-D,

10.1.3 Fittings intended for the transport of potable water shall include the seal or mark of the laboratory making the evaluation for this purpose.

10.1.4 Size, and

10.1.5 This designation number: D 2466.

10.2 Where the size of the fitting does not allow complete marking, omit identification marking in the following sequence: size, material designation, manufacturer's name or trademark.

10.3 Markings or symbols shall be molded, hot-stamped, or applied to fittings by any other suitable method, such as printing.

10.4 Where recessed marking is used, care shall be taken to see that in no case marking causes cracks or reduces the wall thickness below the minimum specified.

11. Quality Assurance

11.1 When the product is marked with this designation, D 2466, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

12. Keywords

12.1 fittings; pressure; PVC; Sch 40; sockets; threads

SUPPLEMENTARY REQUIREMENTS

POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for product to be used to convey or to be in contact with potable water.

S1. Products intended for contact with potable water shall be evaluated, tested and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

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Designation: D 2467 – 01

An American National Standard

Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80[1]

This standard is issued under the fixed designation D 2467; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers poly(vinyl chloride) (PVC) Schedule 80 pipe fittings. Included are requirements for materials, workmanship, dimensions, and burst pressure.

NOTE 1—CPVC plastic pipe fittings, which were formerly included in this standard, are now covered in Specification F 439.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 2—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious saftey hazards should a system fail for any reason.

1.3 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this specification.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only.

1.5 The following safety hazards caveat pertains only to the test method portion, Section 8, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics for Testing[2]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[2]

D 1785 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120[3]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D 2749 Symbols for Dimensions of Plastic Pipe Fittings[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 439 Specification for Socket-Type Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80[3]

F 1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings[3]

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[4]

2.3 *National Sanitation Foundation Standard:*

Standard No. 14 for Plastic Piping Components and Related Materials[5]

Standard No. 61 for Drinking Water Systems Components—Health Effects[5]

3. Terminology

3.1 General—Definitions are in accordance with Terminology F 412 and abbreviations are in accordance with Teminology D 1600, unless otherwise indicated. The abbreviation for poly(vinyl chloride) plastic is PVC.

4. Classification

4.1 *General*—This specification covers Schedule 80 PVC pipe fittings, socket-type, made from four PVC plastic compounds and intended for use with Iron Pipe Size (IPS) outside-diameter plastic pipe.

4.1.1 Fittings covered by this specification are normally molded. In-line fittings, such as couplings, unions, bushings,

[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.10 on Fittings.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[5] Available from the National Sanitation Foundation, P.O. Box 1468, Ann Arbor, MI 48106.

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caps, nipples, etc., shall be molded or machined from extruded stock.

4.1.2 Fittings fabricated by back welding or butt fusion are not included in this specification.

5. Materials and Manufacture

5.1 This specification covers PVC pipe fittings made from five PVC plastics as classified in Specification D 1784. These are PVC 12454-B, 12454-C, 13354-C, 11443-B, and 14333-D.

5.2 *Compound*—The PVC plastic compound shall meet the requirements of PVC 12454-B, 12454-C, 11443-B, or 14333-D, as described in Specification D 1784.

NOTE 3—Mechanical strength, heat resistance, flammability, and chemical resistance requirements are covered in Specification D 1784.

5.3 *Rework Material*—The manufacturers shall use only their own clean rework fitting material and the fittings produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances*:

6.1.1 Fitting sockets inside diameters (waterways), minimum wall thicknesses, and dimensions shall be as shown in Tables 1-4 when measured in accordance with Test Method D 2122.

6.1.2 When multistep reducer bushings are cored out, the inner socket shall be reinforced from the outer wall by a minimum of three ribs extending from the top of the inner socket to the deepest extremity of the coring. The transition from D to DJ (Table 3) shall be straight, tapered as shown, or radiused. A positive taper in the same direction of the taper in the socket on the outside diameter of the bushing is optional.

6.1.3 The maximum angular variation of any opening shall be not more than ½° off the true centerline axis.

6.1.4 The minimum wall thickness of fittings shall be 125 % of the minimum wall thickness of the corresponding size of Schedule 80 pipe for which they are designed to be used, except that for the socket, the wall thickness shall be at least equal to the minimum wall thickness of the corresponding size of Schedule 80 pipe.

6.1.5 The minimum inside diameter of the fittings shall be not less than the minimum specified inside diameter of the corresponding size of Schedule 80 pipe.

6.1.6 Minimum dimensions have zero negative tolerance. Tolerances on other dimensions are shown in Table 1 and Table 3.

6.2 *Threads*—For all fittings having taper pipe threads, threads shall conform to Specification F 1498 and be gaged in accordance with 8.4.

6.3 *Burst Pressure*:

6.4 . Fittings tested in accordance with 8.5 shall withstand the minimum burst pressure shown in Table 5.

6.4.1 Pressures shown are minimum burst pressures and do not imply rated working pressures. The burst pressure shall be used only as an indication of quality.

7. Workmanship, Finish, and Appearance

7.1 The fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 *Conditioning*—Condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Sampling*—A sufficient quantity of fittings as agreed upon between the seller and the purchaser shall be selected at random from each lot or shipment and tested to determine that the basic design is in conformance with this specification.

NOTE 4—For individual orders or specifications where supplemental tests are required, only those tests and numbers of tests specifically agreed upon between purchaser and seller need be conducted.

8.4 *Threads*—All taper pipe threads shall be gaged in accordance with Specification F 1498.

8.5 *Burst Pressure*—Determine the minimum burst pressure in accordance with Test Method D 1599. The pressure shall be applied at a uniform rate such that the minimum allowable burst pressure is attained in 60 to 70 s.

NOTE 5—The time-to-failure may exceed 70 s.

9. Retest and Rejection

9.1 If the results of any test(s) do not meet the requirements of this specification, the tests(s) shall be conducted again only by agreement between the purchaser and seller. Under such agreement, minimum requirements shall not be lowered, changed, or modified, nor shall specification limits be changed. If upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

10. Product Marking

10.1 *Quality of Marking*—The markings shall be applied to the fittings in such a manner that they remain legible under normal handling and installation practices.

10.2 *Content of Marking*—Fittings shall be marked with the following:

10.2.1 Material designation PVC I for PVC 12454-B, PVC 12 for PVC 12454-C, PVC 13 for PVC 13354-C and 11443-B, and PVC II for PVC 14333-D,

10.2.2 The seal or mark of the laboratory making the evaluation for potable water contact,

10.2.3 Size, and

10.2.4 This designation, D 2467, with which the fitting complies.

10.3 Where the size of the fitting does not allow complete marking, omit identification marking in the following sequence: size, material designation (D 2467), manufacturer's name, or trademark.

10.4 Marking or symbols shall be molded, hot-stamped, or applied to fittings by any other suitable method, such as printing.

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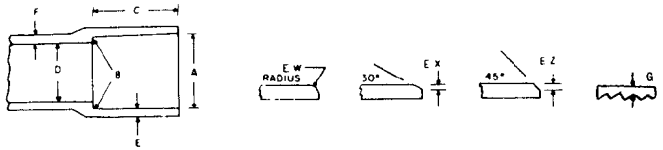
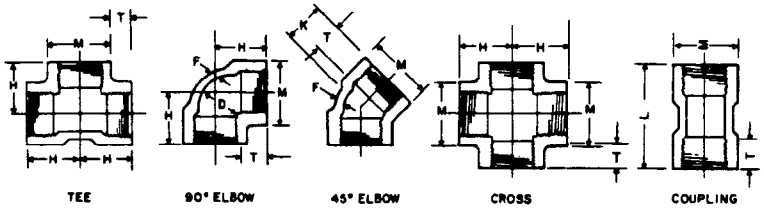
TABLE 1 Tapered Sockets for PVC Pipe Fittings, Schedule 80, in. (mm)[A]



Nominal Pipe Size	A Socket Entrance Diameter			B Socket Bottom Diameter			C[B] Socket Length, min	D[C] Inside Diameter, min	Wall Thickness, min		Entrance, min		
	Diameter	Tolerance on Nominal Diameter	Max Out-of-Round	Diameter	Tolerance on Nominal Diameter	Max Out-of-Round			*E*	*F*	*EW*	*EX*	*EZ*
⅛	0.417 (10.59)	±0.004 (0.10)	0.016 (0.41)	0.401 (10.18)	±0.004 (0.10)	0.016 (0.41)	0.500 (12.7)	0.171 (4.34)	0.095 (2.41)	0.118 (3.00)	1/64 (0.40)	1/64 (0.40)	1/64 (0.40)
¼	0.552 (14.02)	±0.004 (0.10)	0.016 (0.41)	0.536 (13.61)	±0.004 (0.10)	0.016 (0.41)	0.625 (15.88)	0.258 (6.55)	0.119 (3.02)	0.149 (3.78)	1/64 (0.40)	1/64 (0.40)	1/64 (0.40)
⅜	0.687 (17.45)	±0.004 (0.10)	0.016 (0.41)	0.671 (17.04)	±0.004 (0.10)	0.016 (0.41)	0.750 (19.05)	0.379 (9.63)	0.126 (3.20)	0.160 (4.06)	1/32 (0.79)	1/32 (0.79)	1/32 (0.79)
½	0.848 (21.54)	±0.004 (0.10)	0.016 (0.41)	0.836 (21.23)	±0.004 (0.10)	0.016 (0.41)	0.875 (22.22)	0.502 (12.75)	0.147 (3.73)	0.185 (4.70)	1/32 (0.79)	1/32 (0.79)	1/32 (0.79)
¾	1.058 (26.87)	±0.004 (0.10)	0.020 (0.51)	1.046 (26.57)	±0.004 (0.10)	0.020 (0.51)	1.000 (25.40)	0.698 (17.73)	0.154 (3.91)	0.195 (4.95)	1/32 (0.79)	1/32 (0.79)	1/32 (0.79)
1	1.325 (33.65)	±0.005 (0.13)	0.020 (0.51)	1.310 (33.27)	±0.005 (0.13)	0.020 (0.51)	1.125 (28.58)	0.911 (23.14)	0.179 (4.55)	0.225 (5.72)	1/16 (1.59)	1/16(1.59)	1/16 (1.59)
1¼	1.670 (42.42)	±0.005 (0.13)	0.024 (0.61)	1.655 (42.04)	±0.005 (0.13)	0.024 (0.61)	1.250 (31.75)	1.227 (31.17)	0.191 (4.85)	0.239 (6.07)	1/16 (1.59)	1/16 (1.59)	1/16 (1.59)
1½	1.912 (48.56)	±0.006 (0.15)	0.024 (0.61)	1.894 (48.11)	±0.006 (0.15)	0.024 (0.61)	1.375 (34.93)	1.446 (36.73)	0.200 (5.08)	0.250 (6.35)	1/16 (1.59)	1/16 (1.59)	1/16 (1.59)
2	2.387 (60.63)	±0.006 (0.15)	0.024 (0.61)	2.369 (60.17)	±0.006 (0.15)	0.024 (0.61)	1.500 (38.10)	1.881 (47.78)	0.218 (5.54)	0.275 (6.99)	1/16 (1.59)	1/16(1.59)	1/16 (1.59)
2½	2.889 (73.38)	±0.007 (0.18)	0.030 (0.76)	2.868 (72.85)	±0.007 (0.18)	0.030 (0.76)	1.750 (44.45)	2.250 (57.15)	0.276 (7.01)	0.345 (8.76)	3/32 (2.38)	⅛ (3.18)	⅛ (3.18)
3	3.516 (89.31)	±0.008 (0.20)	0.030 (0.76)	3.492 (88.70)	±0.008 (0.20)	0.030 (0.76)	1.875 (47.63)	2.820 (71.63)	0.300 (7.62)	0.375 (9.53)	3/32 (2.38)	⅛(3.18)	⅛ (3.18)
3½	4.016 (102.01)	±0.008 (0.20)	0.030 (0.76)	3.992 (101.4)	±0.008 (0.20)	0.030 (0.76)	2.125 (53.98)	3.280 (83.31)	0.318 (8.08)	0.400 (10.16)	3/32 (2.38)	⅛ (3.18)	⅛ (3.18)
4	4.518 (114.76)	±0.009 (0.23)	0.030 (0.76)	4.491 (114.1)	±0.009 (0.23)	0.030 (0.76)	2.250 (57.15)	3.737 (94.92)	0.337 (8.56)	0.420 (10.67)	3/32 (2.38)	⅛(3.18)	⅛ (3.18)
5	5.583 (141.81)	±0.010 (0.25)	0.060 (1.52)	5.553 (141.0)	±0.010 (0.25)	0.060 (1.52)	2.625 (66.68)	4.703 (119.46)	0.375 (9.53)	0.470 (11.94)	3/32 (2.38)	⅛ (3.18)	⅛ (3.18)
6	6.647 (168.83)	±0.011 (0.28)	0.060 (1.52)	6.614 (168.0)	±0.011 (0.28)	0.060 (1.52)	3.000 (76.20)	5.646 (143.41)	0.432 (10.97)	0.540 (13.72)	⅛ (3.18)	3/16 (4.76)	3/16 (4.76)
8	8.655 (219.84)	±0.015 (0.38)	0.090 (2.29)	8.610 (218.7)	±0.015 (0.38)	0.090 (2.29)	4.000 (101.60)	7.490 (190.25)	0.500 (12.70)	0.625 (15.88)	⅛ (3.18)	3/16 (4.76)	3/16 (4.76)
10	10.780 (273.81)	±0.015 (0.38)	0.100 (2.54)	10.735 (272.67)	±0.015 (0.38)	0.100 (2.54)	5.000 (127.00)	9.407 (238.94)	0.593 (15.06)	0.741 (18.82)	⅛ (3.18)	3/16 (4.76)	3/16 (4.76)
12	12.780 (324.61)	±0.015 (0.38)	0.120 (3.05)	12.735 (323.47)	±0.015 (0.38)	0.120 (3.05)	6.000 (152.40)	11.197 (284.40)	0.687 (17.45)	0.859 (21.82)	⅛ (3.18)	3/16 (4.76)	3/16 (4.76)

[A] *The sketches and designs of fittings are illustrative only (taken from Symbols D 2749).*
[B] Socket depth, measured from socket entrance face to socket bottom face.
[C] See 6.1.5.

TABLE 2 Dimensions of 90° Ells, Tees, Crosses, 45° Elbows and Couplings (Straight Sizes), in. (mm)[A]



Nominal Pipe Size	Center to Thread End, 90° Elbows,Tees, Crosses,[B] *H*, min	Length of Thread, *T*, min	Center to Thread End, 45° Elbow,[B] *K*, min	Inside Diameter of Fitting, *D*, min	Nominal Wall Thickness, *F*, min	Outside Diameter of Band, *M*, min	Thread End to Thread End of Coupling, *L*, min
⅛	0.688 (17.48)	0.38 (9.65)	0.625 (15.88)	0.215 (5.46)	0.118	0.645 (16.40)	0.813 (20.65)
¼	0.812 (20.63)	0.50 (12.70)	0.688 (17.48)	0.302 (7.67)	0.149	0.840 (21.30)	1.063 (27.00)
⅜	0.938 (23.83)	0.50 (12.70)	0.750 (19.05)	0.423 (10.74)	0.160	1.000 (25.40)	1.063 (27.00)
½	1.125 (28.58)	0.64 (16.26)	0.750 (19.05)	0.550 (13.97)	0.185	1.280 (32.50)	1.344 (34.14)
¾	1.250 (31.75)	0.65 (16.51)	1.000 (25.40)	0.750 (19.05)	0.195	1.500 (38.10)	1.500 (38.10)
1	1.500 (38.10)	0.81 (20.57)	1.125 (28.58)	0.960 (24.38)	0.225	1.810 (45.97)	1.688 (42.88)
1¼	1.750 (44.45)	0.85 (21.59)	1.313 (33.35)	1.280 (32.51)	0.261	2.200 (55.88)	1.750 (44.45)
1½	1.938 (49.23)	0.85 (21.54)	1.438 (36.53)	1.500 (38.10)	0.270	2.500 (63.50)	2.000 (50.80)
2	2.250 (57.15)	0.90 (22.86)	1.625 (41.28)	1.940 (49.28)	0.297	3.000 (76.20)	2.063 (52.40)
2½	2.688 (68.28)	1.21 (30.73)	1.938 (49.23)	2.320 (58.93)	0.345	3.580 (90.42)	2.625 (66.68)
3	3.063 (77.80)	1.30 (33.02)	2.125 (53.48)	2.900 (73.66)	0.405	4.300 (104.22)	2.750 (69.85)
4	3.625 (92.08)	1.38 (35.05)	2.625 (66.68)	3.830 (97.28)	0.450	5.430 (137.92)	3.000 (76.20)
6	5.125 (130.18)	1.50 (38.10)	3.250 (82.55)	5.761 (146.33)	0.540	7.625 (193.68)	3.250 (82.55)

[A] The sketches and designs of fittings shown are illustrative only.
[B] This dimension locates the end of the fitting.

10.5 Where recessed marking is used, care shall be taken to see that in no case marking causes cracks or reduces the wall thickness below the minimum specified.

11. Quality Assurance

11.1 *Quality Assurance*—When the product is marked with this designation, D 2467, the manufacturer affirms that the product was inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

12. Keywords

12.1 blunt start thread; fittings; IPS; PVC; Schedule 80; sockets; thread

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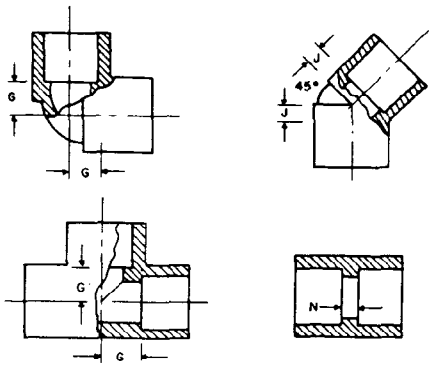
TABLE 3 Minimum Dimensions from Center to End of Sockets (Laying Length) for Couplings, Tees, 90° and 45° Elbows, PVC Socket-Type Pipe Fittings, Schedule 80, in. (mm)[A]



Nominal Pipe Size	*G*, min	*J*, min	*N*, min
⅛	¼ (6.35)	⅛ (3.18)	1/16 (1.59)
¼	5/16 (7.94)	5/32(3.97)	1/16 (1.59)
⅜	⅜ (9.53)	3/16 (4.76)	3/32 (2.38)
½	½ (12.70)	¼ (6.35)	3/32 (2.38)
¾	9/16 (14.29)	5/16(7.94)	3/32 (2.38)
1	11/16 (17.46)	5/16 (7.94)	3/32 (2.38)
1¼	⅞ (22.22)	⅜ (9.53)	3/32 (2.38)
1½	1 (25.40)	7/16 (11.11)	3/32 (2.38)
2	1¼ (31.75)	⅝ (15.88)	3/32 (2.38)
2½	1½ (38.10)	11/16 (17.46)	3/16 (4.76)
3	1 13/16 (46.04)	¾ (19.05)	3/16 (4.76)
3½	2⅛ (53.98)	1 (25.40)	3/16 (4.76)
4	2 5/16 (58.74)	1 (25.40)	3/16 (4.76)
5	3 (76.20)	1⅜ (34.93)	3/16(4.76)
6	3½ (88.90)	1¾ (44.45)	¼ (6.35)
8	4½ (114.30)	2 (50.80)	¼ (6.35)
10	5 11/16 (144.46)	2¼ (57.15)	¼ (6.35)
12	6⅞ (174.63)	2½ (63.50)	⅜ (9.53)

[A] The sketches and designs of fittings are illustrative only (taken from Symbols D 2749).

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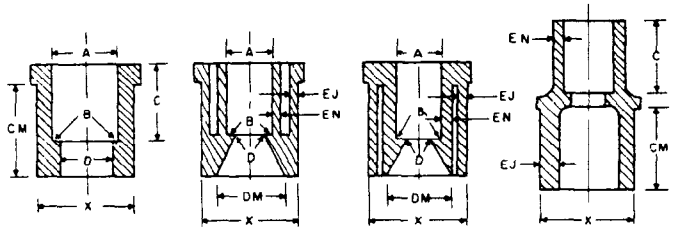
TABLE 4 Symbols for Dimensions of Reducer Bushings, PVC Socket-Type Pipe Fittings, Schedule 80,[A] in. (mm)



Nominal Size	*X*, Outside Diameter[B]	Tolerance on Outside Diameter	Out-of-Roundness Max. Min.
¼ by ⅛	0.540 (13.72)	±0.004	0.016
⅜ by ¼, ⅛	0.675 (17.41)	±0.004	0.016
½ by ⅜, ¼	0.840 (21.34)	±0.004	0.020
¾ by ½, ⅜, ¼	1.050 (26.67)	±0.005	0.020
1 by ½, ¾	1.315 (33.40)	±0.005	0.020
1¼ by ½, ¾, 1	1.660 (42.16)	±0.006	0.024
1½ by ½, ¾, 1, 1¼	1.900 (48.26)	±0.006	0.024
2 by ½, ¾, 1, 1¼, 1½	2.375 (60.33)	±0.006	0.024
2½ by 2	2.875 (73.03)	±0.007	0.030
3 by 2½, 2	3.500 (88.90)	±0.008	0.030
3½ by 2½, 2	4.000 (101.60)	±0.008	0.030
4 by 3½, 3, 2½, 2	4.500 (114.30)	±0.009	0.030
5 by 4	5.563 (141.30)	±0.010	0.060
6 by 5	6.625 (168.28)	±0.011	0.070
8 by 6	8.626 (219.10)	±0.015	0.090
10 by 6	10.750 (273.05)	±0.015	0.100
10 by 8	10.750 (273.05)	±0.015	0.100
12 by 6	12.750 (323.85)	±0.015	0.120
12 by 8	12.750 (323.85)	±0.015	0.120
12 by 10	12.750 (323.85)	±0.015	0.120

[A] The sketches and designs of fittings are illustrative only (taken from Symbols D 2749).
[B] Dimensions not shown in Table 1.

TABLE 5 Dimensions of Plugs and Caps, in.

Nominal Pipe Size	Length of Male Thread, *S*, min	Length of Female Thread, *T*, min	Width of Flats,[A] *Q*, min	Nominal Wall Thickness, *F*, min	Height of Head, *R*, min	Cap Height, *W*, min	Outside Diameter of Band, *M*, min
⅛	0.31 (7.87)	0.38 (9.65)	0.469 (11.19)	0.108 (2.74)	0.188 (4.76)	0.625 (15.88)	0.645 (16.38)
¼	0.44 (11.18)	0.50 (12.70)	0.625 (15.88)	0.135 (3.43)	0.188 (4.76)	0.688 (17.48)	0.840 (21.34)
⅜	0.44 (11.18)	0.50 (12.70)	0.750 (14.05)	0.144 (3.66)	0.188 (4.76)	0.688 (17.48)	1.000 (25.40)
½	0.53 (13.45)	0.64 (16.26)	0.938 (23.83)	0.198 (5.03)	0.188 (4.76)	0.875 (22.23)	1.280 (32.51)
¾	0.55 (13.97)	0.65 (16.51)	1.125 (28.58)	0.207 (5.26)	0.219 (5.56)	1.000 (25.40)	1.450 (36.80)
1	0.68 (17.27)	0.81 (20.57)	1.375 (34.93)	0.225 (5.72)	0.219 (5.56)	1.188 (30.18)	1.810 (45.97)
1¼	0.71 (18.03)	0.85 (21.59)	1.750 (44.45)	0.261 (6.63)	0.281 (7.14)	1.250 (31.75)	2.200 (55.88)
1½	0.72 (18.29)	0.85 (21.59)	1.875 (47.63)	0.270 (6.86)	0.313 (7.95)	1.250 (31.75)	2.450 (62.23)
2	0.76 (19.30)	0.90 (22.86)	1.875 (47.63)	0.297 (7.54)	0.313 (7.45)	1.375 (34.93)	3.000 (76.20)
2½	1.14 (28.96)	1.21 (30.73)	1.875 (47.63)	0.369 (9.37)	0.375 (9.53)	1.625 (41.28)	3.560 (90.42)
3	1.20 (30.48)	1.30 (33.02)	2.000 (50.80)	0.405 (10.29)	0.375 (9.53)	1.750 (44.45)	4.250 (107.90)
4	1.30 (33.02)	1.38 (35.05)	2.000 (50.80)	0.450 (11.43)	0.375 (9.53)	2.000 (50.80)	5.350 (134.62)
6	1.44 (36.58)	1.50 (38.10)	2.000 (50.80)	0.504 (12.80)	0.500 (12.70)	2.125 (53.98)	7.625 (193.00)

[A] At the manufacturer's option the head of the plug may be hexagonal, octagonal, square, or round. The sketches and designs of fittings shown are illustrative only.

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TABLE 6 Burst Pressure Requirements for Water at 73°F (23°C) for PVC Socket-Type Pipe Fittings, Schedule 80

Nominal Size, in.	Minimum Burst Strength			
	Classes 12454, 13354, and 11443		Class 14333	
	psi	MPa	psi	MPa
⅛	3920	27.03	3060	21.10
¼	3620	24.96	2830	19.51
⅜	2940	20.27	2300	15.86
½	2720	18.75	2120	14.62
¾	2200	15.17	1720	11.36
1	2020	13.93	1580	10.89
1¼	1660	11.44	1300	8.96
1½	1510	10.41	1180	8.14
2	1290	8.89	1010	6.96
2½	1360	9.38	1060	7.31
3	1200	8.27	940	6.48
3½	1110	7.65	860	5.93
4	1040	7.17	810	5.58
5	930	6.41	720	4.96
6	890	6.14	700	4.83
8	790	5.45	620	4.27
10	600	4.14	...	...
12	580	4.00	...	...

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT / MILITARY PROCUREMENT

These requirements apply *only* to Federal / Military procurement, not domestic sales or transfers.

S1. *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless the purchaser disapproves. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE S1.1—In U.S. Federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1— The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this document.

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POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for product to be used to convey or to be in contact with potable water.

S3. Products intended for contact with potable water shall be evaluated, tested and certified for conformance with ANSI/ NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

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An American National Standard

Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings[1]

This standard is issued under the fixed designation D 2657; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This practice describes general procedures for making joints with polyolefin pipe and fittings by means of heat fusion joining techniques in either a shop or field environment. These procedures are general ones. Specific instructions for heat fusion joining are obtained from product manufacturers.

1.2 The techniques covered are applicable only to joining polyolefin pipe and fittings of related polymer chemistry, for example, polyethylenes to polyethylenes, polypropylenes to polypropylenes, or polybutylenes to polybutylenes. Material, density, and flow rate shall be taken into consideration in order to develop uniform melt viscosities and formation of a good fusion bond, when joining the same material to itself or to other materials of related polymer chemistry.

1.3 Parts that are within the dimensional tolerance given in present ASTM specifications are required to produce sound joints between polyolefin pipe and fittings when using the joining techniques described in this practice.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The text of this practice references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the practice.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See specific safety precautions in 4.2, 5.1.1, 8.2.3.1, Notes 8 and 9, and A1.1.

2. Referenced Documents

2.1 *ASTM Standards:*

F 905 Practice for Qualification of Polyethylene Saddle Fusion Joints[2]

F 1056 Specification for Socket Fusion Tools for Use in Socket Fusion Joining Polyethylene Pipe or Tubing and Fittings[2]

3. Significance and Use

3.1 The procedures described in Sections 7, 8, and 9, when implemented using suitable equipment and procedures in either a shop or field environment, produce strong pressure-tight joints equal to the strength of the piping material. Some materials are more adaptable to one technique than another. Average molecular weight and molecular weight distribution are influential factors in establishing suitable fusion parameters; therefore, consider the manufacturer's instructions in the use or development of a specific fusion procedure.

4. Operator Experience

4.1 Skill and knowledge on the part of the operator are required to obtain a good quality joint. This skill and knowledge is obtained by making joints in accordance with proven procedures under the guidance of skilled operators. Evaluate operator proficiency by testing sample joints.

4.2 These procedures require the use of heating and cutting equipment. The person actually responsible for the joining of polyolefin pipe and fittings shall ensure that detailed procedures developed in conjunction with the manufacturers of the pipe, fittings, and the joining equipment involved, including the safety precautions to be followed, are issued before actual joining operations begin.

5. Summary of Practice

5.1 Heat-fusion joining uses a combination of heat and force resulting in two melted surfaces flowing together to produce a joint. Fusion bonding occurs when the joint cools below the melt temperature of the material. There is a temperature range within which any particular material is satisfactorily joined. The specific temperature used requires consideration of the properties of the specific material, and the joining environment. With Techniques II or III (5.3.2 or 5.3.3), there is also an appropriate force to be applied which depends upon the material, the fusion equipment being used, and fusion temperature.

5.1.1 Electrically powered heat fusion tools and equipment are usually not explosion proof. When performing heat fusion in a potentially combustible atmosphere such as in an excavation where gas is present, all electrically powered tools and equipment that will be used in the combustible atmosphere shall be disconnected from the electrical power source and operated manually to prevent explosion and fire. For the heating tool, this requires bringing the heating tool up to or slightly above temperature in a safe area, then disconnecting it from electrical power immediately before use. This procedure is limited to smaller sizes where heating is accomplished before the heating tool drops below acceptable temperature.

[1] This practice is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.20 on Joining.

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[2] *Annual Book of ASTM Standards*, Vol 08.04.

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5.2 Adequate joint strength for testing is attained when all of the joint material cools to ambient temperature. The joint shall not be disturbed or moved until it has cooled.

NOTE 1—Polybutylene undergoes a crystalline transformation for several days after cooling below its melt temperature. Although this phenomenon has an effect on the ultimate physical properties of the material, its effect on testing of joints has not been found to be significant. If there is any question of its effect, a comparison should be made between joints that have been conditioned for different periods of time in order to establish the conditioning-time relationship.

5.3 Three fusion techniques are covered in this practice as follows:

5.3.1 *Procedure 1, Socket Fusion*—The socket-fusion technique involves simultaneously heating the outside surface of a pipe end and the inside of a fitting socket, which is sized to be smaller than the smallest outside diameter of the pipe. After the proper melt has been generated at each face to be mated, the two components are joined by inserting one component into the other. See Fig. 1. The fusion bond is formed at the interface resulting from the interference fit. The melts from the two components flow together and fuse as the joint cools. Optional alignment devices are used to hold the pipe and socket fitting in longitudinal alignment during the joining process; especially with pipe sizes 3 in. IPS (89 mm) and larger.

5.3.2 *Procedure 2, Butt Fusion*—The butt-fusion technique in its simplest form consists of heating the squared ends of two pipes, a pipe and a fitting, or two fittings, by holding them against a heated plate, removing the plate when the proper melt is obtained, promptly bringing the ends together, and allowing the joint to cool while maintaining the appropriate applied force. See Fig. 2. An alignment jig shall be used to obtain and maintain suitable alignment of the ends during the fusion operation.

5.3.3 *Procedure 3, Saddle Fusion*—The saddle-fusion technique involves melting the concave surface of the base of a saddle fitting, while simultaneously melting a matching pattern on the surface of the pipe, bringing the two melted surfaces together and allowing the joint to cool while maintaining the appropriate applied force. See Fig. 3.

6. Apparatus: General Recommendations

6.1 *Heating Tool*—The tool may be heated by gas or electricity. Gas-fired heaters shall have heat sinks of sufficient capacity to prevent excessive draw down of the tool temperature. Electric heating plates maintain consistent fusion temperatures when provided with an adequate power source. Electric heating plates for general fusion use shall be controlled thermostatically and adjusted over a temperature range from 300 to 575°F (150 to 300°C). Some tools may have a fixed set point for a particular application.

6.2 *Heating Tool Faces*—Heating tools may be made from materials such as aluminum, stainless steel, copper, or copper alloys. Copper or copper-alloy heating faces are not suitable, unless chromium-plated or clad with another suitable metal, because some polyolefins react with copper. Plastic materials may stick to hot metal heating surfaces. This sticking may be minimized by applying a non-stick coating to the heating surfaces or by fitting a high-temperature, non-stick fabric over the heating surfaces. The heating plate surfaces, coated or uncoated, shall be kept clean and free of contaminants such as dirt, grease and plastic build-up, which may cause excessive sticking and create unsatisfactory joints. Most of these contaminants are removed from the hot tool surfaces using a clean, dry, oil-free lint-free cloth. Do not use synthetic fabrics which may char and stick to the fusion surface. Some pigments, such as carbon black, may stain a heating surface and probably cannot be removed; such stains will not contaminate the joint interface.

6.2.1 After a period of time in service, non-stick coatings or fabrics will deteriorate and become less effective. Deteriorated fabrics should be replaced, and worn, scratched, or gouged non-stick coatings should be re-coated when they lose effectiveness. Heat fusion quality may be adversely

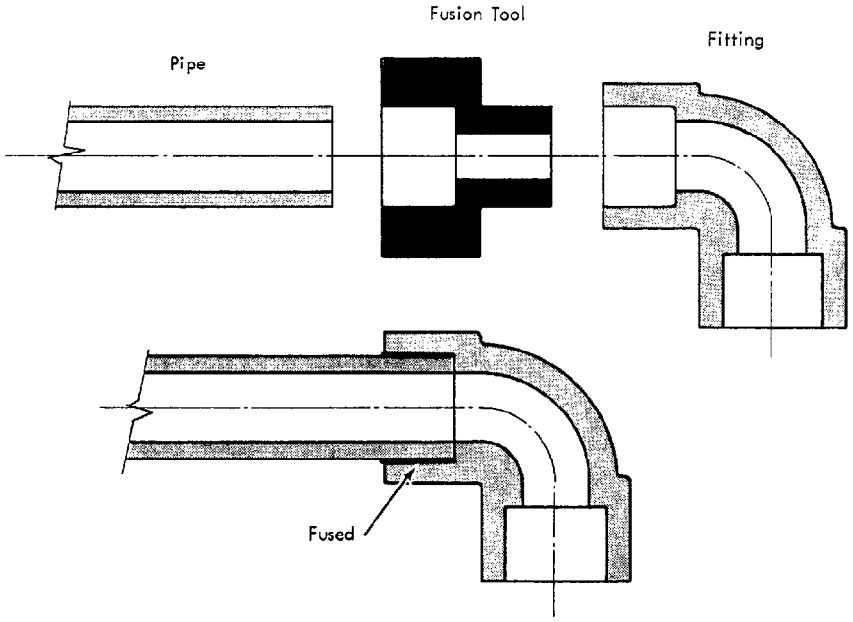

FIG. 1 Socket Fusion

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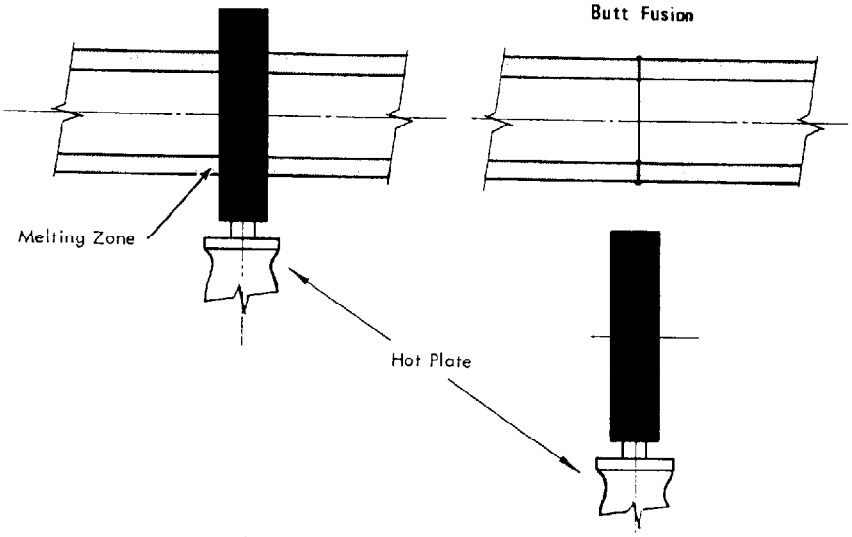

FIG. 2 Typical Butt Fusion Operation

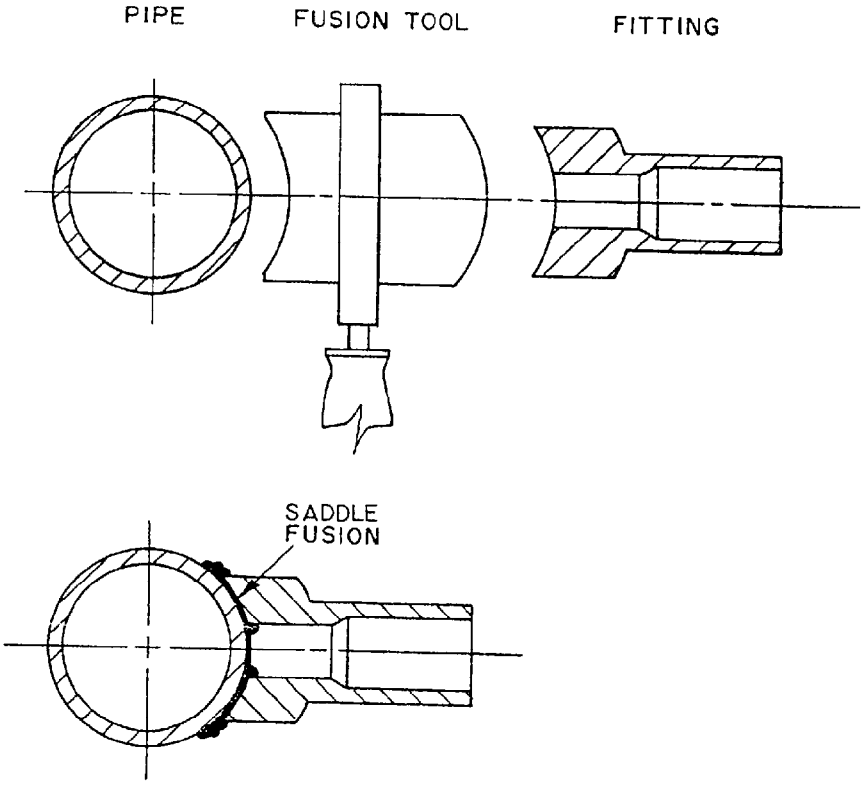

FIG. 3 Saddle Fusion

affected by deteriorated non-stick surfaces. Spray-on chemicals, such as non-stick lubricants or oils shall not be applied to heating iron surfaces as they will contaminate the joint.

6.3 *Temperature Indicator*—Heating tools shall be equipped with a thermometer or other built-in temperature indicating device. This device indicates the internal temperature of the heating iron which is usually higher than temperature of the fusion surfaces. Use a pyrometer periodically to verify the temperature of the tool surfaces within the pipe or fitting contact area. Select multiple checkpoints to ensure uniform surface temperature.

NOTE 2—A significant temperature variation, that is, cold spots, on the fusion surfaces may indicate a faulty heating iron which may need to be serviced before it can be used.

7. Procedure 1—Socket Fusion

7.1 *Apparatus*—Socket fusion tools manufactured in ac-

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cordance with Specification F 1056 should be used for joining polyethylene pipe, tubing, and fittings.

7.1.1 *Heating Tool*—In order to obtain a proper melt, it is necessary for a uniform temperature to be maintained across the heating surface. Therefore, gas-fired tools are generally restricted to use with pipe sizes of 2 in. IPS (63 mm) or less.

7.1.2 *Heating Tool Faces*—Consisting of two parts, a male end for the interior socket surface and a female end for the exterior pipe surface. Both parts shall be made to such tolerances as to cause an interference fit.

7.1.3 *Alignment Jig*—The alignment jig is an optional tool which consists of two sets of devices holding the components in alignment to each other. One set of holding devices is fixed, and the other allows longitudinal movement for making the joint.

7.1.4 *Rounding Clamps*, (cold ring) to maintain roundness of the pipe and control the depth of pipe insertion into the socket during the joining operation.

7.1.5 *Depth Gage*, for proper positioning of the rounding clamp.

7.1.6 *Chamfering Tool*, to bevel the end of the pipe.

NOTE 3—The depth gage and chamfering tool may be combined into a single tool.

7.1.7 *Tubing Cutter*, to obtain a square end cut on the pipe.

7.1.8 *Fitting Puller*, an optional tool to assist in the removal of the fitting from the heating tool and to hold the fitting during assembly.

7.2 *Procedure:*

7.2.1 Attach the proper size heater faces to the heating tool, and heat the tool to the fusion temperature for the material.

7.2.2 Cut the pipe end squarely, and clean the pipe end and fitting, both inside and outside, by wiping with a clean, dry, oil-free, lint-free cloth.

7.2.3 Chamfer the outside edge of the pipe end slightly and fix the rounding clamp about the pipe as determined from the depth gage.

NOTE 4—Chamfering may not be required by some procedures or some fusion tools. Pipe sizes 1 in. (25.4 mm) and smaller are not usually chamfered, regardless of tooling design.

NOTE 5—Some recommend using a 50 to 60-grit emery or garnet cloth to roughen the outside of the pipe and inside of the fitting as a means of minimizing any possible skin interface when making the fusion. Sandpaper is not recommended for this purpose, as it might disintegrate and contaminate the joint interface. If roughening is performed, first clean the surfaces before roughening. Clean dust and particles from the roughened surfaces afterwards by wiping with a clean, dry, oil-free, lint-free cloth.

7.2.4 Bring the preheated tool faces into contact with the outside surface of the end of the pipe and the inside surface of the socket.

7.2.5 Heat the pipe end and the fitting socket for the time required to obtain a proper melt. Proper melt is a function of material, time, tool temperature, and the size of the parts. Pipe and fittings of larger diameters require more time to reach the proper melt consistency than those of smaller diameters. Underheated or overheated materials will not form a good bond.

7.2.6 At the end of the heating time, simultaneously remove the pipe and fitting straight out from the tool, using a snap action. Immediately insert the pipe straight into the socket of the fitting so the rounding clamp is flush against the end of the fitting socket. Hold or block the joint in place until the melts of the mating surfaces have solidified. The exact cooling time depends on the size of the pipe and the material being fused.

7.2.7 Remove the rounding clamp, and inspect the melt pattern at the end of the socket for a complete impression of the rounding clamp in the melt surface. There shall no gaps, voids, or unbonded areas. Clean the heating tool of any residual material using a wood stick or a clean, dry, oil-free, lint-free, non-synthetic cloth. Take care not to damage the heating surfaces. Plastic left on the tool tends to char when reheated, causing a loss of heater efficiency and joint contamination.

7.2.8 Allow for extremes in weather when making field joints. Heating times, operation of alignment jig, dimensional changes, and the like, are affected by extreme conditions.

7.3 *Testing*—Evaluate sample joints in order to verify the skill and knowledge of the fusion operator. Cut joints into straps, (see Fig. 4) and visually examine and test for bond continuity and strength. Bending, peeling, and elongation tests are useful for this purpose.

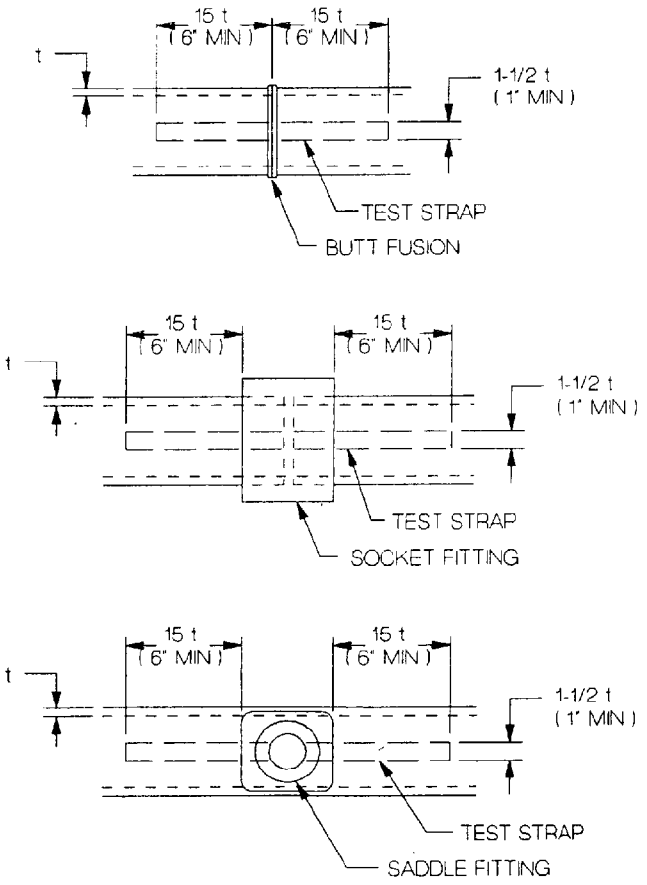

FIG. 4 Bent Strap Test Specimen

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8. Procedure 2—Butt Fusion

8.1 *Apparatus:*

8.1.1 *Heating Tool*—The heating tool shall have sufficient area to adequately cover the ends of the size of pipe to be joined.

8.1.2 *Alignment Jig*—The alignment jig is three basic parts: (*1*) a stationary clamping fixture and a movable clamping fixture for holding each of the two parts to be fused in alignment; (*2*) a facer for simultaneously preparing the ends of the parts to be joined (Note 6); and (*3*) appropriate adapters for different pipe sizes. Alignment jigs are manually or hydraulically powered.

NOTE 6—A facer is a rotating cutting device used to square-off the pipe or fitting ends to obtain properly mating fusion surfaces.

8.2 *Procedure:*

8.2.1 Bring the heater plate surfaces to proper temperature.

8.2.2 Clean the inside and outside of the components (pipe or pipe and fitting) to be joined. Remove all foreign matter from the surface of the component where it will be clamped in the alignment jig.

8.2.3 Align each component with its alignment jig clamp, and close the clamp. Check component to component alignment, adjust as needed, and face off the ends.

8.2.3.1 Take care when placing pipe or fittings in the alignment jig. Pipes shall be aligned before the alignment clamp is closed; however, do not force the pipe into alignment by pushing it against the side of an open alignment jig clamp.

8.2.4 Bring the piping components together and check for high-low alignment, and out-of-roundness. Adjust as required. Re-face after adjustment. The ends of the piping components shall be square to each other around their full circumference.

8.2.5 Place the heater plate between the component ends, and move the component ends against the heater plate with sufficient force to ensure complete circumferential contact against the heater plate. Hold the components against the heater plate briefly, using limited force to ensure that proper contact with the plate has been made. Release the force, but hold the components against the heater plate until an appropriately sized bead of molten plastic develops circumferentially around each component end as a result of the thermal expansion of the material. Do not push the components into the heater plate as the melting progresses.

8.2.6 Move the melted component ends away from the heater plate, and remove the heater plate. Then immediately bring the melted ends together with enough force to roll both component melt beads over to the pipe surface around the entire circumference of the joint. When the bead touches the pipe surface, stop moving the component ends together, but do not release the force. Hold the force on the joint until the joint has cooled.

8.2.6.1 Do not use excessive or insufficient force. If the components are brought together with too much force, all molten material may be pushed out of the joint and cold material brought into contact forming a "cold" joint. If too little force is used, only the melt in the beads may be fused together and, as the molten material in the joint cools and contracts, voids or non-fused areas may be formed. If the softened material sticks to the heater plate, discontinue the joining procedure. Clean the heater plate, re-square the component ends, and repeat the process from the beginning (8.2.2).

8.2.7 Allow the assembly to stand at least until cool before removing the clamps or other aligning device (Note 7). Do not subject the joint to high stress until it has cooled to less than approximately 130°F. Do not apply internal pressure until the joint and surrounding material have reached ambient air temperature.

NOTE 7—The joint is usually cool enough to remove from the alignment jig if a bare hand can be held against the beads without discomfort (less than approximately 130°F). Further cooling is recommended prior to ditching the pipe.

8.2.8 Visually inspect the joint against recommended appearance guidelines. The beads should be uniformly shaped and sized all around the joint.

8.3 *Testing*—Evaluate sample joints to verify the skill and knowledge of the fusion operator. Butt-fusion joints can be nondestructively examined using ultrasonic equipment to detect voids or other discontinuities. For destructive tests, cut joints into straps (see Fig. 4), visually examine, and test for bond continuity and strength. Tests that have been found useful for this purpose include inside face bend, outside face bend, tensile elongation, torque, and impact. Quantifiable data may be obtained by the use of laboratory procedures and comparing data against that from control samples.

9. Procedure 3—Saddle Fusion

9.1 *Apparatus:*

9.1.1 *Heating Tool Faces*—The faces are matched sets, by pipe size, of concave and convex blocks which bolt or clamp onto a flat or round core heater.

9.1.2 *Alignment Jigs*—Various types of alignment jigs are available. Alignment jigs provide a means to mount the alignment jig on the pipe, hold the fitting and align it to the pipe, and move the fitting towards and away from the pipe. Alignment jigs are used for saddle fusions for optimum results and are required for certain materials.

NOTE 8—Some materials may be saddle fused using a hand-stab procedure. Consult the manufacturer for a hand-stab procedure.

9.2 *Procedure:*

9.2.1 Bring heater plate and faces to proper temperature.

9.2.2 Clean the mating surfaces of the pipe and the concave surface of the fitting base and roughen the mating surfaces. Emery or garnet cloth of 50 to 60 grit is used to remove the tough outer surface skin. It is essential to remove the surface skin completely without altering the contours of the mating surfaces and to keep the surface clean. Remove dust and particles from the surface after roughing with a clean, dry, oil-free, lint-free cloth.

9.2.3 Install the alignment jig on the pipe. For smaller pipe sizes, install a bolster plate under the pipe to provide additional support.

9.2.4 Install the fitting in the alignment jig. Press the fitting against the pipe to align the fitting base to the pipe, then secure the fitting in the alignment jig.

9.2.5 Place the heater on the pipe and press the fitting against the heater to obtain a melt on both the pipe and the fitting.

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NOTE 9—When saddle fittings are fused to pipes that are under pressure, it is important that the surface melt be obtained quickly without too much heat penetration. Otherwise, the pipe may rupture from internal pressure. Consult the manufacturer for specific recommendations for fusing saddle fittings to pipe under pressure.

9.2.6 When a proper melt is achieved, remove the heater, quickly examine the pipe and fitting to ensure proper melt patterns, and immediately place the fitting on the pipe. Hold in place while exerting suitable force for the specified cooling time.

NOTE 10—If a suitable melt pattern has not been achieved, do not reheat; however, continue with the fusion and apply the fitting to the pipe. When the joint has cooled, remove the alignment jig, cut off the top of the fitting to prevent use, and start over at another location.

9.3 Visually inspect the joint against recommended visual inspection guidelines.

9.4 *Testing*—Evaluate sample joints to verify the skill and knowledge of the fusion operator. Cut joints into straps (see Fig. 4), visually examine, and test for bond continuity and strength. See Practice F 905 for methods for evaluating the quality of fusion joints.

10. Keywords

10.1 butt fusion; fitting; heat fusion; joining; pipe; polybutylene; polyethylene; polyolefin; polypropylene; saddle fusion; socket fusion

ANNEX

(Mandatory Information)

A1. COLD WEATHER PROCEDURES

A1.1 *Cold Weather Handling*—Pipe should be inspected for damage. Polyolefin pipes have reduced impact resistance in sub-freezing conditions. Avoid dropping pipe in sub-freezing conditions. When handling coiled pipe at temperatures below 40°F, it is helpful to uncoil the pipe prior to installation and let it straighten out. Gradually uncoil the pipe and cover it with dirt at intervals to keep it from recoiling. Always use caution when cutting the straps on coils of pipe because the outside end of a coil may spring out when the strapping is removed.

A1.2 *Preparation for Socket, Saddle, and Butt Fusion Joining:*

A1.2.1 *Wind and Precipitation*—The heating tool should be shielded in an insulated container to prevent excessive heat loss. Shield the pipe fusion area and fusion tools from wind, snow, and rain by using a canopy or similar device.

A1.2.2 *Pipe and Fitting Surface Preparation*—The pipe and fitting surfaces to be "joined" or held in clamps should be dry and clean and free of ice, frost, snow, dirt, and other contamination. Regular procedures for preparation of surfaces to be joined, such as facing for butt fusion and roughening for saddle fusion should be emphasized. After preparation, the surfaces should be protected from contamination until joined. Contamination of the area to be fused will likely cause incomplete fusion. Frost and ice on the surfaces of the pipe to be clamped in either a cold ring or alignment jigs may cause slippage during fusion. Inspect coiled pipe to see if it has flattened during storage which could cause incomplete melt pattern or poor fusion. It may be necessary to remove several inches at the pipe ends to eliminate such distortion. Pipe may have a slight toe-in or reduced diameter for several inches at the end of the pipe. The toe-in may need to be removed before butt fusing to a freshly cut pipe end, or to a fitting.

A1.2.3 *Heating*—Work quickly once pipe and fitting have been separated from the heating tool, so that melt heat loss is minimized, but still take time (no more than 3 s) to inspect both melt patterns. Keep the heater dry at all times. Check the temperature of the heating tool regularly with a pyrometer. Keep the heating tool in an insulated container between fusions.

A1.3 *Socket Fusion:*

A1.3.1 *Pipe Outside Diameter*—Pipe outside diameter contracts when cold. This results in loose or slipping cold rings. For best results, clamp one cold ring in its normal position adjacent to the depth gage. Place shim material (that is, piece of paper or rag, etc.) around the inside diameter of a second rounding ring and clamp this cold ring directly behind the first cold ring to prevent slippage. The first cold ring allows the pipe adjacent to the heated pipe to expand to its normal diameter during the heating cycle.

A1.3.2 *Fitting Condition*—If possible, store socket fittings at a warm temperature, such as in a truck cab, prior to use. This will make it easier to place the fitting on the heating tool because fittings contract when cold.

A1.3.3 *Heating*—At colder temperatures the pipe and fitting contract, thus the pipe slips more easily into the heating tool. At very cold outdoor temperatures (particularly with 2, 3, and 4 in. IPS pipe), the pipe may barely contact the heating surface. Longer heating cycles are used so that the pipe first expands (from tool heat) to properly contact the heating tool, then develops complete melt. The length of cycle necessary to obtain a complete melt pattern will depend not only on the outdoor (pipe) temperature but wind conditions and operator variation. Avoid cycles in excess of that required to achieve a good melt pattern. To determine the proper cycle time for any particular condition, make a melt pattern on a scrap piece of pipe, using the heating cycle as instructed by the pipe manufacturer. If the pattern is incomplete (be sure rounding rings are being used), try a 3-s longer cycle on a fresh (cold) end of pipe. If the melt pattern is still not completely around the pipe end, add an additional 3 s and repeat the procedure. Completeness of melt pattern is the key. Keep the heater dry at all times. Check the temperature of the heating tool regularly and keep the heating tool in an insulated container between fusions.

A1.4 *Butt Fusion:*

A1.4.1 *Joining*—The heating cycles shall be as recom-

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mended by the pipe manufacturer. It will take longer to develop the initial melt bead completely around the pipe ends. Do not increase pressure during heating. When proper melt bead has been obtained, the pipe and heater shall be separated in a rapid, snap-like motion. The melted surfaces shall then be joined immediately in one smooth motion so as to minimize cooling of the melted pipe ends.

A1.5 *Saddle Fusion:*

A1.5.1 *Surface Preparations*—Regular procedures for roughening the surfaces to be fused on the pipe and the fitting should be emphasized. After the surfaces have been prepared, particular care should be taken to protect against contamination.

A1.5.2 *Heating Time*—Make a trial melt pattern on a scrap piece of pipe. A clean, dry piece of wood is used to push the heating tool against the pipe. If the melt pattern is incomplete, add 3 s to the cycle time and make another trial melt pattern on another section of cold pipe. If the pattern is still incomplete, continue 3-s additions on a fresh section of cold pipe until a complete melt pattern is attained. Use this heating cycle for fusions during prevailing conditions. Regardless of the weather or the type of tools used, the important point to remember is that complete and even melt must occur on the fitting and the pipe in order to produce a good fusion joint. This requires pipe preparation to make it clean, straight, round, and well supported.

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Designation: D 2661 – 01

An American National Standard

Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe and Fittings[1]

This standard is issued under the fixed designation D 2661; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers fittings and single and coextruded acrylonitrile-butadiene-styrene (ABS) plastic drain, waste, and vent pipe (DWV) made to Schedule 40 iron pipe sizes (IPS). Plastic which does not meet the material requirements specified in Section 5 is excluded from single layer and all coextruded layers.

1.2 Specification for fittings for use with pipe meeting the requirements of this specification are given in Annex A1.

1.3 Acrylonitrile-butadiene-styrene plastic, which does not meet the definition of virgin ABS plastic as given in 3.2.2, is excluded, as performance of plastic other than those defined as virgin was not determined. ABS rework plastic, which meets the requirements of rework plastic as given in 5.3, is acceptable.

1.4 Reprocessed plastic or recycled plastic as defined in Terminology D 883 is excluded.

1.5 Recommendations for storage, joining, and installation are provided in Appendix X1, Appendix X2, and Appendix X3, respectively.

1.6 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.7 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics for Testing[2]

D 883 Terminology Relating to Plastics[2]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 1898 Practice for Sampling of Plastics[2]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D 2235 Specification for Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings[3]

D 2321 Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications[3]

D 2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Pipe Loading[3]

D 2444 Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)[3]

D 3311 Specification for Drain, Waste, and Vent (DWV) Plastic Fittings Patterns[3]

D 3965 Specification for Rigid Acrylonitrile-Butadiene-Styrene (ABS) Materials for Pipe and Fittings[4]

E 105 Practice for Probability Sampling of Materials[5]

E 122 Practice for Calculating Sample Size to Estimate, With a Specified Tolerable Error, the Average for a Characteristic of a Lot or Process[5]

F 402 Practice for Safe Handling of Solvent Cements, Primers, and Cleaners Used for Joining Thermoplastic Pipe and Fittings[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 1498 Specification for Taper Threads 60° for Thermoplastic Pipe and Fittings[3]

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[6]

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[6]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise specified. The abbreviation for acrylonitrile-butadiene-styrene is ABS.

3.1.1 *coextruded pipe*—pipe consisting of two or more concentric layers of material bonded together in processing by any combination of temperature, pressure, grafting, crosslinking, or adhesion.

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[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.63 on DWV.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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3.1.2 *coextrusion*—a process whereby two or more heated or unheated plastic material streams forced through one or more shaping orifice(s) become one continuously formed piece.

3.1.3 *room temperature*—a temperature in the range from 68 to 85 ± 3.6°F (20 to 30 ± 2°C).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *lot*—a lot shall consist of all pipe of the same size produced from one extrusion line during one designated 24-h period.

3.2.2 *recycled plastic*—a plastic prepared from discarded articles that have been cleaned and reground.

3.2.3 *reprocessed plastic*—a thermoplastic usually prepared from melt processed scrap or reject parts by a plastics processor, or from nonstandard or nonuniform virgin material.

3.2.4 *virgin ABS plastic*—plastic in the form of pellets, granules, powder, floc, or liquid that has not been subjected to use or processing other than that required for its initial manufacture.

4. Classification

4.1 The requirements of this specification are intended to provide pipe suitable for the drainage and venting of sewage and certain other liquid wastes.

NOTE 1—Industrial waste disposal lines should be installed only with the specific approval of the cognizant building code authority since chemicals not commonly found in drains and sewers and temperatures in excess of 180°F (82°C) may be encountered.

5. Materials

5.1 *Material Specification*—Virgin black ABS plastic shall conform to the requirements prescribed in Specification D 3965 with a cell classification of 4-2-2-2-2. The form of the material shall be as agreed upon between the seller and the purchaser in accordance with Specification D 3965.

5.2 The ABS plastic shall conform to the following requirements:

5.2.1 *Acrylonitrile-Butadiene-Styrene (ABS) Plastic*—Plastic containing polymers or blends of polymers shall contain a minimum of 15 % acrylonitrile, 6 % butadiene, and 15 % styrene or substituted styrene, or both. ABS plastic shall contain no more than 10 % of other monomeric or polymeric components plus other necessary compounding ingredients.

5.3 *Rework Material*—The manufacturer shall use only his own clean pipe or fitting rework material conforming with these cell class requirements. The pipe or fittings produced shall meet all the requirements of this specification.

6. Requirements

6.1 *General*—The pipe and fittings shall be homogeneous throughout and free of visible cracks, holes, foreign inclusions, or other injurious defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

6.1.1 The requirements in this section are intended only for use as quality control tests, not as simulated service tests.

6.2 *Dimensions and Tolerances*:

6.2.1 *Outside Diameter*—The outside diameter and tolerances shall meet the requirements of Table 1 when measured in accordance with Test Method D 2122. The tolerance for out-of-roundness shall apply to pipe prior to shipment.

6.2.2 *Wall Thickness*—The wall thickness and tolerances shall meet the requirements of Table 2 when measured in accordance with Test Method D 2122.

6.2.3 *Length*—The pipe shall be in either 10 or 20-ft (3.05 or 6.1-m) lengths, unless otherwise specified. The allowable tolerance on length shall be +½, –0 in. (+12, –0 mm).

6.3 *Performance Requirements*:

6.3.1 *Pipe Stiffness*— The minimum pipe stiffness values at 5 % deflection when measured in accordance with Test Method D 2412, shall equal or exceed the values in Table 3. The rate of crosshead motion shall be 0.20 to 0.25 in./min (5.1 to 6.3 mm/min). Three specimens shall be tested. If all three meet this requirement, the sample meets this requirement. If one or two fail, additional testing shall be conducted in accordance with 6.3.1.1. If all three fail, the sample does not meet the requirement.

6.3.1.1 *Pipe Stiffness and Lower Confidence Limit*—In the event that one or two of the specimens tested in 6.3.1 fail to meet the minimum requirement, the average pipe stiffness of eleven specimens shall meet or exceed the minimum requirement given in Table 3. The 99 % lower confidence limit (LCL) shall be within 15 % of the average value. The LCL shall be calculated using the Student's "*t*" distribution, with *N*-1 degrees of freedom, where *N* is the number of specimens. The critical *t* value shall be used to at least three significant digits. Alternatively, if the LCL exceeds the minimum PS requirement in Table 3, but is not within 15 % of the average, the sample meets the requirements of the Pipe Stiffness testing. The eleven

TABLE 1 Outside Diameters and Tolerances for ABS Schedule 40 Plastic Drain, Waste, and Vent Pipe

Nominal Pipe Size, in.	Outside Diameter		
	Average, in. (mm)	Tolerance on Average, in. (mm)	Out-of-Roundness Maximum Diameter Minus Minimum Diameter, in. (mm)[A]
1¼	1.660 (42.16)	+0.010, –0.000 (+0.25, –0.00)	0.024 (0.60)
1½	1.900 (48.26)	+0.010, –0.000 (+0.25, –0.00)	0.024 (0.60)
2	2.375 (60.32)	+0.010, –0.000 (+0.25, –0.00)	0.024 (0.60)
3	3.500 (88.90)	+0.015, –0.000 (+0.38, –0.00)	0.030 (0.76)
4	4.500 (114.30)	+0.015, –0.000 (+0.38, –0.00)	0.030 (0.76)
6	6.625 (168.28)	+0.011, –0.011 (+0.28, –0.28)	0.050 (1.27)

[A]Measured at time of manufacturing.

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TABLE 2 Wall Thickness and Tolerance for ABS Schedule 40 Drain, Waste, and Vent Pipe

Nominal Pipe Size, in.	Wall Thickness[A]	
	Minimum Wall, in. (mm)	Tolerance, in. (mm)
1¼	0.140 (3.56)	+0.015 (+0.38) −0.000 (−0.00)
1½	0.145 (3.68)	+0.015 (+0.38) −0.000 (−0.00)
2	0.154 (3.91)	+0.015 (+0.38) −0.000 (−0.00)
3	0.216 (5.42)	+0.020 (+0.51) −0.000 (−0.00)
4	0.237 (6.02)	+0.024 (+0.61) −0.000 (−0.00)
6	0.280 (7.11)	+0.030 (+0.76) −0.000 (−0.00)

[A]The minimum is the lowest wall thickness of the pipe at any cross section.

TABLE 3 Pipe Stiffness of ABS Schedule 40 Plastic Drain, Waste, and Vent Pipe

Nominal Pipe Size, in.	Minimum Pipe Stiffness at 5 % Deflection	
	psi	(MPa)
1¼	870	(6.00)
1½	630	(4.34)
2	370	(2.55)
3	320	(2.20)
4	190	(1.31)
6	95	(0.65)

specimens include the three tested under 6.3.1, and an additional eight with rotation by 35°, as specified in Test Method D 2412, continuing throughout the remaining specimens.

6.3.1.2 The LCL based on testing eleven specimens is calculated as follows:

$$\text{LCL} = (\text{avg PS}) - \{2.76(\text{std. dev.})/\sqrt{(N)}\} \quad (1)$$

where:

$$(\text{avg PS}) = [\Sigma(PS_i)]/(11)$$

$$(\text{std. dev.}) = \left[\frac{\Sigma PS^2 - (\Sigma PS)^2/N}{N-1}\right]^{1/2}$$

$$N = 11.$$

6.3.1.3 The 15 % requirement is calculated as follows:

$$(Avg - LCL)/(Avg) \times 100 \leq 15\ \% \quad (2)$$

NOTE 2—For quality control testing, a single specimen may be used with the thinnest wall at the top.

NOTE 3—The 5 % deflection criteria is arbitrarily selected for testing convenience. It should not be considered as a limitation with respect to in-use deflection. The engineer is responsible for establishing the acceptable deflection limit.

NOTE 4—The strength and load-carrying capabilities of plastic pipe are measured and reported as pipe stiffness, which is determined in accordance with Test Method D 2412. The term "crush strength" is not applicable to plastic piping because the values obtained can be significantly different, depending on the bedding, loading, or testing technique used, and because the term derives from rigid pipe and refers to its ultimate strength at rupture.

6.3.2 *Pipe Flattening*—There shall be no evidence of rupture when pipe is deflected 40% of the initial inside diameter when tested in accordance with Test Method D 2412. The rate of head approach shall be 0.20 to 0.25 in./min (5.1 to 6.3 mm/min). Three specimens shall be tested. All shall meet the requirements. Failure shall be a crack or break extending entirely through the pipe wall visible to the unaided eye.

6.3.3 *Impact Resistance*—The minimum impact resistance, when tested at the time of manufacture, shall comply with Table 4. Test in accordance with Test Method D 2444 using Tup B and Holder B. Use a 30-lb (13.6 kg) tup for testing all pipe sizes.

6.3.3.1 Test 10 specimens. When 9 or 10 specimens pass, accept the lot. When 2 or more specimens fail, test 10 additional specimens. When 17 of 20 specimens tested pass, accept the lot. When 4 or more of 20 specimens fail, test 20 additional specimens. When 32 of 40 specimens pass, accept the lot. When 9 or more of 40 specimens fail, the lot does not meet the requirements of this specification.

6.3.3.2 Failure of the test specimen shall be shattering or any crack or break extending entirely through the pipe wall and visible to the unaided eye.

6.4 *Coextruded Pipe*:

6.4.1 *Thickness of Outer Layer*—For pipe produced by the coextrusion process, that is, pipe containing two or more concentric layers, the outer layer shall be at least 0.020 in. (0.50 mm) thick and shall contain pigments or screening agents to provide protection against UV radiation.

6.4.2 *Bond*—For pipe produced by the coextrusion process, that is, pipe containing two or more concentric layers, the bond between the layers shall be strong and uniform. It shall not be possible to separate any two layers with a probe or point of a knife blade so that the layers separate cleanly so the probe or knife blade moves freely between the layers. Nor shall separation of bond occur between layers during testing performed under the requirements of this specification.

6.5 *Other Requirements*:

6.5.1 *Inspection*—Before installation the pipe shall be inspected. Pipe which does not meet the requirements of this specification shall be returned to the seller.

6.5.2 *Joining*—ABS schedule 40 drain, waste, and vent (DWV) are joined using molded fittings meeting the requirements of Annex A1 of this specification.

6.5.3 *Solvent Cement*—In the assembly of solvent cement joints, the safety requirements of Practice F 402 shall be

TABLE 4 Impact Resistance of ABS Schedule 40 Plastic Drain, Waste, and Vent Pipe

Nominal Pipe Size, in.	Minimum Impact Resistance, ft·lbf (J)	
	At 73°F	(23°C)
1¼	20	(27)
1½	30	(41)
2	40	(54)
3	60	(81)
4	60	(81)
6	100	(136)

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followed using solvent cement meeting the requirements of Specification D 2235.

7. Sampling and Conditioning

7.1 *Sampling*—For the purpose of testing, the lot shall consist of all pipe produced of one size, from one extrusion line, during one designated 24-h period. The number of specimens designated for each test shall be taken from pipe selected at random from each lot in accordance with the random sampling plan of Practice D 1898.

NOTE 5—Refer to Practices E 105 and E 122.

7.2 *Number of Tests for Quality Control*—When evaluating the product against this specification, the following minimum number of specimens shall be tested for each lot.

7.2.1 *Outside Diameter*—One specimen per extrusion line.

7.2.2 *Wall Thickness*—One specimen per extrusion line.

7.2.3 *Length*—One specimen per extrusion line.

7.2.4 *Pipe Stiffness*—A minimum of three specimens per extrusion line. (See Note 2.)

7.2.5 *Pipe Flattening*—A minimum of three specimens per extrusion line.

7.2.6 *Impact Strength*—A minimum of ten specimens and a maximum of 40.

7.2.7 *Bond*—One specimen for each extrusion line.

7.3 *Conditioning*:

7.3.1 For referee purposes, condition the specimens prior to test at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity in accordance with Practice D 618, Procedure A.

7.3.2 For routine quality control testing, condition the specimens at the temperature and humidity of the manufacturers testing facility for not less than 1 h or until the specimens are at room temperature.

7.4 *Test Conditions*:

7.4.1 For referee purposes, conduct tests in the standard laboratory atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity.

7.4.2 For routine quality control testing, conduct tests at the room temperature and humidity of the manufacturers testing area.

7.5 *Test Methods*—Use only the specified ASTM test methods.

8. Retest and Rejection

8.1 If the results of any test(s) do not meet the requirements of this specification, the test(s) shall be conducted again only by agreement between the purchaser and the seller. Under such agreement, minimum requirements shall not be lowered, changed, or modified, nor shall specification limits be changed. If, upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

9. Product Marking

9.1 *Quality of Marking*—The markings shall be applied to the pipe in such a manner that they remain legible (easily read) after installation and inspection.

9.2 *Content of Marking*—The pipe shall be marked on two sides 180° apart at least every 2 ft (0.6 m) in letters not less than 3/16 in. (5 mm) high, in a contrasting color with the following information:

9.2.1 The manufacturer's name (or trademark).

9.2.2 The designation "ASTM D 2661".

9.2.3 Nominal pipe size (for example, 2 in. (51 mm)).

9.2.4 The manufacturer's code for resin manufacturer, lot number, and date of manufacture.

9.2.5 *Single Extrusion Pipe*—The pipe produced by single extrusion process shall be marked "ABS DWV".

9.2.6 *Coextruded Pipe*—The pipe produced by the coextrusion process shall be marked "COEXTRUDED ABS DWV".

10. Quality Assurance

10.1 When the product is marked with this designation, D 2661, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

11. Keywords

11.1 ABS; DWV; fittings; pipe; plastic; Schedule 40; thermoplastic

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply *only* to federal/military procurement, not domestic sales or transfers.

S1. *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless the purchaser disapproves. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE S1.1—In U.S. Federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the material shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor

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Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S1.1—The inclusion of U.S. Federal Government procurement requirements should not be construed as an indication that the U.S. Federal Government uses or endorses the products described in this specification.

ANNEX

(Mandatory Information)

A1. ABS FITTINGS

A1.1 The pattern, dimension, and laying length of fittings shall meet the requirements of Specification D 3311 and Table A1.1 when determined in accordance with Test Method D 2122.

A1.2 Fittings produced by any molding process shall be made of virgin black ABS plastic which shall conform to the requirements prescribed in Specification D 3965 with a cell classification of 3-2-2-2-2. The form of the material shall be as agreed upon between the seller and the purchaser in accordance with Specification D 3965.

A1.3 *Rework Material*—The manufacturer shall use only his own clean rework fitting material and the fittings produced shall meet all the requirements of this specification.

A1.4 The spigot dimensions of the fittings shall meet the requirements of Table 1 and Table 2.

A1.5 For all fittings having taper pipe threads, threads shall conform to and be gaged in accordance with Specification F 1498.

A1.6 Individual fittings unassembled shall withstand a minimum load of 750 lbf/ft (11 kN/m) of centerline length without visible evidence of failure when tested in accordance with Test Method D 2412.

A1.7 Individual fittings unassembled shall meet a minimum impact of 20 ft·lbf (27 J) when tested in accordance with Test Method D 2444 at 73°F (23°C) using a 12-lb (5-kg) Tup C and Holder B. Test inline couplings cemented to short pieces of pipe and allow to dry for at least 24 h.

A1.8 Solvent cement meeting the requirements of Specification D 2235 shall be used to join pipe and fittings.

A1.9 Fittings shall be marked on the body or hub with the manufacturer's name or trademark, and the symbol "ABS".

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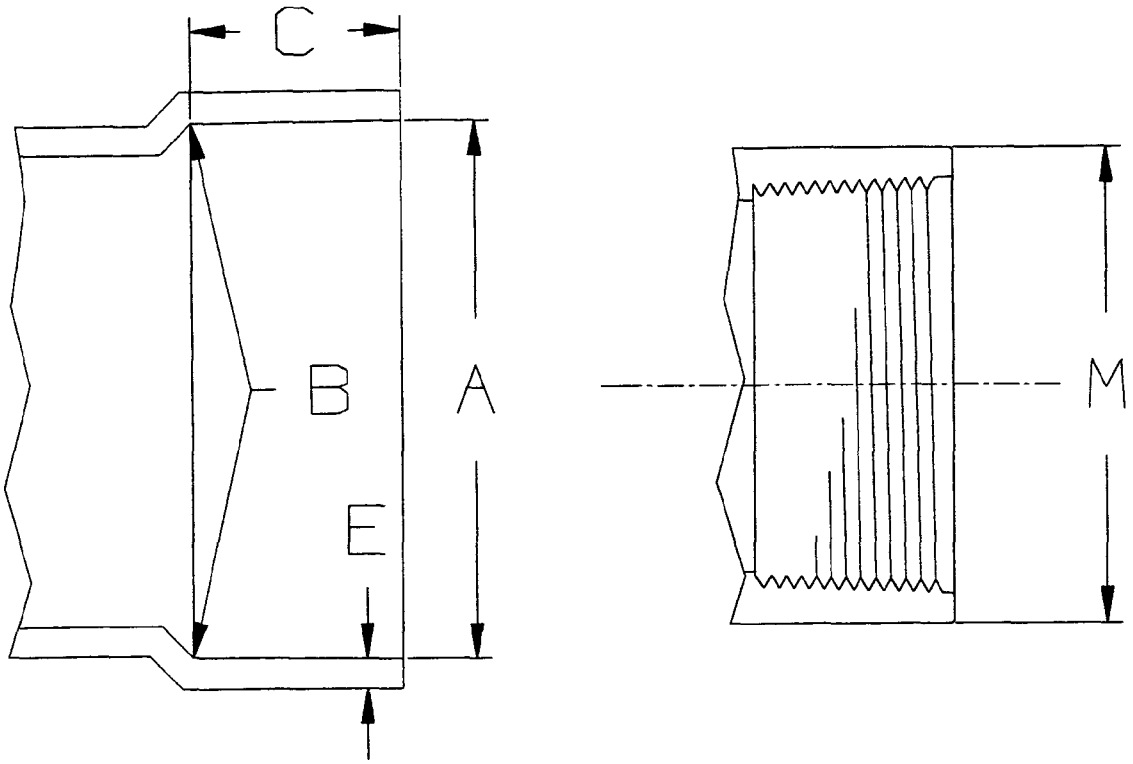
TABLE A1.1 Dimensions and Tolerances for ABS Schedule 40 Drain, Waste, and Vent Fittings



Nominal Pipe Size	A Socket Entrance Diameter			B Socket Bottom Diameter[A]			C Socket Depth,[B] min	E Wall Thickness[C]		Internal Threads	
	Average	Tolerance on Diameter	Out-of-Roundness (maximum minus minimum)	Average	Tolerance on Diameter	Out-of-Roundness (maximum minus minimum)		Average, min	Minimum After Core Shift	M Outside Diameter of Hub, min	Thread Length, min
1¼	1.670	+0.010 −0.005	0.024	1.655	±0.005	0.024	0.687	0.156	0.140	1.871	0.687
1½	1.910	+0.010 −0.005	0.024	1.895	±0.005	0.024	0.687	0.156	0.140	2.127	0.687
2	2.385	+0.010 −0.005	0.024	2.370	±0.005	0.024	0.750	0.156	0.140	2.634	0.750
3	3.515	+0.010 −0.005	0.030	3.495	+0.005 −0.010	0.030	1.500	0.218	0.196	3.841	1.187
4	4.515	+0.010 −0.005	0.030	4.495	+0.005 −0.010	0.030	1.750	0.250	0.225	4.907	1.281
6	6.647	±0.011	0.060	6.614	±0.011	0.060	3.000	0.281	0.253	7.203	1.500

[A] Measure at the intersection of pipe stop cone with socket cylinder.
[B] Measure from socket entrance to intersection of pipe stop cone with socket cylinder.
[C] The average wall thickness is the minimum wall thickness plus the opposite wall thickness divided by 2. The average shall equal or exceed that shown in Table A1.1. The minimum wall thickness, due to core shift, shall equal or exceed the value shown in the table. The minimum wall thickness is determined by allowing a 10 % variation due to core shift.

APPENDIXES

(Nonmandatory Information)

X1. STORAGE

X1.1 *Outside Storage*—Plastic pipe should be stored on a flat surface or supported in a manner that will prevent sagging or bending. Do not store pipe in direct sunlight forlong periods.

X1.2 Inventories of plastic pipe should be used on a first-in, first-out basis.

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X2. JOINING

X2.1 *Field Inspection*—Prior to use, all pipe should be carefully inspected for cuts, gouges, deep scratches, damaged ends, or other major imperfections. Defective pipe should be rejected or the damaged sections should be cut out.

X2.2 *Pipe Fit*—Pipe is manufactured to close tolerances to ensure satisfactory "interference" fit between the pipe and the fittings socket during assembly. Use only combinations of pipe and fittings that give interference fits. Pipe that is a loose fit in the socket may not properly bond. The allowable tolerance assures a forced fit and when solvent cement is applied, the pipe and fitting will readily mate, thus assuring proper adhesion. The pipe should enter the dry fitting socket to between one half and two thirds of the fitting socket depth.

X2.3 *Cutting*—Pipe can be easily cut with an ordinary hacksaw or carpenter's saw. Fine-tooth blades with little or no set should be used for best results. The pipe should be cut square and all burrs removed with a sharp knife, a fine-tooth file, or other suitable tool such as chamfering tool or reamer. A miter box is recommended to ensure square cut ends. Standard steel pipe or tubing cutters are not recommended for cutting ABS pipe since they may cause excessive heat and pressure, that can result in cracked or irregular pipe ends. There are special plastic pipe cutters available with extra wide rollers and thin cutting wheels that have been especially designed for cutting plastic pipe, and their use is recommended.

X2.4 *Cleaning*—Remove burrs from inside and outside pipe edges. Wipe off all dust, dirt, and moisture from surfaces to be cemented with a clean dry rag or a paper towel. At no time should pipe or fittings be assembled that are wet or damp. Pipe and fittings must be dry before assembly to obtain good joints.

X2.5 *Safety Requirements for Solvent Cement and Primers*—Follow Practice F 402.

X2.6 *Solvent Cement*—Use only solvent cement designed for ABS. Use a solvent cement meeting the requirements of Specification D 2235.

X2.6.1 *Application of Cement*—Using the applicator supplied with the can of solvent cement, or a brush or roll with a width of about one half the pipe diameter for pipe sizes above 2 in. (51 mm), apply a moderate, even coating of cement in the fitting socket to cover only the surfaces to be joined. Heavy or excessive application of solvent cement may become an obstruction in the pipe and prevent satisfactory joining. Quickly apply a heavy coat of solvent cement to the outside of the pipe. Make sure that the coated distance on the pipe is equal to the depth of the fitting socket.

X2.7 *Assembly*—Make the joint as quickly as possible after application of the solvent cement and before the solvent cement dries. Should the solvent cement dry partially before the joint is made up, reapply solvent cement before assembling. Insert the pipe into the fitting socket, making sure that the pipe is inserted to the full depth of the fitting socket. Hold the joint together firmly for about 30 s for small diameter pipe and 60 s for diameters above 6 in. (152 mm) to avoid push-out. Remove excessive solvent cement from the exterior of the joint with a clean, dry cloth.

X2.8 *Set Time*—Do not attempt to disturb the pipe and fitting joint until after the solvent cement has set, or damage to the joint and loss of fit may result. Reasonable handling of assembly is permissible within 2 min after joining. Allow 15 min for the joint to develop good handling strength and the joint will withstand the stresses of normal installation. A badly misaligned installation will cause excessive stresses in the joint, pipe, and fittings and constitutes a plumbing code violation and should be avoided. The recommendation of the solvent cement manufacturer should be followed for best results.

X2.9 *Cure Time*—Joint strength development is very rapid during periods of high ambient temperatures, low relative humidity, and using interference-type fittings. Joint strength development is not as rapid during periods of low ambient temperatures, high relative humidity, and using loose fits. Therefore, the recommendations of the solvent cement manufacturer should be followed for best results prior to leak testing.

X3. INSTALLATION

X3.1 *Underground Installation*—Underground installations of pipe shall be in accordance with the Plumbing Code, except maximum aggregate size shall be limited to ½ in. (13 mm) for angular and ¾ in. (19 mm) for rounded particles. For special conditions Design Engineers may wish to consult Practice D 2321.

X3.2 *DWV Installation*—Pipe should be installed in conformance with governing building codes. In areas not governed by codes, pipe should be installed in accordance with accepted engineering practices.

X3.3 *Installation Under Freezing Conditions*—Plastic pipe has decreased resistance to impact under freezing conditions. Increased care should be exercised if installation is likely to occur under these conditions, particularly during handling, transportation, installation, and backfilling. Where possible, installation should be avoided during freezing conditions. Allowance shall be made for expansion that will occur when the temperature of the pipe is raised.

X3.4 *Alignment and Grade*—Align all piping system components properly without strain. Do not bend or pull pipe into

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position after being solvent cemented. The grade of horizontal drainage and vent piping shall be as specified in the applicable code.

X3.5 *Supports and Spacing*—Hangers and straps should not compress, distort, cut, or abrade the piping and should allow free movement of pipe. Support horizontal piping at intervals of not more than 4 ft (1.2 m) at end of branches and at changes of direction or elevation. Supports should allow free movement. Maintain vertical piping in straight alignment with supports at each floor level or at 10-ft (3.1-m) intervals, whichever is less. Support trap arms in excess of 3 ft (0.9 m) in length as close as possible to the trap. Securely fasten closed flanges with corrosion-resistant fasteners to the floor with the top surface ¼ in. (6.4 mm) above the finish floor level. Stabilize closet bends or stubs against all horizontal or vertical movement. Protect pipe exposed to damage by sharp surfaces with grommets or sleeves of rubber or plastic.

X3.6 *Threaded Connections*—Do not cut threads on pipe. Molded threads on adapter fittings for transition to threaded construction are necessary except in the case of cleanout plugs. The joint between the pipe and transition fittings should be of the solvent cement type. Only approved thread tape or thread lubricant specifically intended for use with ABS plastic pipe should be used. Conventional pipe thread compound, putty, linseed oil base products, and unknown mixtures should be avoided.

X3.7 *Thread Tightness*—Where a threaded joint is made, obtain tightness by a maximum hand tightening plus additional tightening with a strap wrench, not to exceed one full turn.

X3.8 *Connection to Nonplastic Pipe*—When connecting plastic pipe to other types of piping, use only approved types of fittings and adapters designed for the specific transition.

X3.9 *Connections to Traps*—Connect traps by means of approved threaded trap adapters.

X3.10 *Connection to Closet Flanges*—Install screw-type closet flanges in the drainage system by means of a threaded connection.

X3.11 *Transition to Bell-and-Spigot Pipe*—Make connections or transition to bell-and-spigot cast iron soil pipe and fittings, and to bell-and-spigot pipe and fittings of other materials with approved mechanical compression joints designed for this use, or caulk joints made in an approved manner.

X3.12 *Building Drains Under Floor Slabs*—Make trench bottoms smooth and of uniform grade with either undis-turbed soil or a layer of selected and compacted-backfill so that no settlement will be encountered. Bottom of pipe must rest on this material throughout the entire length.

X3.13 *Thermal Expansion*—Allow for thermal expansion and movement in all piping installations by the use of approved methods. Support but do not rigidly restrain piping at branches or changes of direction. Do not anchor pipe rigidly in walls. Holes through framing members should be adequately sized to allow for free movement. Thermal expansion for installations subject to temperature changes may be determined from Table X3.1. The linear expansion shown is independent of the diameter of the pipe. Buried piping or piping installed in the crawl space under a building is normally subject to less than the ambient temperature changes.

X3.14 *Exposed Piping*—Provide adequate support where piping is exposed to wind, snow, and ice loading. Plumbing vents exposed to sunlight should be protected by water-base synthetic latex paints. Where surface temperatures exceed 165°F (74°C), piping shall be protected by means of shielding or some type of lightweight insulation. Exposure to sunlight during normal construction periods is not harmful. It is good practice to store pipe and fittings under suitable cover prior to installation.

X3.15 *Antifreeze Protection*—When necessary to protect traps and fixtures from freezing, do not use alcohol or petroleum products. Use only approved plastic pipe antifreeze packaged for this purpose or one of the following solutions:

X3.15.1 Sixty percent, by mass, of glycerin in water.

X3.15.2 Twenty-two percent, by mass, of magnesium chloride in water. Strong solutions of common table salt (sodium chloride) may also be used.

X3.16 *Commercial and Industrial Applications*—The DWV pipe will accommodate temperature of 180°F (82°C) encountered in household applications, but the nature of some applications to run to higher temperatures; for example, commercial dishwashers, require special consideration.

X3.17 *Fire-Rated Construction*—When the piping is to be installed within or penetrating fire-rated constructions, the cognizant building code authorities should be consulted for approved methods of construction or fire barriers.

TABLE X3.1 Thermal Expansion Table of ABS Schedule 40 Drain, Waste, and Vent Pipe

Length, ft	Temperature Change, °F[A]						
	40	50	60	70	80	90	100
	Length of Change, in.[B]						
20	0.5	0.7	0.8	0.9	1.0	1.2	1.3
40	1.1	1.3	1.6	1.9	2.0	2.4	2.7
60	1.6	2.0	2.4	2.8	3.2	3.6	4.0
80	2.1	2.7	3.2	3.8	4.3	4.8	5.4
100	2.7	3.4	4.0	4.7	5.4	6.0	6.7

Length, m	Temperature Change, °C			
	20	30	40	50
	Length of Change, mm			
10	20	30	40	50
20	40	60	80	100
30	60	90	120	150

[A] *Example of Temperature Change:*

Highest temperature expected	100°F
Lowest temperature expected	50°F
Total variation	50°F

[B] For a length of run of 60 ft (20 m) the chart indicates that the installation should provide for a linear expansion of 2 in. (51 mm).

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NOTE X3.1—Fire barriers are either mechanical devices that close off penetration openings or intumescent materials that expand with heat to form a char that make a flame and water-resistant seal.

X3.17.1 All fire barriers should bear the seal of approval and classification of the approving laboratory recognized as qualified to perform such evaluations, for example UL.

NOTE X3.2—Use fire barrier products meeting this requirement.[7]

[7] Fire barrier products that have been found satisfactory for this purpose are: "Flamarest," available from AVCO Systems Division, Lowell Industrial Park, Lowell, MA 01851; "Flameseal," available from Nelson Electric, P.O. Box 726, Tulsa, OK 74101; "Firebarrier," available from 3M Electrical Products Division, 225-4N 3M Center, St. Paul, MN 55144; and "Fire Stop Foam," available from Dow Corning, Dept. A6009, Midland, MI 48686.

X4. PREFABRICATED PLUMBING TREES

X4.1 When prefabricated plumbing trees are assembled, it is important that the recommendation of Appendix X2 on joining and Appendix X3 on installation, where applicable, be followed for satisfactory results.

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Standard Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings[1]

This standard is issued under the fixed designation D 2855; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This practice describes a procedure for making joints with poly(vinyl chloride) plastic (PVC) pipes, both plain ends and fittings, and bell ends, by means of solvent cements. These procedures are general ones for PVC piping. In non-pressure applications, simplified procedures may be used. Manufacturers should supply specific instructions for their particular products, if and when it seems necessary.

1.2 The techniques covered are applicable only to PVC pipe, both plain and bell-end, and fittings of the same classes as described in Specification D 1784.

1.3 Pipe and fittings are manufactured within certain tolerances to provide for the small variations in the extrusion, belling, and molding processes and are not to exact size. A partial list of standards for PVC pipe, fittings, and cements suitable for use in making solvent-cemented joints is given in Appendix X1.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The text of this practice references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the practice.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D 740 Specification for Methyl Ethyl Ketone[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[4]

D 1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[4]

D 2564 Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems[5]

F 402 Practice for Safe Handling of Solvent Cements, Primers, and Cleaners Used for Joining Thermoplastic Pipe and Fittings[5]

F 412 Terminology Relating to Plastic Piping Systems[5]

F 656 Specification for Primers for Use in Solvent Cement Joints of Poly(Vinyl Chloride) (PVC) Plastic Pipe and Fittings[5]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise specified.

4. Summary of Practice

4.1 To consistently make good joints, the following should be clearly understood and adhered to:

4.1.1 The joining surfaces must be softened (dissolved) and made semi-fluid.

4.1.2 Sufficient cement must be applied to fill the gap between pipe and fitting.

4.1.3 Assembly of pipe and fittings must be made while the surfaces are still wet and fluid.

4.1.4 Joint strength develops as the cement dries. In the tight part of the joint the surfaces will tend to fuse together; in the loose part the cement will bond to both surfaces.

4.2 Penetration and dissolving can be achieved by the cement itself, by a suitable primer, or by the use of both primer and cement. A suitable primer will penetrate and dissolve the plastic more quickly than cement alone. In cold weather, more time and additional applications are required (see Fig. 1).

4.3 More than sufficient cement to fill the loose part of the joint must be applied (see Fig. 2). Besides filling the gap, adequate cement layers will penetrate the surfaces and also remain wet until the joint is assembled.

4.4 If the cement coatings on the pipe and fittings are wet and fluid when assembly takes place, they will tend to flow together and become *one* cement layer. Also, if the cement is wet the surfaces beneath them will still be soft, and these dissolved surfaces in the tight part of the joint will tend to fuse together (see Fig. 3).

4.5 As the solvent dissipates, the cement layer and the dissolved surfaces will harden with a corresponding increase

[1] This practice is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.20 on Joining.

Current edition approved March 10, 1996. Published May 1996. Originally published as D 2855 – 70. Last previous edition D 2855 – 93.

[2] Other standards suitable for use in making solvent-cemented joints for PVC pipe and fittings are listed in Appendix X1.

[3] *Annual Book of ASTM Standards*, Vol 06.04.

[4] *Annual Book of ASTM Standards*, Vol 08.01.

[5] *Annual Book of ASTM Standards*, Vol 08.04.

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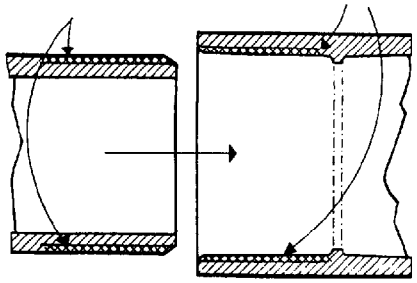

FIG. 1 Areas of Pipe and Fittings to Be Softened (Dissolved) and Penetrated

in joint strength. A good joint will take the required working pressure long before the joint is fully dry and final strength is obtained. In the tight (fused) part of the joint, strength will develop more quickly than in the looser (bonded) part of the joint. Completed joints should not be disturbed until they have cured sufficiently to withstand handling. Joint strength develops as the cement dries. Information about the development of bond strength of solvent cemented joints is available (see Fig. 4).

5. Significance and Use

5.1 The techniques described herein can be used to produce strong pressure-tight joints between PVC pipe and fittings, either in shop operations or in the field. However, skill and knowledge on the part of the operator are required to obtain a good quality joint. This skill and knowledge can be obtained by making joints under the guidance of skilled operators and testing them until good quality joints are obtained.

6. Materials

6.1 *Pipe and Fittings*—The pipe and fittings should meet the requirements of current applicable PVC piping standards. A list of these standards is given in Appendix X1.

6.2 *Solvent Cement:*

6.2.1 *Specification*—The solvent cement should meet all the requirements of Specification D 2564.

6.2.2 *Selection*—PVC solvent cements are available in a variety of viscosities and wet film thicknesses to cover the range of pipe sizes from ⅛ to 12 in. and for interference-fit joints as well as noninterference joints, as found in some Schedule 80 pipe and fittings. One of the general principles of solvent cementing that should be strictly adhered to is: sufficient cement must be applied to fill the gap between pipe and fitting.

6.2.2.1 The ability of a solvent cement to fill a gap in a

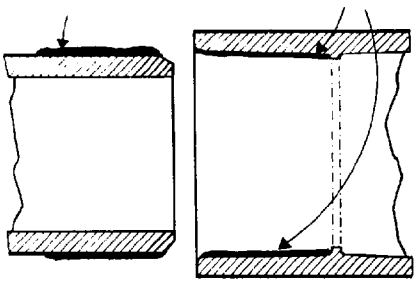

FIG. 2 Cement Coatings of Sufficient Thickness

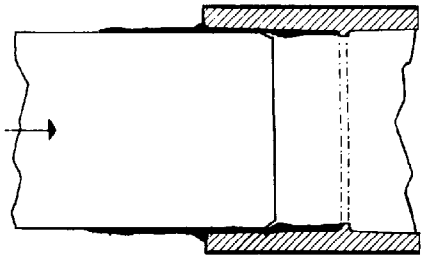

FIG. 3 Assembly of Surfaces While They Are Wet and Soft

pipe joint can be determined by considering its viscosity and wet-film thickness (see Note X3.1). A guide to the proper selection of a solvent cement for the various pipe sizes is given in Tables X3.1 and X3.2, where PVC solvent cements are classified (for purposes of identification) as regular-bodied, medium-bodied, and heavy-bodied cement based on minimum viscosity and minimum wet-film thickness.

6.2.3 *Storage*—PVC solvent cements should be stored in a cool place except when actually in use at the job site. These cements have a limited shelf life when not stored in hermetically sealed containers. Screw top containers are not considered to be hermetically sealed. Consult the cement manufacturer for specific storage recommendations on storage conditions and shelf life. The cement is unsuitable for use on the job if it exhibits an appreciable change from the original viscosity, or if a sign of gelation is apparent. Restoration of the original viscosity or removal of gelation by adding solvents or thinners is not recommended.

6.3 *Cleaners*—Cleaners are of two types, chemical and mechanical (abrasives). Cleaners are used to remove surface impurities (oil, dirt, etc.) and surface gloss.

6.3.1 *Chemical Cleaners*—The chemical cleaners are as follows:

6.3.1.1 Cleaner recommended by the pipe, fittings, or cement manufacturer, and

6.3.1.2 Methyl ethyl ketone (MEK) in accordance with Specification D 740.

6.3.2 *Mechanical Cleaners*—The mechanical cleaners are as follows:

6.3.2.1 Fine abrasive paper or cloth (180 grit or finer), and

6.3.2.2 Clean, oil-free steel wool.

6.4 *Primers*—Primers are used to clean, soften, and dissolve the joining surfaces in order to better prepare them for solvent cementing. Primers must be capable of dissolving 10 weight % of PVC resin as required in Specification F 656.

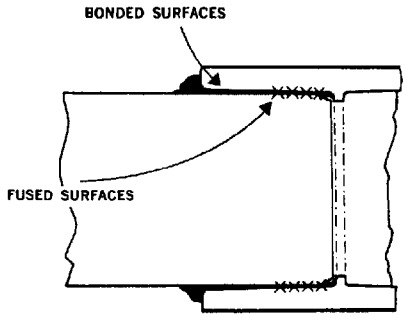

FIG. 4 Bonded and Fused Surfaces of Joined Pipe

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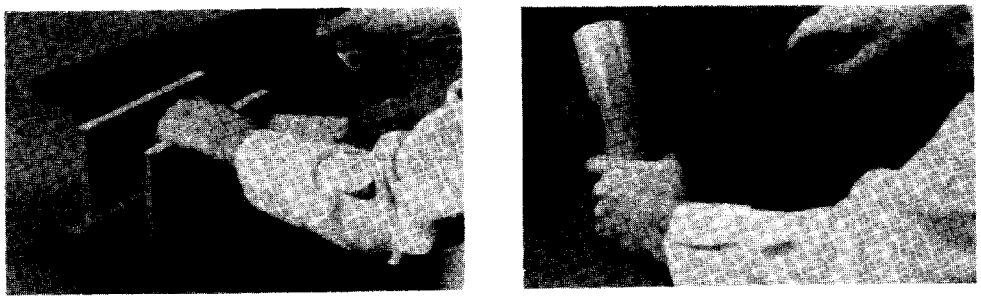

FIG. 5 Apparatus for Cutting Pipe

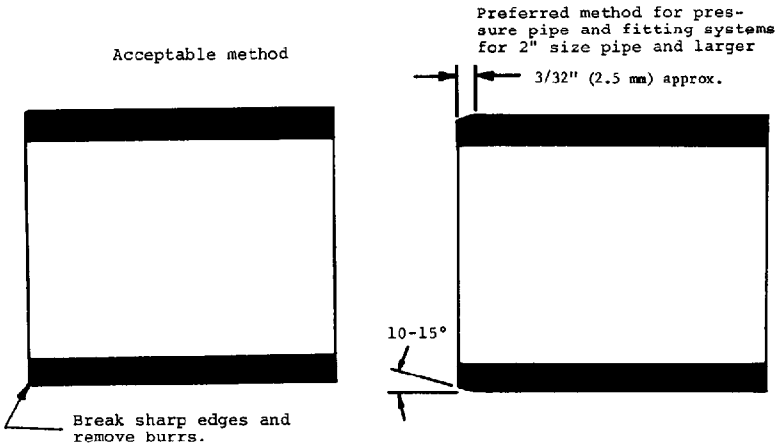

FIG. 6 Chamfer and Deburring of Pipe Edges

Primers may also be used as cleaners; refer to specific recommendations of the manufacturer.

NOTE 1—In the event of conflicting instructions from the pipe, fittings, or cement manufacturer, use a primer as well as solvent cement in the joining procedure.

6.4.1 *Primer Specification*—The primer shall meet the requirements of Specification F 656.

7. Procedure

7.1 *Cutting the Pipe*—Cut pipe square with the axis, using a fine-tooth hand saw and a miter box, or a fine-tooth power saw with a suitable guide (see Fig. 5). Wood-working blades may be used. A rotary cutter may be used if the cutting blades are specifically designed for cutting plastic pipe in such a way as not to raise a burr or ridge (flare) at the cut end of the pipe. If other tools are not available, a standard rotary metal pipe cutter may be used, provided great care is taken to remove all the ridge raised at the pipe end by the wedging action of the cutting wheels. Failure to remove the ridge will result in the cement in the fitting socket being scraped from the socket surface, producing a dry joint with a high probability of joint failure. Remove all burrs with a knife, file, or abrasive paper.

FIG. 7 Pipe Entering Dry Fitting

7.2 *Joint Preparation*—Chamfer or deburr pipe, or both, approximately as illustrated in Fig. 6. Failing to chamfer the edge of the pipe may remove the cement and softened material from the fitting socket, and result in a leaking joint.

7.3 *Test Dry Fit of the Joint* (see Fig. 7)—The solvent cement joint is designed so that there will generally be interference of pipe wall with the fitting socket before the pipe is fully inserted. Insert the pipe into the fitting and check that the interference occurs about ⅓ to ⅔ of the socket depth. Sometimes, when the pipe and fittings are at their tolerance extremes or when Schedule 80 pipe is used, it may be possible to fully insert the dry pipe into the fitting socket until it bottoms. If this occurs, the fit between the pipe and fitting should be snug. If the fit is loose or wobbly, other fittings or pipe should be selected which give a proper fit.

7.4 *Cleaning*—Surfaces to be joined must be cleaned and be free of dirt, moisture, oil, and other foreign material (see Fig. 8). If this cannot be accomplished by wiping with a clean dry cloth, a chemical or mechanical cleaner must be used. If

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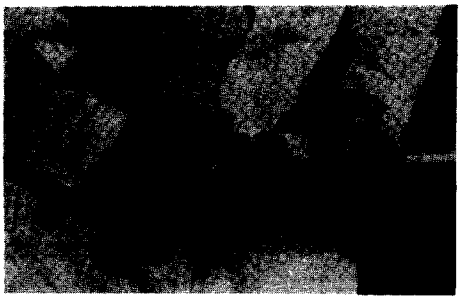

FIG. 8 Cleaning of Pipe with Dry Cloth to Remove Foreign Matter

FIG. 10 Liberal Application of Primer to Soften Surface of End of Pipe

a chemical cleaner is used, apply with an applicator. Skin contact with chemical cleaners should be avoided.

7.5 *Application Procedure:*

7.5.1 *Handling Cement*—Keep the cement can closed and in a shady place when not actually in use. *Discard* the cement when an appreciable change in viscosity takes place, or at the first sign of gelation. The cement should not be thinned. Keep the brush immersed in cement between applications.

NOTE 2—A gel condition is indicated when the cement does not flow freely from the brush or when the cement appears lumpy and stringy.

7.5.2 *Applicator Size*—Apply the cement with a natural bristle, nylon brush or suitable applicator, using a ½-in. (12-mm) brush or dauber for nominal pipe size ½-in. and less, a 1-in. (25-mm) brush or dauber for pipe up through 2-in. nominal pipe size, and a brush width at least ½ of nominal pipe size for sizes above 2 in., except that for pipe sizes 6 in. and larger a 2½-in. (60-mm) brush is adequate. Other applicators may be used provided their use results in an equivalent amount of cement being applied to the joining surfaces.

7.5.3 *Application of Primer and Cement*—PVC solvent cement is fast drying, and therefore the cement shall be applied as quickly as possible, consistent with good workmanship. It may be necessary for two workers to perform this operation for larger sizes of pipe. Under conditions of high atmospheric humidity, quick application is important to minimize condensation of moisture from the air on the cement surface. The surface temperature of the mating surfaces should not exceed 110°F (45°C) at the time of assembly. In direct sunlight or in ambient temperatures above 110°F, the pipe surface may exceed 110°F. The pipe temperature may be reduced by swabbing the surface to be cemented with clean wet rags provided the pipe is thoroughly dried before the primer and cement are applied.

7.5.3.1 First apply primer to inside socket surface (see 7.5.2 for applicator or brush size). Use a scrubbing motion to ensure penetration. Repeated applications may be necessary (see Fig. 9).

7.5.3.2 Next, soften surface of male end of pipe, to be inserted into socket, to depth of fitting socket by uniformly applying a liberal coat of primer. Be sure entire surface is well softened (dissolved) (see Fig. 10).

7.5.3.3 Again, brush inside socket surface with primer; then, without delay, apply cement to pipe while the surfaces are still wet with primer (see Fig. 11).

7.5.3.4 Apply cement lightly but uniformly to inside of socket, taking care to keep excess cement out of socket. This is to prevent solvent damage to pipe (see Fig. 12). Time is important at this stage. Apply a second coat of cement to the pipe end (see Fig. 11).

7.5.4 *Low-Temperature Application*—At temperatures below freezing, 32°F (0°C), solvents penetrate and soften the PVC surfaces more slowly than in warmer weather. For this reason it is recommended that testing be done on a piece of scrap pipe of the same lot to determine if satisfactory penetration of the surfaces can be achieved at the existing temperature. This test can be done by applying the primer, waiting a few minutes and scraping the surface with a knife edge. If sufficient penetration is achieved, some of the plastic surface of the pipe should be soft enough to be removed. If sufficient penetration is not achieved, even with multiple applications of primer, it is unlikely that a suitable joint will result.

7.5.4.1 Individual scrape tests may be needed for pipes and fittings from different manufacturers or even for pipes

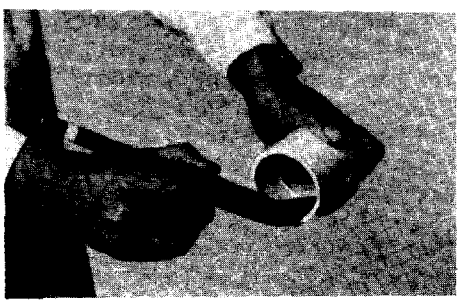

FIG. 9 Application of Primer to Inside Socket Surface

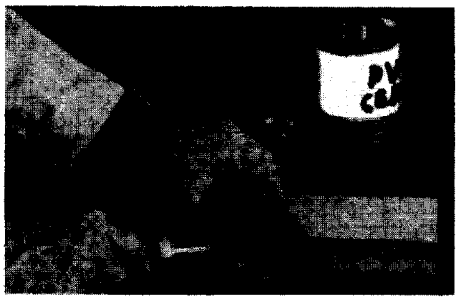

FIG. 11 Uniform Application of Cement to Outside of Pipe

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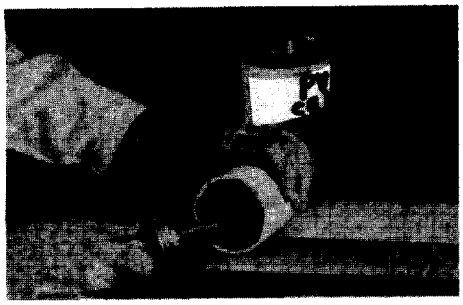

FIG. 12 Uniform But Light Application of Cement to Inside of Socket

FIG. 14 Wiping Excess Cement from Pipe After Assembly

and fittings of different lots from the same manufacturer, because of possible surface variations. Furthermore, it is good practice to use this test, regardless of ambient temperature, not only because of possible surface variations in pipes and fittings, but also because of differences in pipe primer formulations. If satisfactory penetration of joining surfaces does not occur when tested as outlined above with available cement or primers, contact your pipe, fitting, cement, or primer manufacturer before proceeding.

7.5.4.2 Important considerations for cementing in cold weather are:

(*1*) Prefabricate as much of the system as possible in a heated work area.

(*2*) Store sealed cements and primers between 40°F (5°C) to 70°F (21°C) when not in use and make sure they remain fluid. Do not use open flame or electric heaters to warm cements or primers.

(*3*) Take special care to remove moisture, including ice and snow, from pipe and fitting surfaces before applying primer or cement.

(*4*) Always use primer to soften the joining surfaces before applying cement. More than one application may be necessary.

(*5*) Allow a longer cure time before the system is used. This is necessary because the solvents evaporate more slowly at cold temperatures. Refer to Table X2.1.

7.6 *Special Instructions for Bell-End Pipe*—The procedure in 7.5 may be followed in the case of bell-end pipe except that great care should be taken not to apply an excess of cement in the bell socket, nor should any cement be applied on the bell-to-pipe transition area. This precaution is particularly important for installation of bell-end pipe with a wall thickness of less than ⅛ in. (3 mm).

7.7 *Assembly of Joint—Immediately* after applying the last coat of cement to the pipe, and while both the inside socket surface and the outside surface of the male end of the pipe are SOFT and WET with solvent cement, forcefully bottom the male end of the pipe in the socket (see Fig. 13). Turn the pipe or fitting ¼ turn during assembly (but not after the pipe is bottomed) to distribute the cement evenly.

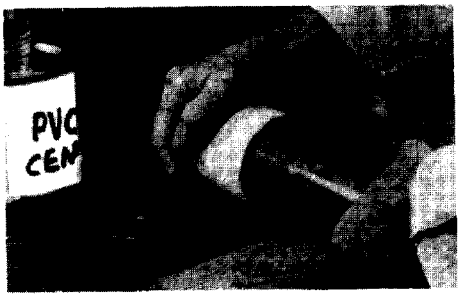

FIG. 13 Assembly of Joint

7.7.1 Assembly should be completed within 20 s after the last application of cement. The pipe should be inserted with a steady even motion. Hammer blows should not be used. If there is any sign of drying of the cement surfaces, due to delay in assembly, the surfaces should be recoated, taking care again not to apply a surplus of cement to the inside of the socket, particularly in bell-end pipe. As large axial forces are necessary for the assembly of interference fit joints in large-size pipe, two or more workers are needed for such joints. Mechanical forcing equipment, "come-alongs," or levers and braces may also be necessary. Until the cement is set in the joint, the pipe may back out of the fitting socket if not held in place for approximately 1 min after assembly. Care should be taken during assembly not to disturb or apply any force to joints previously made. Fresh joints can be destroyed by early rough handling (see 7.5.1).

7.7.2 After assembly, wipe excess cement (Fig. 14) from the pipe at the end of the fitting socket. A properly made joint will normally show a bead around its entire perimeter. Any gaps at this point may indicate a defective assembly job, due to insufficient cement or the use of light-bodied cements on large diameters where standard (heavy-bodied) cement should have been used.

7.8 *Set Time*—Handle the newly assembled joints carefully until the cement has gone through the set period. Recommended set time is related to temperature as follows:

30 min minimum at 60 to 100°F (15 to 40°C)
1 h minimum at 40 to 60°F (5 to 15°C)
2 h minimum at 20 to 40°F (−5 to 5°C)
4 h minimum at 0 to 20°F (−20 to −5°C)

8. Installation

8.1 After the set period, the pipe can be carefully placed in a prepared ditch and snaked from side to side. Prior to backfilling, the pipe shall be brought to approximate operating temperature either by shade backfilling, or by filling with water, or by allowing to stand overnight. The pipe system should be allowed to stand vented to the atmosphere prior to pressure testing. The set period before the system is pressure-tested will depend on the specific cement, the size of the pipe, the ambient temperature, and the dry-joint tightness. Necessary cure time can vary from minutes to days

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depending on conditions and the solvent cement used. Appendix X2 shows cure schedules for several ranges of pipe sizes and temperatures. As a general rule, relatively short cure periods are satisfactory for high-ambient temperatures with low humidity, small pipe sizes, quick-drying cements, and tight-fitting joints. Longer cure periods are required for low temperatures, large pipe sizes, slow-drying cements, loose joints, and relatively high humidity. Shade backfill, leaving all joints exposed so that they can be examined during pressure tests. On long runs pressure tests should be performed on sections no longer than 5000 ft (1500 m). Test pressure should be 150 % of system design pressure and held at this pressure until the system is checked for leaks, or follow the requirements of the applicable code, whichever is higher.

9. Safe Handling of Solvent Cement

9.1 Solvent cements, primers, and cleaners for plastic pipe are made from flammable liquids and should be kept away from all sources of ignition. Good ventilation should be maintained to reduce fire hazard and to minimize breathing of solvent vapors. Avoid contact with skin and eyes.

9.2 Refer to Practice F 402 for additional information.

APPENDIXES

(Nonmandatory Information)

X1. STANDARDS FOR PVC PIPING COMPONENTS

X1.1 Standards for PVC pipe, fittings, and cements suitable for use in making solvent-cemented joints:

X1.1.1 *ASTM Standards:*

* D 1785 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120[5]

* D 2241 Specification for Poly(Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)[5]

* D 2466 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40[5]

* D 2467 Specification for Socket-Type Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80[5]

* D 2513 Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings[5]

* D 2564 Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Pipe and Fittings[5]

* D 2665 Specification for Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings[5]

* D 2672 Specification for Joints for IPS PVC Pipe Using Solvent Cement[5]

* D 2729 Specification for Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings[5]

* D 2949 Specification for 3.25-in. Outside Diameter Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings[5]

* D 3034 Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings[5]

* D 3138 Specification for Solvent Cements for Transition Joints Between Acrylonitrile-Butadiene-Styrene (ABS) and Poly(Vinyl Chloride) (PVC) Non-Pressure Piping Components[5]

F 409 Specification for Thermoplastic Accessible and Replaceable Plastic Tube and Tubular Fittings[5]

F 512 Specification for Smooth-Wall Poly(Vinyl Chloride) (PVC) Conduit and Fittings for Underground Installation[5]

F 656 Specification for Primers for Use in Solvent Cement Joints of Poly(Vinyl Chloride) (PVC) Plastice Pipe and Fittings[5]

F 758 Specification for Smooth-Wall Poly(Vinyl Chloride) (PVC) Plastic Underdrain Systems for Highway, Airport, and Similar Drainage[5]

F 789 Specification for Type PS-46 Poly(Vinyl Chloride) (PVC) Plastic Gravity Flow Sewer Pipe and Fittings[5]

F 891 Specification for Coextruded Poly(Vinyl Chloride) (PVC) Plastic Pipe With a Cellular Core[5]

* These standards are also ANSI standards.

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X2. JOINT CURE SCHEDULE

X2.1 The cure schedules in Table X2.1 are suggested as guides. They are based on laboratory test data, and should not be taken to be the recommendations of all cement manufacturers. Individual manufacturer's recommendations for their particular cement should be followed.

TABLE X2.1 Joint Cure Schedules[A,B]

Temperature Range During Cure Period,[B] °F (°C)	Test Pressures for Pipe Sizes ½ to 1¼ in.		Test Pressures for Pipe Sizes 1½ to 3 in.		Test Pressures for Pipe Sizes 3½ to 5 in.		Test Pressures for Pipe Sizes 6 to 8 in.	
	Up to 180 psi (1240 kPa)	Above 180 to 370 psi (1240 to 2550 kPa)	Up to 180 psi (1240 kPa)	Above 180 to 315 psi (1240 to 2170 kPa)	Up to 180 psi (1240 kPa)	Above 180 to 315 psi (1240 to 2170 kPa)	Up to 180 psi (1240 kPa)	Above 180 to 315 psi (1240 to 2170 kPa)
60 to 100 (15 to 40)	1 h	6 h	2 h	12 h	6 h	18 h	8 h	24 h
40 to 60 (5 to 15)	2 h	12 h	4 h	24 h	12 h	36 h	16 h	48 h
20 to 40 (−7 to 5)	6 h	36 h	12 h	72 h	36 h[A]	4 days[A]	3 days[A]	9 days[A]
10 to 20 (−15 to −7)	8 h	48 h	16 h	96 h	72 h[A]	8 days[A]	4 days[A]	12 days[A]
Colder than 10 (−15)	**Extreme care should be exercised on all joints made where pipe, fittings, or cement is below 10°F (−12°C).**							

[A] It is important to note that at temperatures colder than 20°F (−6.7°C) on sizes that exceed 3 in., test results indicate that many variables exist in the actual cure rate of the joint. The data expressed in these categories represent only estimated averages. In some cases, cure will be achieved in less time, but isolated test results indicate that even longer periods of cure may be required.

[B] These cure schedules are based on laboratory test data obtained on Net Fit Joints (NET FIT = in a dry fit the pipe bottoms snugly in the fitting socket without meeting interference). The relative humidity in these tests was 50 % or less. Higher relative humidity may require longer cure periods.

X3. GUIDELINES FOR PVC SOLVENT CEMENT SELECTION

X3.1 Cement classifications and guidelines shown are an aid to selection, and should not be taken to be the recommendations of all cement manufacturers. Individual manufacturer's cement recommendations for pipe sizes, SDR's, and schedules should be followed, for there are situations where joint fits vary for different applications of the same nominal pipe size. In such cases variations from the guidelines given in Tables X3.1 and X3.2 may be satisfactory and desirable.

NOTE X3.1—The wet-film thickness of a solvent cement can be measured by using a Nordson Wet Film Thickness Gage or equivalent, available from Nordson Corp., Amherst, Ohio 44001, as Nordson No. 79-0015. To use this gage, dip a short length of 1-in. pipe vertically into the cement at a temperature of approximately 73°F (23°C) to a depth of 1.5 to 2 in. (40 to 50 mm) for a period of 15 s. Remove the pipe from the cement and hold the pipe horizontally for 45 s. Measure the wet-film thickness on the top surface of the pipe with the end of the gage about ¼ in. (10 mm) from the end of the pipe. With a little care and experience, the wet cement layer can be readily measured to ±0.002 in. (±0.05 mm).

NOTE X3.2—Solvent cement manufacturer's recommendations should be followed for set times and cure times when joining pipe sizes above 8 in.

NOTE X3.3—Medium-bodied and heavy-bodied cements can generally be used for smaller pipe sizes than those shown in Tables X2.1 and X3.1.

NOTE X3.4—Solvent cement manufacturer's recommendations should be followed in selecting the proper cement for joining Schedule 80 pipe sizes above 6 in.

TABLE X3.1 PVC Cements for Schedule 40 and Interference Fit (Notes X3.2 and X3.3)

Pipe Size Range, in.	Cement Type	Minimum Viscosity		Minimum Wet Film Thickness	
		cP	(mPa·s)	in.	(mm)
⅛ to 2	regular-bodied	90	(90)	0.006	(0.15)
2½ to 6	medium-bodied	500	(500)	0.012	(0.30)
8 to 12	heavy-bodied	1600	(1600)	0.024	(0.60)

TABLE X3.2 Cements for Schedule 80 (Notes X3.3 and X3.4)

Pipe Size Range, in.	Cement Type	Minimum Viscosity		Minimum Wet Film Thickness	
		cP	mPa·s	in.	(mm)
⅛ to 3	medium-bodied	500	(500)	0.012	(0.30)
3½ to 12	heavy-bodied	1600	(1600)	0.024	(0.60)

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

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Designation: D 2996 – 01

An American National Standard

Standard Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[1]

This standard is issued under the fixed designation D 2996; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This specification[2] covers machine-made reinforced thermosetting resin pressure pipe (RTRP) manufactured by the filament winding process up to 24 in. nominal size. Included are a classification system and requirements for materials, mechanical properties, dimensions, performance, methods of test, and marking.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are provided for information purposes only.

1.3 The following safety hazards caveat pertains only to the test method portion, Section 8, of this specification: *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—The term "fiberglass pipe" as described in Section 3 of this specification applies to both reinforced thermosetting resin pipe (RTRP) and reinforced polymer mortar pipe (RPMP). This specification covers only reinforced thermosetting resin pipe (RTRP).

NOTE 2—This specification is applicable to RTRP where the ratio of outside diameter to wall thickness is 10:1 or more.

NOTE 3—There is no similar or equivalent ISO Standard.

NOTE 4—For the purposes of this standard, polymer does not include natural polymers.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics for Testing[2]

D 638 Test Method for Tensile Properties of Plastics[2]

D 883 Terminology Relating to Plastics[2,3]

D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure[3]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2,3]

D 2105 Test Method for Longitudinal Tensile Properties of" Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube[3]

D 2143 Test Method for Cyclic Pressure Strength of Reinforced, Thermosetting Plastic Pipe[3]

D 2310 Classification for Machine-Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[3]

D 2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading[3]

D 2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for" Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[3]

D 3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[3]

F 412 Terminology Relating to Plastic Piping Systems[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions are in accordance with Terminologies D 883 and F 412 and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated. The abbreviation for reinforced thermosetting resin pipe is RTRP.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *coating*—a resin layer, with or without filler or reinforcement, or both, applied to the exterior surface of the pipe structural wall.

3.2.2 *fiberglass pipe*—a tubular product containing glass-fiber reinforcements embedded in or surrounded by cured thermosetting resin; the composite structure may contain aggregate, granular or platelet fillers, thixotropic agents, pigments, or dyes; thermoplastic or thermosetting liners or coatings may be included.

3.2.3 *filament winding*—a process used to manufacture tubular goods by winding continuous fibrous glass strand roving, or roving tape, saturated with liquid resin or preimpregnated with partially cured resin (subsequent heating may be required to polymerize the resin system) onto the outside of a mandrel in a predetermined pattern under controlled tension;

[1] This specification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.23 on Reinforced Plastic Piping Systems and Chemical Equipment.

Current edition approved June 10, 2001. Published August 2001. Originally published as D 2996 – 71. Last previous edition D 2996 – 00.

[2] This specification was revised to include an ISO equivalency statement and a section on keywords.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 08.04.

***A Summary of Changes section appears at the end of this standard.**

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the inside diameter (ID) of the pipe is fixed by the mandrel outside diameter and the outside diameter (OD) of the pipe is determined by the amount of material that is wound on the mandrel.

3.2.4 *liner*—the inner portion of the wall at least 0.005 in. (0.13 mm) in thickness, as determined in 8.3.2, which does not contribute to the strength in the determination of the hydrostatic design basis.

3.2.5 *reinforced polymer mortar pipe (RPMP)*—a fiberglass pipe with aggregate.

3.2.6 *reinforced thermosetting resin pipe (RTRP)*—a fiberglass pipe without aggregate.

3.2.7 *reinforced wall thickness*—the total wall thickness minus the liner or exterior coating thickness, or both.

4. Classification

4.1 *General*—Pipe meeting this specification is classified by type, grade, class, and hydrostatic design basis in accordance with Classification D 2310 and by a secondary cell classification system that defines the basic mechanical properties of the pipe. These types, grades, classes, hydrostatic design basis categories, and cell classification designations are as follows:

4.1.1 *Types:—Type 1*

Filament wound.

4.1.2 *Grades:—Grade 1*

Glass fiber reinforced epoxy resin pipe.

Grade 2—Glass fiber reinforced polyester resin pipe.

Grade 7—Glass fiber reinforced furan resin pipe.

4.1.3 *Classes:—Class A*

No liner.

Class B—Polyester resin liner (nonreinforced).

Class C—Epoxy resin liner (nonreinforced).

Class E—Polyester resin liner (reinforced).

Class F—Epoxy resin liner (reinforced).

Class H—Thermoplastic resin liner (specify).

Class I—Furan resin liner (reinforced).

4.1.4 *Hydrostatic Design Basis*—Two methods of classifying the hydrostatic design basis of the pipe are provided. Pipe meeting this specification may be classified using either the cyclic test method or the static test method, or both, and the designations as shown in Table 1. Appendix X1 explains how these design basis categories are to be used.

4.1.4.1 For pipe subjected to axial or end loads, the effect of these loads shall be represented in the HDB testing. In the designation code, the numeral 1 shall immediately follow the HDB letter class if free-end type closures were used and the numeral 2 shall immediately follow the HDB letter class if restrained-end type closures were used to establish the HDB.

TABLE 1 Hydrostatic Design Basis Categories

Cyclic Test Method		Static Test Method	
Designation	Hoop Stress, psi (MPa)	Designation	Hoop Stress, psi (MPa)
A	2 500 (17.2)	Q	5 000 (34.5)
B	3 150 (21.7)	R	6 300 (43.4)
C	4 000 (27.6)	S	8 000 (55.2)
D	5 000 (34.5)	T	10 000 (68.9)
E	6 300 (43.4)	U	12 500 (86.2)
F	8 000 (55.2)	W	16 000 (110)
G	10 000 (68.9)	X	20 000 (138)
H	12 500 (86.2)	Y	25 000 (172)
		Z	31 500 (217)

4.1.5 *Mechanical Properties*—Table 2 presents a cell classification system for identifying the mechanical properties of pipe covered by this specification.

NOTE 5—All possible combinations covered by the above classification system may not be commercially available.

4.1.6 *Designation Code*—The pipe designation code shall consist of the abbreviation RTRP, followed by the type and grade in Arabic numerals, the class and static or cyclic HDB level in capital letters, the type of end closure used, and four Arabic numbers identifying, respectively, the cell classification designations of the short-term rupture strength, longitudinal tensile strength, longitudinal tensile modulus, and apparent stiffness of the pipe.

Example: RTRP-11FA1-1334. Such a designation would describe a filament-wound, glass-fiber reinforced, epoxy pipe having a reinforced epoxy liner; a cyclic pressure strength exceeding 2500 psi (17.2 MPa) using free-end closures; a short-term rupture strength exceeding 10 000 psi (68.9 MPa); a longitudinal tensile strength exceeding 25 000 psi (172 MPa); a longitudinal tensile modulus exceeding 3×10^6 psi (20.7×10^3MPa); and an apparent stiffness factor exceeding 1500 $in.^3 \cdot lbf/in.^2$ (170 $mm^3 \cdot kPa$).

5. Materials and Manufacture

5.1 *General*—The resins, reinforcements, colorants, fillers, and other materials, when combined as a composite structure, shall produce a pipe that shall meet the performance requirements of this specification.

6. Physical Requirements

6.1 *Workmanship*—The pipe shall be free of all defects including indentations, delaminations, bubbles, pinholes, foreign inclusions, and resin-starved areas which, due to their nature, degree, or extent, detrimentally affect the strength and serviceability of the pipe. The pipe shall be as uniform as commercially practicable in color, opacity, and other physical properties. The pipe shall be round and straight and the bore of the pipe shall be smooth and uniform. All pipe ends shall be cut at right angles to the axis of the pipe and any sharp edges removed.

6.2 *Dimensions and Tolerances*:

6.2.1 *Inside and Outside Diameter*—The inside and outside diameter and tolerances of pipe meeting these specifications shall conform to the requirements in one of the Tables 3-6, when determined in accordance with 8.3.1.

6.2.2 *Wall Thickness*—The minimum wall thickness of pipe furnished under this specification shall not at any point be less than 87.5 % of the nominal wall thickness published in the manufacturer's literature current at the time of purchase when measured in accordance with 8.3.1.

6.3 *Performance*—Pipe meeting this specification shall be categorized by a long-term static or cyclic hydrostatic design basis as shown in Table 1 when tested in accordance with 8.4 or 8.5. Additionally, the pipe shall meet the applicable cell limit

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TABLE 2 Physical Property Requirements

Designation Order Number	Mechanical Property	0[A]	1	2	3	4	5	6
1	Short-term rupture strength hoop tensile stress, min, psi[B]	...	10 000	30 000	40 000	50 000	60 000	70 000
	(MPa)	...	(68.9)	(207)	(276)	(345)	(414)	(483)
2	Longitudinal tensile strength min, psi	...	8 000	15 000	25 000	35 000	45 000	55 000
	(MPa)	...	(55.2)	(103)	(172)	(241)	(310)	(379)
3	Longitudinal tensile modulus, min, psi × 10^6	...	1	2	3	4	5	6
	(MPa)	...	(6 900)	(13 000)	(20 700)	(27 600)	(34 500)	(41 400)
4	Apparent stiffness factor at 5 % deflection, min, $in.^3$-lbf/$in.^2$	...	40	200	1000	1500	2000	2500
	(mm^3·kPa)	...	(4.5)	(22.6)	(113)	(170)	(226)	(282)

[A] Unspecified.
[B] Type of end closure used, that is, free or restrained should be indicated on certification.

TABLE 3 Dimensions and Tolerances for Outside Diameter (OD) Series Pipe with Steel-Pipe-Equivalent (Iron Pipe Size)

Nominal Pipe Size, in.	in.	(mm)
1	1.315 + 0.060 −0.016	33.40 + 1.52 −0.41
1½	1.900 + 0.060 −0.018	48.26 + 1.52 −0.46
2	2.375 + 0.060 −0.018	60.32 + 1.52 −0.46
2½	2.875 + 0.060 −0.018	73.02 + 1.52 −0.46
3	3.500 + 0.060 −0.018	88.90 + 1.52 −0.46
4	4.500 + 0.060 −0.018	114.30 + 1.52 −0.46
6	6.625 + 0.066 −0.028	168.28 + 1.68 −0.64
8	8.625 + 0.086 −0.040	219.08 + 2.18 −1.02
10	10.750 + 0.108 −0.048	273.05 + 2.74 −1.22
12	12.750 + 0.128 −0.056	323.85 + 3.25 −1.42
14	14.000 + 0.145 −0.064	355.60 + 3.68 −1.63
16	16.000 + 0.165 −0.074	406.40 + 4.19 −1.88

[A] Outside diameters other than listed in Tables 3 to 6 shall be permitted by agreement between the manufacturer and the purchaser.

TABLE 4 Dimensions and Tolerances for Inside Diameter (ID) Series Pipe

Nominal Pipe Size, in.	in.	mm
1	1.00 ± 0.06	25.4 ± 1.52
1½	1.500± 0.06	38.1 ± 1.52
2	2.000 ± 0.06	50.8 ± 1.52
2½	2.500± 0.06	63.5 ± 1.52
3	3.000 ± 0.12	76.2 ± 3.05
4	4.000 ± 0.12	101.6 ± 3.05
6	6.000 ± 0.25	152.4 ± 6.35
8	8.000 ± 0.25	203.2 ± 6.35
10	10.000 ± 0.25	254.0 ± 6.35
12	12.000 ± 0.25	304.8 ± 6.35
14	14.000 ± 0.25	355.6 ± 6.35
15	15.000 ± 0.25	381.0 ± 6.35
16	16.000 ± 0.25	406.4 ± 6.35
18	18.000 ± 0.25	457.2 ± 6.35
20	20.000 ± 0.25	508.0 ± 6.35
24	24.000 ± 0.25	609.6 ± 6.35

TABLE 5 Dimensions for Outside Diameter (OD) Series Pipe with Cast-Iron-Pipe-Equivalent

Nominal Pipe Size, in.	in.	mm
2	2.50 + 0.05 −0.05	63.50 + 1.27 −1.27
3	3.96 + 0.06 −0.06	100.58 + 1.52 −1.52
4	4.80 + 0.06 −0.06	121.92 + 1.52 −1.52
6	6.90 + 0.06 −0.06	175.26 + 1.52 −1.52
8	9.05 + 0.06 −0.06	229.87 + 1.52 −1.52
10	11.10 + 0.06 −0.06	281.94 + 1.52 −1.52
12	13.20 + 0.06 −0.06	335.28 + 1.52 −1.52
14	15.30 + 0.05 −0.08	388.62 + 1.27 −2.03
16	17.40 + 0.05 −0.08	441.96 + 1.27 −2.03

requirements for short-term rupture strength, longitudinal tensile strength, longitudinal tensile modulus, and apparent stiffness factor as described in Table 2 when tested in accordance with 8.6 through 8.8.

6.3.1 Any significant changes in the original pipe categorized in 6.3, with respect to materials or manufacturing process, will require recategorizing according to 6.3. These changes include, but are not limited to: a change in reinforcement type, composition, or binder; a change in resin type, composition, or cure; or change in linear composition, thickness, or cure.

NOTE 6—The purchaser should consult the manufacturer for the proper class, type, and grade of pipe to be used under the installation and operating conditions, with respect to temperature, conveyed fluid, pressure, etc., that will exist for the project in which the pipe is to be used.

7. Sampling

7.1 At least one sample of pipe, to determine conformance of the material to the short-term hoop tensile rupture requirements as shown in Table 2, shall be taken at random on a weekly basis or on each production run, whichever is the most frequent. The rate of sampling for the other tests listed shall be in accordance with accepted statistical practice or as agreed upon between the purchaser and the seller.

7.2 For individual orders, only those additional tests and

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TABLE 6 Dimensions for Inside Diameter (ID) Series Pipe with Iron Pipe Size Equivalent

Nominal Pipe Size, in.	in.	mm
2	2.25 + 0.05 −0.05	57.15 + 1.27 −1.27
3	3.34 + 0.06 −0.06	84.84 + 1.52 −1.52
4	4.37 + 0.06 −0.06	111.00 + 1.52 −1.52
6	6.43 + 0.06 −0.06	163.32 + 1.52 −1.52
8	8.39 + 0.06 −0.06	213.11 + 1.52 −1.52
10	10.43 + 0.06 −0.06	264.92 + 1.52 −1.52
12	12.38 + 0.06 −0.06	314.45 + 1.52 −1.52
14	13.60 + 0.05 −0.08	345.44 + 1.27 −2.03
16	15.40 + 0.05 −0.08	391.16 + 1.27 −2.03

number of tests specifically agreed upon between the purchaser and the seller need to be conducted.

8. Test Methods

8.1 *Conditioning*—Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity for not less than 48 h prior to test, in accordance with Procedure A of Methods D 618, for those tests where conditioning is required, and in all cases of disagreement.

8.2 *Test Conditions*—Conduct the tests in the Standard Laboratory Atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity, unless otherwise specified in the test method or in this specification.

8.3 *Dimensions and Tolerances*:

8.3.1 *Wall Thickness and Diameter*—Determine in accordance with Practice D 3567.

8.3.2 *Liner Thickness*—If the test specimens contain a liner, determine the average liner thickness in accordance with Practice D 3567.

8.4 *Long-Term Cyclic Hydrostatic Strength*—Determine in accordance with Procedure A of Method D 2992, following Test Method D 2143.

8.5 *Long-Term Static Hydrostatic Strength*—Determine in accordance with Procedure B of Method D 2992, following Test Method D 1598.

8.6 *Short-Term Hydrostatic Failure Strength*—Determine in accordance with Test Method D 1599.

8.7 *Longitudinal Tensile Properties*— Determine in accordance with Test Methods D 2105 or D 638.

8.8 *Stiffness Factor*—Determine in accordance with Test Method D 2412. The reported stiffness shall be based on 5 % deflection.

9. Certification

9.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance of material. This shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification. Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

9.2 When original identity cannot be established, certification can only be based upon the sampling procedure provided by the applicable specification.

10. Product Marking

10.1 Each piece of pipe shall be marked at least once per section. Each piece of pipe shall be marked with the following information in such a manner that it remains legible under normal handling and installation practices:

10.1.1 Nominal pipe size (for example, 2 in.).

10.1.2 Identification of reinforced thermosetting resin pipe in accordance with the designation code given in Section 4.

10.1.3 ASTM D 2996 with which the pipe complies.

10.1.4 Manufacturer's name (or trademark).

11. Keywords

11.1 filament-wound FRP pipe; mechanical properties; physical properties; pressure rating; tolerances; wall thickness

APPENDIX

(Nonmandatory Information)

X1. HYDROSTATIC DESIGN BASIS, CATEGORIES, SERVICE FACTORS, AND PRESSURE RATINGS

X1.1 Hydrostatic Design Basis

X1.1.1 The hydrostatic design basis for reinforced thermosetting resin pipe is the estimated long-term hydrostatic strength obtained in accordance with Method D 2992. In Method D 2992 either Procedure A, using data obtained in accordance with Test Method D 2143, or Procedure B, using data obtained in accordance with Test Method D 1598, is used to determine the estimated long-term hydrostatic strength. This strength in the wall of the pipe is equal to the circumferential stress due to internal hydrostatic pressure that will fail the pipe when extrapolated to 150×10^6 pressure cycles (Procedure A) or to 100 000 h under continuously applied pressure (Procedure B).

X1.2 Hydrostatic Design Basis Categories

X1.2.1 The hydrostatic design basis category is obtained from Table X1.1 or Table X1.2 using the estimated long-term

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TABLE X1.1 Hydrostatic Design Basis Categories by Procedure A

Hydrostatic Design Basis Category, psi (MPa)	Range of Calculated Values, psi (MPa)
2 500 (17.2)	2 400 to 3 010 (16.5 to 20.8)
3 150 (21.7)	3 020 to 3 020 (20.8 to 26.3)
4 000 (27.6)	3 830 to 4 790 (26.4 to 33.0)
5 000 (34.5)	4 800 to 5 900 (33.1 to 40.7)
6 300 (43.4)	6 000 to 7 500 (41.4 to 51.7)
8 000 (55.2)	7 600 to 9 500 (52.4 to 65.5)
10 000 (68.9)	9 600 to 11 900 (66.2 to 82.0)
12 500 (86.2)	12 000 to 15 200 (82.7 to 105)

TABLE X1.2 Hydrostatic Design Basis Categories by Procedure B

Hydrostatic Design Basis Category, psi (MPa)	Range of Calculated Values, psi (MPa)
5 000 (34.5)	4 800 to 5 900 (33.1 to 40.7)
6 300 (43.4)	6 000 to 7 500 (41.4 to 51.7)
8 000 (55.2)	7 600 to 9 500 (52.4 to 65.5)
10 000 (68.9)	9 600 to 11 900 (66.2 to 82.1)
12 500 (86.2)	12 000 to 15 200 (82.9 to 105)
16 000 (112)	15 300 to 18 900 (105 to 130)
20 000 (138)	19 000 to 23 000 (131 to 159)
25 000 (173)	24 000 to 29 000 (165 to 200)
31 500 (217)	30 000 to 38 000 (207 to 262)

hydrostatic strength as the calculated value.

X1.3 Service (Design) Factor

X1.3.1 The service (design) factor is a number equal to 1.00 or less which takes into consideration all the variables and degree of safety involved in a reinforced thermosetting resin pressure piping installation and is selected for the application on the basis of two general groups of conditions. The first group considers the manufacturing and testing variables (specifically, normal variations in the material, manufacture, dimensions, good handling techniques, and in the evaluation procedures of this method). The second group considers the application or use (specifically, installation, environment, temperature hazard involved, life expectancy desired, and the degree of reliability selected).

NOTE X1.1—It is not the intent of this standard to give service (design) factors. The service (design) factor should be selected by the design engineer after fully evaluating the service conditions and the engineering properties of the specific pipe material under consideration. Recommended service (design) factors will not be developed or issued by ASTM.

X1.4 Hydrostatic Design Stress

X1.4.1 The hydrostatic design stress is the estimated maximum tensile stress in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure that can be applied continuously with a high degree of certainty that failure will not occur. It is obtained by multiplying the hydrostatic design basis as determined by Procedure A or Procedure B by the service (design) factor.

X1.5 Pressure Rating

X1.5.1 The pressure rating is the estimated maximum pressure that the medium in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur.

X1.5.2 The pressure rating for each diameter and wall thickness of pipe and fitting is calculated from hydrostatic design stress for the specific pipe by means of the following formula:

$$S = P\,(D - t)/2t$$

where:

S = hydrostatic design stress, psi (MPa),
P = pressure rating, psi (MPa),
D = average outside diameter, in. (mm), and
t = minimum reinforced wall thickness, in. (mm).

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue D 2996 – 00 that may impact the use of this standard.

(*1*) Changed acronym, RPMP, from reinforced *plastic* mortar pipe to reinforced *polymer* mortar pipe.

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Designation: D 2997 – 01

An American National Standard

Standard Specification for Centrifugally Cast "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[1]

This standard is issued under the fixed designation D 2997; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This specification covers machine-made glass-fiber-reinforced thermosetting-resin pressure pipe manufactured by the centrifugal casting process. Included are a classification system and requirements for materials, mechanical properties, dimensions, performance, test methods, and marking.

NOTE 1—The term "fiberglass pipe" as described in Section 3 applies to both reinforced thermosetting resin pipe (RTRP) and reinforced polymer mortar pipe (RPMP).

NOTE 2—Pipe covered by this specification has been found suitable for conveying gases, petroleum products, or corrosive fluids.

NOTE 3—For the purposes of this standard, polymer does not include natural polymers.

1.2 The values given in parentheses are for information only.

NOTE 4—There is no similar or equivalent ISO standard.

1.3 The following precautionary caveat pertains only to the test method portion, Section 7, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 33 Specification for Concrete Aggregates[2]

D 618 Practice for Conditioning Plastics for Testing[3]

D 883 Terminology Relating to Plastics[3]

D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure[4]

D 1599 Test Method for Short-Term Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings[4]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[3]

D 2105 Test Method for Longitudinal Tensile Properties of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube[4]

D 2143 Test Method for Cyclic Pressure Strength of Reinforced, Thermosetting Plastic Pipe[4]

D 2310 Classification for Machine-Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[4]

D 2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading[4]

D 2992 Practice for Obtaining Hydrostatic Design or Pressure Design Basis for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[4]

D 3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[4]

F 412 Terminology Relating to Plastic Piping Systems[4]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminologies D 883 and F 412 and abbreviations with Terminology D 1600, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:* Descriptions of Terms Specific to This Standard:

3.2.1 *aggregate, n*—a siliceous sand conforming to the requirements of Specification C 33, except that the requirements for gradation shall not apply.

3.2.2 *centrifugal casting, n*—a manufacturing process used to produce tubular goods by applying resin and reinforcement to the inside of a mold that is rotated and heated, subsequently polymerizing the resin system. The outside diameter (OD) of the finished pipe is fixed by the inside diameter (ID) of the mold tube. The inside diameter of the pipe is determined by the amount of material introduced into the mold.

3.2.3 *fiberglass pipe, n*—a tubular product containing glass-fiber reinforcements embedded in or surrounded by cured thermosetting resin; the composite structure may contain aggregate, granular or platelet fillers, thixotropic agents, pigments, or dyes; thermoplastic or thermosetting liners or coatings may be included.

3.2.4 *liner, n*—the inner portion of the wall at least 0.005 in. (0.13 mm) in thickness, as determined in 7.4 which does not

[1] This specification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.23 on Reinforced Plastic Piping Systems and Chemical Equipment.

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 08.04.

***A Summary of Changes section appears at the end of this standard.**

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contribute to the strength in the determination of the hydrostatic design basis.

3.2.5 *reinforced polymer mortar pipe (RPMP), n*—a fiberglass pipe with aggregate.

3.2.6 *reinforced thermosetting resin pipe (RTRP), n*—a fiberglass pipe without aggregate.

3.2.7 *reinforced wall thickness, n*—the total wall thickness minus the liner or exterior surface resin layer thickness, or both.

4. Classification

4.1 *General*—Pipe meeting this specification is classified by type, grade, class, and hydrostatic design basis in accordance with Classification D 2310, and by a secondary cell classification system that defines the basic mechanical properties of the pipe. These types, grades, classes, hydrostatic design basis categories, and cell classification designations are as follows:

4.1.1 *Types: —Type II*

Centrifugally cast pipe.

4.1.2 *Grades: —Grade 1*

Glass-fiber-reinforced epoxy-resin pipe.

Grade 2—Glass-fiber-reinforced polyester-resin pipe.

Grade 3—Glass-fiber reinforced polydicyclopentadiene-resin pipe.

Grade 8—Glass-fiber-reinforced polyester-resin mortar pipe.

Grade 9—Glass fiber reinforced epoxy resin mortar pipe.

4.1.3 *Classes:—Class A*

No liner.

Class B—Polyester-resin liner, nonreinforced.

Class C—Epoxy-resin liner, nonreinforced.

Class D—Polydicyclopentadiene-resin liner, nonreinforced.

4.1.4 *Hydrostatic Design Basis*—Two methods of classifying the hydrostatic design basis of the pipe are provided. Pipe meeting this specification may be classified using either the cyclic test method or the static test method, or both, and the designations are shown in Table 1. Appendix X1 explains how to use the design basis categories shown in Table 1.

4.1.5 *Mechanical Properties*—Table 2 presents a cell classification system for identifying the mechanical properties of pipe covered by this specification.

NOTE 5—All possible combinations covered by the preceding classification system may not be commercially available.

4.1.6 *Designation Code*—The pipe designation code shall consist of the abbreviation RTRP or RPMP, followed by the type and grade in Arabic numerals, the class and static or cyclic hydrostatic design basis level in capital letters, and four Arabic numbers identifying, respectively, the cell classification designations of the short-term rupture strength, longitudinal tensile strength, tensile modulus, and pipe stiffness. Thus, a complete pipe designation code shall consist of four letters, two numerals, two letters, and four numerals.

4.1.6.1 *Example*—RTRP-21CA-1334. Such a designation would describe a centrifugally cast, glass-fiber-reinforced, epoxy pipe having a nonreinforced epoxy liner; a long-term cyclic pressure strength level exceeding 2500 psi (17.2 MPa); a short-term rupture strength exceeding 4000 psi (27.6 MPa); a longitudinal tensile strength exceeding 16 000 psi (110 MPa); a longitudinal tensile modulus exceeding 1.5 by 10^6 psi (10 300 MPa); and a pipe stiffness of 72 psi (496 kPa).

NOTE 6—Although the *Form and Style for ASTM Standards* manual requires that the type classification be roman numerals, it is recognized that few companies have stencil-cutting equipment for this style of type, and it is therefore acceptable to mark the product type in arabic numbers.

TABLE 1 Hydrostatic Design Basis Categories

Cyclic Test Method		Static Test Method	
Designation	Hoop Stress, psi (MPa)	Designation	Hoop Stress, psi (MPa)
A	2 500 (17.2)	Q	5 000 (34.5)
B	3 150 (21.7)	R	6 300 (43.4)
C	4 000 (27.6)	S	8 000 (55.2)
D	5 000 (34.5)	T	10 000 (68.9)
E	6 300 (43.4)	U	12 500 (86.2)
F	8 000 (55.2)	W	16 000 (110)
G	10 000 (68.9)	X	20 000 (138)
H	12 500 (86.2)	Y	25 000 (172)
		X	31 500 (217)

5. Materials

5.1 *General*—The resins, reinforcements, colorants, fillers, and other materials, when combined as a composite structure, shall produce a pipe that shall be classified in accordance to this specification based on performance.

6. Requirements

6.1 *Workmanship*—The pipe shall be free from all defects, including indentations, delaminations, bubbles, pinholes, foreign inclusions, and resin-starved areas which, as a result of their nature, degree, or extent, detrimentally affect the strength and serviceability of the pipe. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties. The pipe shall be round and straight, and the bore of the pipe shall be smooth and uniform. All pipe ends shall be cut at right angles to the axis of the pipe, and any sharp edges removed.

6.2 *Dimensions and Tolerances*:

6.2.1 *Outside Diameter*—The outside diameter and tolerances of pipe meeting this specification shall conform to the requirements in Table 3, when determined in accordance with 7.4.

6.2.2 *Wall Thickness*—The minimum wall thickness of pipe furnished under this specification shall not at any point be less than 87.5 % of the nominal wall thickness published in the manufacturer's literature, current at the time of purchase, when measured in accordance with 7.4.

6.2.3 *Liner Thickness*—Except for Class A unlined products, all other classes shall have a minimum liner thickness of 0.005 in. (5 mil), when measured in accordance with 7.4.

6.3 *Performance*—Pipe meeting this specification shall be categorized by a long-term static or cyclic hydrostatic design basis shown in Table 1, when tested in accordance with 7.5 and 7.6. Additionally, the pipe shall meet the applicable cell limit requirements for short-term rupture strength, longitudinal tensile strength, tensile modulus, and pipe stiffness described in Table 2, when tested in accordance with 7.7, 7.8, and 7.9.

7. Test Methods

7.1 *Conditioning*—Condition the test specimens at 23 ±

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TABLE 2 Physical Property Requirements

Designation Order Number	Mechanical Property	Cell Limits						
		0[A]	1	2	3	4	5	6
1	Short time rupture strength hoop tensile stress, min, psi (MPa)	—	4 000 (27.6)	12 000 (82.7)	22 000 (152)	30 000 (207)	40 000 (276)	50 000 (345)
2	Longitudinal tensile strength, min, psi (MPa)	—	2 000 (13.8)	8 000 (55.2)	16 000 (110)	22 000 (152)	30 000 (207)	40 000 (276)
3	Longitudinal tensile modulus, min, psi × 10^6 (MPa)	—	0.6 (4 100)	1.3 (9 000)	1.5 (10 300)	1.9 (13 100)	2.5 (17 200)	3.0 (20 700)
4	Pipe stiffness at 5 % deflection, psi (kPa)	—	9 (62)	18 (124)	36 (248)	72 (496)	144 (993)	288 (1 986)

[A] 0 = Unspecified.

TABLE 3 Outside Dimensions and Tolerances

Nominal Pipe Size, in.	in.	(mm)
1	1.315 ± 0.009	(33.401 ± 0.229)
1½	1.900 ± 0.009	(48.260 ± 0.229)
2	2.375 ± 0.012	(60.325 ± 0.305)
2½	2.875 ± 0.012	(73.025 ± 0.305)
3	3.500 ± 0.012	(88.900 ± 0.305)
4	4.500 ± 0.015	(114.300 ± 0.381)
6	6.625 ± 0.025	(168.275 ± 0.635)
8	8.625 ± 0.025	(219.075 ± 0.635)
10	10.750 ± 0.025	(273.050 ± 0.635)
12	12.750 ± 0.025	(323.850 ± 0.635)
14	14.000 ± 0.035	(355.600 ± 0.889)

2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity for not less than 48 h prior to test, in accordance with Procedure A of Practice D 618, for those tests where conditioning is required, and in all cases of disagreement.

7.2 *Test Conditions*—Conduct the tests in the Standard Laboratory Atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity, unless otherwise specified in the test specification.

7.3 *Sampling*—Samples of pipe to determine conformance of the material to be short-term rupture requirements shown in Table 2 shall be taken at random on a weekly basis or on each production run, whichever is the most frequent. The rate of sampling for the other tests listed shall be in accordance with the accepted statistical practice and as agreed upon between the purchaser and the seller.

NOTE 7—For individual orders, only those additional tests and number of tests specifically agreed upon between the purchaser and the seller need be conducted.

7.4 *Dimensions and Tolerances*—Determine in accordance with Practice D 3567.

7.5 *Long-Term Cyclic Pressure Strength*—Determine in accordance with Procedure A of Practice D 2992.

7.6 *Long-Term Static Pressure Strength*—Determine in accordance with Procedure B of Practice D 2992.

7.7 *Short-Term Rupture Strength*—Determine in accordance with Test Method D 1599.

7.8 *Longitudinal Tensile Properties*—Determine in accordance with Test Method D 2105.

7.9 *Pipe Stiffness*—Determine in accordance with Test Method D 2412. The reported stiffness shall be based on 5 % deflection.

8. Certification

8.1 When agreed upon in writing by the purchaser and the seller, a certification shall be made the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the seller accompanied by a copy of the test results, that the material has been sampled, tested, and inspected in accordance with the provisions of the specification. Each certification so furnished shall be signed by an authorized agent of the seller or the manufacturer.

8.2 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

9. Marking

9.1 Each piece shall be marked at least once and at lengths of at least every 15 ft. Each piece of pipe shall be marked with the following information in such a manner that it remains legible under normal handling and installation practices:

9.1.1 Nominal pipe size (for example, 2 in.),

9.1.2 Identification of fiberglass pipes in accordance with the designation code given in Section 5,

9.1.3 This designation, D 2997, with which the pipe complies, and

9.1.4 Manufacturer's name (or trademark).

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APPENDIX

(Nonmandatory Information)

X1. HYDROSTATIC DESIGN BASIS, CATEGORIES, SERVICE FACTORS, AND PRESSURE RATINGS

X1.1 Hydrostatic Design Basis

X1.1.1 The hydrostatic design basis is the estimated long-term hydrostatic strength on which service factors (1.0 or less) are applied to obtain a hydrostatic design stress. The long-term hydrostatic strength is obtained by Practice D 2992. In Practice D 2992, either Procedure A using data obtained in accordance with Test Method D 2143 or Procedure B using data obtained in accordance with Test Method D 1598 is used to determine the long-term hydrostatic strength extrapolated at 50 years.

X1.1.2 The long-term hydrostatic strength is the estimated tensile stress in the wall of the pipe in the hoop orientation due to internal hydrostatic pressure that will cause failure after 50 years (657×10^6 pressure cycles by Procedure A or 438 000 h of static pressure by Procedure B).

X1.2 Hydrostatic Design Basis Categories

X1.2.1 The hydrostatic design basis is obtained by categorizing the long-term strength in accordance with Table X1.1 or Table X1.2.

X1.3 Service (Design) Factor

X1.3.1 The service (design) factor is a number equal to 1.00 or less that takes into consideration all the variables and degree of safety involved in a fiberglass pressure piping installation, and is selected for the application on the basis of two general groups of conditions.

X1.3.2 The first group considers the manufacturing and testing variables, specifically normal variations in the material, manufacture, dimensions, good handling techniques, and in the evaluation procedures of this method. The second group considers the application or use, specifically installation, environment, temperature, hazard involved, life expectance desired, and the degree of reliability selected.

TABLE X1.1 Hydrostatic Design Basis Categories by Procedure A

Hydrostatic Design Basis Category, psi (MPa)	Range of Calculated Values, psi (MPa)
2 500 (17.2)	2 400 to 3 010 (16.5 to 20.8)
3 150 (21.7)	3 020 to 3 820 (20.8 to 26.3)
4 000 (27.6)	3 830 to 4 790 (26.4 to 33.0)
5 000 (34.5)	4 800 to 5 900 (33.1 to 40.7)
6 300 (43.4)	6 000 to 7 500 (41.4 to 51.7)
8 000 (55.2)	7 600 to 9 500 (52.4 to 65.5)
10 000 (68.9)	9 600 to 11 900 (66.2 to 82.0)
12 500 (86.2)	12 000 to 15 200 (82.7 to 105)

TABLE X1.2 Hydrostatic Design Basis Categories by Procedure B

Hydrostatic Design Basis Category, psi (MPa)	Range of Calculated Values, psi (MPa)
5 000 (34.5)	4 800 to 5 900 (33.1 to 40.7)
6 300 (43.4)	6 000 to 7 500 (41.4 to 51.7)
8 000 (55.2)	7 600 to 9 500 (52.4 to 65.5)
10 000 (68.9)	9 600 to 11 900 (66.2 to 82.0)
12 500 (86.2)	12 000 to 15 200 (82.7 to 105)
16 000 (110)	15 300 to 18 900 (106 to 130)
20 000 (138)	19 000 to 23 000 (131 to 159)
25 000 (172)	24 000 to 29 000 (166 to 200)
31 500 (217)	30 000 to 38 000 (207 to 262)

NOTE X1.1—It is not the intent of this specification to give service (design) factors. The service (design) factor should be selected by the design engineer after evaluating fully the service conditions and the engineering properties of the specific pipe material under consideration. Recommended service (design) factors will not be developed or issued by ASTM.

X1.4 Hydrostatic Design Stress

X1.4.1 The hydrostatic design stress is the estimated maximum tensile stress in the wall of the pipe in the circumferential orientation as a result of internal hydrostatic pressure that can be applied continuously with a high degree of certainty that failure will not occur. It is obtained by multiplying the hydrostatic design basis as determined by Procedure A or Procedure B by the service (design) factor.

X1.5 Pressure Rating

X1.5.1 The pressure rating is the estimated maximum pressure that the medium in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur.

X1.5.2 The pressure rating for each diameter and wall thickness of pipe and fitting is calculated from the hydrostatic design stress for the specific pipe by means of the ISO formula:

$$S = P(D - t)/2t$$

where:

S = hoop stress,
P = internal pressure,
D = average outside diameter, and
t = minimum reinforced wall thickness.

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SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue, D 2997–99, that may impact this standard.

(*1*) Changed acronym, RPMP, definition from reinforced *plastic* mortar pipe to reinforced *polymer* mortar pipe.

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Standard Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals[1]

This standard is issued under the fixed designation D 3139; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the types of joints required for plastic pipe pressure systems with a wall thickness equal to or greater than that of SDR 64 and intended for use in supply and distribution lines for water, using flexible elastomeric seals. This specification covers the test requirements, test method, and materials. The test methods described are not intended to be routine quality control tests, but are to evaluate the performance characteristics of the joint.

1.2 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.3 The following safety hazards caveat pertains to the test method portion, Section 6, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials[2]

F 477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe[2]

2.2 *AWWA Standard:*

AWWA C 651 Standard for Disinfecting Water Mains[3]

2.3 *NSF Standard:*

ANSI/NSF Standard No. 61 for Drinking Water System Components-Health Effects[4]

3. Terminology

3.1 Definitions—This specification covers two types of mechanical joints based on effecting water tightness through compression of an elastomeric seal or ring:

3.1.1 *mechanical joint*—a joint in which a positive seal is achieved when a gasket is compressed by means of a mechanical device.

3.1.2 *push-on-joint*—a joint in which a continuous elastomeric ring gasket is compressed into an annular space formed by the pipe or fitting socket and the spigot end of the pipe, and forms a positive seal after being assembled. Details of the joint design and assembly shall be in accordance with the manufacturer's instructions.

4. Materials and Manufacture

4.1 The materials used in elastomeric seals shall meet the requirements of Specification F 477.

4.2 *Lubricant*—The lubricant shall be nontoxic and shall have no deteriorating effects on the gasket and pipe materials. It shall not impart taste or odor to water in a pipe that has been flushed in accordance with AWWA C 651. When used in a potable water system, the lubricant shall meet the requirements of ANSI/NSF Standard No. 61. The lubricant container shall be labeled with the manufacturer's trademark or the pipe manufacturer's name.

5. Performance Requirements

5.1 The joint shall be designed to provide a permanent seal and shall be qualified in accordance with Section 8.

5.1.1 All surfaces of the joint upon or against which the gasket may bear shall be free of imperfections that could adversely affect the performance of the joint.

5.2 *Pressure Rating*—Designs not meeting the requirements of 6.2 shall be tested to verify that the hydrostatic design basis category for joint assemblies shall not be lower than the hydrostatic design basis category for pipe when tested under the same procedure. The hydrostatic design basis for this joint design shall be established on a representative size at a minimuim test level of 10 points and 2000 h in accordance with Test Method D 2837, except that the ends shall be restrained. Test pressure levels for establishing hydrostatic design basis shall be calculated on pipe minimum wall dimensions.

5.2.1 Joint designs shall require retesting under this section only if the joint design is changed or if the pipe compound is altered in any manner that produces a lower hydrostatic design basis category when compared with the compound used in the previous validation testing of the joint design.

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[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.20 on Joining.

Current edition approved April 10, 1998. Published August 1998. Originally published as D 3139 – 73. Last previous edition D 3139 – 96a.

[2] *Annual Book of ASTM Standards*, Vol 08.04.

[3] Available from American Water Works Assn., 6666 W. Quincy Ave., Denver, CO 80235.

[4] Available from NSF International P.O. Box 130140, Ann Arbor, MI 48113-0140.

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5.3 *Mechanical Joint*—The mechanical joint shall provide a pressure rating equal to or greater than that of the corresponding pipe.

5.3.1 *Internal Stiffener*—The pipe spigot shall have a wall thickness sufficient to withstand, without deformation or collapse, the compressive force exerted when the fitting is tightened. If the wall is not sufficient to withstand the compressive force, then a rigid tubular internal stiffener shall be used in conjunction with compressive-type mechanical joint fittings. A stiffener specified by the manufacturer for this purpose shall be used.

5.4 *Joint Deflection*—The joint shall provide a seal when the pipe spigot is deflected axially in the socket to the maximum unstressed limit permitted by dimensional clearance between the spigot and bell.

6. Dimensions, Mass, and Permissible Variations

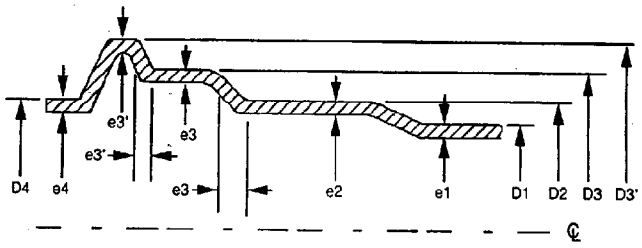
6.1 *Joint Dimensions and Tolerances*— The dimensions of the bell, socket, and plain end shall be in accordance with the manufacturer's standard design dimensions of the joint.

6.2 *Push-On Joint*—The minimum wall thickness of the bell at any point between the ring groove (annular gasket space) and the pipe barrel, shall conform to the dimension ratio requirements for the pipe barrel. The minimum wall thickness in the sealing portion of the ring groove and bell entry sections shall equal or exceed the minimum wall thickness requirements of the pipe barrel (see Fig. 1 or Fig. 2).

6.3 *Gasket Dimensions*—Gasket dimensions shall be in accordance with the manufacturer's standard design dimensions and tolerances. The gasket shall be of such size and shape as to provide an adequate compressive force against the spigot and socket after assembly to effect a positive seal under all combinations of permitted joint and gasket tolerances. The gasket shall be the sole element depended upon to make the joint flexible and water tight. The gasket shall be a continuous elastomeric ring.

7. Workmanship, Finish, and Appearance

7.1 The manufacturer of these joints shall produce joints meeting the requirements of this specification. Components of the joints shall be homogenous throughout and free from visible cracks, holes, foreign inclusions, or injurious defects.



C_L = center line
D_1 = average outside diameter - pipe
D_2 = average outside diameter - socket
D_3 = average outside diameter - sealing portion of the annular gasket space
D_3' = average outside diameter - locking portion of the annular gasket space
D_4 = average outside diameter - entry lip
e_1 = minimum wall thickness - pipe
e_2 = minimum wall thickness - socket
e_3 = minimum wall thickness - sealing portion of the annular gasket space
e_3' = minimum wall thickness - locking portion of the annular gasket space
e_4 = minimum wall thickness - entry lip
S_W = hydrostatic design stress
P_w = pressure rating shall be determined as follows:
$S_W = P_w(D - e)/2e$ (Method D 2837)
$e_1 = D_1[(2S_W/P_W) + 1]$
$e_2 = D_2/[(2S_W/P_W) + 1]$
$e_3 \geq e_1$
$e_3' \geq 0.9e1$
$e_4 \geq e_1$

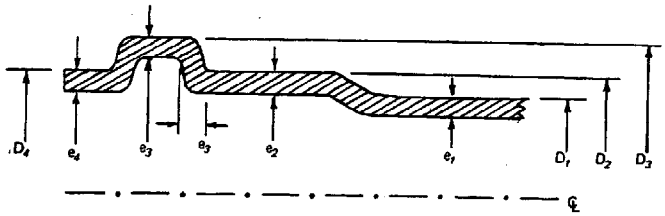
FIG. 2 Relationship of Dimensions in 6.2

The components of the joints shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 The assembled joints shall pass the following laboratory qualifying tests. (For referee testing, standard laboratory conditions of 73°F and 50 % relative humidity will apply.)

8.1.1 *Internal Pressure Testing*—Laboratory hydrostatic pressure tests on joints shall be made on an assembly of two sections of pipe properly connected in accordance with the joint design and deflected to the limit defined in 5.4. No coatings, fillings, or packings, other than lubricants recommended in 4.2, shall be placed prior to water tightness tests. After the pipe sections are fitted together with the gasket or gaskets in place, the assembly shall be subjected to separate internal pressure tests, first at 50 % of rated pressure for 60 min, then at 2½ times the rated pressure for 60 min without leakage at either pressure for the duration of either test. The pressure shall then be continuously increased to the minimum short-term rupture requirement of the applicable pipe without



C_L = center line
D_1 = average outside diameter - pipe
D_2 = average outside diameter - socket
D_3 = average outside diameter - annular gasket space
D_4 = average outside diameter - entry lip
e_1 = minimum wall thickness - pipe
e_2 = minimum wall thickness - socket
e_3 = minimum wall thickness - sealing portion of the annular gasket space
e_4 = minimum wall thickness - entry lip
S_W = hydrostatic design stress
P_w = pressure rating shall be determined as follows:
$S_W = P_w(D - e)/2e$ (Method D 2837)
$e_1 = D_1[(2S_W/P_W) + 1]$
$e_2 = D_2/[(2S_W/P_W) + 1]$
$e_3 \geq e_1$
$e_4 \geq e_1$
$[(2S_W/P_W) + 1]$ = SDR

FIG. 1 Relationship of Dimensions in 6.2

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leakage. The pressure increase from 2½ times rated to minimum short-term rupture requirement shall occur over a 60 to 70-s period.

8.1.2 *Vacuum Test*—The assembled joint shall withstand a vacuum of 75-kPa gage (22 in. Hg) for 1 h with no leakage while in the auxiliary deflected position in accordance with 8.1.1.

9. Rejection and Rehearing

9.1 If the results of any test(s) do not meet the requirements of this specification, the test(s) shall be conducted again only by agreement between the purchaser and the seller. Under such agreement, minimum requirements shall not be lowered, nor tests omitted, substituted, changed, or modified, nor shall specification limits be changed. If upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

10. Certification

10.1 When specified in the purchase order or contract, the purchaser shall be furnished certification by affidavit that samples representing each lot of production have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test or inspection results shall be furnished.

11. Keywords

11.1 compression-type; elastometric; joints; push-on joint; rigid; seals

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Designation: D 3222 – 99

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Standard Specification for Unmodified Poly(Vinylidene Fluoride) (PVDF) Molding Extrusion and Coating Materials[1]

This standard is issued under the fixed designation D 3222; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This specification covers melt processable molding and extrusion materials, as well as coating materials of poly(vinylidene fluoride) fluoroplastic, commonly abbreviated PVDF (or PVF_2 in scientific literature). This specification covers thermoplastic resin materials supplied in pellet or powder form.

1.2 This specification applies only to the virgin homopolymer prepared from vinylidene fluoride, not copolymers, reinforced, filled grades or special grades with additives or treatments for modification of attributes.

1.3 The tests involved are intended to provide information for specification of unmodified PVDF homopolymer resins. It is not the purpose of this specification to provide engineering data for design purposes.

1.4 PVDF fluoroplastics melt between 156 and 180°C (312 and 356°F) and are thermally stable up to about 370°C (698°F).

NOTE 1—**Warning:** Evolution of corrosive and toxic hydrogen fluoride can occur under certain conditions.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

NOTE 2—PVDF exhibits polymorphism.[2] The type and extent of crystalline structure varies with the thermomechanical history of the sample. Specimens prepared by techniques different than prescribed in this specification could have properties that may vary from the values specified.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Note 1 and Section 10.

NOTE 3—There is no equivalent ISO standard for this specification. Information in this specification is technically equivalent to related information in ISO 12086-1 and ISO 12086-2.

2. Referenced Documents

2.1 *ASTM Standards:*

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies[3]

D 150 Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials[3]

D 256 Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials[4]

D 257 Test Methods for D-C Resistance or Conductance of Insulating Materials[3]

D 542 Test Methods for Index of Refraction of Transparent Organic Plastics[4]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[4]

D 638 Test Method for Tensile Properties of Plastics[4]

D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[4]

D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement[4]

D 883 Terminology Relating to Plastics[4]

D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer[4]

D 1505 Test Method for Density of Plastics by the Density-Gradient Technique[4]

D 1898 Practice for Sampling of Plastics[4]

D 2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-like Combustion of Plastics (Oxygen Index)[5]

D 3295 Specification for PTFE Tubing[5]

D 3418 Test Method for Transition Temperatures of Polymers by Thermal Analysis[5]

D 3835 Test Method for Determination of Properties of Polymeric Materials by Means of a Capillary Rheometer[6]

D 3892 Practice for Packaging/Packing of Plastics[5]

D 4895 Specification for Polytetrafluoroethylene (PTFE) Resins Produced From Dispersion[6]

[1] This specification is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.15 on Thermoplastic Materials.

Current edition approved April 10, 1999. Published July 1999. Originally published as D 3222 – 73. Last previous edition D 3222 – 97.

[2] Lovinger, A. J., "Poly(Vinylidene Fluoride)" *Developments in Crystalline Polymers*, Vol 1, Chapter 5, D. C. Bassett, Ed., Applied Science, London, 1982.

[3] *Annual Book of ASTM Standards*, Vol 10.01.

[4] *Annual Book of ASTM Standards*, Vol 08.01.

[5] *Annual Book of ASTM Standards*, Vol 08.02.

[6] *Annual Book of ASTM Standards*, Vol 08.03.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Classification of PVDF Resins

Property	Typical Values or Ranges		
	Type I		
	Grade 1	Grade 2	Type II
Specific Gravity	1.75 to 1.79	1.75 to 1.79	1.76 to 1.79
Peak Melting Endotherm, °C	156 to 162	162 to 170	164 to 180
Apparent Melt Viscosity,[A] Pa·s:			
High Viscosity	2800 to 3800	2800 to 3100	2500 to 4000
Medium Viscosity	2300 to 2800	1300 to 2800	1300 to 2500
Low Viscosity	...	500 to 1300	500 to 1300

[A] Reported for a shear rate of 100 s^{-1} determined by capillary rheometry at 232°C (450°F) using 0.027 radian (60°) entrance angle die with L/D of 15 and according to procedures of Test Method D 3835. Multiply the pascal second values by ten to obtain poise values.

E 380 Practice for Use of the International System of Units (SI)[7]

2.2 *IEC and ISO Standards:*

ISO 12086-1 Plastics—Fluoropolymer Dispersion and Moulding and Extrusion Materials—Part 1: Designation and Basis for Specification[8]

ISO 12086-2 Plastics—Fluoropolymer Dispersion and Molding and Extrusion Materials—Part 2: Preparation of Test Specimens and Determination of Properties[8]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of plastics terms used in this specification, see Terminology D 883.

3.2 *Units, Symbols, and Abbreviations:*

3.2.1 For units, symbols and abbreviations used in this specification see Practice E 380.

4. Classification

4.1 This specification covers two types[9] of natural, unmodified PVDF fluoroplastics supplied in pellet form for molding and extrusion, and in powder form for solutions, dispersions, or coatings.

4.1.1 *Type I*—PVDF fluoroplastics are polymerized in emulsion. Depending upon the polymerization conditions, the peak melting point of the resin can be varied between 156 and 170°C. The diameter of the primary particle isolated from the emulsion is typically less than 1 μm; the dried powder has an average agglomerate diameter range of 3 to 15 μm.

4.1.1.1 Two distinctly different Type I emulsion PVDF resins are available commercially. These are differentiated by peak melting endotherm values, as shown in Table 1, and this difference is the basis for subdividing Type I resins into Grades 1 and 2. Table 1 shows the melt viscosity ranges encompassing resin grades available from several sources and are provided for information purposes only.

4.1.2 *Type II*—PVDF fluoroplastics are polymerized in suspension. Peak melting temperatures of these resins range from 164 to 180°C. The particles isolated from suspension are spherical and range typically from 20 to 150 μm in diameter.

4.1.2.1 Type II resins are available commercially, and the data of Table 1 reflect ranges encompassing values typical for the properties of available grades.

4.2 A one-line system may be used to specify materials covered by this specification. The system uses predefined cells to refer to specific aspects of this specification, as illustrated below.

	Specification			
Standard Number Block	Type	Grade	Class	Special notes
Example: Specification D 3222 – 97	I	2	...	...

For this example (D 3222 – 97, I2), the line callout describes a PVDF resin polymerized in emulsion, having a specific gravity between 1.75 and 1.79, and a peak melting endotherm between 162 to 170°C. A comma is used as the separator between the Standard Number and the Type. Separators are not needed between the Type, Grade, and Class.[10] Provision for Special Notes is included so that other information, such as a preferred viscosity range, can be provided when required. When special notes are used, they should be preceded by a comma.

5. General Requirements

5.1 The material shall be of uniform composition and free of foreign matter to the contamination level agreed upon between the purchaser and seller.

6. Detail Requirements

6.1 *General Attributes*:

6.1.1 *Peak Melting Endotherm*—The material covered by this specification shall have a minimum peak melting endotherm for the type and class as shown in Table 1 when tested in accordance with Test Method D 3418. For Type I resins, this shall involve heating a solid specimen of 5 ± 1 mg from room temperature to 200°C at 10°C/min, maintaining the temperature at 200°C for 5 min, followed by cooling at a controlled rate of 10°C/min to about 30°C, then reheating at 10°C/min to 200°C. Record the peak melting endotherm during the second melting cycle.

6.1.1.1 *Temperature*—Test Type II resins likewise except that the maximum is 250°C.

6.1.2 *Specific Gravity*—A solid specimen of the material covered by this specification shall have the minimum specific gravity indicated in Table 1 (1.75 for Type I, Class 1 and 1.76 for all others) when tested in accordance with Test Methods D 792 or D 1505.

6.1.3 *Refractive Index*—The material covered in this specification shall have a refractive index of 1.42 when measured at the sodium D line at 25°C (77°F) in accordance with the refractometer procedure in Test Methods D 542, using specimens that have not been subjected to any processes which induce orientation of the polymer chains or crystal-lites.

[7] *Annual Book of ASTM Standards*, Vol 14.02.

[8] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[9] Dohany, J. E., and Robb, L. E., "Poly(Vinylidene Fluoride)" *Kirk-Othmer Encyclopedia of Chemical Technology*, Vol 11, 3rd Edition, 1980, pp. 64–74.

[10] See the ASTM *Form and Style for ASTM Standards*, available from ASTM Headquarters.

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Compression-molded specimens at least 2-mm (0.079-in.) thick that have been quenched rapidly in water are preferred.

6.1.4 *Limiting Oxygen Index*—The material covered in this specification shall have a minimum limiting oxygen index of 42 when tested in accordance with Test Method D 2863.

NOTE 4—If a column with a restricted opening is used, the top of the specimen should be positioned 40 mm below the opening.

6.2 *Processing Related Attributes*:

6.2.1 *Flow Rate*—Materials conforming to this specification may be tested for melt flow rate according to Test Method D 1238, using 232°C and 21.6-kg load for medium or high melt viscosity grades; low melt viscosity grades may be tested at 232°C (450°F) using a 5 kg weight.

6.2.2 *Rheological Properties*—The preferred method for measuring flow characteristics is capillary rheometry. Thus rheological properties of the materials should be tested according to Test Method D 3835 at 232°C (450°F) using a die with an entrance angle of 60° (cone angle of 120°) and a minimum capillary L/D of 15. See Table 1.

6.3 *Mechanical Properties*:

6.3.1 *Tensile Properties*—The material covered in this specification shall have a tensile yield strength exceeding 36 MPa (5200 psi) at 23°C (74°F) and a minimum elongation at break of 10 % when tested according to Test Method D 638 at 51 mm (2 in.)/min, using Type I specimens 3.2-mm (0.125-in.) thick as specified in Test Method D 638. Condition in accordance with Procedure A of Test Method D 638, except that a minimum time of 16 h before testing is satisfactory. Preferably, compression-molded samples should be used (see Section 8), but injection molded specimens may be used, providing that the samples yield and rupture in the gage region and not near the heel. Specimens should be molded under conditions specified by the resin suppliers. Generally, injection molded specimens show low and variable elongation values compared to compression-molded specimens.

6.3.2 *Flexural Properties*—The material covered in this specification shall have a minimum flexural modulus of 1.38 GPa (190×10^3 psi) when tested according to Method I of Test Methods D 790, using 6.4-mm (0.25-in.) thick specimens prepared by injection molding under conditions specified by the resin supplier. Samples should be conditioned in accordance with Procedure A of Methods D 618 except that a minimum time of 16 h before testing is satisfactory. Alternatively, compression-molded samples may be used (see Section 8) and tested after the 16-h conditioning period.

6.3.3 *Impact Resistance*—The material covered in this specification shall have a minimum impact strength of 101.4 J/m (1.90 ft·lbf/in.) determined by Test Methods D 256 using 6.4-mm (0.25-in.) thick specimens prepared by injection molding under conditions specified by the manufacturer. Specimens shall be conditioned in accordance with the provisions of Procedure A of Methods D 618, except that the conditioning period prior to testing shall be at least 16 h. Alternatively, specimens may be compression-molded and tested after the conditioning period as specified above.

6.4 *Electrical Properties*:

6.4.1 *D-C Resistance*—The material covered in this specification shall have a d-c volume resistivity greater than $1.2\Omega \cdot m$ (1.2×10^{14} Ω·cm) when tested as a 0.76-mm (0.030-in.) compression-molded specimen (see Section 8) in accordance with Test Methods D 257.

6.4.2 *Dielectric Strength*—The material covered in this specification shall have a dielectric strength in air no less than 57 kV/mm (1280 V/0.001 in.) by the "short-time" method of Test Methods D 149 with 0.13-mm (0.05-in.) thick compression-molded specimens (see Section 8) tested in air using 25.4-mm (1-in.) Type 3 electrodes.

6.4.3 *Dielectric Constant*—The material covered in this specification shall have a dielectric constant less than 11.0 at 100 Hz and greater than 7.2 at 1 MHz when tested as a 3.2-mm (0.125-in.) thick compression-molded specimen (see Section 8) according to Test Methods D 150 at 23°C (73°F).

6.4.4 *Dissipation Factor*—The material covered in this specification shall have a dissipation factor of less than 0.045 at 100 Hz and less than 0.24 at 1 MHz when tested as 3.2-mm (0.125-in.) compression-molded specimens (see Section 8) according to Test Methods D 150 at 23°C (73°F).

NOTE 5—Since this material has very low water-absorption characteristics, maintenance of constant humidity during testing or specimen preparation is not necessary except as required for a specific test method. However, no moisture should be present in the resin when preparing specimens for testing. Heat the resin sample at 110°C (230°F) in an air-circulating oven until the adventitious moisture is removed.

7. Sampling

7.1 Materials shall be sampled in accordance with Practice D 1898. Adequate statistical sampling shall be considered an acceptable alternative.

8. Preparation of Compression Molded Specimens

8.1 *Equipment*:

8.1.1 Press with approximately 180 kN (20 ton) capacity and heating capability for maintaining platens between 220 and 240°C (428 to 464°F).

8.1.2 Two smooth chromium-finished plates with approximate dimensions $150 \times 250 \times 5$ mm ($10 \times 10 \times 0.02$ in.), or, if more appropriate to the press type, $150 \times 150 \times 5$ mm ($6 \times 6 \times 0.02$ in.).

8.1.3 Flat open-cavity steel molds, that is, frames, to provide the shape and thicknesses requisite for the specific tests.

8.1.4 Timing device.

8.1.5 Appropriate equipment to handle the hot mold assembly when removed from the press.

8.1.6 Balance and containers for weighing the resin samples.

8.1.7 Water-filled container to quench-cool the samples in the mold frame.

8.1.8 Aluminum foil approximately 0.1-mm thick (0.004-in.).

8.2 *Compression Molding Specimens Less Than 2 mm (0.08 in.)*:

8.2.1 For the given mold cavity establish, by initial trial preparations, the amount of material necessary to overfill slightly and yield a minimum flash after forming.

8.2.2 Place the appropriate amount of material in the center of the mold between thin sheets of polished aluminum foil.

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8.2.3 Place the assembly between the chrome-finished plates.

8.2.4 Place the mold assembly in the press so that it is in contact with the hot platens, using a ram force that barely registers on the force gage and hold for a 5-min period. The temperature preferably should be 230°C (446°F) but may be as slow as 228°C (442°F) and as high as 232°C (450°F).

8.2.5 After the preheat period, slowly increase the ram force to 130 kN (30 000 lbf) and hold for 1 min.

8.2.6 Remove the sandwiched material and immediately quench in cold water.

8.2.7 After standing for 1 min, disassemble and remove the molded plaque from the frame.

NOTE 6—The alternative method of allowing the assembly to cool at ambient room temperature under a heavy weight, or under pressure in a cold press, may result in specimens having properties that may vary from values in specification tests.

8.2.8 If the mold shape is not appropriate for the test, cut test specimens from the molded sample.

NOTE 7—The edges of the specimen may affect performance in mechanical tests. Die-cutting is the preferred method to prepare such specimens; the cutting edges should be leveled and sharp.

8.3 *Compression Molding Specimens Thicker Than 2 mm (0.08 in.)*:

8.3.1 Pellets of PVDF can be compression-molded directly in thick sections without difficulty.

8.3.2 Powdered PVDF samples tend to entrap air when thick sections are molded under compression. Such specimens are not suitable for any tests in this specification. The preferred method to obtain bubble-free thick moldings involves preparation of thin compression-molded sheets, as described in 8.2, and a subsequent second molding cycle filling the thick section mold with several layers of the thin sheet specimens cut to fill the mold dimension. To assure complete filling, the stack of thin samples must be slightly higher than the mold cavity thickness.

9. Test Conditions

9.1 *Specific Gravity, Mechanical Properties, and Electrical Properties*:

9.1.1 Condition the molded test specimens in accordance with Procedure A of Practice D 618, except that the period shall be at least 16 h prior to test.

9.1.2 Conduct tests at the standard laboratory temperature of 23 ± 2°C (73.4 ± 3.6°F).

NOTE 8—PVDF is a partially crystalline polymer. Unless molded and conditioned equivalently for a sufficient period to assure consistent crystallinity, samples prepared by any other method may give variable results.

9.1.3 The specific gravity of two specimens cut from a compression-molded sample shall be determined according to Test Methods D 792 or D 1505. If the latter method is used, the tube should have a linear gradient over the range from about 1.65 to 1.90.

NOTE 9—Test Methods D 792 is particularly convenient, but care must be exercised to eliminate air bubbles that may be attached to the specimen upon immersion. Dipping the specimens in a very dilute solution (less than 0.1 weight percent) of an ammonium perfluorooctanoate surfactant minimizes this problem.

9.2 *Melting Temperature*—Determine the melting endotherm peak on the as-received resin sample according to Test Method D 3418 by differential scanning calorimetry under conditions given in 5.1.1. The test for melting endotherm peak requires no conditioning.

10. Handling

10.1 As is the case with any synthetic resin, it is advisable to wear a dust mask when handling large quantities of powder grades to prevent ingestion.

11. Packaging

11.1 The packing, packaging, and marking provisions of Practice D 3892 shall apply to this standard.

12. Precision and Bias

12.1 The precision and bias statements of ASTM test methods referenced herein apply to the specific tests required in this specification.

13. Keywords

13.1 extrusion materials; fluorohydrocarbon plastics; fluoropolymers; molding materials; polyvinylidene fluoride (PVDF)

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SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification. For the convenience of the user, Committee D-20 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both.

D 3222 – 97:

(*1*) Changed SI statement (1.5).

(*2*) Added new Note 3.

(*3*) Added ISO 12086-01 and ISO 12086-02 and Terminology D 883 to list of referenced documents.

(*4*) Removed reference to Military specifications.

(*5*) Added new Sections 3, 3.1, and 3.2.

(*6*) In Table 1, changed Class 1 and 2 classifications to Grades 1 and 2 classifications.

(*7*) Changed 5.1.1.1 to reflect change from class to grade and qualified the inclusion of viscosity ranges in Table 1 as information only.

(*8*) In 5.2 changed one-line callout example to refer to D 3222 – 97.

D 3222 – 99:

(*1*) Revised the impact strength to 101.4 J/m (1.90 ft·lbf/in.) in 6.3.3.

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Designation: D 3307 – 00

An American National Standard

Standard Specification for Perfluoroalkoxy (PFA)-Fluorocarbon Resin Molding and Extrusion Materials[1]

This standard is issued under the fixed designation D 3307; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers melt processable molding and extrusion materials of PFA-perfluoro(alkoxy alkane) fluorocarbon resin. The materials are copolymers of TFE-fluorocarbon resins containing perfluoroalkoxy side chains.

1.2 This specification does not cover recycled plastics.[2]

1.3 The tests involved are intended to provide information for identifying the materials covered. It is not the function of this specification to provide engineering data for design purposes. Specimens prepared by injection molding or extrusion could yield test results that may vary from the values in this specification.

1.4 The values stated in SI units[3] are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The following precautionary caveat pertains only to the test methods portions, Sections 8 and 9 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—This specification, ISO 12086–1(1995), and ISO 12086–2(1995) differ in approach or detail. Data obtained using either may not be technically equivalent.

2. Referenced Documents

2.1 *ASTM Standards:*

D 150 Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials[4]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[5]

D 638 Test Method for Tensile Properties of Plastics[5]

D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement[5]

D 883 Terminology Relating to Plastics[5]

D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer[5]

D 1505 Test Method for Density of Plastics by the Density-Gradient Technique[5]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[5]

D 3892 Practice for Packaging/Packing of Plastics[6]

D 4591 Test Method for Determining Temperatures and Heats of Transitions of Fluoropolymers by Differential Scanning Calorimetry[7]

D 5033 Guide for the Development of Standards Relating to the Proper Use of Recycled Plastics[7]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[8]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[8]

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System[8]

2.2 *ISO Standards:*

ISO 12086–1 Plastics–Fluoropolymer Dispersions and Moulding and Extrusion Materials–Part 1[9]

ISO 12086–2 Plastics–Fluoropolymer Dispersions and Moulding and Extrusion Materials–Part 2[9]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology D 883.

3.1.1 *lot, n*—one production run or a uniform blend of two or more productions runs.

4. Classification

4.1 This specification covers six types of PFA-fluorocarbon resins supplied in pellet form for molding and extrusion.

4.2 A one-line system may be used to specify materials covered by this specification. The system uses predefined cells

[1] This specification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.15 on Thermoplastic Materials (Section D20.15.12).

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[2] As defined in Guide D 5033.

[3] As defined in IEEE/ASTM SI 10.

[4] *Annual Book of ASTM Standards*, Vol 10.01.

[5] *Annual Book of ASTM Standards*, Vol 08.01.

[6] *Annual Book of ASTM Standards*, Vol 08.02.

[7] *Annual Book of ASTM Standards*, Vol 08.03.

[8] *Annual Book of ASTM Standards*, Vol 14.02.

[9] Available from the American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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to refer to specific aspects of this specification, as illustrated as follows:

Specification				
Standard Number Block	Type	Grade	Class	Special Notes
Example: Specification D 3307 – 98,	I			

In this standard, the only specifications are type; no grade or class is required. A comma is used as the separator between the standard number and the type. Separators are not needed between the type, grade, and class.[10] Provision for special notes is included so that other information can be provided when required. An example would be in Specification D 3295 where dimensions and tolerances are specified for each AWG size within type and class. When special notes are used, they should be preceded by a comma.

5. General Requirements

5.1 The materials shall be of uniform composition and so prepared as to conform to the requirements of this specification.

5.2 The materials described in this specification shall be free of foreign matter to such a contamination level as may be agreed upon between the purchaser and the seller.

6. Detail Requirements

6.1 The materials covered by this specification shall conform to the requirements prescribed in Table 1 and Table 2 when tested by the procedures specified herein. Table 2 lists those tests requiring a specimen molded as described in 9.1.

7. Sampling

7.1 Sampling shall be statistically adequate to satisfy the requirements of 10.4.

8. Number of Tests

8.1 One set of test specimens as prescribed in Section 9 shall be considered sufficient for testing each sample. The average result of the specimens tested shall conform to the requirements of this specification.

9. Test Methods

9.1 *Test Specimens*:

9.1.1 Prepare a molded sheet 1.5 ± 0.25-mm (0.060± 0.010-in.) thick. Use a picture-frame-type chase having a suitable blanked-out section and thickness to produce the desired sheet. Use clean aluminum foil, 0.13 to 0.18 mm (0.005 to 0.007 in.) thick, in contact with the resin. A high temperature mold release agent may be sprayed on the aluminum foil to help prevent the foil from sticking to the sheet. Use steel molding plates at least 1.0 mm (0.040 in.) thick and of an area adequate to cover the chase.

9.1.2 Lay down and smoothly cover one plate with a sheet of aluminum foil. Place the mold chase on top of this assembly. Place within the mold chase sufficient molding material to produce the required sheet in such manner that the polymer charge is a mound in the middle of the chase. Place a second sheet of aluminum foil on top of the granules and add the top mold plate. Place the assembly in a compression molding press having platens that have been heated to 380 ± 5°C (716 ± 10°F).

9.1.3 Bring the press platens to incipient contact with the mold assembly. Hold for 2 to 4 min without pressure. Apply approximately 1 MPa (145 psi) and hold for 1 to 1.5 min. Then apply 2 to 4 MPa (290 to 580 psi) and hold for 1 to 1.5 min. Maintain the press at 380 ± 5°C (716 ± 10°F) during these steps. Remove the assembly from the press and place between two 20 ± 7-mm (0.75 ± 0.25-in.) steel plates whose temperature is less than 40°C (104°F).

9.1.4 When the sheet is cool enough to touch (about 50 to 60°C (122 to 140°F)), remove the aluminum foil from the sheet. (If the sheet is allowed to cool to room temperature, the aluminum foil cannot be pulled free.)

9.2 *Conditioning*:

9.2.1 For tests of specific gravity, tensile properties, and electrical properties, condition the molded test specimens in accordance with Procedure A of Practice D 618 for a period of at least 4 h prior to test. The other tests require no conditioning.

9.2.2 Conduct tests at the Standard Laboratory Temperature of 23 ± 2°C (73.4 ± 3.6°F) for determination of specific gravity, tensile properties, and electrical properties only. Since the resin does not absorb water, the maintenance of constant humidity during testing is not necessary. Conduct tests for melt flow rate and melting endotherm under ordinary laboratory conditions.

9.3 *Melt Flow Rate*—Determine the melt flow rate in

[10] See *ASTM Form and Style Manual.*

TABLE 1 Detail Requirements for Test on Molding and Extrusion Materials

	Type I	Type II	Type III	Type IV	Type V	Type VI
Melt flow,[A] g/10min:						
min	>7	1	>3	>10	1	>3
max	18	3	7	30	3	10
Melting endotherm peak,[B] min, °C	300	300	300	285	285	285

[A] See 9.3 of this specification.
[B] See 9.4 of this specification.

TABLE 2 Detailed Requirements for Molded Specimens

	Type I	Type II	Type III	Type IV	Type V	Type VI
Specific gravity, 23°C (73.4°F):[A]						
min	2.12	2.12	2.12	2.12	2.12	2.12
max	2.17	2.17	2.17	2.17	2.17	2.17
Tensile strength, min, 23°C (73.4°F):[B]						
MPa	20.68	25	20.68	22.75	25.51	22.75
psi	3000	3625	3000	3300	3700	3300
Elongation, 23°C (73.4°F), min, %[B]	275	300	275	275	260	275
Dielectric constant, max:[C]						
10^2 Hz	2.2	2.2	2.2	2.2	2.2	2.2
10^6 Hz	2.2	2.2	2.2	2.2	2.2	2.2
Dissipation factor, max:[C]						
10^2	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
10^6	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005

[A] See 9.5 of this specification.
[B] See 9.6 of this specification.
[C] See 9.7 of this specification.

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accordance with Test Method D 1238, Test Method A or B, with a temperature of 372 ± 1°C and using a total load, including piston, of 5000 g. The same requirements apply for the use of corrosion-resistant alloy for the barrel lining, orifice, and piston tip.

9.4 *Melting Endotherm Peak*:

9.4.1 Determine the melting endotherm peak with a different thermal analyzer. Place a 20-mg specimen in a 4-mm tube with a thermocouple. Premelt the specimen at 325°C, and push the thermocouple into intimate contact with the melt. Cool the sample in air. Run the differential thermal analysis at 10°C/min with glass beads as a reference to a maximum temperature of 350°C. Extend straight lines down tangent to both sides of the melting endotherm, and take the temperature at which the lines intersect (peak minimum) as the melting endotherm peak.

9.4.2 *Precision*—The single instrument precision of the differential thermal analysis applied to this material is± 1.2°C (2S) as defined in Practice E 177.

9.4.3 Other thermal techniques capable of measuring the melting endotherm giving equivalent results may be used, such as Test Method D 4591.

9.5 *Specific Gravity*—Cut two specimens from the compression molded sheet and test in accordance with Test Method D 792 or Test Method D 1505. If the latter is used, the tube should have a linear gradient over the range from about 2.10 to 2.19.

9.6 *Tensile Properties*—Cut five specimens with the microtensile die shown in Fig. 1, which is exactly the same as Fig. 1 of Test Method D 1708. The die shall be of the steel-rule type of curvature of 5 ± 0.5-mm (0.20 ± 0.02-in.) type. Determine the tensile properties in accordance with the procedures described in Test Method D 638, except that the specimens used shall be as detailed above, the initial jaw separation shall be 22 ± 0.13 mm (0.866 ± 0.005 in.), and the speed of testing shall be 50 mm/min (2 in./min). Clamp the specimens with essentially equal lengths in each jaw. Determine the elongation from the chart, expressing it as a percentage of the initial jaw separation. Details appear in the Tensile Properties section of Specification D 2116.

9.7 *Dielectric Constant and Dissipation Factor*—Determine dielectric constant and dissipation factor on three specimens, each 101.6 mm (4 in.) in diameter in accordance with Test Methods D 150. Testing shall be at 10^2 Hz and 10^6 Hz.

10. Inspection and Certification

10.1 Inspection and certification of the material supplied with reference to a specification based on this classification system shall be for conformance to the requirements specified herein.

10.2 *Lot*—Acceptance shall be the basis on which acceptance or rejection of the lot is made. The lot acceptance inspection shall consist of melting endotherm peak temperature and melt flow rate.

10.3 Periodic check inspection with reference to a specification based on this classification system shall consist of the test for all requirements of the material in accordance with this specification.

10.4 Certification shall be that the material was manufactured by a process in statistical control, sampled, tested, and inspected in accordance with this classification system, and that the average values for the lot meet the requirements of this specification (line callout).

10.5 A report of test results shall be furnished when requested. The report shall consist of results of the lot-acceptance inspection for the shipment and the results of the most recent periodic-check inspection.

11. Packaging and Package Marking

11.1 All packing, packaging, and marking provisions of Practice D 3892 shall apply to this specification.

12. Precision and Bias [11]

12.1 A round robin was conducted in 1985–1986 in accordance with Practice E 691, involving seven materials tested by six laboratories (see Table 3). For each material, the sheeting from which the test specimens were to be cut was obtained from one source. Using a steel rule die, one set of test specimens for each laboratory was cut by one of the laboratories. Sheeting and a duplicate die were furnished each participating laboratory and used to cut a second set of test specimens. Each test result was the average of five individual determinations. Each laboratory obtained four test results on each material, two test results each on the specimens furnished and two on the specimens cut by the laboratory doing the testing.

12.1.1 The properties used in the analysis are tensile strength and elongation at break. The stress-strain curves of the fluorocarbon polymers (but not the fluoropolymers: modified ETFE and poly(vinylidene fluoride), PVDF) are similar in shape. Data on ETFE and PVDF, therefore, were excluded from the analysis used for this precision and bias statement but are available for use in precision and bias statements and are to be included in the research report at ASTM. Based on advice from experts in statistical analysis of round-robin data, and since use of fillers is excluded in the applicable standards, information from the testing on glass-fiber filled PTFE also is not included in Table 3. In addition, the experts advised that information from the samples cut in one laboratory and tested by all the laboratories should not be included in Table 3. The data are available in the report.

NOTE 2—**Caution:** The following explanations of I_r and I_R (12.3-12.3.3) are intended only to present a meaningful way of considering the approximate precision of this specification. The data in Table 3 should not be applied rigorously to acceptance or rejection of material, as those data are specific to the round robin and may not be representative of other lots, conditions, materials, or laboratories.

12.2 Users of this test method should apply the principles outlined in Practice E 691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of 12.3-12.3.3 would then be valid for such data.

12.3 *Concept of I_r and I_R*—If CV_r and CV_R have been calculated from a large enough body of data, and for test results that were averages from testing five specimens:

[11] Supporting data are available from ASTM Headquarters. Request RR:D20-1067.

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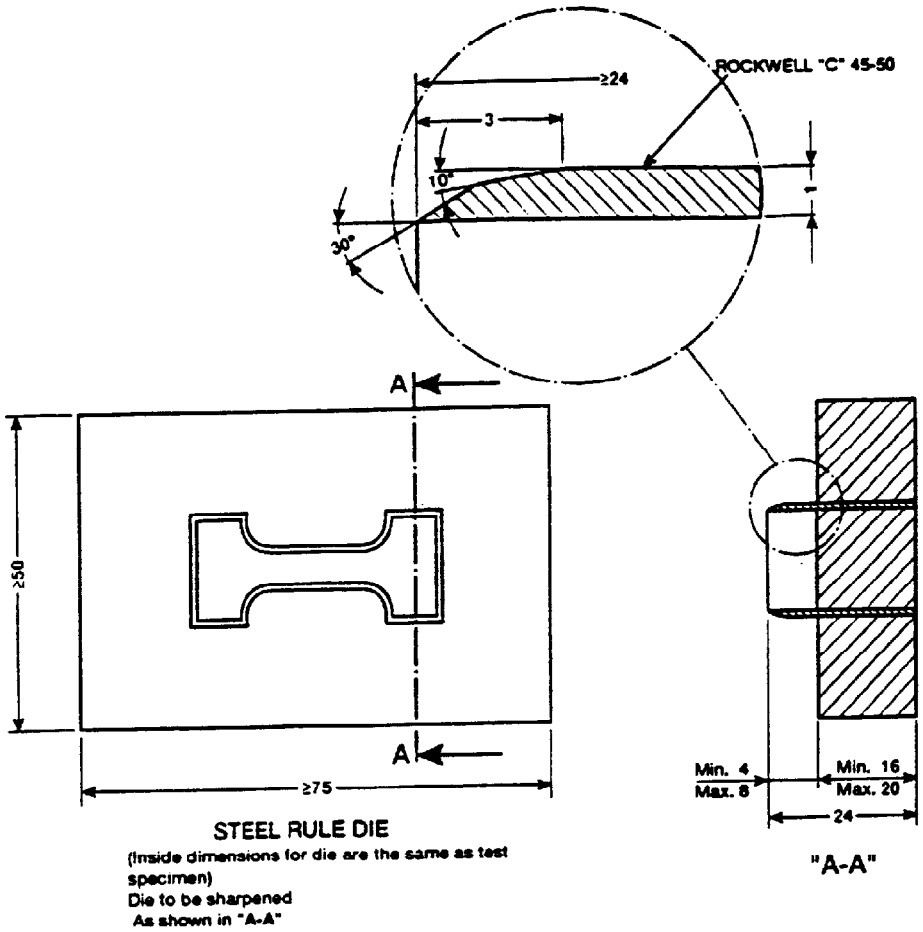
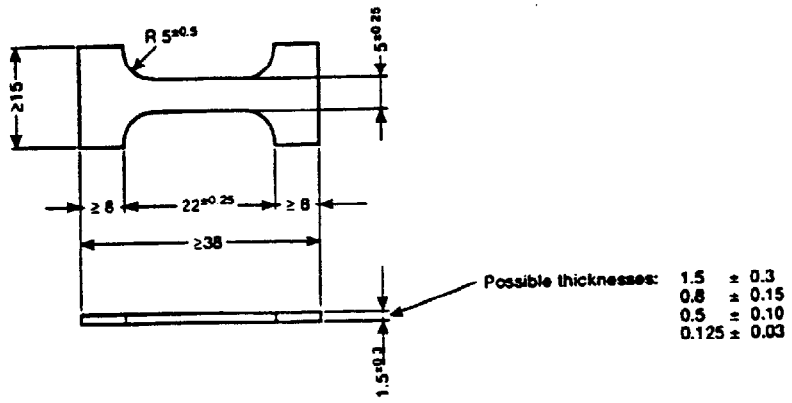


STEEL RULE DIE
(Inside dimensions for die are the same as test specimen)
Die to be sharpened
As shown in "A-A"



TEST SPECIMEN

NOTE 1—All dimensions are in millimetres.

FIG. 1 Microtensile Die and Test Specimen

12.3.1 *Repeatability (I_r)*—In comparing two test results for the same material, obtained by the same operator using the same equipment on the same day, the two test results should be judged not equivalent if they differ by more than the I_r value for that material.

12.3.2 *Reproducibility (I_R)*—In comparing two test results for the same material, obtained by different operators using different equipment on different days, the two test results should be judged not equivalent if they differ by more than the I_R value for that material.

12.3.3 Any judgment in accordance with 12.3.1 and 12.3.2 would have an approximate 95 % (0.95) probability of being correct.

12.4 *Bias*—Bias is systematic error that contributes to the

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TABLE 3 Precision Summary, Tensile Strength and Elongation at Break

NOTE 1—$I_r = 2.8 \times CV_r$; $I_R = 2.8 \times CV_R$.

Material	Tensile Strength				
	Mean psi	CV_r%	CV_R %	I_r %	I_R %
Granular:					
PTFE	4801	2.79	8.85	7.81	24.78
Coagulated Dispersion:					
PTFE	4807	2.71	3.37	7.59	9.46
PFA	4164	3.11	9.03	8.71	25.28
FEP	4144	2.98	7.98	8.34	22.34
Material	Percentage Elongation at Break				
	Mean % E	CV_r %	CV_R %	I_r %	I_R %
Granular:					
PTFE	337	2.83	16.43	7.92	46.00
Coagulated Dispersion:					
PTFE	300	2.17	13.74	6.08	38.47
PFA	336	3.27	9.66	9.16	27.05
FEP	319	2.21	7.60	6.19	21.28

difference between a test result and a true (or reference) value. There are no recognized standards on which to base an estimate of bias for this test procedure.

13. Keywords

13.1 extrusion; injection molding; fluoropolymer, perfluoroalkoxy; PFA-fluorocarbon resin; tetrafluoroethylene copolymer; TFE-fluorocarbon

SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification. For the convenience of the user, Committee D20 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both.

D 3307–98:

(*1*) Added perfluoro(alkoxy alkane) to Section 1 and to the title.

(*2*) Inserted in 1.3: This section does not cover recycled plastics.

(*3*) Inserted Note 1 to include ISO equivalency statement.

(*4*) Renumbered Section 1 and added Footnotes 2 and 3.

(*5*) Inserted in 2.1: Test Methods D 1238, D 1708, and D 4591; Guide D 5033; IEEE/ASTM SI 10; and ISO 12086–1 and 2.

(*6*) In 2.1, updated footnote information.

(*7*) In 4.2, upgraded callout section to reflect this specification.

(*8*) In 9.3, added reference to Test Method D 1238 and eliminated reference to Specification D 2116.

(*9*) In 9.4, added reference to Test Method D 4591.

(*10*) In 9.6, upgraded dimensions to reflect ISO tensile strength die and replaced Fig. 1 with ISO equivalent.

(*11*) In 12.1, at the end of first sentence added reference to Table 3.

(*12*) In 7.1, removed incorrect wording.

(*13*) In 9.1, added qualification statement.

(*14*) Added Section 13, Keywords.

(*15*) Added Summary of Changes.

(*16*) In Section 2, changed Tensile Strength, Type II, from 3800 psi to 3625 psi and changed 26.20 MPa to 25.0 MPa.

D 3307 – 00:

(*1*) Added Terminologies D 883 and D 1600 to Section 2.

(*2*) Deleted Test Method D 1708, Practice D 1898, and Specification D 2116 from Section 2.

(*3*) Added Section 3 on Terminology, including a definition for *lot*.

(*4*) Renumbered all following sections accordingly.

(*5*) Deleted 6.1 and replaced with upgraded sampling process (now 7.1).

(*6*) Added three additional types to Table 1.

(*7*) Added three additional types to Table 2.

(*8*) Changed Section 9, Retest and Rejection, to Section 10, Inspection and Certification, with appropriate subheadings.

(*9*) Added footnotes to Tables 1 and 2 referencing sections within this specification.

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Designation: D 3311 – 94

An American National Standard

Standard Specification for Drain, Waste, and Vent (DWV) Plastic Fittings Patterns[1]

This standard is issued under the fixed designation D 3311; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification provides standard fitting geometries and laying lengths for plastic fittings intended for use in drain, waste, and vent applications.

1.2 Fittings meeting the requirements of this standard specification are designed for use with outside diameter controlled pipe. The inside diameter can vary significantly as the wall thickness and outside diameter varies and therefore is not suitable for use as a fitting socket.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

D 2661 Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe Fittings[2]

D 2665 Specification for Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings[2]

D 2749 Symbols for Dimensions of Plastic Pipe Fittings[2]

F 628 Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe with a Cellular Core[2]

F 891 Specification for Coextruded Poly(Vinyl Chloride) (PVC) Plastic Pipe with a Cellular Core[2]

3. Requirements

3.1 Fittings shall conform to the geometries and laying lengths as shown in Tables 1-42 and Fig. 1. Tolerances shall be ±1/16 in. unless otherwise specified.

3.2 Spigot and hub dimensions shall conform to the requirements of the referencing standard.

3.3 The exact outside shape of a fitting is not determined by the outline drawings shown in this specification but rather by the socket dimensions, wall thickness requirements, waterway, laying lengths, and any other critical dimensions that may be specified.

3.4 The pitch of sockets for patterns with 90° angles (except vent fittings) shall be ¼ in./ft or 1° 12 min.

3.5 On double reducing sanitary tees, the *G2* dimension on branches will be calculated on the larger size and centerlines shall remain the same for both branches.

3.6 All other dimensions, materials and property requirements shall be in conformance with the referencing standard.

4. Keywords

4.1 DWV; fittings; plastic; Schedule 40; thermoplastic

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[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.63 on Drain, Waste, and Vent Pipe and Tube.

Current edition approved Dec. 15, 1994. Published February 1995. Originally published as D 3311 – 74. Last previous edition D 3311 – 92.

[2] *Annual Book of ASTM Standards*, Vol 08.04.

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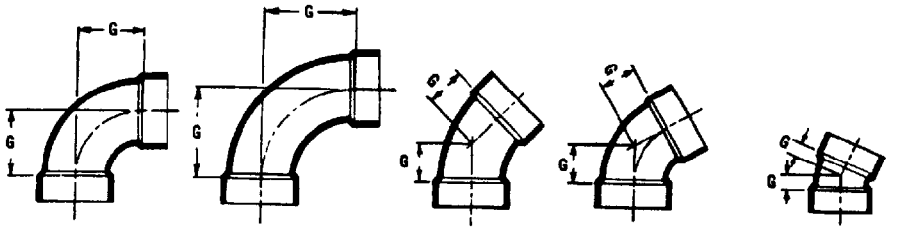
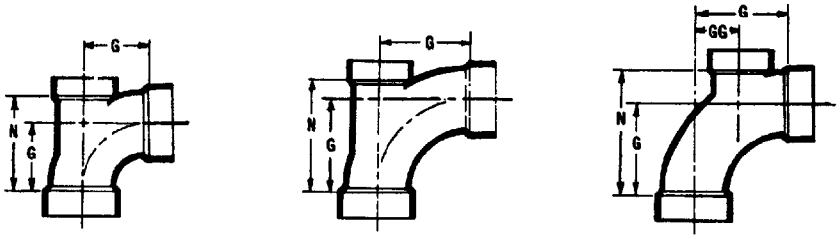
TABLE 1 Bends, in. (mm)



1/4 BEND | **LONG SWEEP 1/4 BEND** | **1/8 BEND** | **1/6 BEND** | **1/16 BEND**

Nominal Pipe Size	¼ Bend	Long Sweep ¼ Bend	⅛ Bend	⅙ Bend	1/16 Bend
	G	*G*	*G*	*G*	*G*
1¼	1 9/16 (40)	2 1/4 (57)	1 (25)	7/8 (22)	7/16 (11)
1 ½	1 ¾ (44)	2 ¾ (70)	1 ⅛ (29)	1 (25)	½ (13)
2	2 5/16 (59)	3 ¼ (83)	1 ½ (38)	1 5/16 (33)	11/16 (17)
3	3 1/16 (78)	4 1/8 (103)	1 ¾ (44)	1 11/16 (43)	13/16 (21)
4	3 ⅞ (98)	4 15/16 (125)	2 3/16 (56)	2 1/16 (52)	1 (25)
6	5 (min) (127)	9 (229)	2 (min) (51)	3 ⅜ (86)	1 ½ (38)
8	6 (152)	...	2 1/16 (52)	...	1 ½ (38)

TABLE 2 Bends with Inlets, in. (mm)



1/4 BEND With Low Heel Inlet | **LONG SWEEP 1/4 BEND With Low Heel Inlet** | **LONG SWEEP 1/4 BEND With High Heel Inlet**

Nominal Pipe Size	¼ Bend with Low Heel Inlet		Long-Sweep ¼ Bend with Low Heel Inlet		Long-Sweep ¼ Bend with High Heel Inlet		
	G	*N*	*G*	*N*	*G*	*N*	*GG*
3 by 3 by 1 ½	3 1/16 (78)	4 3/16 (106)	4 1/16 (103)	4 ¾ (121)	...	...	...
3 by 3 by 2	3 1/16 (78)	4 7/16 (113)	4 1/16 (103)	4 15/16 (125)	4 1/16 (103)	5 ⅝ (143)	2 ¼ (57)
4 by 4 by 2	3 ⅞ (98)	5 7/16 (138)	4 15/16 (125)	6 (152)	...	...	...

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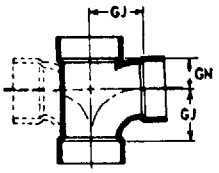
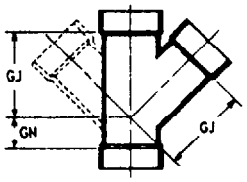
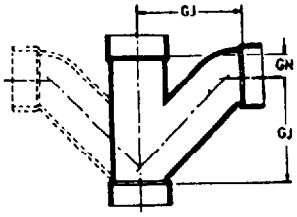
TABLE 3 Sanitary Tees, 45° Wyes, Combination Wyes and ⅛ Bends, in. (mm)



SANITARY TEE
Single & Double



45° WYE
Single & Double

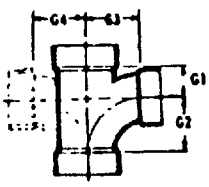


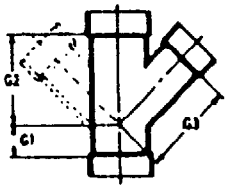
COMBINATION WYE
& 1/8 BEND
Single & Double

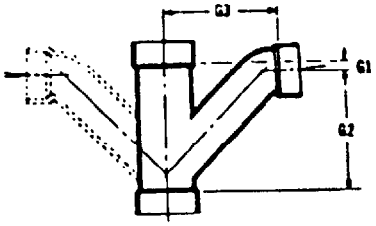
Nominal Pipe Size	Sanitary Tee Single and Double[A]		45° Wye, Single and Double		Combination Wye and ⅛ Bend Single and Double	
	GN	*GJ*	*GN*	*GJ*	*GN*	*GJ*
1 ¼	¾ (19)	1 ⁹⁄₁₆ (40)	1 ¹⁄₁₆ (27)	2 ⁹⁄₁₆ (65)	⁷⁄₁₆ (11)	2 ¹⁵⁄₁₆ (75)
1 ½	1 (25)	1 ¾ (44)	1 ⅛ (29)	2 ⅞ (73)	½ (13)	3 ⅜ (86)
2	1 ⅜ (35)	2 ⁵⁄₁₆ (59)	1 ⅜ (35)	3 ⅝ (92)	1 (25)	4 ½ (114)
3	1 ¹³⁄₁₆ (46)	3 ¹⁄₁₆ (78)	1 ⅝ (41)	5 (127)	1 ⅛ (29)	6 ⁵⁄₁₆ (160)
4	2 ¼ (57)	3 ⅞ (98)	1 ⅞ (48)	6 ⅜ (162)	1 ¹³⁄₁₆ (46)	8 ⅝ (219)
6	3 ½ (89)	5 (127)	1 ¾ (44)	8 ⁷⁄₁₆ (214)	*B*	*B*
8	4 ½ (114)	6 (152)	2 ⅜ (60)	11 ¾ (298)	*B*	*B*

[A]Non-reducing double sanitary tees are for vent use only.
[B]Combination wye and ⅛ bend is assembled from two standard fittings.

TABLE 4 Reducing Sanitary Tees, 45° Wyes, Combination Wyes, and ⅛ Bends, in. (mm)







Nominal Pipe Size	Sanitary Tee, Reducing Single and Double[A]				45° Wye, Reducing Single and Double			Combination Wye and ⅛ Bend Reducing Single and Double		
	G1	G2	G3	G4	G1	G2	G3	G1	G2	G3
1½ by 1¼ by 1¼	¹¹⁄₁₆ (17)[B]	1 ½ (38)[B]	1 ¹¹⁄₁₆ (43)[B]	1 ¹¹⁄₁₆ (43)[B]	—	—	—	—	—	—
1½ by 1¼ by 1½	1 (25)	1 ¾ (44)	1 ¾ (44)	1 ¾ (44)	—	—	—	—	—	—
1½ by 1½ by 1¼	¹³⁄₁₆ (21)	1 ¹¹⁄₁₆ (43)	1 ¹³⁄₁₆ (46)	1 ¹³⁄₁₆ (46)	—	—	—	½ (13)	3 ¼ (83)	3 ³⁄₁₆ (81)
2 by 1¼ by 1½	1 ³⁄₁₆ (30)	1 ¹⁵⁄₁₆ (49)	2 ³⁄₁₆ (56)	2 ³⁄₁₆ (56)	—	—	—	—	—	—
2 by 1½ by 1½	1 ³⁄₁₆ (30)	1 ¹⁵⁄₁₆ (49)	2 ³⁄₁₆ (56)	2 ³⁄₁₆ (56)	¾ (19)[B]	2 ¹³⁄₁₆ (71)[B]	2 ¹⁵⁄₁₆ (75)[B]	⁹⁄₁₆ (14)	3 ¹¹⁄₁₆ (94)	3 ⅝ (92)
2 by 1½ by 2	1 ⅜ (35)	2 ⁵⁄₁₆ (59)	2 ⁵⁄₁₆ (59)	2 ⁵⁄₁₆ (50)	1 (25)[B]	3 ½ (89)[B]	3 ⅜ (86)[B]	1 (25)	4 ½ (114)	4 ½ (114)
2 by 2 by 1¼	1 ³⁄₁₆ (30)	1 ¹⁵⁄₁₆ (49)	2 ³⁄₁₆ (56)	2 ³⁄₁₆ (56)	—	—	—	—	—	—
2 by 2 by 1 ½	1 ³⁄₁₆ (30)	1 ¹⁵⁄₁₆ (49)	2 ³⁄₁₆ (56)	2 ³⁄₁₆ (56)	1 ¹⁄₁₆ (27)	3 ⁵⁄₁₆ (84)	3 ⁷⁄₁₆ (87)	⁹⁄₁₆ (14)	3 ¹¹⁄₁₆ (170)	3 ⅝ (92)
3 by 3 by 1½	¹⁵⁄₁₆ (24)	1 ¾ (44)	2 ⁹⁄₁₆ (65)	2 ⁹⁄₁₆ (65)	½ (13)	3 ¾ (95)	4 ⁵⁄₁₆ (110)	⅛ (3)	3 ⁷⁄₁₆ (87)	4 ¼ (108)
3 by 3 by 2	1 ³⁄₁₆ (30)	2 ⅛ (54)	2 ⅞ (73)	2 ⅞ (73)	⅞ (22)	4 ⅛ (105)	4 ⅝ (117)	⁷⁄₁₆ (11)	4 ¾ (121)	5 ⁵⁄₁₆ (135)
3 by 3 by 2 by 1½	¹⁵⁄₁₆ (24)[B]	2 ¹⁄₁₆ (52)[B]	2 ⁷⁄₁₆ (62)[B]	2 ½ (64)[B]	—	—	—	—	—	—
4 by 4 by 1½	1 ¹⁄₁₆ (27)[B]	2 (51)[B]	3 ¼ (83)[B]	3 ¼ (83)[B]	0 (0)[B]	3 ⁵⁄₁₆ (84)[B]	3 ¹⁵⁄₁₆ (100)[B]	—	—	—
4 by 4 by 2	1 ⅛ (29)	2 ¹⁄₁₆ (52)	3 ⁵⁄₁₆ (84)	3 ⁵⁄₁₆ (84)	⅜ (10)	4 ¹¹⁄₁₆ (119)	5 ⁹⁄₁₆ (141)	⁵⁄₁₆ (8)	4 ¾ (121)	5 ⅞ (149)
4 by 4 by 3	1 ¾ (44)	3 (76)	3 ⁹⁄₁₆ (90)	3 ⁹⁄₁₆ (90)	1 ¹⁄₁₆ (27)	5 ⁹⁄₁₆ (141)	6 (152)	1 ¹⁄₁₆ (27)	6 ⅜ (162)	6 ⅞ (175)
6 by 6 by 3	—	—	—	—	³⁄₁₆ (5)[B]	6 ¹⁵⁄₁₆ (176)[B]	7 ⁷⁄₁₆ (189)[B]	¹¹⁄₁₆ (17)[B]	7 ¹³⁄₁₆ (198)[B]	8 ¹³⁄₁₆ (224)[B]
6 by 6 by 4	2 ³⁄₁₆ (56)[B]	3 ⅝ (92)[B]	4 ⁵⁄₁₆ (110)[B]	4 ⁵⁄₁₆ (110)[B]	³⁄₁₆ (5)[B]	6 ¹¹⁄₁₆ (170)[B]	7 ⁷⁄₁₆ (189)[B]	⁹⁄₁₆ (14)[B]	7 ¹³⁄₁₆ (198)[B]	8 ¹⁵⁄₁₆ (227)[B]
8 by 8 by 4	2 ⅝ (67)	4 ⅛ (105)	5 ¼ (133)	5 ¼ (133)	⅜ (10)	7 ⅝ (194)	8 ⅝ (219)	*C*	*C*	*C*
8 by 8 by 6	3 ⁹⁄₁₆ (90)	4 ¹³⁄₁₆ (122)	5 ½ (140)	5 ½ (140)	1 (25)	9 ½ (241)	9 ¹³⁄₁₆ (249)	*C*	*C*	*C*

[A]Non-reducing double sanitary tees are for vent use only.
[B]This dimension is a minimum with no upper maximum limit.
[C]Combination Wye and ⅛ bend is assembled from two standard fittings.

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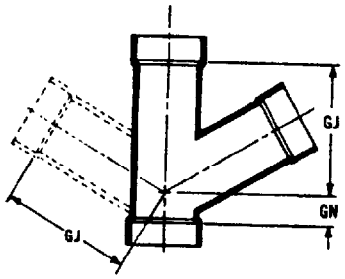
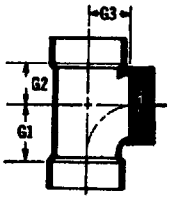
TABLE 5 60° Wyes, Single, and Double, in. (mm)



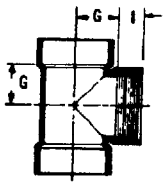
Nominal Pipe Size	GN	GJ
1½	1 ⅛ (40)	2 ⅞ (73)
2	1 ⅜ (37)	3 5/8 (92)
3	1 ⅝ (37)	5 (127)

TABLE 6 Fixture Tees, In. (mm)



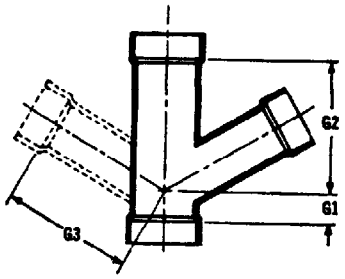
Nominal Pipe Size	G1	G2	G3
1 ½	1 9/16 (40)	1 3/16 (30)	1 ¼ (32)
2 by 1 ½ by 1 ½	1 7/16 (37)	1 3/16 (30)	1 ¼ (32)
2 by 2 by 1 ½	1 7/16 (37)	1 5/16 (33)	1 ¼ (32)

TABLE 7 Cleanout Tees, in. (mm)



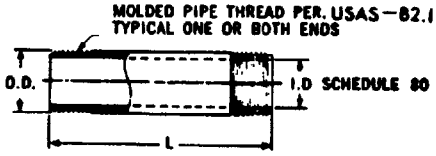
Nominal Pipe Size	G	I
1 ½	1 3/16 (30)	5/8 (16)
2	1 ½ (38)	5/8 (16)
3	1 ⅞ (48)	¾ (19)
4	2 ½ (64)	⅞ (22)

TABLE 8 60° Reducing Wyes, Single and Double, in. (mm)



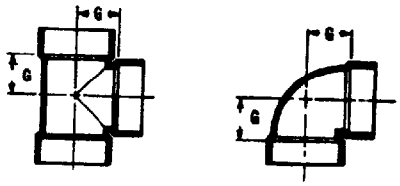
Nominal Pipe Size	G1	G2	G3
2 by 2 by 1 ½	1 1/16 (27)	3 7/16 (87)	3 7/16 (87)
3 by 3 by 1 ½	½ (13)	3 ¾ (95)	4 5/16 (110)
3 by 3 by 2	⅞ (22)	4 ⅛ (105)	4 5/8 (117)

TABLE 9 Molded Nipples, in. (mm)



Nominal Pipe Size	OD	ID	Length
1 ½	1.900	1.500	½ -in. increments from close to 18 in. long
2	2.375	1.939	
3	3.500	2.900	

TABLE 10 Vent Tees and ¼ Bend Vents, in. (mm)



Nominal Pipe Size	Vent Tee	¼ Bend Vent
1 ¼	1 (25)	1 (25)
1 ½	1 3/16 (30)	1 3/16 (30)
2	1 ½ (38)	1 ½ (38)
3	1 ⅞ (48)	1 ⅞ (48)
4	2 ½ (64)	2 ½ (64)

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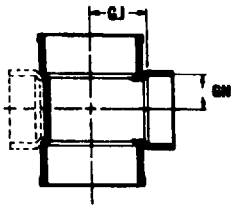
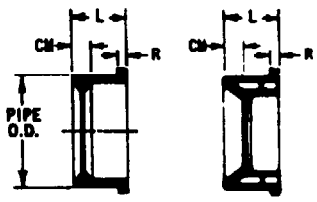
TABLE 11 Reducing Vent Tees, Single, and Double, in. (mm)

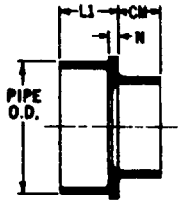


Nominal Pipe Size	GN	GJ
2 by 1 ½ by 1 ½	1 3/16 (30)	1 ½ (38)
2 by 2 by 1 ½	1 3/16 (30)	1 ½ (38)
3 by 3 by 1 ½	1 3/16 (30)	1 7/8 (48)
3 by 3 by 2	1 ½ (38)	1 7/8 (48)

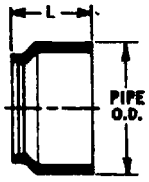
TABLE 12 Bushings, in. (mm)



BUSHING Style 1



BUSHING Style 2



BUSHING Style 3

Nominal Pipe Size	Style 1 (a and b)[A]			Style 2			Style 3
	L	CM	R	L1	CM	N	L
1½ by 1 ¼	15/16 (24)	3/16 (5)	3/16 (5)	...	...	...	1 (25)
2 by 1 ¼	1 1/16 (27)	5/16 (8)	3/16 (5)	...	...	...	1 1/8 (29)
2 by 1 ½	1 1/16 (27)	5/16 (8)	3/16 (5)	...	...	...	1 3/32 (28)
3 by 1 ½	1 3/4 (44)	1 (25)	¼ (6)	1 3/4 (44)	3/4 (19)	¼ (6)	1 ½ (38)
3 by 2	1 3/4 (44)	7/8 (22)	¼ (6)	1 3/4 (44)	7/8 (22)	¼ (6)	1 5/8 (41)
4 by 2	2 (51)	1 1/8 (29)	¼ (6)	2 (51)	7/8 (22)	¼ (6)	...
4 by 3	2 (51)	½ (13)	¼ (6)	2 (51)	1 ½ (38)	¼ (6)	...
6 by 4	3 ½ (89)	1 3/4 (44)	½ (13)	...	...	...	...
8 by 4	4 5/8 (117)	2 7/8 (73)	5/8 (16)	...	...	...	...
8 by 6	4 5/8 (117)	1 5/8 (41)	5/8 (16)	...	...	...	...

[A]No less than four ribs shall be used to support walls.

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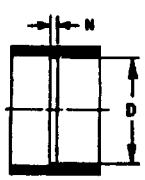
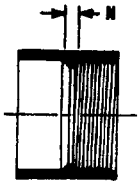
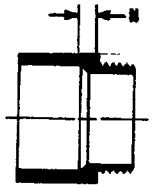
TABLE 13 Couplings, Adapters, in. (mm)



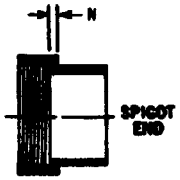
COUPLING



FEMALE ADAPTER Socket x FPT



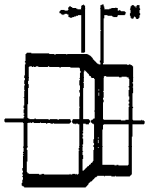
MALE ADAPTER Socket x MPT



FEMALE FITTING ADAPTER

Nominal Pipe Size	Coupling		Female Adapter	Male Adapter		Female Fitting Adapter
	D	*N*, min	*N*, min	*N*, min	*A*, max	*N*, min
1 ¼	1.600 to 1.380	⅛ (3)	¼ (6)	3/16 (5)	1.290 (32.77)	5/32 (4)
1 ½	1.840 to 1.610	⅛ (3)	¼ (6)	3/16 (5)	1.552 (39.42)	5/32 (4)
2	2.320 to 2.067	⅛ (3)	¼ (6)	3/16 (5)	2.067 (52.50)	5/32 (4)
3	3.440 to 3.068	3/16 (5)	5/16 (8)	⅜ (10)	3.068 (77.93)	7/32 (6)
4	4.440 to 4.026	¼ (6)	11/32 (9)	⅜ (10)	4.026 (102.26)	¼ (6)
6	6.550 to 6.065	¼ (6)	...	...	...	...
8	8.655 to 8.610	¼ (6)	...	...	...	...

TABLE 14 Pipe Increasers, in. (mm)



Nominal Pipe Size	*N*, min
1 ¼ by 1 ½	13/32 (10)
1 ½ by 2	17/32 (13)
1 ½ by 3	1 3/32 (28)
2 by 3	⅞ (22)
2 by 4	1 ⅜ (35)
3 by 4	15/16 (24)

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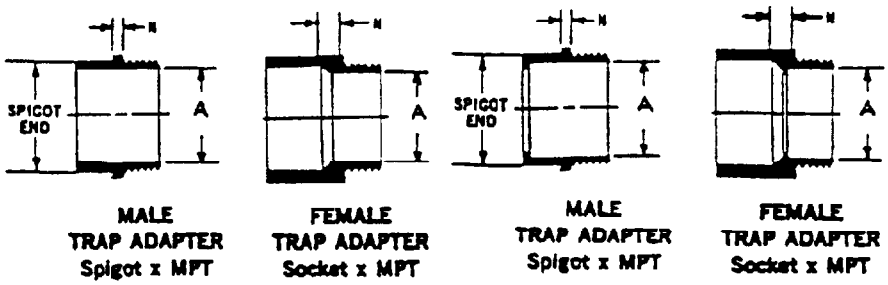
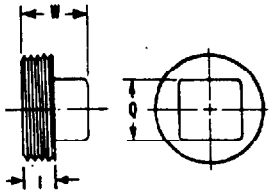
TABLE 15 Trap Adapters, in. (mm)



Without stop		*With Stop*
Nominal Pipe Size	*N*, min	*A*, min
1 ¼	3/16 (5)	1.250 (32)
1 ½	3/16 (5)	1.500 (38)
2	3/16 (5)	2.000 (51)
1 ¼ by 1 ½	3/16 (5)	1.250 (32)

TABLE 16 Pipe Plugs, In. (mm)



Nominal Pipe Size	I	W	Q
1¼	½ (13)	1 (25)	1 (25)
1½	5/8 (16)	1 3/8 (35)	1 (25)
2	5/8 (16)	1 3/8 (35)	1 ¼ (32)
2½	¾ (19)	1 ½ (38)	1 ¼ (32)
3	¾ (19)	1 ¾ (44)	1 5/8 (41)
3½	¾ (19)	1 ¾ (44)	1 5/8 (41)
4	7/8 (22)	1 7/8 (48)	2 (51)

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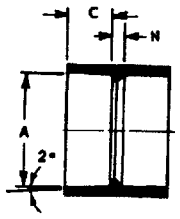
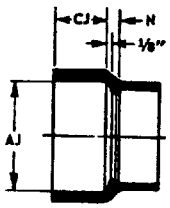
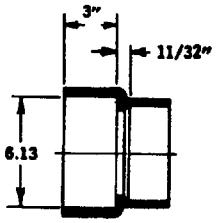
TABLE 17 Hubs, in. (mm)



PLASTIC HUB
Adapts Bituminized Fibre Spigot to Plastic Pipe



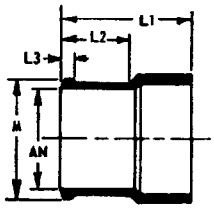
PLASTIC HUB
Adapts Cast Iron Spigot to Plastic Pipe



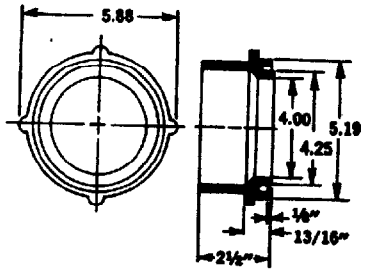
PLASTIC HUB
Adapts Clay Pipe Spigot to Plastic Pipe

Nominal Pipe Size	A	C	N	AJ	CJ	N
2	...	...	...	2.94 (74.7)	2 3/8 (60)	3/8 (10)
3	3.448 (87.58)	1 11/16 (43)	5/16 (8)	3.94 (100.1)	2 5/8 (67)	7/16 (11)
4	4.493 (114.12)	1 15/16 (49)	11/32 (9)	4.94 (125.5)	2 7/8 (73)	1/2 (13)
Reducing 4 by 3	4.493 (114.12)	1 15/16 (49)	5/16 (8)	4.94 (125.5)	2 7/8 (73)	7/16 (11)

TABLE 18 Spigots, in. (mm)



PLASTIC SPIGOT
Adapts Cast Iron Hub to Plastic Pipe



PLASTIC SPIGOT
Adapts Clay Pipe Hub to Plastic Pipe

Nominal Pipe Size	*L2*, min	*L1*, min	*L3*, min	*M*		*AN*
				max	min	
2	3 1/2 (89)	4 5/8 (117)	3/8 (10)	2.75 (69.9)	2.63 (66.8)	2.00 (50.8)
3	3 3/4 (95)	5 5/8 (143)	3/8 (10)	3.88 (98.6)	3.63 (92.2)	3.00 (76.2)
4	4 (102)	6 1/8 (156)	3/8 (10)	4.88 (124.0)	4.63 (117.6)	4.00 (101.6)

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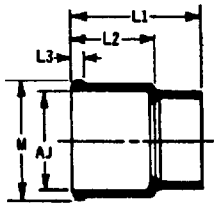
TABLE 19 Reducing Spigots, in. (mm)

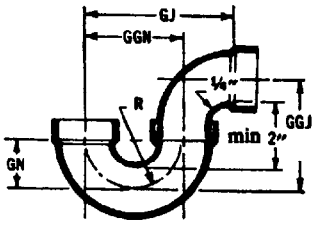


PLASTIC SPIGOT, Reducing
Adapts Cast Iron Hub
to Plastic Pipe

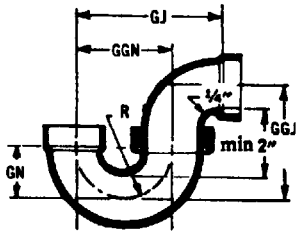
Nominal Pipe Size	*L2* min	*L1* min	*L3* min	*M*		*AJ*
				max	min	
2 by 1 ½	3 ½ (89)	4 ¼ (108)	⅜ (10)	2.75 (69.9)	2.63 (66.8)	2.00 (50.8)
3 by 1 ½	3 ¾ (95)	4 ½ (114)	⅜ (10)	3.88 (98.6)	3.63 (92.2)	3.00 (76.2)
3 by 2	3 ¾ (95)	4 ⅝ (117)	⅜ (10)	3.88 (98.6)	3.63 (92.2)	3.00 (76.2)
4 by 2	4 (102)	4 ⅞ (124)	⅜ (10)	4.88 (124.0)	4.63 (117.6)	4.00 (101.6)
4 by 3	4 (102)	5 ½ (140)	⅜ (10)	4.88 (124.0)	4.63 (117.6)	4.00 (101.6)

TABLE 20 P Traps, in. (mm)

'P' TRAP With Solvent Weld Joint



'P' TRAP With Union Seal



Nominal Pipe Size	min *GJ*	min *GGJ*	min *GGN*	min *GN*	min *R*
1 ¼	4 ⅛ (105)	3 ⅜ (86)	3 (76)	1 ⅜ (35)	1 ⅝ (41)
1 ½	4 7/32 (107)	3 ⅝ (92)	3 (76)	1 ⅜ (35)	1 ⅝ (41)
2	7 ¼ (184)	4 1/16 (103)	5 (127)	2 ¼ (57)	2 ½ (64)
3	8 7/16 (214)	6 5/16 (160)	6 ¼ (159)	2 ⅝ (67)	3 ⅛ (79)
4	10 13/16 (275)	7 ⅞ (200)	8 1/16 (205)	3 7/16 (87)	4 1/16 (103)

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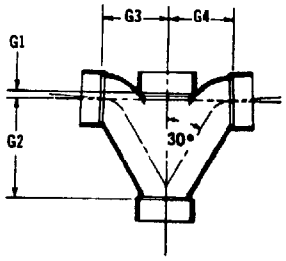
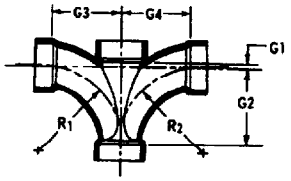
TABLE 21 Double Fixture Fitting, in. (mm)



Nominal Pipe Size	G1	G2	G3	G4
1 ½	⅜ (10)	3 9/16 (90)	2 7/16 (62)	2 7/16 (62)
2	⅜ (10)	4 9/16 (116)	3 1/16 (78)	3 1/16 (78)
3	½ (13)	6 ¾ (171)	4 ½ (114)	4 ½ (114)
Reducing:				
2 by 1½ by 1½ by 1½	⅜ (10)	3 9/16 (90)	2 7/16 (62)	2 7/16 (62)
2 by 1½ by 2 by 2	⅜ (10)	4 9/16 (116)	3 1/16 (78)	3 1/16 (78)
2 by 1½ by 2 by 1½	⅜ (10)	4 9/16 (116)	3 1/16 (78)	3 1/16 (78)

TABLE 22 Double Fixture Fitting, in. (mm)



Nominal Pipe Size	Interchanges with Double Fixture Fittings					
	Double Fixture Fitting					
	G1	*G2*	*G3*	*G4*	*R1*	*R2*
1 ½	⅜ (10)	3 ⅛ (79)	2 11/16 (68)	2 11/16 (68)	3 ⅝ (92)	3 ⅝ (92)
2	⅜ (10)	4 ¼ (108)	3 ½ (89)	3 ½ (89)	4 ½ (114)	4 ½ (114)
3	½ (13)	6 ¼ (159)	4 15/16 (125)	4 15/16 (125)	6 ⅝ (168)	6 ⅝ (168)
			Reducing			
2 by 1½ by 1½ by 1½	⅜ (10)	3 ⅛ (79)	2 ⅞ (73)	2 ⅞ (73)	3 ⅝ (92)	3 ⅝ (92)
2 by 1½ by 1½ by 2	⅜ (10)	4 ¼ (108)	2 ⅞ (73)	3 ½ (69)	3 ⅝ (92)	4 ½ (114)
2 by 1½ by 2 by 2	⅜ (10)	4 ¼ (108)	3 ½ (89)	3 ½ (89)	4 ½ (114)	4 ½ (114)
3 by 2 by 3 by 3	½ (13)	6 ¼ (159)	4 15/16 (125)	4 15/16 (125)	6 ⅝ (168)	6 ⅝ (168)

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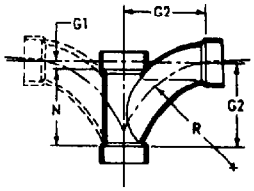
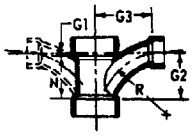
TABLE 23 Single and Double Long Turn Tee, in. (mm)



Nominal Pipe Size	Interchanges with Combination Wye ⅛ Bend			
	Single and Double Long Turn Tee			
	G1	*G2*	*N*	*R*
1¼	⅜ (10)	3 7/16 (87)	3 1/16 (78)	4 ¾ (121)
1½	7/16 (11)	3 15/16 (100)	3 ½ (89)	5 ⅞ (149)
2	11/16 (17)	5 ⅛ (130)	4 7/16 (113)	7 (178)
3	1 1/16 (27)	7 9/16 (192)	6 ½ (165)	10 ⅛ (257)
4	1 ½ (38)	10 (254)	8 ½ (216)	13 ¼ (337)
6	2 ½ (64)	15 ⅜ (391)	12 ⅞ (327)	19 (483)

TABLE 24 Single and Double Long Turn Tee Reducing, in. (mm)



Nominal Pipe Size	Interchanges with Reducing Combination Wye ⅛ Bend				
	Single and Double Long Turn Tee Reducing				
	G1	*G3*	*N*	*G2*	*R*
1½ by 1¼ by 1¼	⅜ (10)	3 5/8 (92)	3 1/16 (78)	3 7/16 (87)	4 ¾ (121)
1½ by 1½ by 1¼	⅜ (10)	3 5/8 (92)	3 1/16 (78)	3 7/16 (87)	4 ¾ (121)
2 by 1½ by 1½	7/16 (11)	4 3/16 (107)	3 ½ (89)	3 15/16 (100)	5 ⅞ (200)
2 by 1½ by 2	11/16 (17)	5 ⅛ (130)	4 7/16 (113)	5 ⅛ (130)	7 (178)
2 by 2 by 1¼	⅜ (10)	3 13/16 (97)	3 1/16 (78)	3 7/16 (87)	4 ¾ (121)
2 by 2 by 1½	7/16 (11)	4 3/16 (102)	3 ½ (89)	3 15/16 (100)	5 ⅞ (149)
3 by 3 by 1½	7/16 (11)	4 ¾ (121)	3 ½ (89)	3 15/16 (100)	5 ⅞ (149)
3 by 3 by 2	11/16 (17)	5 11/16 (128)	4 7/16 (113)	5 ⅛ (130)	7 (178)
4 by 4 by 1½	⅜ (10)	5 3/16 (132)	3 9/16 (90)	3 15/16 (100)	5 ⅞ (149)
4 by 4 by 2	⅝ (16)	6 ⅛ (156)	4 ½ (114)	5 ⅛ (130)	7 (178)
4 by 4 by 3	1 1/16 (27)	8 1/16 (205)	6 ½ (165)	7 9/16 (192)	10 ⅛ (257)
6 by 6 by 2	9/16 (14)	7 ⅛ (181)	4 9/16 (116)	5 ⅛ (130)	7 (178)
6 by 6 by 3	15/16 (24)	9 1/16 (230)	6 ⅝ (168)	7 9/16 (192)	10 ⅛ (257)
6 by 6 by 4	1 ½ (38)	11 (279)	8 ½ (216)	10 (254)	13 ¼ (337)
6 by 6 by 5	2 (51)	13 5/16 (338)	10 ¾ (273)	12 ¾ (324)	16 (406)

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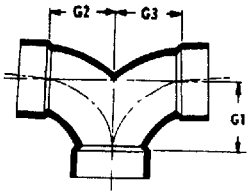
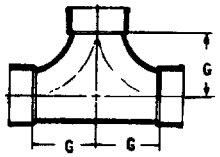
TABLE 25 Three-Way Ell, in. (mm)



Nominal Pipe Size	*G1*	*G2*	*G3*
1½	1 ¾ (44)	1 ¾ (44)	1 ¾ (44)
2	2 5/16 (59)	2 5/16 (59)	2 5/16 (59)
3	3 1/16 (78)	3 1/16 (78)	3 1/16 (78)
4	3 7/8 (98)	3 7/8 (98)	3 7/8 (98)
Reducing			
2 by 1½ by 1½ (short)	1 5/8 (41)	1 5/8 (41)	1 5/8 (41)
3 by 2 by 3	3 1/16 (78)	2 7/8 (73)	3 1/16 (78)
2 by 1½ by 1½ (long)	1 15/16 (49)	2 3/16 (56)	2 3/16 (56)

TABLE 26 Two Way Cleanout, in. (mm)



Nominal Pipe Size	*G*
3	4 1/16 (103)
4	4 15/16 (125)

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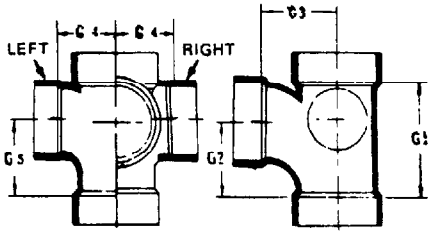
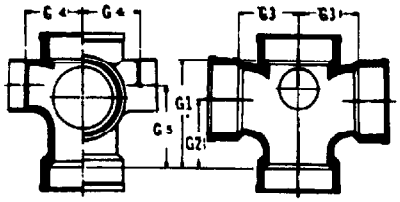
TABLE 27 Sanitary Tees, with Side Inlet, in. (mm)



Nominal Pipe Size	*G1*	*G2*	*G3*	*G4*	*G5*
Left-Hand Side Inlet					
1½ by 1½ by 1½ by 1½	2 ¾ (70)	1 ¾ (44)	1 ¾ (44)	1 ¾ (44)	1 ¾ (44)
2 by 2 by 1½ by 1½	3 11/16 (94)	2 5/16 (59)	2 5/16 (59)	2 5/16 (59)	2 5/16 (59)
3 by 3 by 2 by 1½	3 5/16 (84)	2 1/8 (54)	2 7/8 (73)	2 9/16 (65)	2 1/8 (54)
3 by 3 by 2 by 2	3 5/16 (84)	2 1/8 (54)	2 7/8 (73)	2 7/8 (73)	2 1/8 (54)
3 by 3 by 3 by 1½	4 7/8 (124)	3 1/16 (78)	3 1/16 (78)	2 9/16 (65)	3 11/16 (94)
3 by 3 by 3 by 2	4 7/8 (124)	3 1/16 (78)	3 1/16 (78)	2 7/8 (73)	3 11/16 (94)
4 by 4 by 4 by 2	6 1/8 (156)	3 7/8 (98)	3 7/8 (98)	3 5/16 (84)	5 (127)
Right-Hand Side Inlet					
3 by 3 by 2 by 1½	3 5/16 (84)	2 1/8 (54)	2 7/8 (73)	2 9/16 (65)	2 1/8 (54)
3 by 3 by 2 by 2	3 5/16 (84)	2 1/8 (54)	2 7/8 (73)	2 7/8 (73)	2 1/8 (54)
3 by 3 by 3 by 1½	4 7/8 (124)	3 1/16 (78)	3 1/16 (78)	2 9/16 (65)	3 11/16 (94)
3 by 3 by 3 by 2	4 7/8 (124)	3 1/16 (78)	3 1/16 (78)	2 7/8 (73)	3 11/16 (94)
4 by 4 by 4 by 2	6 1/8 (156)	3 7/8 (98)	3 7/8 (98)	3 5/16 (84)	5 (127)
Side Inlet Both Sides					
3 by 3 by 2 by 1½ by 1½	3 5/16 (84)	2 1/8 (54)	2 7/8 (73)	2 9/16 (65)	2 1/8 (54)
3 by 3 by 2 by 2 by 2	3 5/16 (84)	2 1/8 (54)	2 7/8 (73)	2 7/8 (73)	2 1/8 (54)
3 by 3 by 3 by 1½ by 1½	4 7/8 (124)	3 1/16 (78)	3 1/16 (78)	2 9/16 (65)	3 11/16 (94)
3 by 3 by 3 by 2 by 2	4 7/8 (124)	3 1/16 (78)	3 1/16 (78)	2 7/8 (73)	3 11/16 (94)
4 by 4 by 4 by 2 by 2	6 1/8 (156)	3 7/8 (98)	3 7/8 (98)	3 5/16 (84)	5 (127)

TABLE 28 Sanitary Tee, Double with Side Inlets, in. (mm)



Nominal Pipe Size	*G1*	*G2*	*G3*	*G4*	*G5*
Single Side Inlet					
3 by 3 by 3 by 3 by 1½	4 7/8 (124)	3 1/16 (78)	3 1/16 (78)	2 9/16 (65)	3 11/16 (94)
3 by 3 by 3 by 3 by 2	4 7/8 (124)	3 1/16 (78)	3 1/16 (78)	2 7/8 (73)	3 11/16 (94)
4 by 4 by 4 by 4 by 2	6 1/8 (156)	3 7/8 (98)	3 7/8 (98)	3 5/16 (84)	3 7/8 (min) (98)
Inlet Both Sides					
3 by 3 by 3 by 3 by 1½ by 1½	4 7/8 (124)	3 1/16 (78)	3 1/16 (78)	2 9/16 (65)	3 11/16 (94)
3 by 3 by 3 by 3 by 2 by 2	4 7/8 (124)	3 1/16 (78)	3 1/16 (78)	2 7/8 (73)	3 11/16 (94)
4 by 4 by 4 by 4 by 2 by 2	6 1/8 (156)	3 7/8 (98)	3 7/8 (98)	3 5/16 (84)	5 (127)

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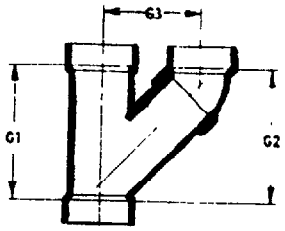
TABLE 29 Sanitary Tees, with Slip Joint, in. (mm)

Nominal Pipe Size	Sanitary Tee			Sanitary Tee Through Wall		
	G1	*G2*	*G3*, min	*G1*	*G2*	*G3, min*
1¼	2 ¼ (57)	1 ½ (38)	2 3/16 (56)	2 ¼ (57)	1 ½ (38)	3 (76)
1 ½	2 ¾ (70)	1 ¾ (44)	2 7/16 (62)	2 ¾ (70)	1 ¾ (44)	3 (76)
1½ by 1¼ by 1½	2 ½ (64)	1 ¾ (44)	2 7/16 (62)	2 ½ (64)	1 ¾ (44)	3 (76)

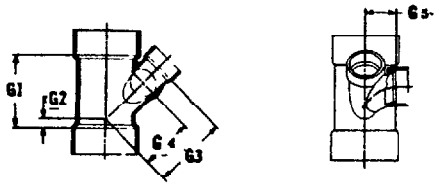
TABLE 30 Upright Wye, in. (mm)



Nominal Pipe Size	*G1* min	*G2* min	*G3* min
2 by 2 by 2	5 ½ (140)	5 3/16 (132)	3 ¾ (95)
3 by 3 by 3	7 ½ (191)	7 ⅜ (187)	5 ¼ (133)
Reducing			
2 by 2 by 1 ½	4 ¼ (108)	4 ⅛ (105)	3 1/16 (78)
3 by 3 by 2	5 3/16 (132)	5 5/16 (135)	4 9/16 (116)

TABLE 31 Single 45° Wye, with Auxiliary Inlet, in. (mm)

NOTE—RH.AI = Right Hand Auxiliary Inlet
LH.AI = Left Hand Auxiliary Inlet
DBL.AI = Double Auxiliary Inlets
V = Vent



Nominal Pipe Size	G1	G2	G3	G4	G5
3 by 3 by 1½ V by 1½ RH.AI	4 ¼ (108)	½ (13)	4 5/16 (110)	3 3/16 (81)	1 ¾ (44)
3 by 3 by 1½ V by 1½ LH.AI	4 ¼ (108)	½ (13)	4 5/16 (110)	3 3/16 (81)	1 ¾ (44)
3 by 3 by 2 V by 2 RH.AI	5 (127)	⅞ (22)	4 ⅝ (117)	3 ¼ (83)	2 5/16 (59)
3 by 3 by 2 V by 2 LH.AI	5 (127)	⅞ (22)	4 ⅝ (117)	3 ¼ (83)	2 5/16 (59)

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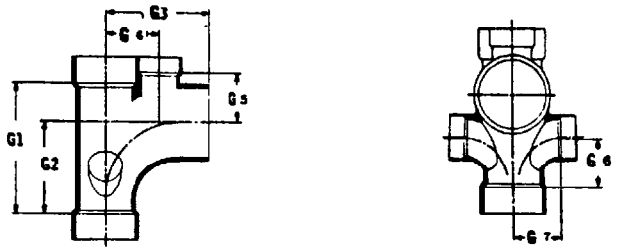
TABLE 32 Vertical Closet Bend, with Auxiliary Inlets, in. (mm)

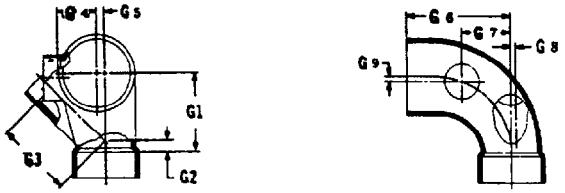
NOTE—RH.AI = Right Hand Auxiliary Inlet
LH.AI = Left Hand Auxiliary Inlet
DBL.AI = Double Auxiliary Inlets
V = Vent



Nominal Pipe Size	G1	G2	G3	G4	G5	G6	G7
3 by 3 by 4 by 2V by 2 RH.AI	7 ½ (191)	5 ⅜ (137)	6 ⅛ (156)	3 5/32 (80)	2 ¾ (70)	2 ⅞ (73)	2 ⅞ (73)
3 by 3 by 4 by 2V by 2 LH.AI	7 ½ (191)	5 ⅜ (137)	6 ⅛ (156)	5 5/32 (80)	2 ¾ (70)	2 ⅞ (73)	2 ⅞ (73)
3 by 3 by 4 by 2V by 2 by 2 DBL.AI	7 ½ (191)	5 ⅜ (137)	6 ⅛ (156)	3 5/32 (80)	2 ¾ (70)	2 ⅞ (73)	2 ⅞ (73)

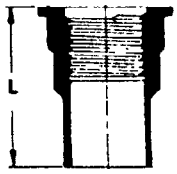
TABLE 33 Horizontal Closet Bend, with Auxiliary Inlets, in. (mm)

NOTE—RH.AI = Right Hand Auxiliary Inlet
LH.AI = Left Hand Auxiliary Inlet
DBL.AI = Double Auxiliary Inlets
V = Vent

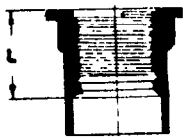


Nominal Pipe Size	G1	G2	G3	G4	G5	G6	G7	G8	G9
3 by 4 by 2V by 2 RH.AI	4 5/8 (117)	9/16 (14)	4 ½ (114)	2 5/16 (59)	15/32 (12)	6 3/16 (157)	2 ⅞ (73)	9/32 (7)	¼ (6)
3 by 4 by 2V by 2 LH.AI	4 5/8 (117)	9/16 (14)	4 ½ (114)	2 5/16 (59)	15/32 (12)	6 3/16 (157)	2 ⅞ (73)	9/32 (7)	¼ (6)

TABLE 34 Strainer Adapter, in. (mm)



TRAY PLUG ADAPTER
Fem. NPSM x Spigot



TRAY PLUG ADAPTER
Fem. NPSM x Hub

Nominal Pipe Size	Fem. NPSM × Spigot	Fem. NPSM ×Hub
	L	*L*, min
1 ½	3 ⅜ (86)	1 ⅞ (48)

TABLE 35 Swivel Strainer, Adapter, in. (mm)

Nominal Pipe Size	Short		Long	
	L1	*L2*	*L1*	*L2*
1 ½	1 11/16 (43)	5/8 (16)	2 7/16 (62)	5/8 (16)

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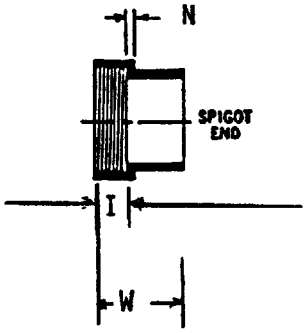
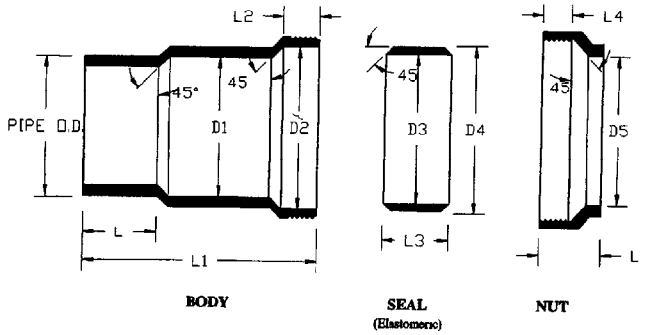
TABLE 36 Cleanout Female Fitting Adapter, in. (mm)



Nominal Pipe Size	*N*, min	*I*, min	*W*, min
1 ¼	5/32 (4)	½ (13)	1 11/32 (34)
1 ½	5/32 (4)	5/8 (16)	1 15/32 (37)
2	5/32 (4)	5/8 (16)	1 17/32 (39)
3	7/32 (6)	¾ (19)	2 15/32 (63)
4	¼ (6)	7/8 (22)	2 ¾ (70)

TABLE 37 Cut-In Adapter

NOTE 1—Adjustable plastic ring optional.
NOTE 2—Knockout optional in all configurations.
NOTE 3—Adjustable metal ring optional and must be protected by a corrosion-resisant coating.



Minimum Dimensions, in. (mm)

	1 ½	2	3	4
L	...	1 ¼ (32)	...	...
L1	...	2 ½ (64)	...	...
L2	...	0.60 (15.2)	...	...
L3	...	1 (25)	...	...
L4	...	0.53 (13.5)	...	...
L5	...	1 ¼ (32)	...	...
D1	...	2.385 (60.58)	...	...
D2	...	2.940 (74.69)	...	...
D3	...	2.380 (60.45)	...	...
D4	...	2.577 (65.46)	...	...
D5	...	2.385 (60.58)	...	...

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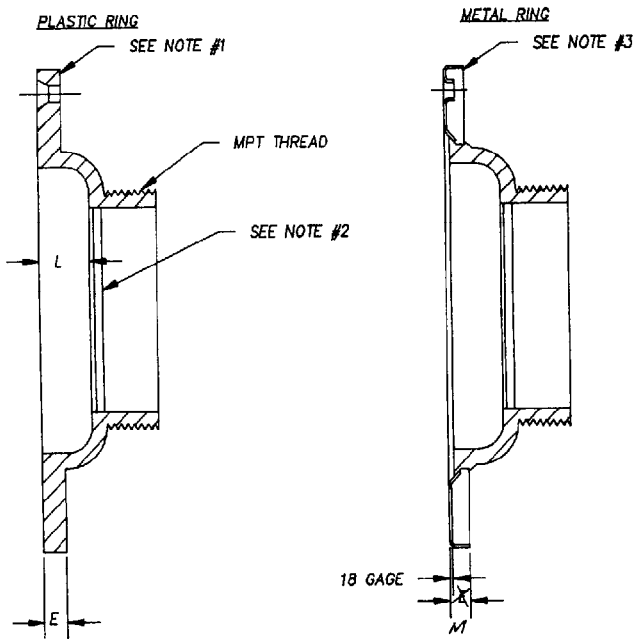
TABLE 38 4 by 3 in. Closet Flange (MPT)



M (min)	E (min)	L (min)	TH'D (min)
1 7/32 (5 1/2)	1/4 (6)	3/4 (18)	3"–8

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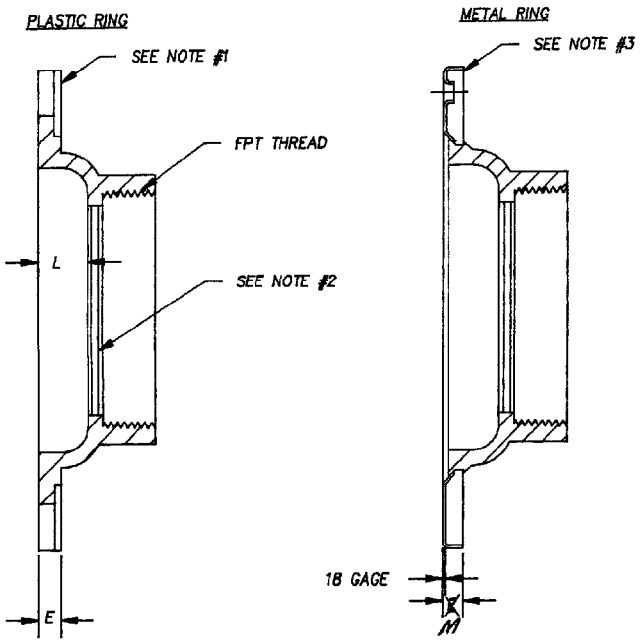
TABLE 39 4 by 3 in. Threaded Closet Flange (FPT)

NOTE 1—Adjustable plastic ring optional.
NOTE 2—Knockout optional in all configurations.
NOTE 3—Adjustable metal ring optional and must be protected by a corrosion-resisant coating.



M (min)	E (min)	L (min)	TH'D (min)
7/32 (5 1/2)	1/4 (6)	3/4 (18)	3"–8

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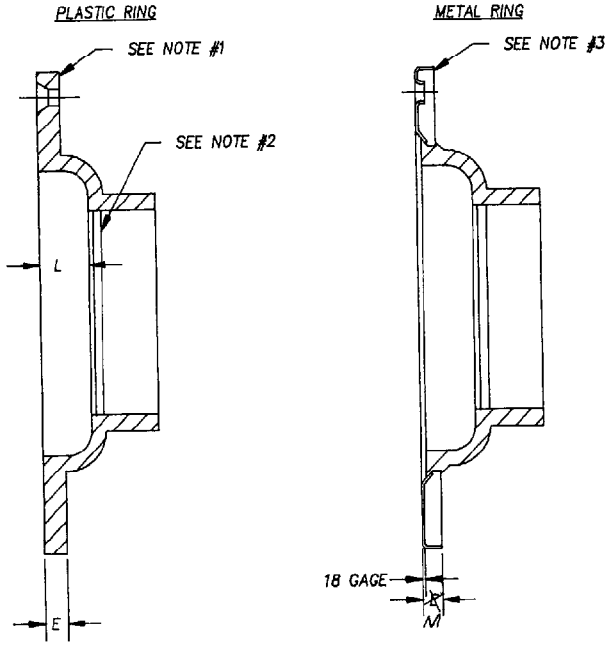
TABLE 40 4 by 3 in. Closet Flange (Spigot)

NOTE 1—Adjustable plastic ring optional.
NOTE 2—Knockout optional in all configurations.
NOTE 3—Adjustable metal ring optional and must be protected by a corrosion-resisant coating.



M (min)	E (min)	L (min)
7/32 (5 ½)	¼ (6)	¾ (18)

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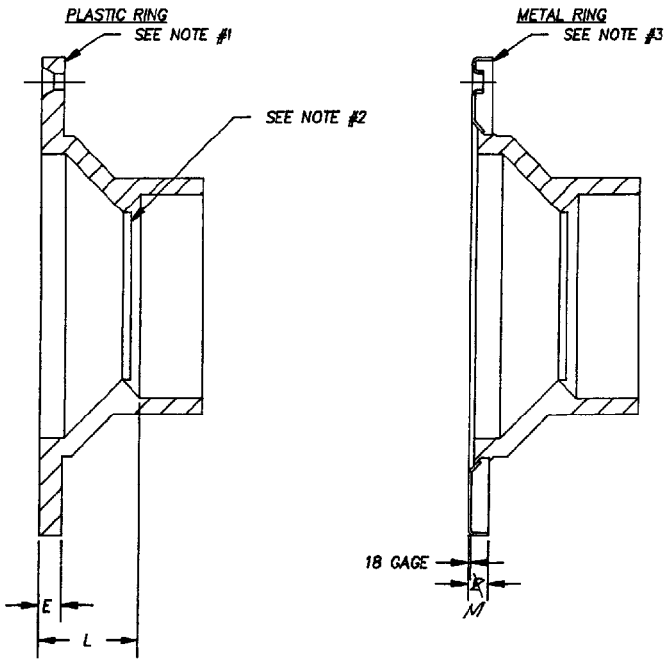
TABLE 41 4 by 3 In. Closet Flange (HUB)

NOTE 1—Adjustable plastic ring optional.
NOTE 2—Knockout optional in all configurations.
NOTE 3—Adjustable metal ring optional and must be protected by a corrosion-resisant coating.



M (min)	E (min)	L (min)
7/32 (5 ½)	¼ (6)	1 ¼ (32)

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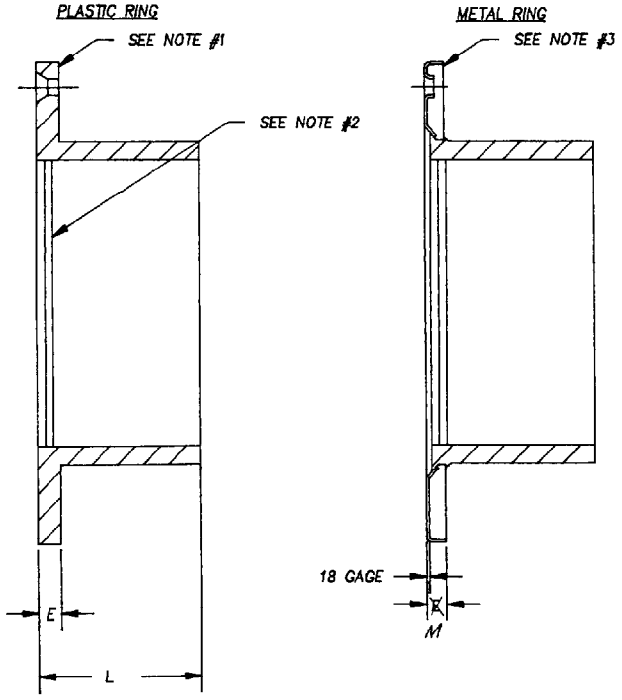
TABLE 42 4 by 4 in. Closet Flange (HUB)

NOTE 1—Adjustable plastic ring optional.
NOTE 2—Knockout optional in all configurations.
NOTE 3—Adjustable metal ring optional and must be protected by a corrosion-resisant coating.



M (min)	E (min)	L (min)
7/32 (5 ½)	¼ (6)	2 (51)

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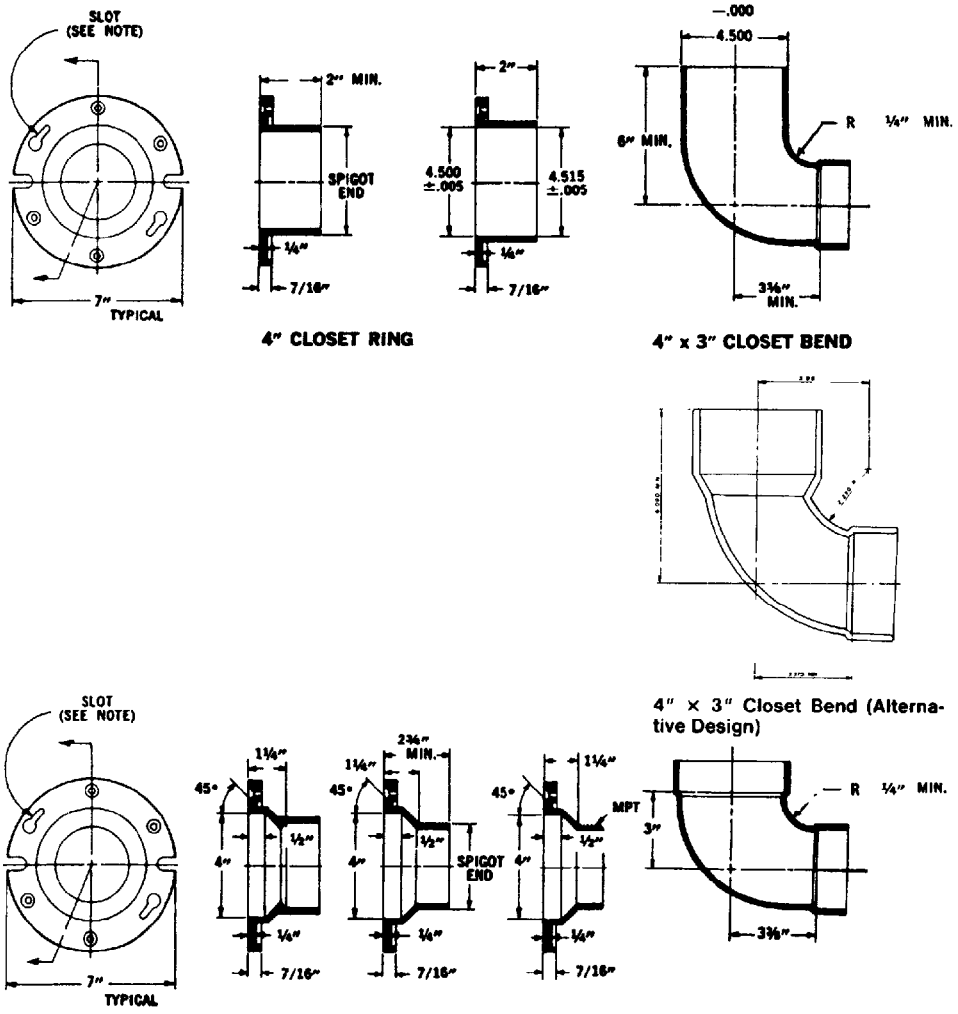

FIG. 1 Closet Rings and Closet Bends[A], in.

NOTE-Slot is optional if fully reinforced with a corrosion-resistant material.

[A] **All dimensions minimum, unless otherwise noted.**

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Designation: D 3517 – 01

Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe[1]

This standard is issued under the fixed designation D 3517; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This specification covers machine-made fiberglass pipe, 8 in. (200 mm) through 144 in. (3700 mm), intended for use in water conveyance systems which operate at internal gage pressures of 250 psi (1.72 MPa) or less. Both glass-fiber-reinforced thermosetting-resin pipe (RTRP) and glass-fiber-reinforced polymer mortar pipe (RPMP) are fiberglass pipes. The standard is suited primarily for pipes to be installed in buried applications, although it may be used to the extent applicable for other installations such as, but not limited to, sliplining and rehabilitation of existing pipelines.

NOTE 1—For the purposes of this standard, polymer does not include natural polymers.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

NOTE 2—There is no similar or equivalent ISO standard.

1.3 The following safety hazards caveat pertains only to the test methods portion, Section 8, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 33 Specification for Concrete Aggregates[2]

D 638 Test Method for Tensile Properties of Plastics[3]

D 695 Test Method for Compressive Properties of Rigid Plastics[3]

D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[3]

D 883 Terminology Relating to Plastics[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[3]

D 2290 Test Method for Apparent Tensile Strength of Ring or Tubular Plastics and Reinforced Plastics by Split Disk Method[4]

D 2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading[4]

D 2584 Test Method for Ignition Loss of Cured Reinforced Resins[5]

D 2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[4]

D 3567 Practice for Determining Dimensions of "Fiberglass" (Glass–Fiber–Reinforced Thermosetting Resin) Pipe and Fittings[4]

D 3892 Practice for Packaging/Packing of Plastics[6]

D 4161 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals[4]

F 412 Terminology Relating to Plastic Piping Systems[4]

F 477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe[4]

2.2 *ISO Standard:*

ISO 1172 Textile Glass Reinforced Plastics—Determination of Loss on Ignition[7]

2.3 *NSF Standard:*

Standard No. 14 for Plastic Piping Components and Related Materials[8]

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions are in accordance with Terminology D 833 and Terminology F 412 and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *surface layer*—a resin layer, with or without filler, or

[1] This specification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.23 on Reinforced Plastic Piping Systems and Chemical Equipment.

Current edition approved June 10, 2001. Published August 2001.. Originally published as D 3517 – 76. Last previous edition D 3517 – 96. This specification replaces Specification D 4163.

[2] *Annual Book of ASTM Standards,* Vol 04.02.

[3] *Annual Book of ASTM Standards,* Vol 08.01.

[4] *Annual Book of ASTM Standards,* Vol 08.04.

[5] *Annual Book of ASTM Standards,* Vol 08.02.

[6] *Annual Book of ASTM Standards,* Vol 08.03.

[7] Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

[8] Available from the National Sanitation Foundation, P.O. Box 1468, Ann Arbor, MI 48106.

***A Summary of Changes section appears at the end of this standard.**

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reinforcements, or both, applied to the exterior surface of the pipe structural wall.

3.2.2 *fiberglass pipe*—a tubular product containing glass-fiber reinforcements embedded in or surrounded by cured thermosetting resin. The composite structure may contain aggregate, granular, or platelet fillers, thixotropic agents, pigments, or dyes. Thermoplastic or thermosetting liners or coatings may be included.

3.2.3 *liner*—a resin layer, with or without filler, or reinforcement, or both, forming the interior surface of the pipe.

3.2.4 *qualification test*—one or more tests used to prove the design of a product. Not a routine quality control test.

3.2.5 *reinforced polymer mortar pipe (RPMP)*—a fiberglass pipe with aggregate.

3.2.6 *reinforced thermosetting resin pipe (RTRP)*—a fiberglass pipe without aggregate.

4. Classification

4.1 *General*—This specification covers fiberglass pressure pipe defined by raw materials in the structural wall (type) and liner, surface layer material (grade), operating pressure (class), and pipe stiffness. Table 1 lists the types, liners, grades, classes, and stiffnesses that are covered.

NOTE 3—All possible combinations of types, liners, grades, classes, and stiffnesses may not be commercially available. Additional types, liners, grades, and stiffnesses may be added as they become commercially available. The purchaser should determine for himself or consult with the manufacturer for the proper class, type, liner, grade and stiffness of pipe to be used under the installation and operating conditions that will exist for the project in which the pipe is to be used.

4.2 *Designation Requirements*—The pipe materials designation code shall consist of the standard designation, ASTM D 3517, followed by type, liner, and grade in Arabic numerals, class by the letter C and two or three Arabic numerals, and pipe stiffness by a capital letter. Table 1 presents a summary of the designation requirements. Thus, a complete material code shall consist of ASTM D 3517... three numerals, C ... and two or three numerals, and a capital letter.

NOTE 4—Examples of the designation are as follows: *(1)* ASTM D 3517-1-1-3-C50-A for glass-fiber reinforced aggregate and polyester resin mortar pipe with a reinforced thermoset liner and an unreinforced polyester resin and sand surface layer, for operation at 50 psi (345 kPa), and having a minimum pipe stiffness of 9 psi (62 kPa), *(2)* ASTM D 3517-4-2-6-C200-C for glass-fiber reinforced epoxy resin pipe with a non-reinforced thermoset liner, no surface layer, for operation at 200 psi (1380 kPa), and having a minimum pipe stiffness of 36 psi (248 kPa).

NOTE 5—Although the "Form and Style for ASTM Standards" manual requires that the type classification be roman numerals, it is recognized that companies have stencil cutting equipment for this style of type, and it is therefore acceptable to mark the product type in arabic numbers.

5. Materials and Manufacture

5.1 *General*—The resins, reinforcements, colorants, fillers, and other materials, when combined as a composite structure, shall produce a pipe that shall meet the performance requirements of this specification.

5.2 *Wall Composition*—The basic structural wall composition shall consist of thermosetting resin, glass fiber reinforcement, and, if used, an aggregate filler.

5.2.1 *Resin*—A thermosetting polyester or epoxy resin, with or without filler.

5.2.2 *Reinforcement*—A commercial grade of E-type glass fibers with a finish compatible with the resin used.

5.2.3 *Aggregate*—A siliceous sand conforming to the requirements of Specification C 33, except that the requirements for gradation shall not apply.

NOTE 6—Fiberglass pipe intended for use in the transport of potable water should be evaluated and certified as safe for this purpose by a testing agency acceptable to the local health authority. The evaluation should be in accordance with requirements for chemical extraction, taste, and odor that are no less restrictive than those included in National Sanitation Foundation (NSF) Standard 61. The seal or mark of the laboratory making the evaluation should be included on the fiberglass pipe.

5.3 *Liner and Surface Layers*—Liner or surface layer, or both, when incorporated into or onto the pipe, shall meet the

TABLE 1 General Designation Requirements for Fiberglass Pressure Pipe

Designation Order	Property	Cell Limits[A]								
1	Type	1 glass-fiber-reinforced thermosetting polyester[B] resin mortar (RPMP polyester[B])		2 glass-fiber-reinforced thermosetting polyester[B] resin (RTRP polyester[B])		3 glass-fiber-reinforced thermosetting epoxy resin mortar (RPMP epoxy)			4 glass-fiber-reinforced thermosetting epoxy resin (RTRP epoxy)	
2	Liner	1 reinforced thermoset liner		2 non-reinforced thermoset liner		3 thermoplastic liner			4 no liner	
3	Grade	1 polyester[B] resin surface layer—reinforced	2 polyester[B] resin surface layer—non-reinforced	3 polyester[B] resin and sand surface layer nonreinforced		4 epoxy resin surface layer—reinforced		5 epoxy resin surface layer—non-reinforced		6 no surface layer
4	Class[C]	C50	C75	C100	C125	C150	C175	C200	C225	C250
5	Pipe Stiffness psi (kPa)	A 9 (62)		B 18 (124)			C 36 (248)		D 72 (496)	

NOTE 1— [A] The cell-type format provides the means of identification and specification of piping materials. This cell-type format, however, is subject to misapplication since unobtainable property combinations can be selected if the user is not familiar with non-commercially available products. The manufacturer should be consulted.

NOTE 2— [B] For the purposes of this standard, polyester includes vinyl ester resins.

NOTE 3— [C] Based on operating pressure in psig (numerals).

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structural requirements of this specification.

5.4 *Joints*—The pipe shall have a joining system that shall provide for fluid tightness for the intended service condition.

5.4.1 *Unrestrained*—Pipe joints capable of withstanding internal pressure but not longitudinal forces.

5.4.1.1 *Coupling or Bell-and-Spigot Gasket Joints*, with a groove either on the spigot or in the bell to retain an elastomeric gasket that shall be the sole element of the joint to provide watertightness. For typical joint detail see Fig. 1.

5.4.1.2 *Mechanical Couplings*..

5.4.2 *Restrained*—Pipe joints capable of withstanding internal pressure and longitudinal forces.

5.4.2.1 Joints similar to those in 5.4.1.1 with supplemental restraining elements.

5.4.2.2 *Butt Joint*, with laminated overlay.

5.4.2.3 *Bell-and-Spigot*, with laminated overlay.

5.4.2.4 *Bell-and-Spigot*, adhesive bonded.

5.4.2.5 *Flanged*.

5.4.2.6 *Mechanical*.

NOTE 7—Other types of joints may be added as they become commercially available.

5.5 *Gaskets*—Elastomeric gaskets when used with this pipe shall conform to the requirements of Specification F 477.

6. Requirements

6.1 *Workmanship*:

6.1.1 Each pipe shall be free from all defects including indentations, delaminations, bubbles, pinholes, cracks, pits, blisters, foreign inclusions, and resin-starved areas that due to their nature, degree, or extent, detrimentally affect the strength and serviceability of the pipe. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

6.1.2 The inside surface of each pipe shall be free of bulges, dents, ridges, and other defects that result in a variation of inside diameter of more than ⅛ in. (3.2 mm) from that obtained on adjacent unaffected portions of the surface. No glass fiber reinforcement shall penetrate the interior surface of the pipe wall.

6.1.3 Joint sealing surfaces shall be free of dents, gouges, and other surface irregularities that will affect the integrity of the joints.

6.2 *Dimensions*:

6.2.1 *Pipe Diameters*—Pipe shall be supplied in the nominal diameters shown in Table 2 or Table 3. The pipe diameter tolerances shall be as shown in Table 2 or Table 3, when measured in accordance with 8.1.1.

6.2.2 *Lengths*—Pipe shall be supplied in nominal lengths of 10, 20, 30, 40, and 60 ft. (3.05, 6.10, 9.15, 12.19, and 18.29 m). The actual laying length shall be the nominal length ±2 in. (±51 mm), when measured in accordance with 8.1.2. At least 90 % of the total footage of any one size and class, excluding special order lengths, shall be furnished in the nominal lengths specified by the purchaser. Random lengths, if furnished, shall not vary from the nominal lengths by more than 5 ft (1.53 m) or 25 %, whichever is less.

6.2.3 *Wall Thickness*—The average wall thickness of the pipe shall not be less than the nominal wall thickness published in the manufacturer's literature current at the time of purchase, and the minimum wall thickness at any point shall not be less than 87.5 % of the nominal wall thickness when measured in accordance with 8.1.3.

6.2.4 *Squareness of Pipe Ends*—All points around each end of a pipe unit shall fall within ±¼ in. (±6.4 mm) or ±0.5 % of the nominal diameter of the pipe, whichever is greater, to a plane perpendicular to the longitudinal axis of the pipe, when measured in accordance with 8.1.4.

6.3 *Soundness*—Unless otherwise agreed upon between purchaser and supplier, test each length of pipe up to 54 in. (1370 mm) diameter hydrostatically without leakage or cracking, at the internal hydrostatic proof pressures specified for the applicable class in Table 4, when tested in accordance with 8.2. For sizes over 54 in., the frequency of hydrostatic leak tests shall be as agreed upon by purchaser and supplier.

6.4 *Hydrostatic Design Basis*:

6.4.1 *Long-Term Hydrostatic Pressure*—The pressure classes shall be based on long-term hydrostatic pressure data obtained in accordance with 8.3 and categorized in accordance with Table 5. Pressure classes are based on extrapolated strengths at 50 years. For pipe subjected to longitudinal loads or circumferential bending, the effect of these conditions on the hydrostatic design pressure, classification of the pipe must be considered.

6.4.2 *Control Requirements*—Test pipe specimens periodically in accordance with Practice D 2992.

NOTE 8—Hydrostatic design basis (HDB-extrapolated value at 50 years) determined in accordance with Procedure A of Practice D 2992, may be substituted for the Procedure B evaluation required by 8.3. It is generally accepted that the Procedure A HDB value times 3 is equivalent to the Procedure B HDB value.

6.5 *Stiffness*—Each length of pipe shall have sufficient strength to exhibit the minimum pipe stiffness ($F/\Delta y$) specified in Table 6, when tested in accordance with 8.4. At deflection level A per Table 7, there shall be no visible damage in the test specimen evidenced by surface cracks. At deflection level B per Table 7, there shall be no indication of structural damage as evidenced by interlaminar separation, separation of the liner or surface layer (if incorporated) from the structural wall, tensile failure of the glass fiber reinforcement, and fracture or buckling of the pipe wall.

NOTE 9—This is a visual observation (made with the unaided eye) for quality control purposes only and should not be considered a simulated service test. Table 7 values are based on an in-use long-term deflection limit of 5 % and provide an appropriate uniform safety margin for all pipe stiffnesses. Since the pipe stiffness values ($F/\Delta y$) shown in Table 6 vary, the percent deflection of the pipe under a given set of installation

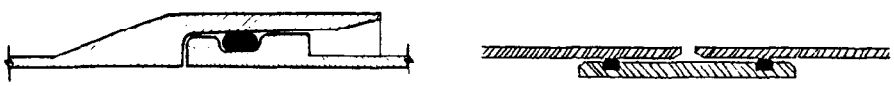

FIG. 1 Typical Joints

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TABLE 2 Nominal Inside Diameters (ID) and Tolerances Inside Diameter Control Pipe

Inch-Pound Units		SI Units			
Nominal Diameter[A], in.	Tolerance, in.	Nominal Metric Diameter[B], mm	ID Range[B], mm		Tolerance[B] on Declared ID, mm
			Minimum	Maximum	
8	±0.25	200	196	204	±1.5
10	±0.25	250	246	255	±1.5
12	±0.25	300	296	306	±1.8
14	±0.25	400	396	408	±2.4
15	±0.25	500	496	510	±3.0
16	±0.25	600	595	612	±3.6
18	±0.25	700	695	714	±4.2
20	±0.25	800	795	816	±4.2
21	±0.25	900	895	918	±4.2
24	±0.25	1000	995	1020	±5.0
27	±0.27	1200	1195	1220	±5.0
30	±0.30	1400	1395	1420	±5.0
33	±0.33	1600	1595	1620	±5.0
36	±0.36	1800	1795	1820	±5.0
39	±0.39	2000	1995	2020	±5.0
42	±0.42	(2200)	2195	2220	±6.0
45	±0.45	2400	2395	2420	±6.0
48	±0.48	(2600)	2595	2620	±6.0
51	±0.51	2800	2795	2820	±6.0
54	±0.54	(3000)	2995	3020	±6.0
60	±0.60	3200	3195	3220	±7.0
66	±0.66	(3400)	3395	3420	±7.0
72	±0.72	3600	3595	3620	±7.0
78	±0.78	(3800)	3795	3820	±7.0
84	±0.84	4000	3995	4020	±7.0
90	±0.90	...	...	...	...
96	±0.96	...	...	...	...
102	±1.00	...	...	...	...
108	±1.00	...	...	...	...
114	±1.00	...	...	...	...
120	±1.00	...	...	...	...
132	±1.00	...	...	...	...
144	±1.00	...	...	...	...

[A] Inside diameters other than those shown shall be permitted by agreement between purchaser and supplier.
[B] Values are taken from International Standards Organization documents. Parentheses indicate non-preferred diameters.

conditions will not be constant for all pipes. To avoid possible misapplication, take care to analyze all conditions which might affect performance of the installed pipe.

6.5.1 For other pipe stiffness levels, appropriate values for Level A and Level B deflections (Table 7) may be computed as follows:

$$\text{Level A at new PS} = \left(\frac{72}{\text{new PS}}\right)^{0.33} (9) \qquad (1)$$

$$\text{Level B at new PS} = \text{new Level A} \div 0.6$$

6.5.2 Since products may have use limits of other than 5 % long-term deflection, Level A and Level B deflections (Table 7) may be proportionally adjusted to maintain equivalent in-use safety margins. For example, a 4 % long-term limiting deflection would result in a 20 % reduction of Level A and Level B deflections, while a 6 % limiting deflection would result in a 20 % increase in Level A and Level B deflection values. However, minimum values for Level A and Level B deflections shall be equivalent to strains of 0.6 and 1.0 % respectively (as computed by Eq X1.4 in Appendix X1 of Specification D 3262).

6.6 *Hoop-Tensile Strength*—All pipe manufactured under this specification shall meet or exceed the hoop-tensile strength shown for each size and class in Table 8, when tested in accordance with 8.5.

6.6.1 *Alternative Requirements*—When agreed upon between the purchaser and the supplier, the minimum hoop-tensile strength shall be as determined in accordance with 8.5.1.

6.7 *Joint Tightness*—The pipe joint shall meet the Laboratory Performance Requirements section of Specification D 4161. Restrained rigid joints (see 5.4.2.2, 5.4.2.3, 5.4.2.4, and 5.4.2.5) shall be exempt from angular deflection requirements.

6.8 *Longitudinal Strength*:

6.8.1 *Beam Strength*—For pipe sizes up to 27 in. the pipe shall withstand, without failure, the beam loads specified in Table 9, when tested in accordance with 8.6.1. For pipe sizes larger than 27 in., and alternatively for smaller sizes, adequate beam strength is demonstrated by tension and compression tests conducted in accordance with 8.6.2 and 8.6.3, respectively, for pipe wall specimens oriented in the longitudinal direction, using the minimum tensile and compressive strength specified in Table 9.

6.8.2 *Longitudinal Tensile Strength*—All pipe manufactured under this specification shall meet or exceed the longitudinal tensile strength shown for each size and class in Table 10, when tested in accordance with 8.6.2.

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TABLE 3 Nominal Outside Diameters (OD) and Tolerances

Outside Diameter Control Pipe				
Nominal Pipe Size, in.	Steel Pipe Equiv. (IPS) OD's, in.	Tolerance, in.	Cast Iron Pipe Equivalent OD's, in.	Tolerance, in.
8	8.625	+0.086 −0.040	9.05	±0.06
10	10.750	+0.108 −0.048	11.10	±0.06
12	12.750	+0.128 −0.056	13.20	±0.06
14	14.000	+0.140 −0.062	15.30	+0.05 −0.08
16	16.000	+0.160 −0.070	17.40	+0.05 −0.08
18	...	...	19.50	+0.05 −0.08
20	...	...	21.60	+0.05 −0.08
24	...	...	25.80	+0.05 −0.08
30	...	...	32.00	+0.08 −0.06
36	...	...	38.30	+0.08 −0.06
42	...	...	44.50	+0.08 −0.06
48	...	...	50.80	+0.08 −0.06
54	...	...	57.56	+0.08 −0.06
60	...	...	61.61	+0.08 −0.06

Metric Pipe Size, mm	D.I. Pipe Equiv., mm	Tolerance, mm	Int'l OD, mm	Tolerance, mm
200	222	−3.0, +1.0	1.02 × nominal plus 4	+2.0, −2.0
250	274	−3.1, +1.0	1.02 × nominal plus 4	+2.1, −2.0
300	326	−3.3, +1.0	1.02 × nominal plus 4	+2.3, −2.0
350	378	−3.4, +1.0	1.02 × nominal plus 4	+2.4, −2.0
400	429	−3.5, +1.0	1.02 × nominal plus 4	+2.5, −2.0
500	532	−3.8, +1.0	1.02 × nominal plus 4	+2.8, −2.0
600	635	−4.0, +1.0	1.02 × nominal plus 4	+3.0, −2.0
700	738	−4.3, +1.0	1.02 × nominal plus 4	+3.3, −2.0
800	842	−4.5, +1.0	1.02 × nominal plus 4	+3.5, −2.0
900	945	−4.8, +1.0	1.02 × nominal plus 4	+3.8, −2.0
1000	1048	−5.0, +1.0	1.02 × nominal plus 4	+4.0, −2.0
1100	1152	−5.3, +1.0	1.02 × nominal plus 4	+4.3, −2.0
1200	1255	−5.5, +1.0	1.02 × nominal plus 4	+4.5, −2.0
1400	1462	−6.0, +1.0	1.02 × nominal plus 4	+5.0, −2.0
1600	1668	−7.4, +1.0	1.02 × nominal plus 4	+5.5, −2.0
1800	1875	−8.2, +1.0	1.02 × nominal plus 4	+6.0, −2.0
2000	2082	−9.0, +1.0	1.02 × nominal plus 4	+6.5, −2.0
2200 to 4000	...	...		increase (+) tol. 0.5 each 200 mm

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TABLE 4 Hydrostatic-Pressure Test

Class	Hydrostatic Proof Pressure, gage, psi (kPa)
C50	100 (689)
C75	150 (1034)
C100	200 (1379)
C125	250 (1723)
C150	300 (2068)
C175	350 (2412)
C200	400 (2757)
C225	450 (3102)
C250	500 (3445)

TABLE 5 Long-Term Hydrostatic Pressure Categories

Class	Minimum Calculated Values of Long-Term Hydrostatic Pressure gage, psi (kPa)
C50	90 (621)
C75	135 (931)
C100	180 (1241)
C125	225 (1551)
C150	270 (1862)
C175	315 (2172)
C200	360 (2482)
C225	405 (2792)
C250	450 (3103)

TABLE 6 Minimum Stiffness at 5 % Deflection

Nominal Diameter, in.	Pipe Stiffness, psi (kPa)			
	Designation			
	A	B	C	D
8	...	...	36 (248)	72 (496)
10	...	18 (124)	36 (248)	72 (496)
12 and greater	9 (62)	18 (124)	36 (248)	72 (496)

TABLE 7 Ring Deflection Without Damage or Structural Failure

	Nominal Pipe Stiffness, psi			
	9	18	36	72
Level A	18 %	15 %	12 %	9 %
Level B	30 %	25 %	20 %	15 %

NOTE 10—The values listed in Table 10 are the minimum criteria for products made to this standard. The values may not be indicative of the axial strength of some products, or of the axial strength required by some installation conditions and joint configurations.

6.8.3 Conformance to the requirements of 6.8.1 shall satisfy the requirements of 6.8.2 for those pipe sizes and classes where the minimum longitudinal tensile strength values of Table 9 are equal to the values of Table 10. Conformance to the requirements of 6.8.2 shall satisfy the longitudinal tensile strength requirements of 6.8.1.

7. Sampling

7.1 *Lot*—Unless otherwise agreed upon between the purchaser and the supplier, one lot shall consist of 100 lengths of each type, grade, and size of pipe produced.

7.2 *Production Tests*—Select one pipe at random from each lot and take one specimen from the pipe barrel to determine conformance of the material to the workmanship, dimensional, and stiffness, and strength requirements of 6.1, 6.2, 6.5, and 6.6, respectively. Unless otherwise agreed upon between purchaser and supplier, all pipes (up to 54-in. (1370-mm) diameter) shall meet the soundness requirements of 6.3.

7.3 *Qualification Tests*—Sampling for qualification tests (see section 3.2.4) is not required unless otherwise agreed upon between the purchaser and the supplier. Qualification tests, for which a certification and test report shall be furnished when requested by the purchaser include the following:

7.3.1 *Long-Term Hydrostatic Pressure Test.*

7.3.2 *Joint-Tightness Test* (See 6.7).

7.3.3 *Longitudinal-Strength Test*, including:

7.3.3.1 Beam strength and

7.3.3.2 Longitudinal tensile strength.

7.4 *Control Tests*—The following test is considered a control requirement and shall be performed as agreed upon between the purchaser and the supplier:

7.4.1 *Soundness Test*—60-in. (1520-mm) diameter pipe and larger.

7.4.2 Perform the sampling and testing for the control requirements for hydrostatic design basis at least once every two years.

7.5 For individual orders conduct only those additional tests and numbers of tests specifically agreed upon between the purchaser and the supplier.

8. Test Methods

8.1 *Dimensions*:

8.1.1 *Diameters*:

8.1.1.1 *Inside Diameter*—Take inside diameter measurements at a point approximately 6 in. (152 mm) from the end of the pipe section using a steel tape or an inside micrometer with graduations of 1/16 in. (1 mm) or less. Make two 90° opposing measurements at each point of measurement and average the readings.

8.1.1.2 *Outside Diameter*—Determine in accordance with Test Method D 3567.

8.1.2 *Length*—Measure with a steel tape or gage having graduations of 1/16in. (1 mm) or less. Lay the tape or gage on or inside the pipe and measure the overall laying length of the pipe.

8.1.3 *Wall Thickness*—Determine in accordance with Test Method D 3567.

8.1.4 *Squareness of Pipe Ends*—Rotate the pipe on a mandrel or trunnions and measure the runout of the ends with a dial indicator. The total indicated reading is equal to twice the distance from a plane perpendicular to the longitudinal axis of the pipe. Alternatively, when squareness of pipe ends is rigidly fixed by tooling, the tooling may be verified and reinspected at frequent enough intervals to ensure that the squareness of the pipe ends is maintained within tolerance.

8.2 *Soundness*—Determine soundness by a hydrostatic proof test procedure. Place the pipe in a hydrostatic pressure testing machine that seals the ends and exerts no end loads. Fill the pipe with water, expelling all air, and apply internal water pressure at a uniform rate not to exceed 50 psi (345 kPa)/s until the Table 4 test pressure specified in accordance with 6.3 is reached. Maintain this pressure for a minimum of 30 s. The

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TABLE 8 Minimum Hoop Tensile Strength of Pipe Wall

Inch-Pound Units

Nominal Diameter, in.	Hoop Tensile Strength, lbf/in. Width								
	C50	C75	C100	C125	C150	C175	C200	C225	C250
8	800	1 200	1 600	2 000	2 400	2 800	3 200	3 600	4 000
10	1 000	1 500	2 000	2 500	3 000	3 500	4 000	4 500	5 000
12	1 200	1 800	2 400	3 000	3 600	4 200	4 800	5 400	6 000
14	1 400	2 100	2 800	3 500	4 200	4 900	5 600	6 300	7 000
15	1 500	2 250	3 000	3 750	4 500	5 250	6 000	6 750	7 500
16	1 600	2 400	3 200	4 000	4 800	5 600	6 400	7 200	8 000
18	1 800	2 700	3 600	4 500	5 400	6 300	7 200	8 100	9 000
20	2 000	3 000	4 000	5 000	6 000	7 000	8 000	9 000	10 000
21	2 100	3 150	4 200	5 250	6 300	7 350	8 400	9 450	10 500
24	2 400	3 600	4 800	6 000	7 200	8 400	9 600	10 800	12 000
27	2 700	4 050	5 400	6 750	8 100	9 450	10 800	12 150	13 500
30	3 000	4 500	6 000	7 500	9 000	10 500	12 000	13 500	15 000
33	3 300	4 950	6 600	8 250	9 900	11 450	13 200	14 850	16 500
36	3 600	5 400	7 200	9 000	10 800	12 600	14 400	16 200	18 000
39	3 900	5 850	7 800	9 750	11 700	13 650	15 600	17 550	19 500
42	4 200	6 300	8 400	10 500	12 600	14 700	16 800	18 900	21 000
45	4 500	6 750	9 000	11 250	13 500	15 750	18 000	20 250	22 500
48	4 800	7 200	9 600	12 000	14 400	16 800	19 200	21 600	24 000
54	5 400	8 100	10 800	13 500	16 200	18 900	21 600	24 300	27 000
60	6 000	9 000	12 000	15 000	18 000	21 000	24 000	27 000	30 000
66	6 600	9 900	13 200	16 500	19 800	23 100	26 400	29 700	33 000
72	7 200	10 800	14 400	18 000	21 600	25 200	28 800	32 400	36 000
78	7 800	11 700	15 600	19 500	23 400	27 300	31 200	35 100	39 000
84	8 400	12 600	16 800	21 000	25 200	29 400	33 600	37 800	42 000
90	9 000	13 500	18 000	22 500	27 000	31 500	36 000	40 500	45 000
96	9 600	14 400	19 200	24 000	28 800	33 600	38 400	43 200	48 000
102	10 200	15 300	20 400	25 500	30 600	35 700	40 800	45 900	51 000
108	10 800	16 200	21 600	27 000	32 400	37 800	43 200	48 600	54 000
120	12 000	18 000	24 000	30 000	36 000	42 000	48 000	54 000	60 000
132	13 200	19 800	26 400	33 000	39 600	46 200	52 800	59 400	66 000
144	14 400	21 600	28 800	36 000	43 200	50 400	57 600	64 800	72 000

SI Units

Nominal Diameter, in.	Hoop Tensile Strength, kN/m Width								
	C50	C75	C100	C125	C150	C175	C200	C225	C250
8	140	210	280	350	420	490	560	630	700
10	175	263	350	438	525	613	700	788	875
12	210	315	420	525	630	735	840	945	1 050
14	245	368	490	613	735	858	980	1 103	1 225
15	263	394	525	656	788	919	1 050	1 181	1 313
16	280	420	560	700	840	980	1 120	1 260	1 400
18	315	473	630	788	945	1 103	1 226	1 418	1 575
20	350	525	700	875	1 050	1 225	1 400	1 575	1 750
21	368	552	735	919	1 103	1 287	1 470	1 654	1 838
24	420	630	840	1 050	1 260	1 470	1 680	1 890	2 100
27	473	709	945	1 181	1 418	1 654	1 890	2 126	2 363
30	525	788	1 050	1 313	1 575	1 838	2 100	2 363	2 625
33	578	866	1 155	1 444	1 733	2 004	2 310	2 599	2 888
36	630	945	1 260	1 575	1 890	2 205	2 520	2 835	3 150
39	683	1 024	1 365	1 706	2 048	2 389	2 730	3 071	3 413
42	735	1 103	1 470	1 838	2 205	2 573	2 940	3 308	3 675
45	788	1 181	1 575	1 969	2 363	2 756	3 150	3 544	3 938
48	840	1 260	1 680	2 100	2 520	2 940	3 360	3 780	4 200
54	945	1 418	1 890	2 363	2 835	3 308	3 780	4 253	4 725
60	1 050	1 575	2 100	2 625	3 150	3 675	4 200	4 725	5 250
66	1 155	1 733	2 310	2 888	3 465	4 043	4 620	5 198	5 775
72	1 260	1 890	2 520	3 150	3 780	4 410	5 040	5 670	6 300
78	1 365	2 048	2 730	3 413	4 095	4 778	5 460	6 143	6 825
84	1 470	2 205	2 940	3 675	4 410	5 145	5 880	6 615	7 350
90	1 575	2 363	3 150	3 938	4 725	5 513	6 300	7 088	7 875
96	1 680	2 520	3 360	4 200	5 040	5 880	6 720	7 560	8 400
102	1 785	2 678	3 570	4 463	5 355	6 248	7 140	8 033	8 925
108	1 890	2 835	3 780	4 725	5 670	6 615	7 560	8 505	9 450
120	2 100	3 150	4 200	5 250	6 300	7 350	8 400	9 450	10 500
132	2 310	3 465	4 620	5 775	6 930	8 085	9 240	10 395	11 550
144	2 520	3 780	5 040	6 300	7 560	8 820	10 800	11 340	12 600

Note—The values in this table are equal to $2PD$, where P is the pressure class in psi and D is the nominal diameter in inches.

pipe shall show no visual signs of weeping, leakage, or fracture of the structural wall.

8.3 *Long-Term Hydrostatic Pressure*—Determine the long-term hydrostatic pressure at 50 years in accordance with

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TABLE 9 Beam-Strength Test Loads

Nominal Diameter, in.	Beam Load (*P*)		Minimum Longitudinal Tensile Strength, per Unit of Circumference		Minimum Longitudinal Compressive Strength, per Unit of Circumference	
	lbf	(kN)	lbf/in.	(kN/m)	lbf/in.	(kN/m)
8	800	(3.6)	580	(102)	580	(102)
10	1200	(5.3)	580	(102)	580	(102)
12	1600	(7.1)	580	(102)	580	(102)
14	2200	(9.8)	580	(102)	580	(102)
15	2600	(11.6)	580	(102)	580	(102)
16	3000	(13.3)	580	(102)	580	(102)
18	4000	(17.8)	580	(102)	580	(102)
20	4400	(19.6)	580	(102)	580	(102)
21	5000	(22.2)	580	(102)	580	(102)
24	6400	(28.5)	580	(102)	580	(102)
27	8000	(35.6)	580	(102)	580	(102)
30	...	...	580	(102)	580	(102)
33	...	...	640	(111)	640	(111)
36	...	...	700	(122)	700	(122)
39	...	...	780	(137)	780	(137)
42	...	...	800	(140)	800	(140)
45	...	...	860	(150)	860	(150)
48	...	...	920	(161)	920	(161)
51	...	...	980	(171)	980	(171)
54	...	...	1040	(182)	1040	(182)
60	...	...	1140	(200)	1140	(200)
66	...	...	1260	(220)	1260	(220)
72	...	...	1360	(238)	1360	(238)
78	...	...	1480	(260)	1480	(260)
84	...	...	1600	(280)	1600	(280)
90	...	...	1720	(301)	1720	(301)
96	...	...	1840	(322)	1840	(322)
102	...	...	1940	(340)	1940	(340)
108	...	...	2060	(360)	2060	(360)
114	...	...	2180	(382)	2180	(382)
120	...	...	2280	(400)	2280	(400)
132	...	...	2520	(440)	2520	(440)
144	...	...	2740	(480)	2740	(480)

Procedure B of Practice D 2992, with the following exceptions permitted:

8.3.1 Test at ambient temperatures between 50 and 110°F (10 and 43.5°C) and report the temperature range experienced during the tests.

NOTE 11—Tests indicate no significant effects on long-term hydrostatic pressure within the ambient temperature range specified.

8.3.2 Determine the hydrostatic design basis for the glass fiber reinforcement in accordance with the method in Annex A1.

8.3.3 Calculate the long-term hydrostatic pressure and categorize by class in accordance with Table 5. A1.6 explains how to calculate the long-term hydrostatic pressure.

8.4 *Stiffness*—Determine the pipe stiffness ($F/\Delta y$) at 5 % deflection for the specimen, using the apparatus and procedure of Test Method D 2412, with the following exceptions permitted:

8.4.1 Measure the wall thickness to the nearest 0.01 in. (0.25 mm).

8.4.2 Load the specimen to 5 % deflection and record the load. Then load the specimen to deflection level A per Table 7 and examine the specimen for visible damage evidenced by surface cracks. Then load the specimen to deflection level B per Table 7 and examine for evidence of structural damage, as evidenced by interlaminar separation, separation of the liner or surface layer (if incorporated) from the structural wall, tensile failure of the glass fiber reinforcement, and fracture or buckling of the pipe wall. Calculate the pipe stiffness at 5 % deflection.

8.4.3 For production testing, test only one specimen to determine the pipe stiffness.

8.4.4 The maximum specimen length shall be 12 in. (305 mm), or the length necessary to include stiffening ribs, if they are used, whichever is greater.

NOTE 12—As an alternative to determining the pipe stiffness using the apparatus and procedure of Test Method D 2412 the supplier may submit to the purchaser for approval a test method and test evaluation on Test Method D 790, accounting for the substitution of curved test specimens and measurement of stiffness at 5 % deflection.

8.5 *Hoop-Tensile Strength*—Determine the hoop-tensile strength by Test Method D 2290, except that the sections on Apparatus and Test Specimens may be modified to suit the size of specimens to be tested, and the maximum load rate may not exceed 0.10 in/min. Alternatively, Test Method D 638 may be employed. Specimen width may be increased for pipe wall thicknesses greater than 0.55 in. (14 mm). Means may be provided to minimize the bending moment imposed during the test. Cut three specimens from the test sample. Record the load to fail each specimen and determine the specimen width as close to the break as possible. Use the measured width and failure load to calculate the hoop-tensile strength.

8.5.1 *Alternative Minimum Hoop-Tensile Strength Requirement*—As an alternative, the minimum hoop-tensile strength values may be determined as follows:

$$F = (S_i/S_r)(Pr) \quad (2)$$

where:

F = required minimum hoop tensile strength, lbf/in.,
S_i = initial design hoop tensile stress, psi,
S_r = hoop tensile stress at rated operating pressure, psi,
P = rated operating pressure class, psi, and
r = inside radius of pipe, in.

NOTE 13—A value of F less than 4 Pr results in a lower factor of safety on short term loading than required by the values in Table 8.

The value for S_i should be established by considering the variations in glass reinforcement strength and manufacturing methods, but in any case should not be less than the 95 % lower confidence value on stress at 0.1 h, as determined by the manufacturer's testing carried out in accordance with 6.4. The value for S_r should be established from the manufacturer's hydrostatic design basis.

8.6 *Longitudinal Strength*:

8.6.1 *Beam Strength*—Place a 20-ft (6.1-m) nominal length of pipe on saddles at each end. Hold the ends of the pipe round during the test. Apply beam load for the diameter of pipe shown in Table 9 simultaneously to the pipe through two saddles located at the third points of the pipe (see Fig. 2). The loads shall be maintained for not less than 10 min with no evidence of failure. The testing apparatus shall be designed to minimize stress concentrations at the loading points.

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TABLE 10 Longitudinal Tensile Strength of Pipe Wall

Inch-Pound Units

Nominal Diameter, in.	Longitudinal Tensile Strength, lbf/in. of circumference								
	C50	C75	C100	C125	C150	C175	C200	C225	C250
8	580	580	580	580	580	580	580	580	580
10	580	580	580	580	580	580	580	653	726
12	580	580	580	580	644	644	697	784	871
14	580	580	580	626	751	751	813	914	1 016
15	580	580	580	671	805	805	870	980	1 089
16	580	580	580	716	859	859	929	1 045	1 161
18	580	600	608	759	911	911	972	1 094	1 215
20	580	580	675	844	1 013	1 013	1 080	1 215	1 350
21	580	580	709	886	1 063	1 063	1 134	1 276	1 418
24	580	608	810	1 012	1 215	1 215	1 296	1 458	1 620
27	580	683	911	1 139	1 367	1 367	1 458	1 644	1 823
30	580	714	952	1 190	1 428	1 428	1 499	1 686	1 873
33	640	785	1 047	1 309	1 570	1 570	1 648	1 854	2 060
36	700	857	1 142	1 428	1 713	1 713	1 798	2 023	2 248
39	780	928	1 237	1 547	1 856	1 856	1 948	2 192	2 435
42	800	999	1 332	1 666	1 998	1 998	2 098	2 360	2 622
45	860	999	1 332	1 666	1 998	1 998	2 126	2 392	2 658
48	920	1 045	1 393	1 742	2 090	2 090	2 268	2 552	2 835
51	980	1 110	1 480	1 850	2 220	2 220	2 410	2 711	3 012
54	1 040	1 176	1 567	1 959	2 351	2 351	2 552	2 876	3 189
60	1 140	1 306	1 742	2 177	2 612	2 612	2 835	3 189	3 544
66	1 260	1 437	1 916	2 395	2 873	2 873	3 119	3 508	3 898
72	1 360	1 567	2 090	2 612	3 135	3 135	3 402	3 827	4 253
78	1 480	1 580	2 106	2 633	3 159	3 159	3 475	3 909	4 344
84	1 600	1 701	2 268	2 835	3 402	3 402	3 742	4 210	4 678
90	1 720	1 823	2 430	3 038	3 645	3 645	4 010	4 511	5 012
96	1 840	1 944	2 592	3 240	3 888	3 888	4 277	4 811	5 346
102	1 940	2 066	2 754	3 443	4 131	4 131	4 544	5 112	5 680
108	2 060	2 191	2 916	3 645	4 374	4 374	4 811	5 413	6 014
114	2 180	2 309	3 078	3 848	4 617	4 617	5 079	5 714	6 348
120	2 280	2 430	3 240	4 050	4 860	4 860	5 346	6 014	6 683
132	2 520	2 673	3 564	4 455	5 340	5 340	5 881	6 616	7 351
144	2 740	2 918	3 888	4 860	5 832	5 832	6 415	7 217	8 019

SI Units

Nominal Diameter, in.	Longitudinal Tensile Strength, kN/m of circumference								
	C50	C75	C100	C125	C150	C175	C200	C225	C250
8	102	102	102	102	102	102	102	102	102
10	102	102	102	102	102	102	102	114	127
12	102	102	102	102	113	113	122	137	153
14	102	102	102	110	132	132	142	160	178
15	102	102	102	118	141	141	152	172	191
16	102	102	102	125	150	150	163	183	203
18	102	102	106	133	160	160	170	192	213
20	102	102	118	148	177	177	189	213	236
21	102	102	124	155	186	186	199	223	248
24	102	106	142	177	213	213	227	255	284
27	102	120	156	199	239	239	255	288	319
30	102	125	167	208	250	250	263	295	328
33	111	137	183	229	275	275	289	325	361
36	122	150	200	250	300	300	315	354	394
39	137	163	217	271	325	325	341	384	426
42	140	175	233	292	350	350	367	413	459
45	150	175	233	292	350	350	372	419	465
48	161	183	244	305	366	366	397	447	496
51	171	194	259	324	389	389	422	475	527
54	182	206	274	343	412	412	447	504	558
60	200	229	305	381	457	457	496	558	621
66	220	252	336	419	503	503	546	614	683
72	238	274	366	457	549	549	596	670	745
78	260	277	369	461	553	553	609	685	761
84	280	298	397	496	596	596	655	737	819
90	301	319	426	532	638	638	702	790	878
96	322	340	454	567	681	681	749	843	936
102	340	362	482	603	723	723	796	895	995
108	360	384	511	638	766	766	843	948	1 053
114	382	404	539	674	809	809	889	1 001	1 112
120	400	426	567	709	851	851	936	1 053	1 170
132	440	468	624	780	935	935	1 030	1 159	1 287
144	480	511	681	851	1 021	1 021	1 123	1 264	1 404

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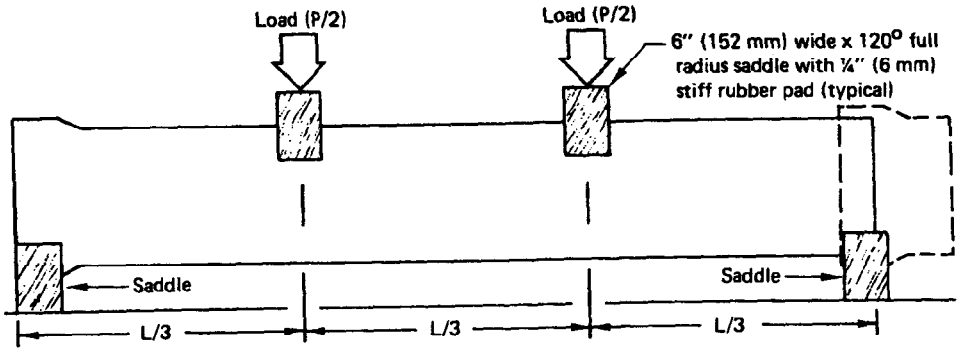

FIG. 2 Beam Strength—Test Setup

8.6.2 *Longitudinal Tensile Strength*—Determine in accordance with Test Method D 638, except the provision for maximum thickness shall not apply.

8.6.3 *Longitudinal Compressive Strength*—Determine in accordance with Test Method D 695.

9. Packaging and Package Marking

9.1 Mark each length of pipe that meets or is part of a lot that meets the requirements of this specification at least once in letters not less than ½ in. (12 mm) in height and of bold-type style in a color and type that remains legible under normal handling and installation procedures. The marking shall include the nominal pipe size, manufacturer's name or trademark, this ASTM specification number: D 3517, type, liner, grade, class, and stiffness in accordance with the designation code in 4.2.

9.2 Prepare pipe for commercial shipment in such a way as to ensure acceptance by common or other carriers.

9.3 All packing, packaging, and marking provisions of Practice D 3892 shall apply to this specification.

ANNEX

(Mandatory Information)

A1. ALTERNATIVE HYDROSTATIC DESIGN METHOD

A1.1 The following symbols are used:

S = tensile stress in the glass fiber reinforcement in the hoop orientation corrected for the helix angle, psi,
P = internal pressure, psig,
P_1 = long-term hydrostatic pressure, psig,
D = nominal inside pipe diameter, in.,
t_h = actual cross-sectional area of glass-fiber reinforcement applied around the circumference of the pipe, $in.^2/in.$,
θ = plane angle between hoop-oriented reinforcement and longitudinal axis of the pipe (helix angle), and
HDB = hydrostatic-design basis, psi.

A1.2 The hydrostatic design is based on the estimated tensile stress of the reinforcement in the wall of the pipe in the circumferential (hoop) orientation that will cause failure after 50 years of continuously applied pressure as described in Procedure B of Practice D 2992. Strength requirements are calculated using the strength of hoop-oriented glass reinforcement only, corrected for the helix angle of the fibers.

A1.3 *Hoop-Stress Calculation* is derived from the ISO equation for hoop stress, as follows:

$$S = PD/2(t_h \sin \theta)$$

This stress is used as the ordinate (long-term strength) in calculating the regression line and lower confidence limit in accordance with Annexes A1 and A3 of Practice D 2992.

NOTE A1.1—The calculated result for S may be multiplied by the factor 6.895 to convert from psi to kPa.

A1.4 *Hydrostatic-Design Basis*—The value of S is determined by extrapolation of the regression line to or 50 years in accordance with Practice D 2992.

A1.5 *Hydrostatic-Design Basis Categories*—Convert the value of the HDB to internal hydrostatic pressure in psig as follows:

$$P_1 = 2(t_h \sin \theta)(\text{HDB})/D$$

The pipe is categorized in accordance with Table A1.1.

NOTE A1.2—The calculated result P_1 may be multiplied by the factor 6.895 to convert from psig to kPa.

A1.6 *Pressure Class Rating*—The classes shown in Table A1.1 are based on the intended working pressure in psig for commonly encountered conditions of water service. The purchaser should determine the class of pipe most suitable to the installation and operating conditions that will exist on the

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TABLE A1.1 Long-Term Hydrostatic Pressure Categories

Class	Minimum Calculated Values of Long-Term Hydrostatic Pressure, P_1 gage, psi (kPa)
C50	90 (621)
C75	185 (931)
C100	180 (1241)
C125	225 (1551)
C150	270 (1862)
C175	315 (2172)
C200	360 (2482)
C225	405 (2792)
C250	450 (3103)

project on which the pipe is to be used by multiplying the values of P_1 from Table A1.1 by a service (design) factor selected for the application on the basis of two general groups of conditions. The first group considers the manufacturing and testing variables, specifically normal variations in the material, manufacture, dimensions, good handling techniques, and in the evaluation procedures in this method. The second group considers the application or use, specifically installation, environment, temperature, hazard involved, life expectancy desired, and the degree of reliability selected.

NOTE A1.3—It is not the intent of this standard to give service (design) factors. The service (design) factor should be selected by the design engineer after evaluating fully the service conditions and the engineering properties of the specific plastic pipe material under consideration. Recommended service (design) factors will not be developed or issued by ASTM.

APPENDIXES

(Nonmandatory Information)

X1. INSTALLATION

X1.1 These specifications are material performance and purchase specifications only and do not include requirements for engineering design, pressure surges, bedding, backfill or the relationship between earth cover load, and the strength of the pipe. However, experience has shown that successful performance of this product depends upon the proper type of bedding and backfill, pipe characteristics, and care in the field construction work. The purchaser of the fiberglass pressure pipe specified herein is cautioned that he must properly correlate the field requirements with the pipe requirements and provide adequate inspection at the job site.

X2. RECOMMENDED METHODS FOR DETERMINING GLASS CONTENT

X2.1 Determine glass content as follows:

X2.1.1 By ignition loss analysis in accordance with Test Method D 2584 or ISO 1172.

X2.1.2 As a process control, by weight of the glass fiber reinforcement applied by machine into the pipe structure.

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue, D 3517–96, that may impact this standard.

(*1*) Changed acronym, RPMP, definition from reinforced *plastic* mortar pipe to reinforced *polymer* mortar pipe.

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Designation: D 3754 – 01

Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer and Industrial Pressure Pipe[1]

This standard is issued under the fixed designation D 3754; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This specification covers machine-made fiberglass pipe, 8 in. (200 mm) through 144 in. (3700 mm), for use in pressure systems for conveying sanitary sewage, storm water, and many industrial wastes, and corrosive fluids. Both glass-fiber-reinforced thermosetting-resin pipe (RTRP) and glass-fiber-reinforced polymer mortar pipe (RPMP) are fiberglass pipes. This standard is suited primarily for pipes to be installed in buried applications, although it may be used to the extent applicable for other installations such as, but not limited to, sliplining and rehabilitation of existing pipelines. Pipe covered by this specification is intended to operate at internal gage pressures of 250 psi (1.72 MPa) or less.

NOTE 1—For the purposes of this standard, polymer does not include natural polymers.

1.2 The values given in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

NOTE 2—There is no similar or equivalent ISO standard.

1.3 The following precautionary caveat pertains only to the test method portion, Section 8, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 33 Specification for Concrete Aggregates[2]

C 581 Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures Intended for Liquid Service[3]

D 638 Test Method for Tensile Properties of Plastics[4]

D 695 Test Method for Compressive Properties of Rigid Plastics[4]

D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[4]

D 883 Terminology Relating to Plastics[4]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[4]

D 2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe by Split Disk Method[5]

D 2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading[3]

D 2584 Test Method for Ignition Loss of Cured Reinforced Resins[6]

D 2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[3]

D 3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[3]

D 3681 Test Method for Chemical Resistance of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe in a Deflected Condition[3]

D 3892 Practice for Packaging/Packing of Plastics[7]

D 4161 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe[3]

2.2 *ISO Standard:*

ISO 1172 Textile Glass Reinforced Plastics—Determination of Loss on Ignition[8]

2.3 *AWWA Standard:*

[1] This specification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.23 on Reinforced Plastic Piping Systems and Chemical Equipment.

Current edition approved June 10, 2001. Published August 2001. Originally published as D 3754 – 79. Last previous edition D 3754 – 96. This specification replaces Specification D 4162.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] *Annual Book of ASTM Standards*, Vol 08.01.

[5] *Annual Book of ASTM Standards*, Vol 15.03.

[6] *Annual Book of ASTM Standards*, Vol 08.02.

[7] *Annual Book of ASTM Standards*, Vol 08.03.

[8] Available from American National Standards Institute (ANSI), 11 West 42nd Street, 13th Floor, New York, NY 10036.

***A Summary of Changes section appears at the end of this standard.**

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AWWA C-950 Glass-Fiber Reinforced Thermosetting Resin Pressure Pipe[9]

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions are in accordance with Terminology D 883 or Terminology F 412 and abbreviations with Terminology D 1600, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *fiberglass pipe*—a tubular product containing glass fiber reinforcements embedded in or surrounded by cured thermosetting resin. The composite structure may contain aggregate, granular or platelet fillers, thixotropic agents, pigments, or dyes. Thermoplastic or thermosetting liners or coatings may be included.

3.2.2 *reinforced thermosetting resin pipe*—a fiberglass pipe without aggregate.

3.2.3 *reinforced polymer mortar pipe*—a fiberglass pipe with aggregate.

3.2.4 *industrial pipe*—pipe designed for internal, or external environments, or both, commonly encountered in industrial piping systems used for many process solutions or effluents.

3.2.5 *qualification test*—one or more tests used to prove the design of a product. Not a routine quality control test.

3.2.6 *liner*—a resin layer, with or without filler or reinforcement, or both, forming the interior surface of the pipe.

3.2.7 *surface layer*—a resin layer, with or without filler or reinforcement, or both, applied to the exterior surface of the pipe structural wall.

4. Classification

4.1 *General*—This specification covers fiberglass sewer and industrial pressure pipe defined by raw materials in the structural wall (type) and liner, surface layer material (grade), operating pressure (class), and pipe stiffness. Table 1 lists the types, liners, grades, classes, and stiffnesses that are covered.

NOTE 3—All possible combinations of types, liners, grades, classes, and stiffness may not be commercially available. Additional types, liners, grades, and stiffnesses may be added as they become commercially available. The purchaser should determine for himself or consult with the manufacturer for the proper class, type, liner, grade, and stiffness of pipe to be used under the installation and operating conditions that will exist for the project in which the pipe is to be used.

4.2 *Designation Requirements*—The pipe materials designation code shall consist of the standard designation, ASTM D 3754, followed by type, liner, and grade in arabic numerals, class by the letter C with two or three arabic numerals, and pipe stiffness by a capital letter. Table 1 presents a summary of the designation requirements. Thus a complete material code shall consist of ASTM D 3754, three numerals, C...and two or three numerals, and a capital letter.

NOTE 4—Examples of the designation codes are as follows: (*1*) ASTM D 3754-1-1-3-C50-A for glass-fiber-reinforced aggregate and polyester resin mortar pipe with a reinforced thermoset liner and an unreinforced polyester resin and sand surface layer, for operation at 50 psi (345 kPa), and having a minimum pipe stiffness of 9 psi (62 kPa). (*2*) ASTM D 3754-4-2-6-C200-C for glass-fiber-reinforced epoxy resin pipe with an unreinforced thermoset liner, no surface layer, for operation at 200 psi (1380 kPa) and having a minimum pipe stiffness of 36 psi (248 kPa).

NOTE 5—Although the "Form and Style for ASTM Standards" manual requires that the type classification be roman numerals, it is recognized that few companies have stencil-cutting equipment for this style of type, and it is therefore acceptable to mark the product type in arabic numbers.

5. Materials and Manufacture

5.1 *General*—The resins, reinforcements, colorants, fillers, and other materials, when combined as a composite structure, shall produce a pipe that shall meet the performance requirements of this specification.

5.2 *Wall Composition*—The basic structural wall composition shall consist of a thermosetting resin, glass-fiber reinforcement, and, if used, an aggregate filler.

[9] Available from the American Water Works Association, 6666 West Quincey Ave., Denver, CO 80235.

TABLE 1 General Designation Requirements for Fiberglass Pressure Pipe

Designation	Property	Cell Limits[A]								
1	Type	1 glass-fiber-reinforced thermosetting polyester[B] resin mortar (RPMP polyester)[B]		2 glass-fiber-reinforced thermosetting polyester[B] resin (RTRP polyester)[B]		3 glass-fiber-reinforced thermosetting epoxy resin mortar (RPMP epoxy)		4 glass-fiber-reinforced thermosetting epoxy resin (RTRP epoxy)	
2	Liner	1 reinforced thermoset liner		2 non-reinforced thermoset liner		3 thermoplastic liner		4 no liner	
3	Grade	1 Polyester resin surface layer—reinforced[B]	2 polyester[B] resin surface layer—nonreinforced[B]	3 polyester[B] resin and sand surface layer nonreinforced		4 epoxy resin surface layer—reinforced		5 epoxy resin surface layer—nonreinforced	6 No surface layer
4	Class[C]	C50	C75	C100	C125	C150	C175	C200	C225	C250
5	Pipe Stiffness psi (kPa)	A 9 (62)		B 18 (124)		C 36 (248)		D 72 (496)[ABC]		

[A] The cell-type format provides the means of identification and specification of piping materials. This cell-type format, however, is subject to misapplication since unobtainable property combinations can be selected if the user is not familiar with commercially available products. The manufacturer should be consulted.

[B] For the purposes of this standard, polyester includes vinyl ester resin.

[C] Based on operating pressure in psig (numerals).

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5.2.1 *Resin*—A thermosetting polyester or epoxy resin, with or without filler.

5.2.2 *Aggregate*—A siliceous sand conforming to the requirements of Specification C 33, except that the requirements for gradation shall not apply.

5.2.3 *Reinforcement*—A commercial grade of glass fiber with a sizing compatible with the resin used.

5.3 *Liner and Surface Layers*—A liner or surface layer, or both, when incorporated into or onto the pipe shall meet the chemical and structural requirements of this specification.

5.4 *Joints*—The pipe shall have a joining system that shall provide for fluid tightness for the intended service condition.

5.4.1 *Unrestrained*—Pipe joints capable of withstanding internal pressure but not longitudinal forces.

5.4.1.1 *Coupling or Bell-and-Spigot Gasket Joints*, with a groove either on the spigot or in the bell to retain an elastomeric gasket that shall be the sole element of the joint to provide watertightness. For typical joint detail see Fig. 1.

5.4.1.2 *Mechanical Couplings*.

5.4.2 *Restrained*—Pipe joints capable of withstanding internal pressure and longitudinal forces.

5.4.2.1 Joints similar to those in 5.4.1.1 with supplemental restraining elements.

5.4.2.2 *Butt Joint*, with laminated overlay.

5.4.2.3 *Bell-and-Spigot*, with laminated overlay.

5.4.2.4 *Bell-and-Spigot*, adhesive bonded.

5.4.2.5 *Flanged*.

5.4.2.6 *Mechanical*.

NOTE 6—Other types of joints may be added as they become commercially available.

5.5 *Gaskets*—Elastomeric gaskets, when used with this pipe, shall conform to the requirements of Specification F 477, except that composition of the elastomer shall be as agreed upon between the purchaser and the supplier for the particular exposure to oily or aggressive-chemical environments.

6. Requirements

6.1 *Workmanship*:

6.1.1 Each pipe shall be free from all defects including indentations, delaminations, bubbles, pinholes, cracks, pits, blisters, foreign inclusions, and resin-starved areas that due to their nature, degree, or extent, detrimentally affect the strength and serviceability of the pipe. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

6.1.2 The inside surface of each pipe shall be free of bulges, dents, ridges, or other defects that result in a variation of inside diameter of more than ⅛ in. (3.2 mm) from that obtained on adjacent unaffected portions of the surface. No glass-fiber reinforcement shall penetrate the interior surface of the pipe wall.

6.1.3 Joint sealing surfaces shall be free of dents, gouges, or other surface irregularities that will affect the integrity of the joints.

6.2 *Dimensions*:

6.2.1 *Pipe Diameters*—The pipe shall be supplied in the nominal diameters shown in Table 2 or Table 3. The pipe diameter tolerances shall be as shown in Table 2 or Table 3, when measured in accordance with 8.1.1.

6.2.2 *Lengths*—The pipe shall be supplied in nominal lengths of 10, 20, 30, 40, and 60 ft (3.05, 6.10, 9.15, 12.19, and 18.29 m). The actual laying length shall be the nominal length ±2 in. (±51 mm), when measured in accordance with 8.1.2. At least 90 % of the total footage of any one size and class, excluding special-order lengths, shall be furnished in the nominal lengths specified by the purchaser. Random lengths, if furnished, shall not vary from the nominal lengths by more than 5 ft (1.53 m), or 25 %, whichever is less.

6.2.3 *Wall Thickness*—The average wall thickness of the pipe shall not be less than the nominal wall thickness published in the manufacturer's literature current at the time of purchase, and the minimum wall thickness at any point shall not be less than 87.5 % of the nominal wall thickness when measured in accordance with 8.1.3.

6.2.4 *Squareness of Pipe Ends*—All points around each end of a pipe unit shall fall within ±¼in. (6.4 mm) or ±0.5 % of the nominal diameter of the pipe, whichever is greater, to a plane perpendicular to the longitudinal axis of the pipe, when measured in accordance with 8.1.4.

6.3 *Chemical Requirements*:

6.3.1 *Sanitary Sewer Service* :

6.3.1.1 *Long-Term*—Pipe specimens, when tested in accordance with 8.2.1 shall be capable of being deflected, without failure, at the 50 year strain level given in Table 4 when exposed to 1.0 *N* sulfuric acid.

NOTE 7—See Appendix X1 for derivation of the minimum sanitary sewer pipe chemical requirements given in Table 4.

6.3.1.2 *Control Requirements*—Test pipe specimens periodically in accordance with 8.2.1.3, following the procedure of 8.2.1.4, or alternatively, the procedure of 8.2.1.5.

6.3.1.3 When the procedure of 8.2.1.4 is used, the following three criteria must be met: a) the average failure time at each strain level must fall at or above the lower 95 % confidence limit of the originally determined regression line, b) no specimen-failure times may be sooner than the lower 95 % prediction limit of the originally determined regression line, and c) one-third or more of the specimen failure times must be on or above the originally determined regression line.

NOTE 8—Determine the lower 95 % confidence limit and the lower 95 % prediction limit in accordance with to Annex A2.

6.3.1.4 When the alternative method of 8.2.1.5 is used, failure shall not occur in any specimen.

6.3.2 *Industrial Service*—The resin component of the liner or of the surface layer, or both, shall be a commercial-grade corrosion-resistant thermoset that has either been evaluated in a laminate by test, in accordance with 8.2.2, or that has been determined by previous documented service to be acceptable

FIG. 1 Typical Joints

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TABLE 2 Nominal Inside Diameters (ID) and Tolerances Inside Diameter Control Pipe

Nominal Diameter,[A] in.	Tolerances, in.	Nominal Metric Diameter,[B] mm	ID Range,[B] mm		Tolerance[B] on Declared ID, mm
			Minimum	Maximum	
8	±0.25	200	196	204	±1.5
10	±0.25	250	246	255	±1.5
12	±0.25	300	296	306	±1.8
14	±0.25	400	396	408	±2.4
15	±0.25	500	496	510	±3.0
16	±0.25	600	595	612	±3.6
18	±0.25	700	695	714	±4.2
20	±0.25	800	795	816	±4.2
21	±0.25	900	895	918	±4.2
24	±0.25	1000	995	1020	±5.0
27	±0.27	1200	1195	1220	±5.0
30	±0.30	1400	1395	1420	±5.0
33	±0.33	1600	1595	1620	±5.0
36	±0.36	1800	1795	1820	±5.0
39	±0.39	2000	1995	2020	±5.0
42	±0.42	(2200)	2195	2220	±6.0
45	±0.45	2400	2395	2420	±6.0
48	±0.48	(2600)	2595	2620	±6.0
51	±0.51	2800	2795	2820	±6.0
54	±0.54	(3000)	2995	3020	±6.0
60	±0.60	3200	3195	3220	±7.0
66	±0.66	(3400)	3395	3420	±7.0
72	±0.72	3600	3595	3620	±7.0
78	±0.78	(3800)	3795	3820	±7.0
84	±0.84	4000	3995	4020	±7.0
90	±0.90	...	...	...	...
96	±0.96	...	...	...	...
102	±1.00	...	...	...	...
108	±1.00	...	...	...	...
114	±1.00	...	...	...	...
120	±1.00	...	...	...	...
132	±1.00	...	...	...	...
144	±1.00	...	...	...	...

[A] Inside diameters other than those shown shall be permitted by agreement between purchaser and supplier.
[B] Values are taken from International Standards Organization documents. Parentheses indicate non-preferred diameters.

for the service conditions. Where service conditions have not been evaluated, a suitable resin may also be selected by agreement between the manufacturer and purchaser.

NOTE 9—The results obtained by this test shall serve as a guide only in the selection of a pipe material for a specific service application. The purchaser is cautioned to evaluate all of the various factors that may enter into the serviceability of a pipe material when subjected to chemical environment, including chemical resistance in the strained condition.

6.4 *Soundness*—Unless otherwise agreed upon between purchaser and supplier, test each length of pipe up to 54 in. (1370 mm) diameter hydrostatically without leakage or cracking, at the internal hydrostatic proof pressures specified for the applicable class in Table 5 when tested in accordance with 8.3. For sizes over 54 in., the frequency of hydrostatic leak tests shall be as agreed upon by purchaser and supplier.

6.5 *Hydrostatic Design Basis*:

6.5.1 *Long-Term Hydrostatic Pressure*—The pressure classes shall be based on long-term hydrostatic pressure data obtained in accordance with 8.4 and categorized in accordance with Table 6. Pressure classes are based on extrapolated strengths at 50 years. For pipe subjected to longitudinal loads or circumferential bending, the effect of these conditions on the hydrostatic design pressure classification of the pipe must be considered.

6.5.2 *Control Requirements*—Test pipe specimens periodically in accordance with the reconfirmation procedures described in Practice D 2992.

NOTE 10—Hydrostatic design basis (HDB—extrapolated value at 50 years) determined in accordance with Procedure A of Practice D 2992, may be substituted for the Procedure B evaluation required by 8.4. It is generally accepted that the Procedure A value multiplied by 3 is equivalent to the Procedure B value.

6.6 *Stiffness*—Each length of pipe shall have sufficient strength to exhibit the minimum pipe stiffness ($F/\Delta y$) specified in Table 7 when tested in accordance with 8.5. At deflection level A per Table 8, there shall be no visible damage in the test specimen evidenced by surface cracks. At deflection level B per Table 8, there shall be no indication of structural damage as evidenced by interlaminar separation, separation of the liner or surface layer (if incorporated) from the structural wall, tensile failure of the glass-fiber reinforcement, fracture, or buckling of the pipe wall.

NOTE 11—This is a visual observation (made with the unaided eye) for quality control purposes only, and should not be considered a simulated service test. Table 8 values are based on an in-use long-term deflection limit of 5 % and provide an appropriate uniform safety margin for all pipe stiffnesses. Since the pipe-stiffness values ($F/\Delta y$) shown in Table 7 vary, the percent deflection of the pipe under a given set of installation conditions will not be constant for all pipes. To avoid possible misapplication, take care to analyze all conditions that might affect performance of the installed pipe.

6.6.1 For other pipe stiffness levels, appropriate values for Level A and Level B deflections (Table 8) may be computed as follows:

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TABLE 3 Nominal Outside Diameters (OD) and Tolerances

Outside Diameter Control Pipe				
Nominal Pipe Size, in.	Steel Pipe Equiv. (IPS) OD's, in.	Tolerance, in.	Cast Iron Pipe Equiv. OD's, in.	Tolerance, in.
8	8.625	+0.086 −0.040	9.05	
10	10.750	+0.108 −0.048	11.10	±0.06
12	12.750	+0.128 −0.056	13.20	
14	14.000	+0.140 −0.062	15.30	
16	16.000	+0.160 −0.070	17.40	+0.05 −0.08
18	...	...	19.50	
20	...	...	21.60	
24	...	...	25.80	
30	...	...	32.00	
36	...	...	38.30	
42	...	...	44.50	+0.08
48	...	...	50.80	−0.06
54	...	...	57.56	
60	...	...	61.61	

Metric Pipe Size, mm	D.I. Pipe Equiv, mm	Tolerance, mm		Int'l OD, mm	Tolerance, mm	
200	222	−3.0			+2.0	
250	274	−3.1			+2.1	
300	326	−3.3			+2.3	
350	378	−3.4			+2.4	
400	429	−3.5			+2.5	
500	532	−3.8			+2.8	
600	635	−4.0			+3.0	
700	738	−4.3			+3.3	
800	842	−4.5	+1.0		+3.5	
900	945	−4.8		1.02 × nominal plus 4	+3.8	−2.0
1000	1048	−5.0			+4.0	
1100	1152	−5.3			+4.3	
1200	1255	−5.5			+4.5	
1400	1462	−6.0			+5.0	
1600	1668	−7.4			+5.5	
1800	1875	−8.2			+6.0	
2000	2082	−9.0			+6.5	
2200 to 4000	...	...			Increase (+) tol. 0.5 each 200 mm	

TABLE 4 Minimum Sanitary Sewer Pipe Chemical Requirements

ϵ_{scv}

Pipe Stiffness, psi (kPa)	Minimum Strain					
	6 min	10 h	100 h	1 000	10 000	50 years
9 (62)	0.97 (*t/de*)	0.84 (*t/d*)	0.78 (*t/d*)	0.73 (*t/d*)	0.68 (*t/d*)	0.60 (*t/d*)
18 (124)	0.85 (*t/d*)	0.72 (*t/d*)	0.66 (*t/d*)	0.61 (*t/d*)	0.56 (*t/d*)	0.49 (*t/d*)
36 (248)	0.71 (*t/d*)	0.60 (*t/d*)	0.55 (*t/d*)	0.51 (*t/d*)	0.47 (*t/d*)	0.41 (*t/d*)
72 (496)	0.56 (*t/d*)	0.48 (*t/d*)	0.44 (*t/d*)	0.41 (*t/d*)	0.38 (*t/d*)	0.34 (*t/d*)

Where: *t* and *d* are the nominal total wall thickness and the mean diameter (inside diameter plus *t*) as determined in accordance with 8.1.

$$\text{Level A at new PS} = \left(\frac{72}{\text{new PS}}\right)^{0.33} (9) \quad (1)$$

$$\text{Level B at new PS} = \text{new Level A} \div 0.6$$

6.6.2 Since products may have use limits of other than 5 % long-term deflection, Level A and Level B deflections (Table 8) may be proportionally adjusted to maintain equivalent in-use safety margins. For example, a 4 % long-term limiting deflection would result in a 20 % reduction of Level A and Level B

TABLE 5 Hydrostatic-Pressure Test

Class	Hydrostatic Proof Pressure, gage, psi (kPa)
C50	100 (689)
C75	150 (1034)
C100	200 (1379)
C125	250 (1723)
C150	300 (2068)
C175	350 (2412)
C200	400 (2757)
C225	450 (3102)
C250	500 (3445)

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TABLE 6 Long-Term Hydrostatic Pressure Categories

Class	Minimum Calculated Values of Long-Term Hydrostatic Pressure. gage, psi (kPa)
C50	90 (621)
C75	135 (931)
C100	180 (1241)
C125	225 (1551)
C150	270 (1862)
C175	315 (2172)
C200	360 (2482)
C225	405 (2792)
C250	450 (3103)

TABLE 7 Minimum Stiffness at 5 % Deflection

Nominal Diameter, in.	Pipe Stiffness, psi (kPa)			
	Designation			
	A	B	C	D
8	...	...	36 (248)	72 (496)
10	...	18 (124)	36 (248)	72 (496)
12 and greater	9 (62)	18 (124)	36 (248)	72 (496)

TABLE 8 Ring Deflection Without Damage or Structural Failure

	Nominal Pipe Stiffness, psi			
	9	18	36	72
Level A	18 %	15 %	12 %	9 %
Level B	30 %	25 %	20 %	15 %

deflections, while a 6 % limiting deflection would result in a 20 % increase in Level A and Level B deflection values. However, minimum values for Level A and Level B deflections shall be equivalent to strains of 0.6 and 1.0 % respectively (as computed by Eq X1.1 in Appendix X1).

6.7 *Hoop-Tensile Strength*—All pipe manufactured under this specification shall meet or exceed the hoop-tensile strength shown for each size and class in Table 9 and Table 10, when tested in accordance with 8.6.

6.7.1 *Alternative Requirements*—When agreed upon by the purchaser and the supplier, the minimum hoop tensile strength shall be as determined in accordance with 8.6.1.

6:8 *Joint Tightness*—The pipe joint shall meet the performance requirements of the applicable section of Specification D 4161. Restrained rigid joints (5.4.2.2, 5.4.2.3, 5.4.2.4, and 5.4.2.5) shall be exempt from angular deflection requirements.

6.9 *Longitudinal Strength:* :

6.9.1 *Beam Strength*—For pipe sizes up to 27 in. (686 mm), the pipe shall withstand, without failure, the beam loads specified in Table 11, when tested in accordance with 8.7.1. For pipe sizes larger than 27 in., and alternatively for smaller sizes, adequate beam strength is demonstrated by tensile and compression tests conducted in accordance with 8.7.2 and 8.7.3 respectively, for pipe wall specimens oriented in the longitudinal direction, using the minimum tensile and compression strengths specified in Table 11.

6.9.2 *Longitudinal Tensile Strength*—All pipe manufactured under this specification shall meet or exceed the longitudinal tensile strength shown for each size and class in Table 12 and

TABLE 9 Minimum Hoop Tensile Strength of Pipe Wall Inch-Pound Units

Nominal Diameter in.	Hoop Tensile Strength, lbf/in. Width								
	C50	C75	C100	C125	C150	C175	C200	C225	C250
8	800	1 200	1 600	2 000	2 400	2 800	3 200	3 600	4 000
10	1 000	1 500	2 000	2 500	3 000	3 500	4 000	4 500	5 000
12	1 200	1 800	2 400	3 000	3 600	4 200	4 800	5 400	6 000
14	1 400	2 100	2 800	3 500	4 200	4 900	5 600	6 300	7 000
15	1 500	2 250	3 000	3 750	4 500	5 250	6 000	6 750	7 500
16	1 600	2 400	3 200	4 000	4 800	5 600	6 400	7 200	8 000
18	1 800	2 700	3 600	4 500	5 400	6 300	7 200	8 100	9 000
20	2 000	3 000	4 000	5 000	6 000	7 000	8 000	9 000	10 000
21	2 100	3 150	4 200	5 250	6 300	7 350	8 400	9 450	10 500
24	2 400	3 600	4 800	6 000	7 200	8 400	9 600	10 800	12 000
27	2 700	4 050	5 400	6 750	8 100	9 450	10 800	12 150	13 500
30	3 000	4 500	6 000	7 500	9 000	10 500	12 000	13 500	15 000
33	3 300	4 950	6 600	8 250	9 900	11 450	13 200	14 850	16 500
36	3 600	5 400	7 200	9 000	10 800	12 600	14 400	16 200	18 000
39	3 900	5 850	7 800	9 750	11 700	13 650	15 600	17 550	19 500
42	4 200	6 300	8 400	10 500	12 600	14 700	16 800	18 900	21 000
45	4 500	6 750	9 000	11 250	13 500	15 750	18 000	20 250	22 500
48	4 800	7 200	9 600	12 000	14 400	16 800	19 200	21 600	24 000
54	5 400	8 100	10 800	13 500	16 200	18 900	21 600	24 300	27 000
60	6 000	9 000	12 000	15 000	18 000	21 000	24 000	27 000	30 000
66	6 600	9 900	13 200	16 500	19 800	23 100	26 400	29 700	33 000
72	7 200	10 800	14 400	18 000	21 600	25 200	28 800	32 400	36 000
78	7 800	11 700	15 600	19 500	23 400	27 300	31 200	35 100	39 000
84	8 400	12 600	16 800	21 000	25 200	29 400	33 600	37 800	42 000
90	9 000	13 500	18 000	22 500	27 000	31 500	36 000	40 500	45 000
96	9 600	14 400	19 200	24 000	28 800	33 600	38 400	43 200	48 000
102	10 200	15 300	20 400	25 500	30 600	35 700	40 800	45 900	51 000
108	10 800	16 200	21 600	27 000	32 400	37 800	43 200	48 600	54 000
120	12 000	18 000	24 000	30 000	36 000	42 000	48 000	54 000	60 000
132	13 200	19 800	26 400	33 000	39 600	46 200	52 800	59 400	66 000
144	14 400	21 600	28 800	36 000	43 200	50 400	57 600	64 800	72 000

Note—The values in this table are equal to $2PD$, where P is the pressure class in psi and D is the nominal diameter in inches.

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TABLE 10 Minimum Hoop Tensile Strength of Pipe Wall SI Units

Nominal Diameter in.	Hoop Tensile Strength, kN/m Width								
	C50	C75	C100	C125	C150	C175	C200	C225	C250
8	140	210	280	350	420	490	560	630	700
10	175	263	350	438	525	613	700	788	875
12	210	315	420	525	630	735	840	945	1 050
14	245	368	490	613	735	858	980	1 103	1 225
15	263	394	525	656	788	919	1 050	1 181	1 313
16	280	420	560	700	840	980	1 120	1 260	1 400
18	315	473	630	788	945	1 103	1 226	1 418	1 575
20	350	525	700	875	1 050	1 225	1 400	1 575	1 750
21	368	552	735	919	1 103	1 287	1 470	1 654	1 838
24	420	630	840	1 050	1 260	1 470	1 680	1 890	2 100
27	473	709	945	1 181	1 418	1 654	1 890	2 126	2 363
30	525	788	1 050	1 313	1 575	1 838	2 100	2 363	2 625
33	578	866	1 155	1 444	1 733	2 004	2 310	2 599	2 888
36	630	945	1 260	1 575	1 890	2 205	2 520	2 835	3 150
39	683	1 024	1 365	1 706	2 048	2 389	2 730	3 071	3 413
42	735	1 103	1 470	1 838	2 205	2 573	2 940	3 308	3 675
45	788	1 181	1 575	1 969	2 363	2 756	3 150	3 544	3 938
48	840	1 260	1 680	2 100	2 520	2 940	3 360	3 780	4 200
54	945	1 418	1 890	2 363	2 835	3 308	3 780	4 253	4 725
60	1 050	1 575	2 100	2 625	3 150	3 675	4 200	4 725	5 250
66	1 155	1 733	2 310	2 888	3 465	4 043	4 620	5 198	5 775
72	1 260	1 890	2 520	3 150	3 780	4 410	5 040	5 670	6 300
78	1 365	2 048	2 730	3 413	4 095	4 778	5 460	6 143	6 825
84	1 470	2 205	2 940	3 675	4 410	5 145	5 880	6 615	7 350
90	1 575	2 363	3 150	3 938	4 725	5 513	6 300	7 088	7 875
96	1 680	2 520	3 360	4 200	5 040	5 880	6 720	7 560	8 400
102	1 785	2 678	3 570	4 463	5 355	6 248	7 140	8 033	8 925
108	1 890	2 835	3 780	4 725	5 670	6 615	7 560	8 505	9 450
120	2 100	3 150	4 200	5 250	6 300	7 350	8 400	9 450	10 500
132	2 310	3 465	4 620	5 775	6 930	8 085	9 240	10 395	11 550
144	2 520	3 780	5 040	6 300	7 560	8 820	10 800	11 340	12 600

Table 13, when tested in accordance with 8.7.2.

NOTE 12—The values listed in Table 12 are the minimum criteria for products made to this standard. The values may not be indicative of the axial strength of some products, or of the axial strength required by some installation conditions and joint configurations.

6.9.3 Conformance to the requirements of 6.9.1 shall satisfy the requirements of 6.9.2 for those pipe sizes and classes where the minimum longitudinal tensile strength values of Table 11 are equal to the values of Table 12. Conformance to the requirements of 6.9.2 shall satisfy the longitudinal tensile strength requirements of 6.9.1.

7. Sampling

7.1 *Lot*—Unless otherwise agreed upon by the purchaser and the supplier, one lot shall consist of 100 lengths of each type, grade, and size of pipe produced.

7.2 *Production Tests*—Select one pipe at random from each lot and take one specimen from the pipe barrel to determine conformance of the material to the workmanship, dimensional, and strength requirements of 6.1, 6.2, 6.6, and 6.7 respectively. Unless otherwise agreed upon between purchaser and supplier, all pipes (up to 54 in. diameter) shall meet the soundness requirements of 6.4.

7.3 *Qualification Tests*—Sampling for qualification tests is not required unless otherwise agreed upon by the purchaser and the supplier. Qualification tests, for which a certification and test report shall be furnished when requested by the purchaser, include the following:

7.3.1 Sanitary sewer service, long-term chemical test.

7.3.2 Industrial service resin component chemical test. A copy of the resin manufacturer's test report may be used as the basis of acceptance for this test as agreed upon by the purchaser and the supplier.

7.3.3 Long-term hydrostatic pressure test.

7.3.4 Joint-tightness test, see 6.8.

7.3.5 Longitudinal strength test, including:

7.3.5.1 Beam strength, and

7.3.5.2 Longitudinal tensile strength.

7.4 *Control Tests*—The following tests are considered control requirements and shall be performed as agreed upon between the purchaser and the supplier.

7.4.1 *Soundness Test*—60 in. (1524 mm) diameter pipe and larger

7.4.2 Perform sampling and testing for the control requirements for sanitary sewer service at least once annually.

7.4.3 Perform sampling and testing for the control requirements for hydrostatic design basis at least once every two years.

7.5 For individual orders, conduct only those additional tests and number of tests specifically agreed upon between purchaser and supplier.

8. Test Methods

8.1 *Dimensions*:

8.1.1 *Diameters*:

8.1.1.1 *Inside Diameter*—Take inside diameter measurements at a point approximately 6 in. (152 mm) from the end of the pipe section using a steel tape or an inside micrometer with

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TABLE 11 Beam Strength Test Loads

Nominal Diameter, in.	Beam Load, *P*,		Minimum Longitudinal Tensile Strength, per Unit of Circumference,		Minimum Longitudinal Compressive Strength per Unit of Circumference,	
	lbf	kN	lbf/in.	(kN/m)	lbf/in.	kN/m
8	800	3.6	580	102	580	102
10	1 200	5.3	580	102	580	102
12	1 600	7.1	580	102	580	102
14	2 200	9.8	580	102	580	102
15	2 600	11.6	580	102	580	102
16	3 000	13.3	580	102	580	102
18	4 000	17.8	580	102	580	102
20	4 400	19.6	580	102	580	102
21	5 000	22.2	580	102	580	102
24	6 400	28.5	580	102	580	102
27	8 000	35.6	580	102	580	102
30	...	...	580	102	580	102
33	...	...	640	111	640	111
36	...	...	700	122	700	122
39	...	...	780	137	780	137
42	...	...	800	140	800	140
45	...	...	860	150	860	150
48	...	...	920	161	920	161
51	...	...	980	171	980	171
54	...	...	1 040	182	1 040	182
60	...	...	1 140	200	1 140	200
66	...	...	1 260	220	1 260	220
72	...	...	1 360	238	1 360	238
78	...	...	1 480	260	1 480	260
84	...	...	1 600	280	1 600	280
90	...	...	1 720	301	1 720	301
96	...	...	1 840	322	1 840	322
102	...	...	1 940	340	1 940	340
108	...	...	2 060	360	2 060	360
114	...	...	2 180	382	2 180	382
120	...	...	2 280	400	2 280	400
132	...	...	2 520	440	2 520	440
144	...	...	2 740	480	2 740	480

graduations of 1/16 in. (1 mm) or less. Take two 90° opposing measurements at each point of measurement and average the readings.

8.1.1.2 *Outside Diameter*—Determine in accordance with Test Method D 3567.

8.1.2 *Length*—Measure with a steel tape or gage having graduations of 1/16in. (1 mm) or less. Lay the tape or gage on or inside the pipe and measure the overall laying length of the pipe.

8.1.3 *Wall Thickness*—Determine in accordance with Test Method D 3567.

8.1.4 *Squareness of Pipe Ends*—Rotate the pipe on a mandrel or trunions and measure the runout of the ends with a dial indicator. The total indicated reading is equal to twice the distance from a plane perpendicular to the longitudinal axis of the pipe. Alternatively, when the squareness of the pipe ends is rigidly fixed by tooling, the tooling may be verified and reinspected at intervals frequent enough to assure that the squareness of the pipe ends is maintained within tolerance.

8.2 *Chemical Tests*:

8.2.1 *Sanitary-Sewer Service*—Test the pipe in accordance with Test Method D 3681.

8.2.1.1 *Long-Term*—To find if the pipe meets the requirements of 6.3.1, determine at least 18 failure points in accordance with Test Method D 3681.

8.2.1.2 *Alternative Qualification Procedure*—Test four specimens each at the 10 and 10 000 h minimum strains given in Table 4 and test five specimens each at the 100 and 1000 h minimum strains given in Table 4. Consider the product qualified if all 18 specimens are tested without failure for at least the prescribed times given in Table 4 (that is, 10, 100, 1000 or 10 000 h respectively).

8.2.1.3 *Control Requirements*—Test at least six specimens in accordance with one of the following procedures and record the results.

8.2.1.4 Test at least 3 specimens at each of the strain levels corresponding to the 100- and 1000-h failure times from the product's regression line established in 8.2.1.

8.2.1.5 When the alternative method described in 8.2.1.2 is used to qualify the product, test at least three specimens each at the 100 and 1000 h minimum strains given in Table 4 for at least 100 and 1000 h respectively.

8.2.1.6 The control test procedures of 8.2.1.5 may be used as an alternative procedure to the reconfirmation procedure described in Test Method D 3681 for those products evaluated by the alternative qualification procedure described in 8.2.1.2.

8.2.2 *Industrial Service*—The resin component of the liner or of the surface layer, or both, to be subjected to an aggressive service environment, shall be tested in accordance with Test Method C 581, except that the specimens tested shall be representative of the laminate construction used in the liner or surface layer, or both.

8.3 *Soundness*—Determine soundness by a hydrostatic proof test procedure. Place the pipe in a hydrostatic pressure

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TABLE 12 Longitudinal Tensile Strength of Pipe Wall

Inch-Pound Units

Nominal Diameter, in.	Longitudinal Tensile Strength, lbf/in. of Circumference								
	C50	C75	C100	C125	C150	C175	C200	C225	C250
8	580	580	580	580	580	580	580	580	580
10	580	580	580	580	580	580	580	653	726
12	580	580	580	580	644	644	697	784	871
14	580	580	580	626	751	751	813	914	1 016
15	580	580	580	671	805	805	870	980	1 089
16	580	580	580	716	859	859	929	1 045	1 161
18	580	580	608	759	911	911	972	1 094	1 215
20	580	580	675	844	1 013	1 013	1 080	1 215	1 350
21	580	580	709	886	1 063	1 063	1 134	1 276	1 418
24	580	608	810	1 012	1 215	1 215	1 296	1 458	1 620
27	580	683	911	1 139	1 367	1 367	1 458	1 644	1 823
30	580	714	952	1 190	1 428	1 428	1 499	1 686	1 873
33	640	785	1 047	1 309	1 570	1 570	1 648	1 854	2 060
36	700	857	1 142	1 428	1 713	1 713	1 798	2 023	2 248
39	780	928	1 237	1 547	1 856	1 856	1 948	2 192	2 435
42	800	999	1 332	1 666	1 998	1 998	2 098	2 360	2 622
45	860	999	1 332	1 666	1 998	1 998	2 126	2 392	2 658
48	920	1 045	1 393	1 742	2 090	2 090	2 268	2 552	2 835
51	980	1 110	1 480	1 850	2 220	2 220	2 410	2 711	3 012
54	1 040	1 176	1 567	1 959	2 351	2 351	2 552	2 876	3 189
60	1 140	1 306	1 742	2 177	2 612	2 612	2 835	3 189	3 544
66	1 260	1 437	1 916	2 395	2 873	2 873	3 119	3 508	3 898
72	1 360	1 567	2 090	2 612	3 135	3 135	3 402	3 827	4 253
78	1 480	1 580	2 106	2 633	3 159	3 159	3 475	3 909	4 344
84	1 600	1 701	2 268	2 835	3 402	3 402	3 742	4 210	4 678
90	1 720	1 823	2 430	3 038	3 645	3 645	4 010	4 511	5 012
96	1 840	1 944	2 592	3 240	3 888	3 888	4 277	4 811	5 346
102	1 940	2 066	2 754	3 443	4 131	4 131	4 544	5 112	5 680
108	2 060	2 191	2 916	3 645	4 374	4 374	4 811	5 413	6 014
114	2 180	2 309	3 078	3 848	4 617	4 617	5 079	5 714	6 348
120	2 280	2 430	3 240	4 050	4 860	4 860	5 346	6 014	6 683
132	2 520	2 673	3 564	4 455	5 340	5 340	5 881	6 616	7 351
144	2 740	2 918	3 888	4 860	5 832	5 832	6 415	7 217	8 019

testing machine that seals the ends and exerts no end loads. Fill the pipe with water, expelling all air, and apply internal water pressure at a uniform rate not to exceed 50 psi (345 kPa)/s until the test pressure shown in Table 5 for the applicable class is reached. Maintain this pressure for a minimum of 30 s. The pipe shall show no visual signs of weeping, leakage, or fracture of the structural wall.

8.4 *Long-Term Hydrostatic Pressure*—Determine the long-term hydrostatic pressure at 50 years in accordance with Procedure B of Practice D 2992, with the following exceptions permitted:

8.4.1 Test at ambient temperatures within the limits of 50°F (10°C) and 110°F (43.5°C) and report the temperature range experienced during the tests.

NOTE 13—Tests indicate no significant effects on long-term hydrostatic pressure within the ambient temperature range specified.

8.4.2 Determine the hydrostatic design basis for the glass-fiber reinforcement in accordance with the method in Annex A1.

8.4.3 Calculate the long-term hydrostatic pressure and categorize by class in accordance with Table 6. Annex A1.6 explains how to calculate the long-term hydrostatic pressure.

8.5 *Stiffness*—Determine the pipe stiffness ($F/\Delta y$) at 5 % deflection for the specimen, using the apparatus and procedure of Test Method D 2412, with the following exceptions permitted:

8.5.1 Measure the wall thickness to the nearest 0.01 in. (0.25 mm).

8.5.2 Load the specimen to 5 % deflection and record the load. Then load the specimen to deflection level A per Table 8 and examine the specimen for visible damage evidenced by surface cracks. Then load the specimen to deflection level B per Table 8 and examine for evidence of structural damage, as evidenced by interlaminar separation, separation of the liner or surface layer (if incorporated) from the structural wall, tensile failure of the glass-fiber reinforcement, fracture, or buckling of the pipe wall. Calculate the pipe stiffness at 5 % deflection.

8.5.3 For production testing, only one specimen need be tested to determine the pipe stiffness.

8.5.4 The maximum specimen length may be 12 in. (305 mm), or the length necessary to include stiffening ribs if they are used, whichever is greater.

NOTE 14—As an alternative to determining pipe stiffness using the apparatus and procedure of Test Method D 2412, the supplier may submit to the purchaser for approval a test method and test evaluation based on Test Method D 790 accounting for the substitution of curved test specimens and measurement of stiffness at 5 % deflection.

8.6 *Hoop-Tensile Strength*—Determine hoop tensile strength by Test Method D 2290, except that the sections on apparatus and test specimens may be modified to suit the size of the specimens to be tested, and the maximum load rate may not exceed 0.10 in./min (2.54 mm/min). Alternatively, Test

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TABLE 13 Longitudinal Tensile Strength of Pipe Wall

SI Units

Nominal Diameter, in.	Longitudinal Tensile Strength, kN/m of Circumference								
	C50	C75	C100	C125	C150	C175	C200	C225	C250
8	102	102	102	102	102	102	102	102	102
10	102	102	102	102	102	102	102	114	127
12	102	102	102	102	113	113	122	137	153
14	102	102	102	110	132	132	142	160	178
15	102	102	102	118	141	141	152	172	191
16	102	102	102	125	150	150	163	183	203
18	102	102	106	133	160	160	170	192	213
20	102	102	118	148	177	177	189	213	236
21	102	102	124	155	186	186	199	223	248
24	102	106	142	177	213	213	227	255	284
27	102	102	156	199	239	239	255	288	319
30	102	125	167	208	250	250	263	295	328
33	111	137	183	229	275	275	289	325	361
36	122	150	200	250	300	300	315	354	394
39	137	163	217	271	325	325	341	384	426
42	140	175	233	292	350	350	367	413	459
45	150	175	233	292	350	350	372	419	465
48	161	183	244	305	366	366	397	447	496
51	171	194	259	324	389	389	422	475	527
54	182	206	274	343	412	412	447	504	558
60	200	229	305	381	457	457	496	558	621
66	220	252	336	419	503	503	546	614	683
72	238	274	366	457	549	549	596	670	745
78	260	277	369	461	553	553	609	685	761
84	280	298	397	496	596	596	655	737	819
90	301	319	426	532	638	638	702	790	878
96	322	340	454	567	681	681	749	843	936
102	340	362	482	603	723	723	796	895	995
108	360	384	511	638	766	766	843	948	1 053
114	382	404	539	674	809	809	889	1 001	1 112
120	400	426	567	709	851	851	936	1 053	1 170
132	440	468	624	780	935	935	1 030	1 159	1 287
144	480	511	681	851	1 021	1 021	1 123	1 264	1 404

Method D 638 may be employed. Specimen width may be increased for pipe wall thickness greater than 0.55 in (13.97 mm). Means may be provided to minimize the bending moment imposed during the test. Three specimens shall be cut from the test sample. Record the load to fail each specimen and determine the specimen width as close to the break as possible. Use the measured width and failure load to calculate the hoop-tensile strength.

8.6.1 *Alternative Minimum Hoop-Tensile Strength Requirement*—As an alternative, the minimum hoop-tensile strength values may be determined through the use of the following formula:

$$F = (S_i/S_r)\,(P_r) \qquad (2)$$

where:

F = required minimum hoop-tensile strength, lbf/in.,
S_i = initial design hoop tensile stress, psi,
S_r = hoop tensile stress at rated operating pressure, psi,
P = rated operating pressure class, psi, and
r = inside radius of pipe, in.

The value for S_i should be established by considering the variations in glass reinforcement strength and manufacturing methods, but in any case, should not be less than the 95 % lower confidence value on stress at 0.1 h, as determined by the manufacturer's testing carried out in accordance with 6.5. The value for S_r should be established from the manufacturer's hydrostatic design basis.

NOTE 15—A value of F less than 4 Pr results in a lower factor of safety on short term loading than required by the values in Table 9.

8.7 *Longitudinal Strength* :

8.7.1 *Beam Strength*—Place a 20-ft (6.1-m) nominal length of pipe on saddles at each end. Hold the ends of the pipe round during the test. Apply the beam load for the diameter of pipe shown in Table 11 simultaneously to the pipe through two saddles located at the third points of the pipe (see Fig. 2). Maintain the loads for not less than 10 min with no evidence of failure. The testing apparatus shall be designed to minimize stress concentrations at the loading points.

8.7.2 *Longitudinal Tensile Strength*—Determine in accordance with Test Method D 638, except the provisions for maximum thickness shall not apply.

8.7.3 *Longitudinal Compressive Strength*—Determine in accordance with Test Method D 695.

9. Packaging, Marking, and Shipping

9.1 Mark each length of pipe that meets or is part of a lot that meets the requirements of this specification at least once, in letters not less than ½ in. (12 mm) in height and of bold-type style in a color and type that remains legible under normal handling and installation procedures. Include in the marking the nominal pipe size, manufacturer's name or trademark, ASTM Specification number D 3754, type, liner, grade, class, and stiffness in accordance with the designation code in 4.2.

9.2 Prepare pipe for commercial shipment in such a way as

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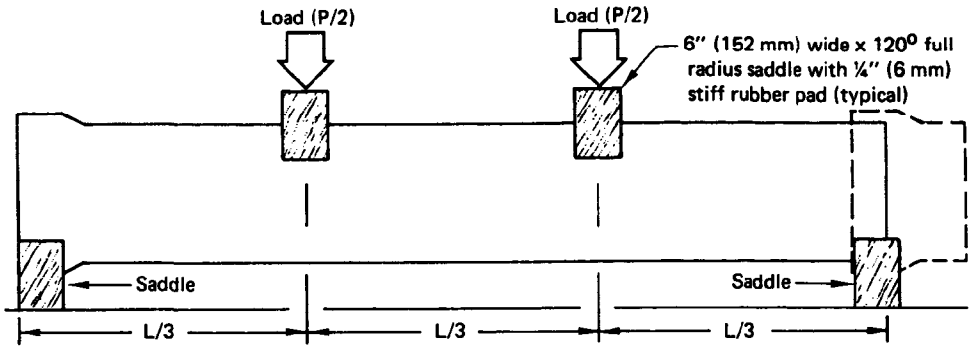

FIG. 2 Beam Strength-Test Setup

to ensure acceptance by common or other carriers.

9.3 All packing, packaging, and marking provisions of Practice D 3892 shall apply to this specification.

ANNEXES

(Mandatory Information)

A1. ALTERNATIVE HYDROSTATIC DESIGN METHOD

A1.1 The following symbols are used:

S = tensile stress in the glass-fiber reinforcement in the hoop orientation corrected for the helix angle, psi,

P = internal pressure, psig,

P_l = long-term hydrostatic pressure, psig,

D = nominal inside pipe diameter, in.,

t_h = actual cross-sectional area of glass-fiber reinforcement applied around the circumference of the pipe, $in.^2/in.$,

θ = plane angle between hoop-oriented reinforcement and longitudinal axis of the pipe (helix angle), and

HDB = hydrostatic design basis, psi.

A1.2 The hydrostatic design is based on the estimated tensile stress of reinforcement in the wall of the pipe in the circumferential (hoop) orientation that will cause failure after 50 years of continuously applied pressure, as described in 8.4 and Practice D 2992, Procedure B. Strength requirements are calculated using the strength of hoop-oriented glass reinforcements only, corrected for the helix angle of the fibers.

A1.3 *Hoop-Stress Calculation,* derived from the ISO formula for hoop stress, is as follows:

$$S = PD/2(t_h \sin \theta)$$

This stress is used as the ordinate (long-term strength) in calculating the regression line and lower confidence limit in accordance with Practice D 2992, Annexes A1 and A3.

NOTE A1.1—The calculated result for S may be multiplied by the factor 6.985 to convert from psi to kPa.

A1.4 *Hydrostatic Design Basis*—The value of S is determined by extrapolation of the regression line to 50 years in accordance with Practice D 2992.

A1.5 *Hydrostatic Design Basic Categories*—Convert the value of the HDB to internal hydrostatic pressure in psig as follows:

$$P_1 = 2\,(t_h \sin \theta)\,(\text{HDB})/D$$

The pipe is categorized in accordance with Table A1.1.

NOTE A1.2—The calculated result P_1 may be multiplied by the factor 6.895 to convert from psig to kPa.

A1.6 *Pressure Class Rating*—The classes shown in Table A1.1 are based on the intended working pressure in psig for commonly encountered conditions of water service. The purchaser should determine the class of pipe most suitable to the installation and operating conditions that will exist on the project on which the pipe is to be used by multiplying the values of P_1 from Table A1.1 by a service (design) factor selected for the application on the basis of two general groups of conditions. The first group considers the manufacturing and testing variables, specifically normal variations in the material, manufacture, dimensions, good handling techniques, and in the evaluation procedures in this method. The second group

TABLE A1.1 Long-Term Hydrostatic Pressure Categories

Class	Minimum Calculated Values of Long-Term Hydrostatic Pressure, P_1, gage, psi (kPa)
C50	90 (621)
C75	135 (931)
C100	180 (1241)
C125	225 (1551)
C150	270 (1862)
C175	315 (2172)
C200	360 (2482)
C225	405 (2792)
C250	450 (3103)

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considers the application or use, specifically installation, environment, temperature, hazard involved, life expectancy desired, and the degree of reliability selected.

NOTE A1.3—It is not the intent of this standard to give service (design) factors. The service (design) factor should be selected by the design engineer after evaluating fully the service conditions and the engineering properties of the specific pipe material under consideration. Recommended service (design) factors will not be developed or issued by ASTM.

A2. CALCULATIONS OF LOWER CONFIDENCE (LCL) AND LOWER PREDICTION (LPL) LIMITS

$$h_{LCL} = (a + bf_o) - ts\sqrt{\frac{(f_o - F)^2}{U} + \frac{1}{N}}$$

$$h_{LPL} = (a + bf_o) - ts\sqrt{\frac{(f_o - F)^2}{U} + \frac{1}{N} + 1}$$

where all symbols are as defined in Annexes A1 and A3 of Practice D 2992 except:

f_o = log of stress (strain) level of interest

NOTE A2.1—Of the expected failures at stress (strain) f_o 97.5 % will occur after h_{LPL}. The average failure time at stress (strain) f_o will occur later than h_{LCL} 97.5 % of the time.

APPENDIXES

(Nonmandatory Information)

X1. STRAIN CORROSION PERFORMANCE REQUIREMENTS

X1.1 From Molin and Leonhardt, the expression for bending strain is given as: $\epsilon_b = D_f (t/d) (\delta v/d)$. With the common acceptance that these pipes must be capable of withstanding 5 % deflection long-term, the maximum installed bending strain may be expressed as:

$$\epsilon_b \text{ max} = (0.05) (D_f) (t/d)$$

Using the AWWA C-950 long-term bending factor of safety of 1.50, the minimum strain corrosion performance extrapolated to 50 years must be:

$$E_{scv} \geq (0.075) (D_f) (t/d)$$

X1.2 The shape factor, D_f, is dependent on both the pipe stiffness and the installation (for example, backfill material, backfill density, compaction method, haunching, trench configuration, native-soil characteristics and vertical loading). Assuming conservatively, installations achieved by tamped compaction with inconsistent haunching that will limit long-term deflections to 5 %, the following values of D_f *have been selected to be realistic, representative and limiting. Substituting these values in the above equation for* E_{SCV} yields the minimum required strain corrosion performances given below and in Table 4.

Pipe Stiffness (psi)	D_f	Minimum E_{SCV} Performance
9	8.0	0.60 (t/d)
18	6.5	0.49 (t/d)
36	5.5	0.41 (t/d)
72	4.5	0.34 (t/d)

NOTE X1.1—Products may have used limits of other than 5 % long-term deflection. In such cases, the requirements should be proportionally adjusted. For example, a 4 % long-term limiting deflection would result in a 50 year requirement of 80 % of Table 4, while a 6 % limiting deflection would yield a requirement of 120 % of Table 4.

X1.3 *Alternative Strain Corrosion Test Requirements:*

X1.3.1 At 0.1 h (6 min), the required strain corrosion performance is based on the level B deflections from Table 6 as follows:

$$\epsilon \text{ test} \geq Df\left[\frac{t}{Id + \delta V/2}\right]\left[\frac{\delta V}{d + \delta V/2}\right] \quad \text{(X1.1)}$$

or

$$\epsilon \text{ test} \geq Df\,(t/d)\,(\delta V/d)\left(\frac{1}{1 + \delta V/2d}\right)^2 \quad \text{(X1.2)}$$

Df for parallel plate loading is 4.28. Making the other substitutions yield:

Pipe Stiffness (psi)	Level B $\delta v / d$ (%)	Minimum Test
9	30	0.97 (t/d)
18	25	0.85 (t/d)
36	20	0.71 (t/d)
72	15	0.56 (t/d)

X1.3.2 The minimum strain values at 10, 100, 1000, and 10 000 h given in Table 4 are defined by a straight line connecting the points at 6 min and 50 years on a log-log plot.

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X2. INSTALLATION

X2.1 This specification is a material performance and purchase specification only and does not include requirements for engineering design, pressure surges, bedding, backfill, or the relationship between earth cover load, and the strength of the pipe. However, experience has shown that successful performance of this product depends upon the proper type of bedding and backfill, pipe characteristics, and care in the field construction work. The purchaser of the fiberglass pressure pipe specified herein is cautioned that he must properly correlate the field requirements with the pipe requirements and provide adequate inspection at the job site.

X3. RECOMMENDED METHODS OF DETERMINING GLASS CONTENT

X3.1 Determine glass content as follows:

X3.1.1 By ignition loss analysis in accordance with Test Method D 2584 or ISO 1172.

X3.1.2 As a process control, by weight of the glass fiber reinforcement applied by machine into the pipe structure.

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue, D 3754–96 that may impact the use of this standard.

(1) Changed acronym, RPMP, definition from reinforced *plastic* mortar pipe to reinforced *polymer* mortar pipe.

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

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Designation: D 4000 – 01

An American National Standard

Standard Classification System for Specifying Plastic Materials[1]

This standard is issued under the fixed designation D 4000; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This standard provides a classification system for tabulating the properties of unfilled, filled, and reinforced plastic materials suitable for processing into parts.

NOTE 1—The classification system may serve many of the needs of industries using plastic materials. The standard is subject to revision as the need requires; therefore, the latest revision should always be used.

1.2 The classification system and subsequent line callout (specification) is intended to be a means of identifying plastic materials used in the fabrication of end items or parts. It is not intended for the selection of materials. Material selection should be made by those having expertise in the plastics field after careful consideration of the design and the performance required of the part, the environment to which it will be exposed, the fabrication process to be employed, the inherent properties of the material not covered in this document, and the economic factors.

1.3 This classification system is based on the premise that plastic materials can be arranged into broad generic families using basic properties to arrange the materials into groups, classes, and grades. A system is thus established which, together with values describing additional requirements, permits as complete a description as desired of the selected material.

1.4 In all cases where the provisions of this classification system would conflict with the referenced ASTM specification for a particular material, the latter shall take precedence.

NOTE 2—When using this classification system the two-letter, three-digit suffix system applies.

NOTE 3—When a material is used to fabricate a part where the requirements are too specific for a broad material callout, it is advisable for the user to consult the supplier to secure callout of the properties to suit the actual conditions to which the part is to be subjected.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies[2]

D 150 Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials[2]

D 256 Test Method for Determining the Izod Pendulum Impact Resistance of Notched Specimens of Plastics[3]

D 257 Test Methods for D-C Resistance or Conductance of Insulating Materials[2]

D 395 Test Methods for Rubber Property—Compression Set[4]

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension[4]

D 471 Test Method for Rubber Property—Effect of Liquids[4]

D 495 Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation[2]

D 569 Method for Measuring the Flow Properties of Thermoplastic Molding Materials[5]

D 570 Test Method for Water Absorption of Plastics[3]

D 573 Test Method for Rubber—Deterioration in an Air Oven[4]

D 575 Test Methods for Rubber Properties in Compression[4]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[3]

D 624 Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers[4]

D 635 Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position[3]

D 638 Test Method for Tensile Properties of Plastics[3]

D 648 Test Method for Deflection Temperature of Plastics Under Flexural Load[3]

D 695 Test Method for Compressive Properties of Rigid Plastics[3]

D 706 Specification for Cellulose Acetate Molding and

[1] This classification system is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.94 on Government/Industry Standardization (Section D20.94.01).

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[2] *Annual Book of ASTM Standards*, Vol 10.01.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 09.01.

[5] *Discontinued*—See *1994 Annual Book of ASTM Standards*, Vol 08.01.

***A Summary of Changes section appears at the end of this standard.**

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Extrusion Compounds[3]
D 707 Specification for Cellulose Acetate Butyrate Molding and Extrusion Compounds[3]
D 747 Test Method for Apparent Bending Modulus of Plastics by Means of a Cantilever Beam[3]
D 785 Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials[3]
D 787 Specification for Ethyl Cellulose Molding and Extrusion Compounds[3]
D 789 Test Methods for Determination of Relative Viscosity, Melting Point, and Moisture Content of Polyamide (PA)[3]
D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[3]
D 792 Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement[3]
D 883 Terminology Relating to Plastics[3]
D 955 Test Method for Measuring Shrinkage from Mold Dimensions of Molded Plastics[3]
D 1003 Test Method for Haze and Luminous Transmittance of Transparent Plastics[3]
D 1149 Test Method for Rubber Deterioration—Surface Ozone Cracking in a Chamber[4]
D 1203 Test Methods for Volatile Loss from Plastics Using Activated Carbon Methods[3]
D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer[3]
D 1248 Specification for Polyethylene Plastics Molding and Extrusion Materials[3]
D 1434 Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheeting[6]
D 1435 Practice for Outdoor Weathering of Plastics[3]
D 1499 Practice for Filtered Open-Flame Carbon-Arc Exposures of Plastics[3]
D 1505 Test Method for Density of Plastics by the Density-Gradient Technique[3]
D 1525 Test Method for Vicat Softening Temperature of Plastics[3]
D 1562 Specification for Cellulose Propionate Molding and Extrusion Compounds[3]
D 1600 Terminology for Abbreviated Terms Relating to Plastics[3]
D 1693 Test Method for Environmental Stress-Cracking of Ethylene Plastics[3]
D 1709 Test Methods for Impact Resistance of Plastic Film by the Free-Falling Dart Method[3]
D 1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[3]
D 1822 Test Method for Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials[3]
D 1898 Practice for Sampling of Plastics[7]
D 1929 Test Method for Ignition Properties of Plastics[3]
D 2116 Specification for FEP-Fluorocarbon Molding and Extrusion Materials[3]
D 2137 Test Methods for Rubber Property—Brittleness Point of Flexible Polymers and Coated Fabrics[4]
D 2240 Test Method for Rubber Property—Durometer Hardness[4]
D 2287 Specification for Nonrigid Vinyl Chloride Polymer and Copolymer Molding and Extrusion Compounds[3]
D 2288 Test Method for Weight Loss of Plasticizers on Heating[3]
D 2565 Practice for Operating Xenon Arc-Type Light-Exposure Apparatus With and Without Water for Exposure of Plastics[8]
D 2583 Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor[8]
D 2584 Test Method for Ignition Loss of Cured Reinforced Resins[8]
D 2632 Test Method for Rubber Property—Resilience by Vertical Rebound[4]
D 2843 Test Method for Density of Smoke from the Burning or Decomposition of Plastics[8]
D 2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)[8]
D 2951 Test Method for Resistance of Types III and IV Polyethylene Plastics to Thermal Stress-Cracking[8]
D 3012 Test Method for Thermal Oxidative Stability of Propylene Plastics, Using a Biaxial Rotator[8]
D 3029 Test Methods for Impact Resistance of Flat, Rigid Plastic Specimens by Means of a Tup (Falling Weight)[9]
D 3294 Specification for PTFE Resin Molded Sheet and Molded Basic Shapes[8]
D 3295 Specification for PTFE Tubing[8]
D 3296 Specification for FEP-Fluorocarbon Tube[8]
D 3350 Specification for Polyethylene Plastics Pipe and Fittings Materials[8]
D 3418 Test Method for Transition Temperatures of Polymers by Thermal Analysis[8]
D 3595 Specification for Polychlorotrifluoroethylene (PCTFE) Extruded Plastic Sheet and Film[8]
D 3638 Test Method for Comparative Tracking Index of Electrical Insulating Materials[10]
D 3713 Test Method for Measuring Response of Solid Plastics to Ignition by a Small Flame[11]
D 3801 Test Method for Measuring the Comparative Extinguishing Characteristics of Solid Plastics in a Vertical Position[8]
D 3892 Practice for Packaging/Packing of Plastics[8]
D 3895 Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry[8]
D 3915 Specification for Poly(Vinyl Chloride) (PVC) and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds for Plastic Pipe and Fittings Used in Pressure Applications[8]
D 3935 Specification for Polycarbonate (PC) Unfilled and Reinforced Material[8]

[6] *Annual Book of ASTM Standards*, Vol 15.09.
[7] *Discontinued*—See *1997 Annual Book of ASTM Standards*, Vol 08.01.
[8] *Annual Book of ASTM Standards*, Vol 08.02.
[9] *Discontinued*—See *1994 Annual Book of ASTM Standards*, Vol 08.02. Replaced by Test Methods D 5420 and D 5628.
[10] *Annual Book of ASTM Standards*, Vol. 10.02.
[11] Discontinued—See 1999 *Annual Book of ASTM Standards*, Vol 08.02.

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D 3965 Specification for Rigid Acrylonitrile-Butadiene-Styrene (ABS) Compounds for Pipe and Fittings[8]
D 3985 Test Method for Oxygen Gas Transmission Rate Through Plastic Film and Sheeting Using a Coulometric Sensor[6]
D 4020 Specification for Ultra-High-Molecular-Weight Polyethylene Molding and Extrusion Materials[8]
D 4066 Specification for Nylon Injection and Extrusion Materials[8]
D 4067 Specification for Reinforced and Filled Polyphenylene Sulfide Injection Molding and Extrusion Materials[8]
D 4101 Specification for Propylene Plastic Injection and Extrusion Materials[8]
D 4181 Specification for Acetal (POM) Molding and Extrusion Materials[8]
D 4203 Specification for Styrene-Acrylonitrile (SAN) Injection and Extrusion Materials[8]
D 4216 Specification for Rigid Poly(Vinyl Chloride (PVC) and Related Plastic Building Products Compounds[8]
D 4329 Practice for Operating Light and Water Apparatus (Fluorescent UV Condensation Type) for Exposure of Plastics[12]
D 4349 Specificaton for Polyphenylene Ether (PPE) Materials[12]
D 4364 Practice for Performing Accelerated Outdoor Weathering of Plastics Using Concentrated Natural Sunlight[12]
D 4396 Specification for Rigid Poly(Vinyl Chloride) (PVC) and Related Plastic Compounds for Nonpressure Piping Products[12]
D 4441 Specification for Aqueous Dispersions of Polytetrafluorethylene[12]
D 4474 Specification for Styrenic Thermoplastic Elastomer Injection Molding and Extrusion Materials (TES)[12]
D 4507 Specification for Thermoplastic Polyester (TPES) Materials[13]
D 4549 Specification for Polystyrene Molding and Extrusion Materials (PS)[12]
D 4550 Specification for Thermoplastic Elastomer-Ether-Ester (TEEE)[12]
D 4617 Specification for Phenolic Compounds (PF)[12]
D 4634 Specification for Styrene-Maleic Anhydride Materials (S/MA)[12]
D 4673 Specification for Acrylonitrile-Butadiene-Styrene (ABS) Molding and Extrusion Materials[12]
D 4745 Specification for Filled Compounds of Polytetrafluoroethylene (PTFE) Molding and Extrusion Materials[12]
D 4812 Test Method for Unnotched Cantilever Beam Impact Strength of Plastics[12]
D 4894 Specification for Polytetrafluoroethylene (PTFE) Granular Molding and Ram Extrusion Materials[12]
D 4895 Specification for Polytetrafluoroethylene (PTFE) Resins Produced from Dispersion[12]
D 4976 Specification for Polyethylene Plastics Molding and Extrusion Materials[12]
D 5021 Specification for Thermoplastic Elastomer–Chlorinated Ethylene Alloy (TECEA)[12]
D 5046 Specification for Fully Crosslinked Elastomeric Alloys (FCEAs)[12]
D 5138 Specification for Liquid Crystal Polymers (LCP)[12]
D 5203 Specification for Polyethylene Plastics Molding and Extrusion Materials from Recycled Post-Consumer HDPE Sources[12]
D 5279 Test Method for Measuring the Dynamic Mechanical Properties of Plastics in Torsion[12]
D 5420 Test Method for Impact Resistance of Flat, Rigid Plastic Specimen by Means of a Striker Impacted by a Falling Weight (Gardner Impact)[12]
D 5436 Specification for Cast Poly(Methyl Methacrylate) Plastic Rods, Tubes, and Shapes[12]
D 5628 Test Method for Impact Resistance of Flat, Rigid Plastic Specimens by Means of a Falling Dart (Tup or Falling Weight)[12]
D 5676 Specification for Recycled Polystyrene Molding and Extrusion Materials[12]
D 5990 Classification System for Polyketone Injection and Extrusion Materials (PK)[12]
D 6339 Specification for Syndiotactic Polystyrene Molding and Extrusion (SPS)[12]
D 6358 Classification System for Poly(Phenylene Sulfide) Injection Molding and Extrusion Materials Using ISO Methods[12]
D 6360 Practice for Enclosed Carbon-Arc Exposures of Plastics[12]
D 6457 Specification for Extruded and Compression Molded Rod and Heavy-Walled Tubing Made from Polytetrafluoroethylene (PTFE)[12]
D 6585 Specification for Unsintered Polytetrafluoroethylene (PTFE) Extruded Film or Tape[12]
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[14]
E 84 Test Method for Surface Burning Characteristics of Building Materials[15]
E 96 Test Methods for Water Vapor Transmission of Materials[16]
E 104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions[17]
E 162 Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source[15]
F 372 Test Method for Water Vapor Transmission of Flexible Barrier Materials Using an Infrared Detection Technique[6]

2.2 *Federal Standard:*[18]

Department of Transportation Federal Motor Vehicle Safety Standard No. 302

[12] *Annual Book of ASTM Standards*, Vol 08.03.
[13] *Discontinued*—See *1998 Annual Book of ASTM Standards*, Vol 08.03. Replaced by Specification D 5927.
[14] *Annual Book of ASTM Standards*, Vol 14.02.
[15] *Annual Book of ASTM Standards*, Vol 04.07.
[16] *Annual Book of ASTM Standards*, Vol 04.06.
[17] *Annual Book of ASTM Standards*, Vol 11.03.
[18] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

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2.3 *Underwriters Laboratories:*[19]

UL94 Standards for Tests for Flammability for Parts in Devices and Appliances

2.4 *IEC and ISO Standards:*[20]

IEC 93 Recommended Methods of Tests for Volume and Surface Resistivities of Electrical Insulation Materials

IEC 112 Recommended Method for Determining the Comparative Tracking Index of Solid Insulation Materials Under Moist Conditions

IEC 243 Recommended Methods of Test for Electrical Strength of Solid Insulating Materials at Power Frequencies

IEC 250 Recommended Methods for the Determination of the Permittivity and Dielectric Dissipation Factor of Electrical Insulation Materials at Power, Audio, and Radio Frequencies Including Metre Wavelengths

IEC 60695-11-10: Fire Hazard Testing—Part 11-10: Test Flames—50 W Horizontal and Vertical Flame Tests

ISO 62 Plastics—Determination of Water Absorption

ISO 75-1 Plastics—Determination of Temperature of Deflection Under Load—Part 1: General Principles

ISO 75-2 Plastics—Determination of Temperature of Deflection Under Load—Part 2: Plastics and Ebonite

ISO 178 Plastics—Determination of Flexural Properties of Rigid Plastics

ISO 179 Plastics—Determination of Charpy Impact Strength of Rigid Materials

ISO 180 Plastics—Determination of Izod Impact Strength of Rigid Materials

ISO 294-4 Plastics—Injection Moulding of Test Specimens of Thermoplastic Materials—Part 4: Determination of Moulding Shrinkage

ISO 527–1 Plastics—Determination of Tensile Properties—Part 1: General Principles

ISO 527-2 Plastics—Determination of Tensile Properties—Part 2: Test Conditions for Moulding and Extrusion Plastics

ISO 604 Plastics—Determination of Compressive Properties

ISO 868 Plastics—Determination of Indention Hardness by Means of a Durometer (Shore Hardness)

ISO 877 Plastics—Determination of Resistance to Change Upon Exposure Under Glass to Daylight

ISO 974 Plastics—Determination of the Brittleness Temperature by Impact

ISO 1183 Plastics—Methods for Determining the Density and Relative Density of Non-Cellular Plastics

ISO 2039-2 Plastics—Determination of Hardness—Part 2: Rockwell Hardness

ISO 3795 Road Vehicles, Tractors, and Machinery for Agriculture and Forestry—Determination of Burning Behavior of Interior Materials

ISO 4577 Plastics—Polypropylene and Propylene—Copolymers—Determination of Thermal Oxidative Stability in Air-Oven Method

ISO 4589 Plastics—Determination of Flammability by Oxygen Index

ISO 4607 Plastics—Method of Exposure to Natural Weathering

ISO 4892 Plastics—Methods of Exposure to Laboratory Light Sources

ISO 4892–4 Plastics—Methods of Exposure to Laboratory Light Sources—Part 4: Open-flame Carbon-arc

ISO 6603-1 Plastics—Determination of Multiaxial Impact Behavior of Rigid Plastics—Part 1: Falling Dart Method

ISO 6721-1 Plastics—Determination of Dynamic Mechanical Properties—Part 1: General Principles

ISO 6721-2 Plastics—Determination of Dynamic Mechanical Properties—Part 2: Torsion-Pendulum Method

ISO 11357-1 Plastics—Differential Scanning Calorimetry—Part 1: General principles

ISO 11357-3 Plastics—Differential Scanning Calorimetry—Part 3: Determination of Temperature and Enthalpy of Melting and Crystallization

[19] Available from Underwriters Laboratories, Inc., Publication Stock, 333 Pfingsten Rd., Northbrook, IL 60062.

[20] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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TABLE 1 Standard Symbols for Generic Families With Referenced Standards and Cell Tables

Standard Symbol	Plastic Family Name	ASTM[A] Standard	Suggested Reference Cell Tables for Materials Without an ASTM Standard[B]	
			Unfilled	Filled
ABA	acrylonitrile-butadiene-acrylate		E	
ABS	acrylonitrile-butadiene-styrene	D 3965 D 4673		
AMMA	acrylonitrile-methyl methacrylate		E	
ARP	aromatic polyester	(see LCP)		
ASA	acrylonitrile-styrene-acrylate		E	
CA	cellulose acetate	D 706		
CAB	cellulose acetate butyrate	D 707		
CAP	cellulose acetate proprionate		E	D
CE	cellulose plastics, general		E	D
CF	cresol formaldehyde		H	H
CMC	carboxymethyl cellulose		E	
CN	cellulose nitrate		E	D
CP	cellulose propionate	D 1562		
CPE	chlorinated polyethylene		F	
CPVC	chlorinated poly(vinyl chloride)	D 4396, D 1784, D 5260, D 3915, D 4216		
CS	casein		H	H
CTA	cellulose triacetate		E	D
EC	ethyl cellulose	D 787	E	D
E-CTFE	ethylene-chlorotrifluoroethylene copolymer	D 3275		
EEA	ethylene-ethyl acrylate		F	
EMA	ethylene-methacrylic acid		F	
EP	epoxy, epoxide		H	H
EPD	ethylene-propylene-diene			
EPM	ethylene-propylene polymer		F	D
ETFE	ethylene-tetrafluoroethylene copolymer	D 3159		
EVA	ethylene-vinyl acetate		F	
FCEA	fully crosslinked elastomeric alloy	D 5046		
FEP	perfluoro (ethylene-propylene) copolymer	D 2116		
FF	furan formaldehyde	D 3296	H	H
IPS	impact polystyrene	(see PS)		
LCP	liquid crystal polymer	D 5138		
MF	melamine-formaldehyde		H	H
PA	polyamide (nylon)	D 4066		
PAEK	polyaryletherketone	D __		
PAI	polyamide-imide	D 5204	G	G
PARA	polyaryl amide			
PB	polybutene-1		F	
PBT	poly(butylene terephthalate)	(see TPES)		
PC	polycarbonate	D 3935		
PCTFE	polymonochlorotrifluoroethylene	D 1430, D 3595		
PDAP	poly(diallyl phthalate)		H	H
PE	polyethylene	D 1248, D 4976, D 3350, D 4020, D 5203		
PEBA	polyether block amide			
PEEK	polyetheretherketone			
PEI	polyether-imide	D 5205		
PEO	poly(ethylene oxide)	D __		
PESV	polyether sulfone			
PET	poly(ethylene terephthalate), general	(see TPES)		
PETG	glycol modified polyethylene terephthalate comonomer	(see TPES)		
PF	phenol-formaldehyde	D 4617		
PFA	perfluoro alkoxy alkane	D 3307		
PI	polyimide		G	G
PIB	polyisobutylene		F	
PK	polyketone	D 5990		
PMMA	Poly(methyl methacrylate)	D 788, D 5436		D
PMP	poly(4-methylpentene-1)		F	
POM	polyoxymethylene (acetal)	D 4181		
POP	polyphenylene oxide	(see PPE)		
PP	poly(propylene plastics)	D 4101		
PPA	polyphthalamide	D 5336		
PPE	polyphenylene ether	D 4349		
PPOX	poly(propylene oxide)			
PPS	poly(phenylene sulfide)	D 4067, D 6358		
PPSU	poly(phenyl sulfone)		G	G
PS	polystyrene	D 4549, D 5676		
PSU	polysulfone	D 6394		
PTFE	polytetrafluoroethylene	D 3294, D 3295, D 4441, D 4745, D 4894, D 4895, D 6457, D 6585		
PUR	polyurethane		F	D

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TABLE 1 *Continued*

Standard Symbol	Plastic Family Name	ASTM[A] Standard	Suggested Reference Cell Tables for Materials Without an ASTM Standard[B]	
			Unfilled	Filled
PVAC	poly(vinyl acetate)		F	D
PVAL	poly(vinyl alcohol)		F	D
PVB	poly(vinyl butyral)		F	D
PVC	poly(vinyl chloride)	D 2287	F	D
PVDC	poly(vinyl idene chloride)		F	D
PVDF	poly(vinyl idene fluoride)	D 3222		
PVF	poly(vinyl fluoride)		F	D
PVFM	poly(vinyl formal)		F	D
PVK	poly(vinylcarbazole)		F	D
PVP	poly(vinyl pyrrolidone)		F	D
SAN	styrene-acrylonitrile	D 4203		
SB	styrene-butadiene		E	D
SI	silicone plastics		G	G
S/MA	styrene-maleic anhydride	D 4634		
SMS	styrene-methylstyrene		E	D
SPS	syndiotactic polystyrene	D 6339		
TECEA	thermoplastic elastomer-chlorinated ethylene alloy	D 5021		
TEEE	thermoplastic elastomer, ether-ester	D 4550		
TEO	thermoplastic elastomer-olefinic	D 5593		
TES	thermoplastic elastomer-stryenic	D 4474		
TPE	thermoplastic elastomer	(see individual material)		
TPES	thermoplastic polyester (general)	D 4507		
TPU	thermoplastic polyurethane	D 5476		
UF	urea-formaldehyde		H	H
UP	unsaturated polyester	D __		
VDF	vinylidene fluoride	D 5575		

[A]The standards listed are those in accordance with this classification. D __ indicates that a standard is being developed by the subcommittee responsible.

[B]Cell Tables A and B have been reserved for the referenced standards and will apply to unfilled and filled materials covered in those standards.

3. Terminology

3.1 *Definitions*—The definitions used in this classification system are in accordance with Terminology D 883.

4. Significance and Use

4.1 The purpose of this classification system is to provide a method of adequately identifying plastic materials in order to give industry a system that can be used universally for plastic materials. It further provides a means for specifying these materials by the use of a simple line call-out designation.

4.2 This classification system was developed to permit the addition of property values for future plastics.

5. Classification

5.1 Plastic materials shall be classified on the basis of their broad generic family. The generic family is identified by letter designations as found in Table 1. These letters represent the standard abbreviations for plastics in accordance with Terminology D 1600.

NOTE 4—For example: PA = polyamide (nylon).

5.1.1 The generic family is based on the broad chemical makeup of the base polymer. By its designation, certain inherent properties are specified.

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TABLE 2 Reinforcement-Filler[A] Symbols[B] and Tolerances

Symbol	Material	Tolerance
C	Carbon and graphite fiber-reinforced	±2 percentage points
G	Glass-reinforced	±2 percentage points
L	Lubricants (for example, PTFE, graphite, silicone, and molybdenum disulfide)	depends upon material and process—to be specified.
M	Mineral-reinforced	±2 percentage points
R	Combinations of reinforcements and fillers	±3 percentage points (based on the total reinforcements or fillers, or both)

[A]Ash content of filled or reinforced materials may be determined using Test Method D 2584 where applicable.
[B]Additional symbols will be added to this table as required.

TABLE 3 Suffix Symbols and Requirements[A]

Symbol	Characteristic
A	Color (unless otherwise shown by suffix, color is understood to be natural) Second letter A = does not have to match a standard B = must match standard Three-digit number 001 = color and standard number on drawing 002 = color on drawing
B	Fluid resistance Second letter A = reference fuel A, ASTM D 471, aged 70 h at 23 ± 2°C B = reference fuel C, ASTM D 471, aged 70 h at 23 ± 2°C C = ASTM #1 oil, ASTM D 471, aged 70 h at 100 ± 2 °C D = IRM 902 oil, ASTM D 471, aged 96 h at 100 ± 2°C E = IRM 903 oil, ASTM D 471, aged 70 h at 100 ± 2°C F = Distilled water, ASTM D 471, aged 70 h at 100 ± 2°C Three digit number is obtained from Suffix Table 1. It indicates change in hardness, tensile strength, elongation, and volume. Example: BC 132 specifies that material, after aging in ASTM #1 oil for 70 h at 100°C, can have changed no more than 2 Shore D points, 5 % tensile strength, 15 % elongation, and 5 % in volume.
C	Melting point—softening point Second letter B = ASTM D 1525, load 10 N, Rate A (Vicat) C = ASTM D 1525, load 10 N, Rate B (Vicat) D = ASTM D 3418 (Transition temperature DSC/DTA) (ISO 11357-1 and 11357-3) G = ISO 306, load 10 N, heating rate 50°C/h (Vicat) H = ISO 306, load 10 N, heating rate 120°C/h (Vicat) I = ISO 306, load 50 N, heating rate 50°C/h (Vicat) J = ISO 306, load 50 N, heating rate 120°C/h (Vicat) K = ASTM D 1525, load 50 N, Rate A (Vicat) L = ASTM D 1525, load 50 N, Rate B (Vicat) Three-digit number = minimum value° C
E	Electrical Second letter A = dielectric strength (short-time), ASTM D 149 (IEC 243) Three-digit number × factor of 0.1 = kV/mm, min B = dielectric strength (step by step), ASTM D 149 (IEC 243) Three-digit number × factor of 0.1 = kV/mm, min C = insulation resistance, ASTM D 257 (IEC 93) Three-digit number × factor of 10^{14} = Ω, min D = dielectric constant at 1 MHz, ASTM D 150, max (IEC 250) Three-digit number × factor of 0.1 = value E = dissipation factor at 1 MHz, ASTM D 150, max (IEC 250) Three-digit number × factor of 0.0001 = value F = arc resistance, ASTM D 495, min Three-digit number = value G = volume resistivity, ASTM D 257 (IEC 93) Three-digit number × factor of 10^{14} = Ω-cm, min H = comparative tracking index, ASTM D 3638, ac frequency, 50 Hz, 0.1 % ammonium chloride (IEC 112) Three-digit number = V, min J = volume resistivity, ASTM D 257 (IEC 93), Ω-cm K = surface resistivity, ASTM D 257 (IEC 93), Ω (per square) First digit indicates: 1 = minimum requirement 2 = maximum requirement Final two digits indicate the exponential value of the base 10 Example: EJ206 specifies a maximum volume resistivity of 10^6Ω-cm
F	Flammability Second letter A = ASTM D 635 (burning rate) (IEC 60695-11-10) 000 = to be specified by user B = ASTM D 2863 (oxygen index) (ISO 4589) Three-digit number = value %, max C = ASTM D 1929, Procedure A (flash-ignition)

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TABLE 3 *Continued*

Symbol	Characteristic
	Three-digit number = value,° C, min
	D = ASTM D 1929, Procedure B (self-ignition)
	Three-digit number = value,° C, min
	E = ASTM D 3713
	000 = to be specified by user
	F = ASTM D 3801
	000 = to be specified by user
	G = ASTM E 162
	First two digits indicate minimum specimen thickness
	00 to be specified; 05 3.00 mm
	01 0.25 mm; 06 6.00 mm
	02 0.40 mm; 07 9.00 mm
	03 0.80 mm; 08 12.70 mm
	04 1.60 mm; 09 >12.70 mm
	Third digit indicates the flame spread
	1 15 max; 5 100 max
	2 25 max; 6 150 max
	3 50 max; 7 200 max
	4 75 max; 8 >200
	H = E84
	000 = to be specified by user
	J = FMVSS 302 (ISO 3795)
	000 = to be specified by user
	K = density of smoke, ASTM D 2843
	000 = to be specified by user
	L = UL 94 (IEC 60695-11-10)
	First digit indicates minimum specimen thickness
	Molding Materials Thin Films
	mm; µm
	0 to be specified; to be specified
	1 0.25; 25.0
	2 0.40; 50.0
	3 0.80; 75.0
	4 1.60; 100.0
	5 2.50; 125.0
	6 3.00; 150.0
	7 6.00; 175.0
	8 12.70; 200.0
	9 >12.70; >200.0
	Second digit indicates type of flame test
	1 = Vertical (94V)
	1 = Horizontal (94H)
	3 = 125mm flame (94-5V)
	4 = Vertical thin materials (94VTM)
	Third digit indicates the flame rating
	0 = (94V/94VTM) 0 - refer to UL94
	1 = (94V/94VTM) 1 - refer to UL94
	2 = (94V/94VTM) 2 - refer to UL94
	3 = (94HB) 1 - burn rate < 40 mm/min
	4 = (94HB) 2 - burn rate < 75 mm/min
	5 = (94-5V) A no holes on plaques
	6 = (94-5V) B with holes on plaques
	7 = (94 foam) 1 refer to UL94
	8 = (94 foam) 2 refer to UL94
	9 = (94 foam) H refer to UL94
G	Specific gravity
	Second letter A = ASTM D 792 (tolerance ± 0.02) (ISO 1183 Method A)
	B = ASTM D 792 (tolerance ± 0.05) (ISO 1183 Method A)
	C = ASTM D 792 (tolerance ± 0.005) (ISO 1183 Method A)
	D = ASTM D 1505 (tolerance ± 0.02)
	E = ASTM D 1505 (tolerance ± 0.05)
	F = ASTM D 1505 (tolerance ± 0.005)
	H = ASTM D 792/D 1505 (max)
	L = ASTM D 792/D 1505 (min)
	Three-digit number × factor of 0.010 = requirement value
H	Heat resistance, properties at temperature
	Second letter A = heat aged for 70 h at 100 ± 2°C, ASTM D 573
	B = heat aged for 70 h at 150 ± 2°C, ASTM D 573
	C = heat aged for 70 h at 200 ± 2°C, ASTM D 573
	Three-digit number is obtained from Suffix Table 1. It indicates change in hardness, tensile strength, elongation and volume.
	Second letter D = tested at 100 ± 2°C
	E = tested at 125 ± 2°C
	F = tested at 150 ± 2°C
	Three-digit numbers obtained from Suffix Table 2. It indicates tensile strength, elongation, and tear strength.

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TABLE 3 *Continued*

Symbol	Characteristic
	Example: HE565 specifies that the material has a minimum of 15 MPA tensile strength, 400 % elongation, and a tear strength of 40 kN/m when tested at 125°C.
	Second letter L = low-temperature brittleness, ASTM D 2137
	Three-digit number indicates the temperature (°C) above which the material is non-brittle. Example: HL055 material is non-brittle according to ASTM D 2137a, above – 55°C.
I	Not to be used at this time
J	Hardness
	Second letter A = ASTM D 2240 (Shore A) tolerance ±5 (ISO 868)
	B = ASTM D 2583 (Barcol), min
	D = ASTM D 2240 (Shore D) tolerance ±3 (ISO 868)
	E = ASTM D 785 (Rockwell E), min
	K = ASTM D 785 (Rockwell K), min
	L = ASTM D 785 (Rockwell L), min (ISO 2039-2)
	M = ASTM D 785 (Rockwell M), min (ISO 2039-2)
	R = ASTM D 785 (Rockwell R), min (ISO 2039-2)
	Three-digit number = value
K	Tensile strength
	Second letter B = at break, ASTM D 638
	C = at rupture, ASTM D 412
	D = tensile stress at break, ISO 527-1 and 527-2
	E = tensile stress at 50 % strain, ISO 527-1 and 527-2
	Three-digit number = value, MPa, min
	Example: KC040 specifies a tensile strength at rupture of 40 MPa
	M = tensile stress, ASTM D 412
	First digit indicates the elongation at which the tensile stress is measured.
	1 = 25 %
	2 = 100 %
	3 = 300 %
	Final two digits = value, MPa, min
	N = tensile modulus, ISO 527-1 and 527-2
	Three-digit number × factor of 100 = value, MPa, min
	S = tensile set, ASTM D 412
	First digit indicates the elongation at which the set is measured.
	1 = 50 %
	2 = 100 %
	3 = at break
	4 = 200 %
	Final two digits indicate the maximum percent set.
	Example: KS208 specifies a maximum tensile set of 8 % when tested at 100 % extension.
	Y = yield, ASTM D 638
	X = tensile stress at yield, ISO 527-1 and 527-2
	Three-digit number = value, MPa, min
L	Elongation
	Second letter B = break, ASTM D 638
	C = break, ASTM D 412
	D = break, ISO 527
	Three-digit number = value, %, min
	R = resilience, ASTM D 2632
	First digit:
	1 = minimum
	2 = maximum
	Final two digits indicate percent rebound
	Example: LR 150 specifies a minimum rebound of 50 %
	T = tear strength, ASTM D 624 Die C
	Three-digit number = value, kN/m, min
	Y = yield, ASTM D 638
	X = yield, ISO 527
	Three-digit number = value, %, min
M	Moisture resistance or content
	Second letter A = ASTM D 570 (24-h immersion) (ISO 62)
	B = ASTM D 570 (2-h immersion)
	C = ASTM D 570 (long-term immersion)
	D = ASTM D 570 (½-h boiling water immersion)
	E = ASTM D 570 (48 h at 50°C immersion)
	F = ASTM D 789 (ISO 15512, Method B), moisture content
	Three-digit number × factor of 0.01 = value, percent max
N	Flexural strength
	Second letter A = ASTM D 790, specimen = 3.2 × 13 × 76 mm, speed = 1.3 mm/min
	B = ASTM D 790, specimen = 6.4 × 13 × 127 mm, speed = 2.7 mm/min
	C = ISO 178, specimen = 80 × 10 × 4 mm, speed = 2 mm/min, 64-mm span
	Three-digit number = value, MPa, min
O	Not to be used at this time
P	Impact resistance
	Second letter A = ASTM D 256 (Test Method A, Izod)

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TABLE 3 *Continued*

Symbol	Characteristic
	000 = no break
	Three-digit number = value, J/m, min
	B = ASTM D 256 (Test Method B, Charpy)
	Three-digit number = value, J/m, min
	C = ASTM D 256 (Test Method C)
	Three-digit number = value, J/m, min
	D = ASTM D 256 (Test Method D)
	Three-digit number = value, J/m, min
	E = ASTM D 256 (Test Method E)
	Three-digit number = value, J/m, min
	F = ASTM D 5628
	1 = Configuration FA
	2 = Configuration FB
	3 = Configuration FC
	4 = Configuration FD
	5 = Configuration FE
	Two-digit number × 10 = value, J, min
	G = ASTM D 5420
	1 = ASTM D 5420 Configuration GA
	2 = ASTM D 5420 Configuration GB
	3 = ASTM D 5420 Configuration GC
	4 = ASTM D 5420 Configuration GD
	5 = ASTM D 5420 Configuration GE
	Two-digit number × 10 = value, J min
	H = ISO 6603-1, specimen = 2-mm thickness
	Three-digit number = value, J
	J = low-temperature brittleness, ISO 974
	Three-digit number = −°C, max
	K = ASTM D 4812
	Three-digit number × factor 10 = value, J/m, min
	000 = no break
	L = Low temperature brittleness, ASTM D 746 (Procedure A)
	Three-digit number = −°C, max
	M = ISO 180/1A (Izod), specimen = 80 · 10 · 4 mm
	N = ISO 179/1A (Charpy), specimen = 80 · 10 · 4 mm
	Three-digit number × factor 0.1 = value kJ/m^2, min
	S = ASTM D 1822, Type S, 3 mm thick
	T = ASTM D 1822, Type L, 3 mm thick
	Three-digit number = value, kJ/m^2, min
Q	Compressive strength
	Second letter A = ASTM D 695
	B = ISO 604
	Three-digit number = value, MPa, min
	D = compression deflection, ASTM D 575, Test Method A
	First digit = % deflection
	1 = 5 %
	2 = 10 %
	3 = 15 %
	4 = 20 %
	5 = 25 %
	6 = 30 %
	7 = 40 %
	8 = 50 %
	Final two digits indicate minimum load in MPa
	Example: QD445 specifies a minimum load of 45 MPa when deflected 20 %
	S = compression set, ASTM D 395, (Test Method B), run for 22 h.
	First digit = test temperature
	1 = 23± 2°C
	2 = 70± 2°C
	3 = 100± 2°C
	4 = 125± 2°C
	5 = 150± 2°C
	Final two digits indicate maximum percent set.
R	Volatile loss, gas and vapor permeability
	Second letter A = ASTM D 1203, Test Method A
	B = ASTM D 1203, Test Method B
	C = ASTM D 2288
	D = ASTM D 2584
	Three-digit number × factor of 0.01 = value, percent, max
	E = ASTM D 3985
	F = ASTM D 1434 (Test Method M)
	G = ASTM E 96 (Test Method E)
	H = ASTM F 372
	First digit 1 = oxygen

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TABLE 3 *Continued*

Symbol	Characteristic
	2 = nitrogen 3 = carbon dioxide 4 = water vapor 5 = hydrogen 6 = methane 7 = Fuel C 8 = helium 9 = hydrogen sulfide
	Second and third digit = value 00 = between user and producer 01 = 1.0 cm^3·mil/m^2·24 h·atm, max 02 = 10.0 cm^3·mil/m^2·24 h·atm, max 03 = 100.0 cm^3·mil/m^2·24 h·atm, max 04 = 1.0 g·mil/m^2·24 h, max 05 = 10.0 g·mil/m^2·24 h, max 06 = 100.0 g·mil/m^2·24 h, max (04 to 06 are water vapor units) These units are currently the industry standard. Conversions to other units may be made using appendixes in ASTM D 1434.
S	Oxidative stability, mold shrinkage, and shear modulus Oxidative stability tests Second letter A = ASTM D 3012 at 150°C (ISO 4577) Three-digit number = value days to failure, min C = ASTM D 3895 Three-digit number = value minutes to failure, min E = environmental stress crack resistance, ASTM D 1693 Three-digit number = f_{20} h, min T = thermal stress crack resistance, ASTM D 2951 Three-digit number = h (without cracking), min Mold shrinkage tests H = ASTM D 955 Mold shrinkage First digit 1 = Compression molded bar 2 = Compression molded disk 3 = Transfer molded bar 4 = Transfer molded disk 5 = Injection molded bar 6 = Injection molded disk 7 = Injection molded plaque, 60 × 60 × 2 mm (ISO 294-4) Two-digit number × factor 0.001 = value, mm/mm ± 0.001 Shear modulus tests M = ASTM D 5279, +23°C, 1 Hz (ISO 6721-1 and 6722-2) Three-digit number × factor 100 = value, MPa, min
T	Transmission-haze Second letter A = ASTM D 1003, specimen 6.4 mm thick B = ASTM D 1003, specimen 3.2 mm thick C = ASTM D 1003, specimen 1.6 mm thick First digit 1 = total luminous transmittance, min 2 = diffuse luminous transmittance, min 3 = haze, %, max Second and third digit = value
U	Flexural modulus, stiffness Second letter A = ASTM D 790, specimen = 3.2 by 13 by 76 mm, speed = 1.3 mm/min B = ASTM D 790, specimen = 6.4 by 13 by 127 mm, speed = 2.7 mm/min C = ASTM D 790 (secant modulus), Test Method I, Procedure A, specimen = 3.2 by 13 mm (1 % strain) speed = 1.3 mm/min Three-digit number × factor 100 = value, MPa, min D = stiffness, ASTM D 747 First digit 1 = −30°C Second and third digits × 1000 = value, MPa, max First digit 2 = 23°C 3 = 70°C Second and third digits × 1000 = value, MPa, min Second letter E = ASTM D 790, specimen-3.2 by 13 by 76 mm, speed – 1.3 mm/min F = ASTM D 790, specimen = 6.4 by 13 by 127 mm, speed = 2.7 mm/min G = ASTM D 790 (secant modulus), Method I, Procedure A, specimen = 3.2 by 13 by 76 (1 % strain) speed = 1.3 mm/min M = ISO 178, chord modulus, specimen 80 × 10 × 4 mm, speed 2 mm/min, 64 mm span Three digit number × factor 100 = value, MPa, max N = ISO 178, chord modulus, specimen 80 × 10 × 4 mm, speed = 2 mm/min, 64-mm span Three digit number × factor 100 = value, MPa, min
V	Viscosity—flow rate Second Letter A = relative viscosity, ASTM D 789 Three-digit number = value, min Second letter B = ASTM D 1238 First digit 1 = Condition 125/0.325 2 = Condition 125/2.16

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TABLE 3 *Continued*

Symbol	Characteristic
	3 = Condition 150/2.16
	4 = Condition 190/0.325
	5 = Condition 190/2.16
	6 = Condition 190/21.60
	7 = Condition 200/5.0
	8 = Condition 230/1.20
	9 = Condition 230/3.80
	0 = Condition 265/12.5
	Second letter C = ASTM D 1238
	First digit 1 = Condition 275/0.325
	2 = Condition 230/2.16
	3 = Condition 190/1.05
	4 = Condition 190/10.00
	5 = Condition 300/1.20
	6 = Condition 190/5.0
	7 = Condition 235/1.05
	8 = Condition 235/2.16
	9 = Condition 235/5.0
	0 = Condition 250/2.16
	Second letter D = ASTM D 1238
	First digit 1 = Condition 310/12.5
	2 = Condition 210/2.16
	3 = Condition 285/2.16
	4 = Condition 315/5.0
	For second letters B, C, and D
	Second and third digit = value
	01 = 0.1 max
	02 = >0.1 to 0.3
	03 = >1 to 4
	04 = >0.3 to 0.5
	05 = >4 to 6
	06 = >0.5 to 0.7
	07 = >6 to 8
	08 = >0.7 to 0.9
	09 = >8 to 10
	10 = >0.9 to 1.1
	15 = >10 to 20
	25 = >20 to 30
	35 = >30 to 40
	45 = >40 to 50
	55 = >50 to 60
	65 = >60 to 70
	75 = >70 to 80
	85 = >80 to 90
	95 = >90 to 100
	99 = >100
	E = flow temperature, ASTM D 569
	Three-digit number = minimum value °C
W	Weather resistance
	Second letter A = ASTM D 1435 (ISO 4607)
	First digit 1 = tensile strength change
	2 = flexural strength change
	3 = flexural modulus change
	4 = weight change
	5 = elongation change
	6 = dimensional change
	Second and third digit = value, percent, max
	B = (enclosed carbon-arc type), ASTM D 6360
	000 = to be specified by user
	C = Ozone resistance, ASTM D 1149 (100-ppm ozone)
	Three-digit number × factor of 10 = h for first crack, min
	D = (fluorescent-UV-condensation type) ASTM D 4329 (ISO 4892-3)
	E = (xenon-arc type) ASTM D 2565 (ISO 4892-2)
	F = (fresnel concentrator type) ASTM D 4364 (ISO 877)
	G = (open-flame carbon-arc) ASTM D 1499 (ISO 4892–4)
	000 = to be specified by user
X	Humidity aging and accelerated service
	Second letter A = ASTM E 104, Test Method A
	B = ASTM E 104, Test Method B
	C = ASTM E 104, Test Method C
	First digit 1 = tensile strength change
	2 = flexural strength change
	3 = flexural modulus change
	4 = weight change

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TABLE 3 *Continued*

Symbol	Characteristic
	5 = elongation change
	6 = dimensional change
	Second and third digit = value, %, max
Y	Deflection temperature
	Second letter A = ASTM D 648, stress 1.82 MPa, unannealed specimen, width, 3.2 mm
	B = ASTM D 648, stress 1.82 MPa, unannealed specimen, width, 6.4 mm
	C = ASTM D 648, stress 1.82 MPa, unannealed specimen, width, 13 mm
	D = ASTM D 648, stress 0.455 MPa, unannealed specimen, width, 3.2 mm
	E = ASTM D 648, stress 0.455 MPa, unannealed specimen, width, 6.4 mm
	F = ASTM D 648, stress 0.455 MPa, unannealed specimen, width, 13 mm
	G = ISO 75-1 and 75-2, stress 1.80 MPa, unannealed specimen, positioned edgewise
	H = ISO 75-1 and 75-2, stress 0.450 MPa, unannealed specimen, positioned edgewise
	I = ISO 75-1 and 75-2, stress 1.80 MPa, unannealed specimen, positioned flatwise
	J = ISO 75-1 and 75-2, stress 0.450 MPa, unannealed specimen, positioned flatwise
	Three-digit number = value, °C, min
Z	Other special requirement
	Second letter from existing list of symbols where test or requirement is not available.
	These characteristics will be spelled out in detail and identified in sequence that is, 01, 02, 03, etc.
	Example ZW01
	Type I, tensile bars (ASTM D 638) when exposed 500 h to Type DH light source per ASTM G 151 and G 153 shall retain 50 % min of their original tensile strength.
	Additional suffixes and requirements will be added to this classification system as test methods or requirements are developed or requested, or both.

[A] ISO documents listed in parentheses are similar to the ASTM documents and the same suffix may be applied.

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SUFFIX TABLE 1 Property Change Table

Designation Order Number	Property	0	1	2	3	4	5	6	7	8	9
1	Hardness change, Shore D points	unspecified	±2	±2	±5	±5	±10	±10	±20	±20	specify value
	Tensile change, ASTM D 412, % change, max	unspecified	±5	±10	±10	±20	±20	±40	±40	±60	specify value
2	Elongation change, ASTM D 412, % change, max	unspecified	±5	±10	±15	±20	±30	±40	±50	±70	specify value
3	Volume change, ASTM D 471, % change, max	unspecified	±2	±5	±10	±15	±25	±30	±40	±60	specify value

SUFFIX TABLE 2 Tensile, Elongation and Tear Properties

Designation Order Number	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile strength, ASTM D 412, MPa, min	unspecified	2	4	6	10	15	20	25	35	specify value
2	Ultimate elongation, ASTM D 412, %, min	unspecified	100	150	200	250	300	400	500	600	specify value
3	Tear strength, ASTM D 624, KN/m, min	unspecified	5	10	20	30	40	60	80	100	specify value

Cell Table C Detail Requirements

Designation Order Number	Property	Cell Limits									
		0	1	2	3	4	5	6	7	8	9
1	Tensile strength, ASTM D 683, MPa, min[A]	unspecified	35	45	50	55	65	70	75	85	specify value
2	Flexural modulus, ASTM D 790, MPa, min[A]	unspecified	1 500	2 000	2 200	2 300	2 400	2 600	2 900	3 000	specify value
3	Izod impact, ASTM D 256, J/m, min[B]	unspecified	15	30	50	135	270	425	670	950	specify value
4	Deflection temperature, ASTM D 648, (1820 kPa), °C, min	unspecified	80	90	100	110	120	130	140	150	specify value
5	To be determined	unspecified	...	...	...	...	...	...	...	...	...

[A] MPa × 145 = psi
[B] J/m × 18.73 × 10^{-3} = ft·lbf/in.

Cell Table D Detail Requirements

Designation Order Number	Property	Cell Limits									
		0	1	2	3	4	5	6	7	8	9
1	Tensile strength, ASTM D 638, MPa, min[A]	unspecified	55	70	80	90	105	115	125	140	specify value
2	Flexural modulus, ASTM D 790, MPa, min[A]	unspecified	700	3 000	5 000	7 000	9 000	12 000	14 500	16 000	specify value
3	Izod impact, ASTM D 256, J/m, min[B]	unspecified	15	33	50	135	270	425	670	950	specify value
4	Deflection temperature, ASTM D 648, (1820 kPa), °C, min	unspecified	75	85	95	110	120	130	140	155	specify value
5	To be determined	unspecified	...	...	...	...	...	...	...	...	...

[A] MPa × 145 = psi
[B] J/m × 18.73 × 10^{-3} = ft·lbf/in.

Cell Table E Detail Requirements

Designation Order Number	Property	Cell Limits									
		0	1	2	3	4	5	6	7	8	9
1	Tensile strength, ASTM D 638, MPa, min[A]	unspecified	10	20	30	40	50	60	70	80	specify value
2	Flexural modulus, ASTM D 790, MPa, min[A]	unspecified	50	1 000	1 500	2 000	2 500	3 000	3 500	4 000	specify value
3	Izod impact, ASTM D 256, J/m, min[B]	unspecified	15	30	50	135	270	425	670	950	specify value
4	Deflection temperature, ASTM D 648, (1820 kPa), °C, min	unspecified	40	50	60	70	85	95	105	115	specify value
5	To be determined	unspecified	...	...	...	...	...	...	...	...	...

[A] MPa × 145 = psi
[B] J/m × 18.73 × 10^{-3} = ft·lbf/in.

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Cell Table F Detail Requirements

Designation Order Number	Property	Cell Limits									
		0	1	2	3	4	5	6	7	8	9
1	Tensile strength, ASTM D 638, MPa, min[A]	unspecified	3	10	15	25	35	40	50	60	specify value
2	Flexural modulus, ASTM D 790, MPa, min[A]	unspecified	10	700	1 000	1 400	1 900	2 400	2 900	3 400	specify value
3	Izod impact, ASTM D 256, J/m, min[B]	unspecified	15	30	50	135	270	425	670	950	specify value
4	Deflection temperature, ASTM D 648, (1820 kPa), °C, min	unspecified	25	40	55	70	80	90	100	110	specify value
5	To be determined	unspecified	...	...	...	...	...	...	...	...	...

[A]MPa × 145 = psi
[B]J/m × 18.73 × 10^{-3} = ft·lbf/in.

Cell Table G Detail Requirements

Designation Order Number	Property	Cell Limits									
		0	1	2	3	4	5	6	7	8	9
1	Tensile strength, ASTM D 638, MPa, min[A]	unspecified	15	40	65	85	110	135	160	185	specify value
2	Flexural modulus, ASTM D 790, MPa, min[A]	unspecified	600	3 500	6 500	10 000	13 000	16 000	19 000	22 000	specify value
3	Izod impact, ASTM D 256, J/m, min[B]	unspecified	15	30	50	135	270	425	670	950	specify value
4	Deflection temperature, ASTM D 648, (1820 kPa), °C, min	unspecified	130	160	200	230	260	300	330	360	specify value
5	To be determined	unspecified	...	...	...	...	...	...	...	...	...

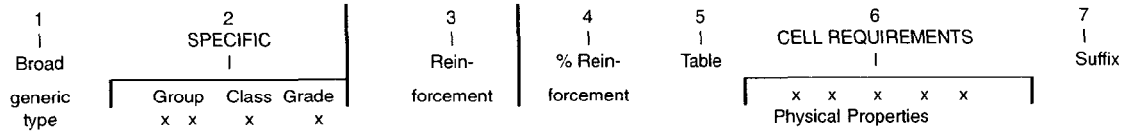
[A]MPa × 145 = psi
[B]J/m × 18.73 × 10^{-3} = ft·lbf/in.

Cell Table H Detail Requirements

Designation Order Number	Property	Cell Limits									
		0	1	2	3	4	5	6	7	8	9
1	Tensile strength, ASTM D 638, MPa, min[A]	unspecified	15	55	95	135	175	215	255	290	specify value
2	Flexural modulus, ASTM D 790, MPa, min[A]	unspecified	200	4 500	9 000	13 000	17 000	20 000	25 000	30 000	specify value
3	Izod impact, ASTM D 256, J/m, min[B]	unspecified	15	30	50	135	270	425	670	950	specify value
4	Deflection temperature, ASTM D 648, (1820 kPa), °C, min	unspecified	35	100	160	230	290	350	420	480	specify value
5	To be determined	unspecified	...	...	...	...	...	...	...	...	...

[A]MPa × 145 = psi
[B]J/m × 18.73 × 10^{-3} = ft·lbf/in.

ASTM D 4000 Line Call-Out



1 = Two or more letters identify the generic family based on Terminology D 1600.
2 = Four digits identify the specific chemical group, the modification or use class, and the grade by viscosity or level of modification. A basic property table will provide property values.
3 = One letter indicates reinforcement type.
4 = Two digits indicate percent of reinforcement.
5 = One letter refers to a cell table listing of physical specifications and test methods.
6 = Five digits refer to the specific physical parameters listed in the cell table.
7 = Suffix codes indicate special requirements based on the application, and identify special tests (see Section 7).

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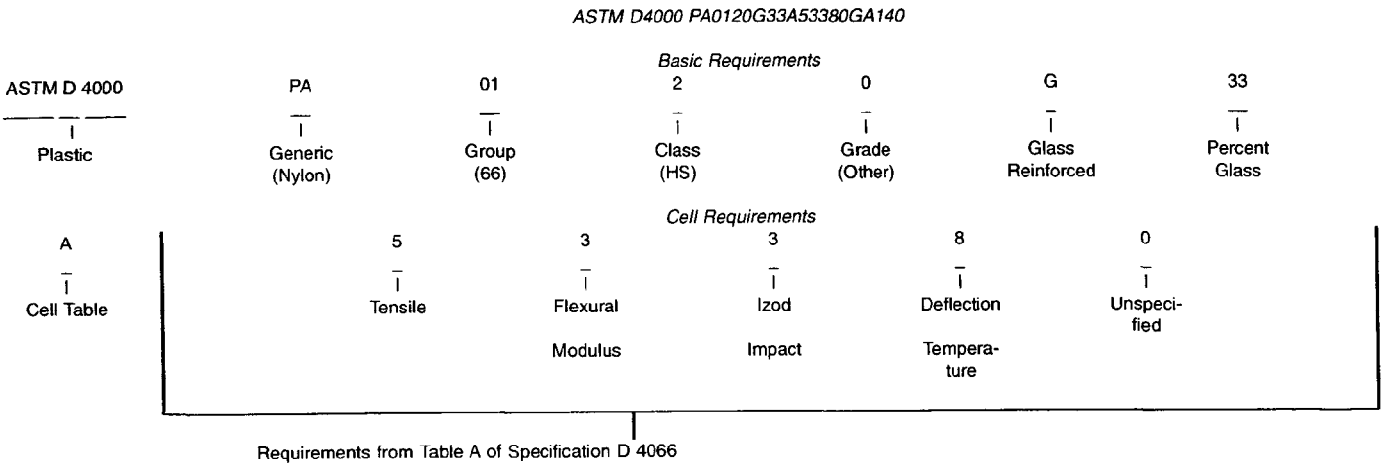

5.2 The generic family is classified into groups according, in general, to the chemical composition. These groups are further subdivided into classes and grades as shown in the basic property table that applies. The letter designation applicable is followed by a four-digit number indicating group, class, and grade. The first two digits indicate the group, the third digit the class, and the fourth digit the grade.

NOTE 5—The previous edition of this standard used three digits for group, class, and grade; 0120 is equivalent to 120.

NOTE 6—An example using the group, class, and grade is as follows: PA0122 would indicate: PA = polyamide (nylon), 01 (group) = 66 nylon, 2 (class) = heat stabilized, and 2 (grade) with requirements given in the (PA) basic property table of Specification D 4066.

5.2.1 The basic property tables have been developed to identify the commercially available unreinforced plastics into groups, classes, and grades. These tables are found in the standards listed in Table 1.

5.2.1.1 Where a standard does not exist for this classification system the letter designation for the generic family will be followed by four O's and the use of cell table that applies (see 5.4.2).

NOTE 7—*Example*—PI0000 would indicate a polyimide plastic (PI) from Table 1, with 0000 indicating no basic property table and G12360 requirements from Cell Table G.

5.3 Reinforced versions of the basic materials are identified by a single letter that indicates the reinforcement used and two digits that indicate the nominal quantity in percent by weight. Thus, a letter designation G for glass-reinforced and 33 for percent of reinforcement, G33, specifies a filled material with a nominal glass level of 33 %. The reinforcement letter designations and associated tolerance levels are shown in Table 2.

NOTE 8—The type and amount of reinforcement will be shown on supplier's technical data sheet unless the materials are proprietary. If necessary, additional control of these reinforcements shall be accomplished by the use of the suffix part of the system (Section 7).

5.4 To facilitate the identification of new, special, and reinforced materials where basic property tables are not provided in a material specification, cell tables have been incorporated in this document. These tables should be used in the same manner as the cell tables that appear in the material specifications.

5.4.1 Although the values listed in cell tables include the range of properties available in existing materials, users should not infer that every possible combination of properties exists or can be obtained.

5.4.2 The requirements for special or reinforced materials will use the classification system as described by the addition of a single letter that indicates the proper cell table in which the properties are listed. A specific value is designated by the cell number for each property in the order in which they are listed in the table. When a property is not to be specified, a zero is entered as the cell number. Likewise, when an acceptable value is not available in the cell table, the number 9 should be used and a suffix used indicating the specific value (see 7.3). Thus, the letter designation "A" for cell table and 53380 for property values shall always be written A53380. The cell tables that may be used for each generic family are listed in Table 1.

NOTE 9—An example of a reinforced plastic identified by this classification system is as follows. The designation PA0120G33A53380 indicates the following with the material requirements from Specification D 4066:

PA0120	=	Nylon 66 heat stabilized from Table PA of Specification D 4066.
G33	=	Glass reinforced with 33 % glass, nominal.
A	=	Table A (D 4066) for property requirements.
5	=	Tensile strength, 175 MPa, min.
3	=	Flexural modulus, 7500 MPa, min.
3	=	Izod impact, 75 J/m, min.
8	=	Deflection temperature, 235°C, min, and
0	=	Unspecified.

6. Basic Requirements

6.1 The cell tables included as a part of the listed referenced standard shall be used to develop a line call-out for the materials listed in Table 1 çovered by a material standard.

6.2 The cell tables included in this classification shall be used to develop a line call-out for the materials not covered by

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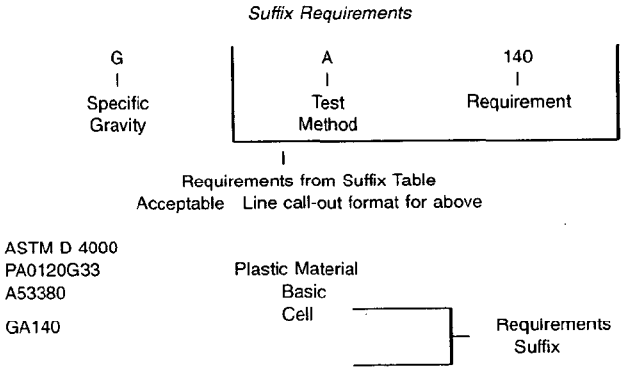
material standards (Table 1). When the existing cell table does not adequately describe the material, then suffixes may be used in place of a cell table designation.

6.3 A line call-out assembled using this classification system becomes a specification. The line call-out shall contain the broad and specific type of plastic, together with the appropriate identifiers followed by special suffix requirements, as they apply. The following summarizes the line call-out and the entire system as detailed in this standard.

7. Suffix Requirements

7.1 When requirements are needed that supersede or supplement the property table or cell table requirements, they shall be specified through the use of suffixes. In general, the first suffix letter indicates the special requirement needed and the second letter indicates the condition or test method, or both, with a three-digit number indicating the specific requirement. The suffixes that may be used are listed in Table 3.

7.2 Basic requirements from property or cell tables, as they apply, are always in effect unless these requirements are superseded by special suffix requirements in the line call-out.



NOTE 10—When using the suffixes for additional requirements of the material, the user must keep in mind that not all tests are routinely conducted by the supplier. When these requirements are necessary to identify particular characteristics important to specific applications they shall be agreed upon between user and supplier.

7.3 The following is an example of a line call-out specification for a reinforced nylon:

7.4 When a standard for a material is listed in Table 1, the requirements of the referenced standard apply. If desired, the referenced standards may be used since a similar system is used in each document. When the requirements for a material are included in this standard, the following sections are applicable.

8. General Requirements

8.1 The composition of the specified material shall be uniform and shall conform to the requirements specified herein.

9. Detail Requirements

9.1 The material shall conform to the requirements prescribed in the table (basic property, reinforced, cell, and suffix) as they apply.

9.2 For the purpose of determining conformance with this specification, all specified limits, in this standard are absolute limits as defined in Practice E 29.

9.3 With the absolute method, an observed value or a calculated value is not rounded, but is to be compared directly with the specified limiting value. Conformance or nonconformance with the specification is based on this comparison.

10. Sampling

10.1 Sampling shall be statistically adequate to satisfy the requirements of 15.4. A lot of material shall be considered as a unit of manufacture as prepared for shipment, and may consist of a blend of two or more "production runs" or batches.

11. Numbers of Tests

11.1 The number of tests conducted shall be consistent with the requirements of Sections 10 and 15.4.

12. Specimen Preparation

12.1 The test specimens shall be molded as specified for the specific materials under test in the ASTM standard specifications for the materials.

13. Conditioning

13.1 Condition the test specimens at 23 ± 2°C and 50 ± 5 % relative humidity for not less than 40 h prior to testing, in accordance with Procedure A of Practice D 618 for those tests where conditioning is specified unless otherwise directed in the ASTM standard specification for the material.

13.2 Conduct tests in the standard laboratory atmosphere of 23 ± 2°C and 50 ± 5 % relative humidity unless otherwise directed in the ASTM standard specification for the material.

13.3 For materials sensitive to atmospheric exposure, special preparations for conditioning and test conditions should be adhered to as provided in the referenced standard for the material.

14. Test Methods

14.1 Determine the properties enumerated in this classification system by means of the test methods referenced.

15. Inspection and Certification

15.1 Inspection and certification of the material supplied under this classification system shall be for conformance to the requirements specified herein.

15.2 Lot-acceptance inspection shall be the basis on which acceptance or rejection of the lot is made. The lot-acceptance inspection shall consist of those tests which ensure process control during manufacture as well as those necessary to ensure certifiability in accordance with 15.4.

15.3 Periodic check inspection shall consist of the tests specified for all requirements of the material under this classification system. Inspection frequency shall be adequate to ensure the material is certifiable in accordance with 15.4.

15.4 Certification shall be that the material was manufactured, sampled, tested, and inspected in accordance with this classification system and that average values meet the requirements at a confidence level of 95 %.

15.5 A report of the test results shall be furnished when requested. The report shall consist of results of the lot-acceptance inspection for the shipment and the results of the most recent periodic-check inspection.

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16. Packaging, Packing, and Marking

16.1 Provisions of Practice D 3892 apply for packaging, packing, and marking of plastic materials.

17. Keywords

17.1 classification; classification system; line callout; plastic; plastic materials

SUMMARY OF CHANGES

This section identifies the location of selected changes to this classification system. For the convenience of the user, Committee D20 has highlighted those changes that may impact the use of this classification system. This section may also include descriptions of the changes or reasons for the changes, or both.

D 4000 – 01:

(*1*) Second letters J and K added for Symbol E in Table 3.

(*2*) Second letter G added for Symbol W in Table 3.

(*3*) Referenced Documents were updated to reflect the revisions to Table 3.

D 4000 – 00a:

(*1*) Referenced Documents were updated to reflect the revisions to Table 3.

(*2*) Table 3, Symbol B: ES 27 was removed; incorporated in Test Method D 471.

(*3*) Table 3, Symbol C: Removed second letters A and E and added second letters K and L for Test Method D 1525, 50-N load.

(*4*) Table 3, Symbol D: Removed.

(*5*) Table 3, Symbol E: Added expression of results for second letter H.

(*6*) Table 3, Symbol F: Substituted IEC reference for Second Letter A to replace withdrawn ISO standard. Deleted repetition of the second letter L which referenced a deleted ASTM standard, Test Method F 814.

(*7*) Table 3, Symbol K: Changed second letter M from tensile modulus to tensile stress.

(*8*) Table 3, Symbol M: Added ISO reference for second letter F.

(*9*) Table 3, Symbol S: Deleted references to withdrawn standards, ASTM Test Method D 2445 and ISO 537. Added ISO 6721-1 and -2 as references for second letter M. Deleted second letter P as it was a repeat of second letter M.

(*10*) Table 3, Symbol U: Added second letter N to permit expression of flexural modulus by ISO 178 as a minimum value.

(*11*) Table 3, Symbol W: Added new ASTM standards for evaluating weather resistance.

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Designation: D 4024 – 00

An American National Standard

Standard Specification for Machine Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Flanges[1]

This standard is issued under the fixed designation D 4024; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers reinforced-thermosetting resin flanges other than contact-molded flanges. Included are requirements for materials, workmanship, performance, and dimensions.

1.2 Flanges may be produced integrally with a pipe or fitting, may be produced with a socket for adhesive bonding to a pipe or fitting, or may be of the type used in conjunction with either a metallic or nonmetallic backup ring.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values in parentheses are given for information only. In cases where materials, products, or equipment are available only in SI units, inch-pound units are omitted.

1.4 The following precautionary caveat pertains only to the test methods portion, Section 11, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—Contact molded flanges are covered in Specification D 5421 and referenced in Specification D 5685.

NOTE 2—There is no similar or equivalent ISO standard.

NOTE 3—For purposes of this specification, polyester includes vinylester resins.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 883 Terminology Relating to Plastics[2]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 1898 Practice for Sampling of Plastics[4]

D 5421 Specification for Contact Molded "Fiberglass" (Glass-Fiber-Reinforced Resin) Flanges[3]

D 5685 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe Fittings[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

2.2 *ANSI Standards:*

B 16.1 Cast Iron Pipe Flanges and Flanged Fittings[5]

B 16.5 Pipe Flanges and Flanged Fittings[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions are in accordance with Terminology D 883 or Terminology F 412. Abbreviations are in accordance with Terminology D 1600, unless otherwise indicated. The abbreviation for reinforced-thermosetting-resin pipe is RTRP.

4. Classification

4.1 *General*—This specification covers machine-made reinforced-thermosetting-resin flanges defined by type (method of manufacture), grade (generic type of resin), class (configuration of joining system), and pressure rating. Flanges complying with this specification are also given numerical classifications relating to rupture pressure, sealing test pressure, and bolt torque limit.

4.1.1 *Types*:

4.1.1.1 *Type 1*—Filament-wound flanges manufactured by winding continuous fibrous glass strand roving or roving tape, either preimpregnated or impregnated during winding, into a flange cavity under controlled tension.

4.1.1.2 *Type 2*—Compression-molded flanges made by applying external pressure and heat to a molding compound that is confined within a closed mold.

4.1.1.3 *Type 3*—Resin-transfer-molded flanges manufactured by pumping a thermosetting resin into glass reinforcements that have been cut to size and clamped between matched molds.

4.1.1.4 *Type 4*—Centrifugally-cast flanges are made by applying resin and reinforcement to the inside of a mold that is

[1] This specification is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.23 on Reinforced Plastic Piping Systems and Chemical Equipment.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

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rotated and heated, subsequently polymerizing the resin system.

4.1.2 *Grades*:

4.1.2.1 *Grade 1*—Epoxy resin.

4.1.2.2 *Grade 2*—Polyester resin.

4.1.2.3 *Grade 3*—Furan resin.

4.1.3 *Classes*:

4.1.3.1 *Class 1*—Integrally-molded flange manufactured directly on a pipe section, pipe stub, or fitting.

4.1.3.2 *Class 2*—Taper to taper adhesive joint flange manufactured with a tapered socket to be used in conjunction with a pipe or fitting with a tapered spigot section and a suitable adhesive. This joining method provides an interference fit over the entire length of the bond line.

4.1.3.3 *Class 3*—Straight-taper adhesive joint flange manufactured with a tapered socket to be used with a pipe or fitting with an untapered spigot section and a suitable adhesive. This joining method provides an interference fit at the bottom of the socket.

4.1.3.4 *Class 4*—Straight adhesive joint flange manufactured with an untapered socket for use with a pipe or fitting with an untapered spigot and a suitable adhesive. This joint provides no interference fit.

4.1.4 *Pressure Rating*—Pressure rating shall be categorized by a single letter designation. Pressure designations are shown in Table 1.

4.1.5 Rupture pressure, sealing test pressure, and bolt torque limit shall be categorized by single arabic number designations as indicated by the cell classification system of Table 2.

4.2 *Designation Code*—The flange designation code shall consist of the abbreviation RTR, followed by the type, grade, and class in arabic numerals, the pressure rating category as a capital letter, and three arabic numbers identifying the cell classification designations of the rupture pressure, sealing test pressure, and the bolt torque limit, respectively. Thus, a complete flange designation code shall consist of three letters, three numerals and one letter, and three numerals.

4.2.1 *Example*—RTR-112D-334. This designation describes a filament-wound, glass fiber-reinforced epoxy resin flange with a taper to taper adhesive joining system. The flange has a 200 psi (1.4 MPa) pressure rating, a burst pressure in excess of 600 psi (4.1 MPa), a sealing test pressure of 225 psi (1.6 MPa), and a bolt torque limit greater than 75 lbf·ft (102 N·m).

NOTE 4—Flanges with identical classification from different manufacturers may not be interchangeable due to nonstandardization of pipe or socket diameter, socket length, taper angle, or combination thereof.

TABLE 1 Pressure Categories

Designation	Pressure Rating	
	psi	MPa
A	50	0.35
B	100	0.69
C	150	1.03
D	200	1.38
E	250	1.72
F	300	2.07
G	400	2.76
H	500	3.45

5. Materials and Manufacture

5.1 Flanges manufactured in accordance with this specification shall be composed of reinforcement imbedded in or surrounded by cured thermosetting resin. The composite structure may contain granular or platelet fillers, thixotropic agents, pigments, or dyes.

5.2 The resins, reinforcements, and other materials, when combined as composite structure, shall produce a flange that will meet the performance requirements of this specification.

6. Performance Requirements

6.1 Flanges shall meet the following performance requirements when joined for testing according to the manufacturer's recommended practice for field installation:

6.1.1 *Sealing*—Flanges shall withstand a pressure of at least 1.5 times the rated design pressure without leakage when tested in accordance with 11.4.

6.1.2 *Short-Term Rupture Strength*—Flanges shall withstand a hydrostatic load of at least four times their rated design pressure without damage to the flange when tested in accordance with 11.5.

6.1.3 *Bolt Torque*—Flanges shall withstand, without visible sign of damage, a bolt torque of at least 1.5 times that recommended by the manufacturer for sealing of the flange at its rated pressure when tested in accordance with 11.6.

7. Content Requirements

7.1 *Percentage Extractable Material*— Flanges shall contain no more than 5 % extractable material when tested in accordance with Annex A1.

7.2 *Recycled or Repprocessed Thermosetting Plastics*—Flanges shall not contain any recylced or reprocessed thermosetting plastics which might otherwise be added as fillers.

8. Dimensions

8.1 *Dimensions and Tolerances*:

8.1.1 *Flange and Bolt Dimensions*—Flanges of 24 in. (610 mm) or smaller diameter shall conform to the values given in Table 3 for bolt circle, number and size of bolt holes, and outside diameter. Flanges larger than 24 in. (610 mm) in diameter shall conform to the values for bolt circle, number and size of bolt holes, and outside diameter for Class 125 cast iron flanges in ANSI B 16.1. The tolerance for the flange dimensions provided in Table 3 shall be the same as those contained in ANSI B 16.1.

8.1.2 *Flange Face*—The flange face shall be perpendicular to the axis of the fitting within ½°, and shall be flat to ±1/32 in. (1 mm) for sizes up to and including 18 in. (457 mm) diameter and ±1/16 in. (2 mm) for larger diameters.

8.1.3 *Washer Bearing Surface*—Washer bearing surface shall be flat and parallel to the flange face within ±1°.

8.2 *Pipe Stop*—Each adhesive joined flange shall provide sufficient taper or a diametral constriction to act as a stop during adhesive joining so that the pipe stub cannot project beyond the face of the flange.

9. Workmanship, Finish, and Appearance

9.1 Flanges shall be free as commercially practical of defects, including indentations, delaminations, bubbles, pinholes, foreign inclusions, and resin-starved areas.

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TABLE 2 Burst Pressure, Sealing Test Pressure, and Bolt Torque Limit

Property	0[A]	1	2	3	4	5	6	7	8
Burst pressure, psi		200	400	600	800	1000	1200	1600	2000
(MPa)		(1.38)	(2.76)	(4.14)	(5.52)	(6.89)	(8.27)	(11.03)	(13.79)
Sealing test pressure, psi		75	150	225	300	375	450	600	750
(MPa)		(0.52)	(1.03)	(1.55)	(2.07)	(2.59)	(3.10)	(4.14)	(5.17)
Bolt torque limit, lbf·ft.		20	30	50	75	100	125	150	200
(N·m)		(27.1)	(40.7)	(67.8)	(101.7)	(135.6)	(169.5)	(203.4)	(271.2)

[A] 0 = unspecified.

TABLE 3 Flange Dimensions, in. (mm)[A]

Nominal Pipe, Size[B]	Outside Diameter of Flange	Drilling			
		Diameter of Bolt Circle	Diameter of Bolt Holes	Number of Bolts	Diameter of Bolts
1/2	3.50 (88.9)	2.38 (60.5)	0.62 (15.75)	4	1/2 (12.70)
3/4	3.88 (98.6)	2.75 (69.9)	0.62 (15.75)	4	1/2 (12.70)
1	4.25 (107.9)	3.12 (79.2)	0.62 (15.75)	4	1/2 (12.70)
1 1/4	4.62 (117.3)	3.50 (88.9)	0.62 (15.75)	4	1/2 (12.70)
1 1/2	5.00 (127.0)	3.88 (98.6)	0.62 (15.75)	4	1/2 (12.70)
2	6.00 (152.4)	4.75 (120.6)	0.75 (19.0)	4	5/8 (15.9)
2 1/2	7.00 (177.8)	5.50 (139.7)	0.75 (19.0)	4	5/8 (15.9)
3	7.50 (190.5)	6.00 (152.4)	0.75 (19.0)	4	5/8 (15.9)
3 1/2	8.50 (215.9)	7.00 (177.8)	0.75 (19.0)	8	5/8 (15.9)
4	9.00 (228.6)	7.50 (190.5)	0.75 (19.0)	8	5/8 (15.9)
5	10.00 (254.0)	8.50 (215.9)	0.88 (22.4)	8	3/4 (19.0)
6	11.00 (279.4)	9.50 (241.3)	0.88 (22.4)	8	3/4 (19.0)
8	13.50 (342.9)	11.75 (298.4)	0.88 (22.4)	8	3/4 (19.0)
10	16.00 (406.4)	14.25 (361.9)	1.00 (25.4)	12	7/8 (22.2)
12	19.00 (482.6)	17.00 (431.8)	1.00 (25.4)	12	7/8 (22.2)
14	21.00 (533.4)	18.75 (476.2)	1.12 (28.4)	12	1 (25.4)
16	23.50 (596.9)	21.25 (539.8)	1.12 (28.4)	16	1 (25.4)
18	25.00 (635.0)	22.75 (577.8)	1.25 (31.7)	16	1 1/8 (28.6)
20	27.50 (698.5)	25.00 (635.0)	1.25 (31.7)	20	1 1/8 (28.6)
24	32.00 (812.8)	29.50 (749.3)	1.38 (35.1)	20	1 1/4 (31.7)

[A] Dimensions conform to ANSI B 16.5 for Class 150 steel flanges.
[B] For larger sizes, see 8.1.1.

10. Sampling

10.1 The rate of sampling of flanges for pressure rating verification shall be in accordance with Annex A2.

10.2 For individual orders, only those additional tests and number of tests specifically agreed upon between the purchaser and seller need be conducted.

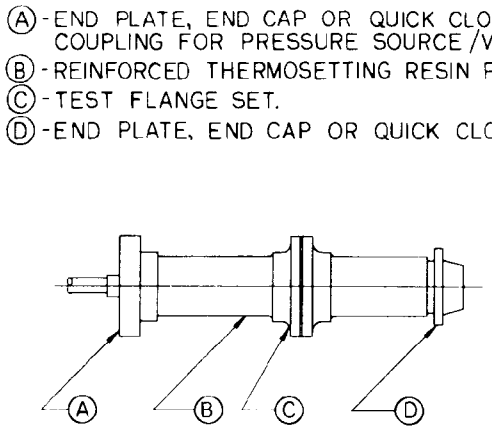
11. Test Methods

11.1 *Conditioning*—When conditioning is required, and in all cases of disagreement, condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test, in accordance with Procedure A of Practice D 618.

11.2 *Test Conditions*—The tests may be conducted at ambient temperature and humidity conditions. When controlled environment testing is specified, tests shall be conducted in the Standard Laboratory Atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity. When elevated temperature testing is specified, the tests shall be conducted at the design operating temperature ±5.4°F (3°C).

11.3 *Dimensions and Tolerances*—Flange dimensions shall be measured with a micrometer of vernier calipers, or other suitable measuring devices accurate to within ±0.001 in. (±0.02 mm). Diameters shall be determined by averaging a minimum of four measurements, equally spaced circumferentially.

11.4 *Sealing*—Flanged components in general arrangement with Fig. 1 shall be bolted together using the gasket and bolt torque recommended for standard field installation by the flange manufacturer. The assembly shall then be pressure tested and be required to hold the test pressure for a period of 168 hours without leakage. Retorquing to the manufacturer's



Ⓐ End plate, end cap, or quick closure with coupling for pressure source/vent line
Ⓑ Reinforced thermosetting resin pipe (RTRP)
Ⓒ Test flange set
Ⓓ End plate, end cap, or quick closure

FIG. 1 Test Assembly Configuration

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specified level after initial pressurization is permitted.

11.5 *Short-Term Rupture Strength*—Flanged components shall be tested in accordance with Test Method D 1599 with free-end closure except as herein noted. The pressure in the specimen shall be increased until failure of the flange occurs. Pressure testing in an atmospheric environment is permissible. Minimum failure time shall be 60 s; no restriction shall be placed on maximum time-to-failure. Leaking past the gasket interface is permissible during this test. Bolt torque may be increased as necessary during the test in order to minimize gasket leaking and to achieve the pressure necessary to cause flange failure. The assembly used for the test in 11.4 may be used for this test.

11.6 *Maximum Bolt Torque*—Using the gasket and hardware recommended by the flange manufacturer, bolt the flange against a flat face steel flange. Tighten the nuts by hand until they are snug. Prior to fit-up, the nuts, bolts, and washers should be well lubricated, using a nonfluid thread lubricant. Establish uniform pressure over the flange face by tightening bolts in 5 lbf·ft (7 N·m) increments according to the sequence shown in Fig. 2. For flanges with more than 20 bolts, similar alternating bolt tightening sequences shall be used. Increase the bolt torque uniformly until flange failure occurs or until all bolts have been torqued to five times the level recommended by the manufacturer for field installation practice to establish the bolt torque cell classification of the flange. Any sign of flange damage (crumbling, flaking, cracking, or other breaking) shall constitute failure.

NOTE 5—The torque limits determined by 11.6 apply only to flanges bolted up against a flat sealing surface. Significantly lower bolt torque value will normally be obtained when RTR flanges are bolted up against raised-faced flanges. When RTR flanges must be used against raised steel flange face, the flange manufacturer should be contacted for his torquing and installation recommendations.

12. Product Marking

12.1 Each flange shall be marked with the following information:

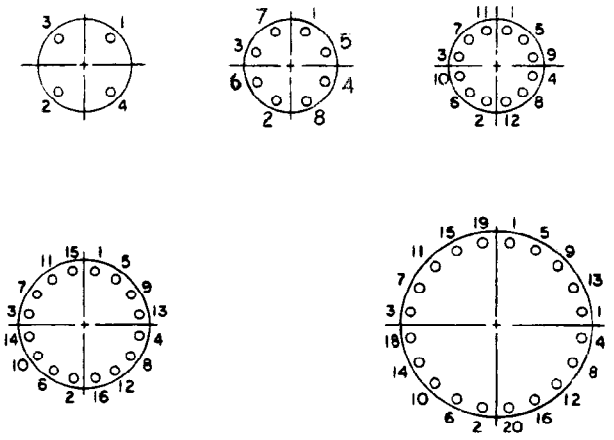

FIG. 2 Bolt Torquing Sequence

12.1.1 The designation "ASTM D 4024" indicating compliance with this specification,

12.1.2 Identification of the flange in accordance with the designation code in 4.2,

12.1.3 Nominal flange size, and

12.1.4 Manufacturer's name (or trademark) and product designation.

12.2 All required markings shall be legible and so applied as to remain legible under normal handling and installation practices.

13. Precision and Bias

13.1 No precision and bias statement can be made for this test method, since controlled round robin test programs have not been run.

NOTE 6—Thw wide variation in raw materials and constructions allowed in this specification make round robin testing difficult to apply.

14. Keywords

14.1 centrifugally-cast; compression-molded; filament-wound; furan; machine-made; polyester; resin-transfer; vinylester

ANNEXES

(Mandatory Information)

A1. TEST METHOD FOR PERCENTAGE EXTRACTABLE MATERIALS

A1.1 Scope

A1.1.1 This test method covers the procedure for determining the percentage extractable materials in RTR flanges.

A1.2 Summary of Test Method

A1.2.1 The test method consists of filing material from the flange, immersing this material in a solvent (methylene chloride), extracting the unreacted material and, by means of gravimetric analysis, determining the quantity of unreacted resin and residual solvent.

NOTE A1.1—For certain classes of resins, it may be necessary to select a different solvent in performing this test.

A1.3 Significance and Use

A1.3.1 This test method measures the amount of extractable material which includes unreacted resin and residual solvent.

A1.4 Apparatus

A1.4.1 *Beakers*, 100-mL

A1.4.2 *Beakers*, 50-mL

A1.4.3 *Graduate*, 25-mL

A1.4.4 *Magnetic Stirrer* and capsule (dental amalgam shaker).

A1.4.5 *Funnel* and filter paper (type) Grade 950, size 15 cm.

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A1.4.6 *Hot Plate.*

A1.4.7 *Oven.*

A1.5 Procedure

A1.5.1 Remove 1 to 2 g of a representative sample by means of a clean file.

A1.5.2 Pulverize the rough sample to a fine powder in a magnetic stirrer capsule. Each capsule should be pulverized for about 3 min.

A1.5.3 Accurately weigh the pulverized sample in a tared 50-mL beaker.

A1.5.4 *Gravimetric Analysis*:

A1.5.4.1 Add 25 mL of methylene chloride (or other suitable solvent) to the pulverized sample and mix.

A1.5.4.2 Place mixture on a steam bath or hot plate for 10 min.

NOTE A1.2—The solvent should not be heated above its boiling point (for methylene chloride, 104°F (40°C)).

A1.5.4.3 Let mixture cool for 10 min and filter into a tared 100-mL beaker. Wash mixture out of the 50-mL beaker and add washing to filtrate. It is very important to wash the 50-mL beaker and filter paper with methylene chloride several times to be sure all extractable material passes through the filter.

A1.5.4.4 Place filtrate in oven and evaporate methylene chloride. Oven temperature should be 194 to 212°F (90 to 100°C).

A1.5.4.5 After solvent evaporates, let beaker cool in a desiccator for 15 min.

A1.5.4.6 Weigh the beaker.

A1.5.4.7 Repeat steps 4, 5, and 6 until a constant weight is reached.

NOTE A1.3—It has been found that a 25-min drying time is satisfactory.

A1.6 Calculation

A1.6.1 Calculate the percentage extractable materials as follows:

$$\% \text{ extractable} = \frac{L}{W \times R} \times 100$$

where:

L = actual weight of residue = weight of beaker plus residue minus weight of beaker,

W = initial weight of pulverized sample = weight of beaker plus sample minus weight of beaker, and

R = resin content of the sample.

NOTE A1.4—The resin content of the sample must be known.

A2. TEST METHOD OF SAMPLING FOR PRESSURE RATING VERIFICATION

A2.1 Scope

A2.1.1 This test method describes the sampling procedure which shall be used in determining the acceptance of a given lot of flanges at the pressure rating specified according to 4.1.4 and Table 1.

A2.2 Sample

A2.2.1 Sample size and selection shall be in accordance with Practice D 1898 except as herein modified.

A2.3 Procedure

A2.3.1 Sample size shall be determined according to Practice D 1898, Appendix X3 and Table X2.1. The Acceptable Quality Level (AQL) shall be 1.50. Inspection Level 1 shall be used in determining the sample size and acceptance constant. A flange set shall be considered to be two samples.

A2.3.2 The specification Limit Value (L) shall be the pressure rating times 4 for burst test qualification and shall be the pressure rating times 1.5 for leak test qualification.

A2.4 Results

A2.4.1 *Acceptance*— If the Quality Level of the sample is greater than or equal to the acceptance constant for both burst and leak testing, the lot shall be accepted at the specified pressure rating category.

A2.4.2 *Rejection*—If the Quality Level is less than the acceptance constant for either burst or leak testing, the lot shall be rejected unless rectification is provided as follows:

A2.4.2.1 The lot shall be resampled at a higher inspection level. The original test results shall be considered a part of the resampled lot. If the lot meets the requirements of A2.4.1 after resampling, the lot shall be accepted at the pressure category specified.

A2.4.2.2 Alternatively, the lot may be derated to a pressure rating that will bring the sample's quality level to a value equal to or greater than the acceptance constant. The lot of flanges shall be reclassified at the lower pressure rating category and appropriately marked according to the designation code in 4.2.

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SUMMARY OF CHANGES

Committee D-20 has identified the location of the following changes to this standard since the last issue D4024–94) which may impact the use of this standard.

(1) Changed Note 1 to reference D 5685.
(2) Corrected grammer in 4.1.
(3) Corrected statement construction in 4.2.
(4) Added 7.2 on recycled materials.
(5) Clarified 11.2 on tolerance of operating temperature.
(6) Deleted dualism in key for drawing in 11.4.
(7) Corrected long standing error in bolt torque sequence on 8 hole flange in Fig. 2.
(8) Clarified wording in 12.1.1.
(9) Added Precision and Bias statement.
(10) Corrected references in A2.3.1 to appendix and table which no longer exsisted.
(11) Added this "Summary of Changes" section.

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Designation: D 4161 – 01

Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals[1,2]

This standard is issued under the fixed designation D 4161; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers axially unrestrained bell-and-spigot gasket joints including couplings required for machine-made "fiberglass" (glass-fiber-reinforced thermosetting-resin) pipe systems, 8 in. (200 mm) through 144 in. (3700 mm), using flexible elastomeric seals to obtain soundness. The pipe systems may be pressure (typically up to 250 psi) or nonpressure systems for water or for chemicals or gases that are not deleterious to the materials specified in this specification. This specification covers materials, dimensions, test requirements, and methods of test.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

NOTE 1—There is a similar but technically different ISO Standard (ISO 8639).

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 883 Terminology Relating to Plastics[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[3]

F 412 Terminology Relating to Plastic Piping Systems[4]

F 477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions and abbreviations are in accordance with Terminology D 883 or Terminology F 412, and Terminology D 1600 unless otherwise indicated.

4. Types of Joints

4.1 This specification covers two types of axially unrestrained joints based on effecting soundness of the joint through compression of an elastomeric seal or ring:

4.1.1 Bell-and-spigot or coupling joint with the gasket placed in the bell in circumferential compression. An elastomeric gasket joint design featuring a continuous elastomeric ring gasket placed in an annular space provided in the bell or socket of the pipe or fitting. The spigot end of the pipe or fitting is forced into the bell, thereby compressing the gasket radially to form a positive seal.

4.1.2 Bell-and-spigot or coupling joint with the gasket placed on the spigot in circumferential tension: A push on joint design featuring a continuous elastomeric ring gasket placed in an annular space provided on the spigot end of the pipe or fitting. The spigot is forced into the bell of the pipe or fitting, thereby compressing the gasket radially to form a positive seal.

NOTE 2—A coupling joint of these types is a loose double-bell sleeve used to connect pipes which have spigots at both ends (see Fig. 1). All references to bells in this specification are applicable to the sleeve coupling as well as to the integral bell of a bell-and-spigot gasket joint.

5. Materials and Manufacture

5.1 The gasket shall be a continuous elastomeric ring of circular or other geometric cross section and shall meet the requirements of Specification F 477, unless otherwise specified in this specification. When a splice is used in the manufacture of the gasket, no more than two splices shall be made in any one gasket.

5.1.1 The chemical composition of the gasket shall be compatible with the type of environment to which it will be subjected. Selection of the gasket composition shall be in accordance with a purchaser and seller agreement.

NOTE 3—Consult the gasket manufacturer for advice as to the suitability of specific rubber compounds for the intended service and joint configurations. Items such as cold set when the joint is deflected under low-temperature conditions and maximum and minimum stretch in the gasket may be dependent upon the specific chemical compounds used.

5.2 Materials in the bell and spigot of the joint shall meet the requirements of the applicable ASTM specification for the pipe or fitting of which the joint is a part.

6. Requirements

6.1 *Joint Surfaces*—All surfaces of the joint upon or against

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[1] This specification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.23 on Reinforced Plastic Piping Systems and Chemical Equipment.

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[2] An ISO equivalency statement was added.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 08.04.

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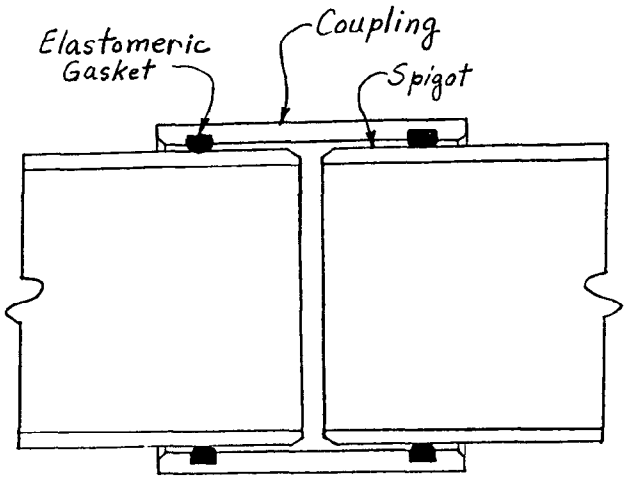

FIG. 1 Typical Coupling Joint Detail

which the gasket may bear shall be smooth and free of cracks, fractures, or other imperfections that would adversely affect the performance of the joint.

6.2 *Joint Geometry*—The design of the joint shall include a means to retain the gasket and prevent it from being unintentionally displaced, either during assembly of the joint or during operation of the completed pipe system.

6.3 *Dimensions and Tolerances*—The provisions of 6.3.1.1 apply only to a joining system utilizing a gasket of circular cross section retained in a rectangular groove. Manufacturers may submit to the purchaser detailed designs for joints utilizing gaskets or grooves, or both, of other geometric shape or for joints not meeting the criteria of 6.3.1. Joints not meeting the requirements of this section shall meet the test requirements of Section 7; such joints shall be acceptable, provided the design is approved by the purchaser prior to manufacture and provided the test pipe complies with the specified test requirements. Test results may be extended to other diameters with the same joint configuration, gasket shape and gasket composition provided substantially similar gasket compressions and gasket hardness are maintained. Gasket dimensions may be increased or decreased provided joint geometry is also appropriately proportioned so that critical relationships like gasket confinement are equal or superior to the tested joint. Design submissions shall include joint geometry, tolerances, gasket characteristics, proposed plant tests, and such other information as required by the purchaser to evaluate the joint design for field performance.

6.3.1 *Joints Using Circular Gasket Cross Sections:*

6.3.1.1 The volume of the annular space provided for the gasket, with the engaged joint at normal joint closure in concentric position, and neglecting ellipticity of the bell and spigot, shall not be less than the design volume of the gasket furnished. For a rectangular gasket groove, the cross-sectional area of annular space shall be calculated for minimum bell inside diameter, maximum spigot outside diameter, minimum width of groove at surface of spigot, and minimum depth of groove. The volume of the annular space shall be calculated at the centerline of the groove and considering the centroid of the cross-sectional area to be at the midpoint between the surface of the groove on which the gasket is seated and the surface of the bell, if the groove is on the spigot, or the surface of the spigot, if the groove is in the bell.

6.3.1.2 When the design volume of the gasket is less than 75 % of the volume of the annular space in which the gasket is confined, the dimensions and tolerances of the gasket, bell, and spigot shall be such that, when the outer surface of the spigot and the inner surface of the bell come into contact at some point in their periphery, the deformation in the gasket shall not exceed 40 % at the point of contact nor be less than 15 % at any point. If the design volume of the gasket is 75 % or more of the volume of the annular space, the deformation of the gasket, as prescribed above, shall not exceed 50 % nor be less than 15 %. The cross-sectional area of annular space shall be calculated for average bell diameter, average spigot diameter, average width of groove at surface of spigot, and average depth of groove. The volume of the annular space shall be calculated at the centerline of the groove and considering the centroid of the cross-sectional area to be at the midpoint between the surface of the groove on which the gasket is seated and the surface of the bell, if the groove is on the spigot, or the surface of the spigot, if the groove is in the bell.

NOTE 4—It is recognized that a relationship exists between the watertightness of a joint, the gasket deformation, and the ratio of gasket volume to space volume. For high-pressure applications, it may be necessary to provide a very high-volume ratio to obtain a sound joint. Some manufacturers also have developed satisfactory joints with very little gasket deformation, but meet the requirements of Section 6 by utilizing a very high-volume ratio.

6.3.1.3 When determining the maximum percent deformation of the gasket, the minimum depth of groove and the stretched gasket diameter shall be used and calculations made at the centerline of the groove. When determining the minimum percent deformation of the gasket, the maximum bell diameter, the minimum spigot diameter, the maximum depth of groove, and the stretched gasket diameter shall be used and calculations made at the centerline of the groove. For gasket deformation calculations, if the gasket is placed on the spigot in circumferential tension, the stretched gasket diameter shall be determined as being the design diameter of the gasket divided by the square root of $(1 + x)$ where x equals the design percent of gasket stretch divided by 100. If the gasket is placed in the bell in circumferential compression, the design diameter of the gasket shall be used.

6.3.1.4 The taper on all sealing surfaces of the bell and spigot on which the elastomeric gasket may bear after closure of the joint and at any degree of partial closure, except within the gasket groove, shall form an angle of not more than 2° with the longitudinal axis of the pipe. If the joint design does not incorporate a mechanical locking feature, the joint shall be designed and manufactured in such a way that at the position of normal joint closure, the parallel surfaces upon which the gasket may bear after closure will extend not less than 0.75 in. (20 mm) away from the edges of the gasket groove.

6.3.1.5 *Circular Gaskets*:

6.3.1.5.1 In a joint in which the gasket is placed in the bell in circumferential compression, the circumferential length of the gasket shall be such that, when inserted into the gasket groove, the amount of circumferential compression will be less than 4 %. In larger pipe diameters, an adhesive may be required to hold the gasket in place prior to installation.

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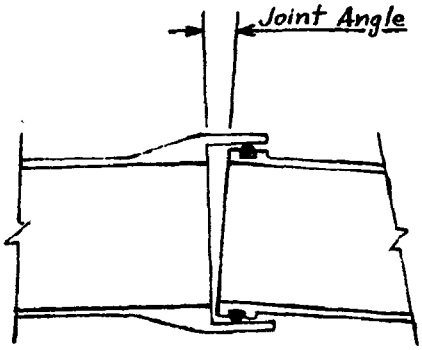
6.3.1.5.2 In an elastomeric joint in which the gasket is placed on the spigot in circumferential tension, the circumferential length of the gasket shall be such that, when installed in the gasket groove, the amount of stretch shall not exceed 30 %.

6.3.1.5.3 Compute the amount of compression or stretch by comparing the circumferential length of the centroid of the relaxed gasket with the circumferential length of the centroid of the compressed or stretched gasket after installation in the bell or on the spigot.

6.3.1.5.4 Each gasket shall be manufactured to provide the volume of elastomer required by the pipe manufacturer's joint design, with a tolerance of ±1 % for gaskets of 1.0-in. (25-mm) diameter and larger. The allowable percentage tolerance shall vary linearly between ±3 % and ±1 % for gasket diameters between 0.5 and 1.0 in. (13 and 25 mm).

6.3.2 The tolerances permitted in the construction of the joint shall be those stated in the pipe manufacturer's design as approved.

6.3.3 *Drawings*—The manufacturer shall furnish drawings of the joint and gasket, including dimensions and tolerances, if requested by the purchaser.



Pipe Size	Joint Angle
≤ 20 in.	3°
>20 in. ≤ 33 in.	2°
>33 in. ≤ 60 in.	1°
> 60 in.	½°

NOTE 1—Joint opening shall not exceed the maximum unstressed limit permitted by dimensional clearance between spigot and bell.

FIG. 2 Typical Bell-and-Spigot Gasket Joint Detail

7. Laboratory Performance Requirements

7.1 *General*:

7.1.1 The gasket shall be the sole element depended upon to make the joint leakproof. The assembled joints shall pass the performance tests listed in this section. The tests shall be performed with components selected to provide minimum compression in the gasket. The internal hydrostatic pressures required in 7.2 and 7.3 shall be two times the rated pressure, if the pipe is manufactured for pressure service, or 29 psi (200 kPa), if the pipe is manufactured for nonpressure service.

7.1.2 Laboratory hydrostatic pressure tests on joints shall be made on an assembly of two sections of pipe properly connected in accordance with the joint design. Suitable bulkheads may be provided within the pipe adjacent to and on either side of the joint, or the outer ends of the two jointed pipe sections may be bulkheaded. Restraints may be provided at the joint to resist transverse thrust. No coatings, fillings, or packings shall be placed prior to the hydrostatic tests.

7.2 *Pipes in Angularly Deflected Position*—Using a pipe and joint system as described in 7.1.2, the test sections shall be deflected angularly, as shown in Fig. 2, and subjected to the appropriate internal hydrostatic test pressure for 10 min without leakage. The angle defined by the joint openings given in Fig. 2 is the angle between the axis of the two joined pipes.

7.2.1 Joints intended for use of pressures greater than 250 psi may have lower allowable angular deflections than those given in Fig. 2 by manufacturer purchaser agreement. The joints shall be tested at the manufacturers maximum allowed angular deflection.

7.2.2 Determine the joint opening by scribing a circumferential index mark on the outside of the pipe a sufficient distance from the spigot end to be visible when the pipe is joined. Measure the maximum and minimum distance from the end of the bell to the mark. The difference equals the joint opening. Fig. 2 illustrates a typical joint in closed and deflected positions and the index mark.

NOTE 5—This test is a laboratory performance test of joint integrity and is not indicative of allowable angular deflections in field installations. In actual installations, deflections greater than the manufacturer's recommended maximum should be avoided, and elbows, bends, or special fittings should be used in such cases.

7.3 *Pipes in Laterally Offset Position (Shear Loading)*—Using a pipe and joint system as described in 7.1.2, the test sections shall be deflected while the pipe units are in a horizontal position, as shown in Fig. 3, by applying a perpendicular load. The load shall be 100 lb/in. (17.5 kN/m) in diameter. The load shall be uniformly applied over an arc of not more than 120° along a longitudinal distance equal to one pipe diameter or 12 in. (300 mm), whichever is the smaller, at the unsupported spigot end of the pipe immediately adjacent to the bell of the assembled joint. The pipe in the test shall be supported on adequate blocks placed immediately behind or on the bells, as indicated in Fig. 3. Bands may be required to secure the pipe to the blocks. There shall be no leakage when the appropriate internal hydrostatic test pressure is applied for 10 min after application of the load.

7.4 *Vacuum or External Pressure Test*—The assembled joint shall withstand an external pressure of 11.6-psi (80-kPa) gage or an internal vacuum of −11.6-psi (−80-kPa) gage while in the angularly deflected position, as in 7.2, and in the laterally offset position, as in 7.3. Allow the pressure to stabilize for 30 min, then seal off for a minimum of 10 min. The maximum permissible pressure increase inside of the pipe during the seal-off period shall be 0.1 psi (0.7 kPa). Some grades of pipe may not have the capability in the pipe wall of withstanding the above vacuum or external pressure. In such cases, the joint design may be considered as meeting these criteria if a pipe and joint system, incorporating a geometrically identical joint and heavier-walled pipe, meets the criteria satisfactorily.

8. Retesting

8.1 If any failure occurs during performance of the tests specified in Section 7, the joint may be retested to establish

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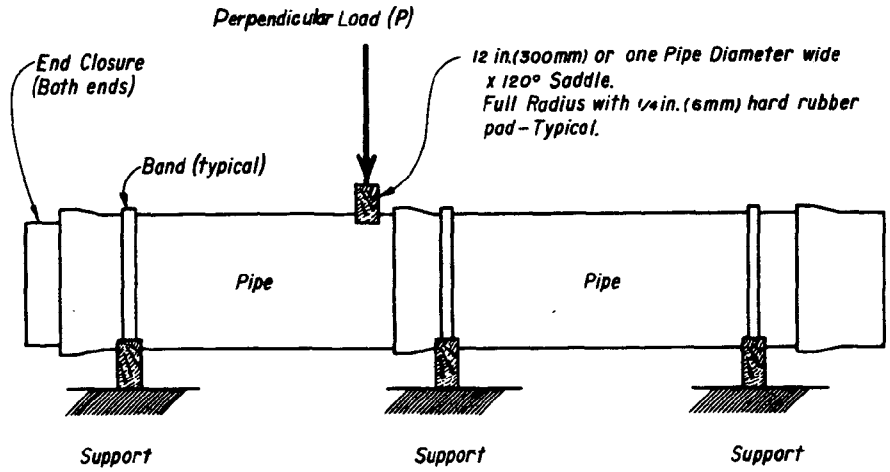

NOTE 1—The load shall be applied perpendicular to the axis of the pipe. It may be applied vertically, as shown in this figure, or at any other circumferential orientation.

FIG. 3 Shear Loading-Test Setup

conformity in accordance with agreement between the purchaser and the manufacturer.

9. Keywords

9.1 angular deflection; bell and spigot; coupling; elastomeric seals; flexible gasket; glass-fiber-reinforced; pipe joints; specification; thermosetting resin

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standards since the last issue (D 4161–96) that may impact the use of this standard.

(1) Modified ISO equivalence statement.
(2) Revised numbering of 6.3 to clarify. (Only applies to circular gaskets.)
(3) Added 7.2.1 relating to high pressure points.

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Designation: E 814 – 00

An American National Standard

Standard Test Method for Fire Tests of Through-Penetration Fire Stops[1]

This standard is issued under the fixed designation E 814; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Characteristically fire spreads from one building compartment to another by the collapse of a barrier, or by openings through which flames or hot gases may pass, or by transfer of sufficient heat to ignite combustibles beyond the barrier. Test Methods E 119 describe the method to be used to measure the fire-resistive performance of these barriers.

However, various techniques of providing for the distribution of services within a structure sometimes require that openings be made in fire-resistive walls and floors to allow the passage of such penetrating items as cables, conduits, pipes, trays, and ducts through to the adjacent compartment. Fire-stop material is installed into these openings to resist the spread of fire.

The performance of through-penetration fire stops should be measured and specified according to a common standard that describes the method of fire exposure and rating criteria.

1. Scope

1.1 This test method is applicable to through-penetration fire stops of various materials and construction. Fire stops are intended for use in openings in fire-resistive walls and floors that are evaluated in accordance with Test Methods E 119.

1.2 Tests conducted in conformance with this test method record fire-stop performance during the test exposure; but such tests shall not be construed to determine suitability of the fire stop for use after test exposure.

1.3 This test method also measures the resistance of fire stops to an external force stimulated by a hose stream. However, this test method shall not be construed as determining the performance of the fire stop during actual fire conditions when subjected to forces such as failure of cable support systems and falling debris.

1.4 The intent of this test method is to develop data to assist others in determining the suitability of the fire stops for use where fire resistance is required.

1.5 *This standard is used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire-hazard or fire-risk assessment of materials, products, or assemblies under actual fire conditions.*

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.7 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

E 119 Test Methods for Fire Tests of Building Construction and Materials[2]

3. Terminology

3.1 *Definition:*

3.1.1 *fire stop*—a through-penetration fire stop is a specific construction consisting of the materials that fill the opening around penetrating items such as cables, cable trays, conduits, ducts, and pipes and their means of support through the wall or floor opening to prevent spread of fire.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *test specimen*—the fire stop being tested.

3.2.2 *test assembly*—the wall or floor into which the test specimen(s) is (are) mounted or installed.

4. Summary of Test Method

4.1 This method of testing through-penetration fire stops exposes fire stops to a standard temperature-time fire, and to a subsequent application of a hose stream.

4.2 Ratings are established on the basis of the period of resistance to the fire exposure, prior to the first development of through openings, flaming on the unexposed surface, limiting

[1] This method is under the jurisdiction of Committee E05 on Fire Standards and is the direct responsibility of Subcommittee E05.11 on Construction Assemblies.

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[2] *Annual Book of ASTM Standards*, Vol 04.07.

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thermal transmission criterion, and acceptable performance under application of a hose stream.

5. Significance and Use

5.1 This test method is used to determine the performance of a fire stop with respect to exposure to a standard time-temperature fire test and a hose stream test. The performance of a fire stop is dependent upon the specific assembly of materials tested including the number, type, and size of penetrations and the floors or walls in which it is installed.

5.2 Two ratings are established for each fire stop. An *F* rating is based upon flame occurrence on the unexposed surface, while the *T* rating is based upon the temperature rise as well as flame occurrence on the unexposed side of the fire stop. These ratings, together with detailed performance data such as the location of through-openings and temperatures of penetrating items are intended to be one factor in assessing performance of fire stops.

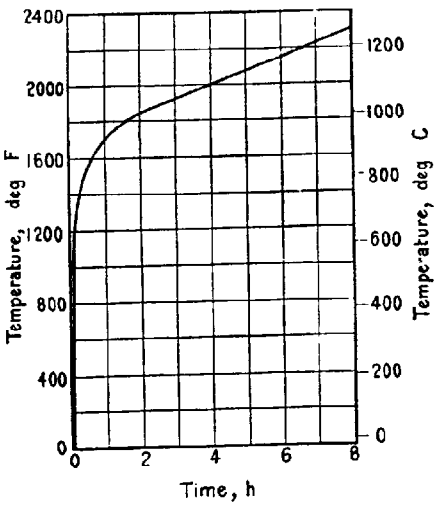
6. Control of Fire Tests

6.1 *Time-Temperature Curve*—The fire environment within the furnace shall be in accordance with the standard time-temperature curve shown in Fig. 1. The points on the curve that determine its character are:

Ambient at 0 min
1000°F (538°C) at 5 min
1300°F (704°C) at 10 min
1550°F (843°C) at 30 min
1700°F (927°C) at 60 min
1850°F (1010°C) at 120 min
2000°F (1093°C) at 240 min
2300°F (1260°C) at 480 min or over

6.2 *Furnace Temperatures*:

6.2.1 The temperature fixed by the curve shall be the average temperature obtained from the readings of thermocouples symmetrically disposed and distributed within the test furnace to show the temperature near all parts of the assembly.



NOTE—For a closer definition of the temperature-time curve, see Annex A1.

FIG. 1 Temperature-Time Curve

Use a minimum of three thermocouples, with not fewer than five thermocouples per 100 ft^2 (9.29 m^2) of floor surface, and not fewer than nine thermocouples per 100 ft^2 of wall specimen surface.

6.2.2 Enclose the thermocouples in sealed protection tubes of such materials and dimensions that the time constant of the protected thermocouple assembly lies within the range (see Note 1) from 300 to 400 s. The exposed length of the pyrometer tube and thermocouple in the furnace chamber shall be not less than 12 in. (300 mm). Use of other types of protection tubes or pyrometers is acceptable provided that temperature measurements obtained in accordance with Fig. 1 are within the limit of accuracy that applies for furnace temperature measurements.

NOTE 1—A typical thermocouple meeting these time-constant requirements may be fabricated by fusion-welding the twisted ends of No. 18 B and S gage (0.040 in.) (1.02 mm) Chromel-Alumel wires, mounting the leads in porcelain insulators and inserting the assembly so the thermocouple bead is 0.50 in. (13 mm) from the sealed end of a standard weight, nominal ½-in. iron, steel, or Inconel pipe. (Inconel is a trademark of Inco Alloys, Inc., 3800 Riverside Dr., P.O. Box 1958, Huntington, WV 25720.) The time constant for this and for several other thermocouple assemblies was measured in 1976. The time constant may also be calculated from knowledge of its physical and thermal properties. See Research Report RR:E05-1001, available from ASTM Headquarters.

6.2.3 For floors, place the junction of the thermocouples 12 in. (300 mm) away from the exposed face of the assembly. In the case of walls, place the thermocouples 6.0 in. (150 mm) away from the exposed face.

6.2.4 Read the temperature at intervals not exceeding 5 min during the first 120 min. Thereafter, the intervals shall not exceed 10 min.

6.2.5 The accuracy of the furnace control shall be such that the area under the temperature-time curve, obtained by averaging the results from the pyrometer or thermoelectric device readings, is within 10 % of the corresponding area under the standard temperature-time curve shown in Fig. 1 for fire tests of 60 min or less duration; within 7.5 % for those over 60 min and not more than 120 min; and within 5 % for tests exceeding 120 min in duration.

6.3 *Unexposed Surface Temperatures*:

6.3.1 Make at least one measurement at each of the following locations on the unexposed surface of the test sample and floor or wall assembly as shown in Fig. 2.

6.3.2 Additional temperature measurements are made at the discretion of the testing agency to obtain representative information on the performance of the fire stops.

6.3.3 Measure temperatures on the surface of the fire stop and assembly with thermocouples placed under flexible pads specified in Annex A2. The pads shall be held firmly against the surface and shall fit closely about the thermocouples. The thermocouple junction shall be located under the center of the pads. The thermocouple leads under the pads shall be not heavier than No. 18 B and S gage (0.040 in.) (1.02 mm) and shall be electrically insulated with heat-resistant moisture-resistant coverings.

6.3.4 Measure temperatures of each type and size of penetrating item with at least one thermocouple located 1.0 in. (25.4 mm) from the unexposed surface of the fire-stop material.

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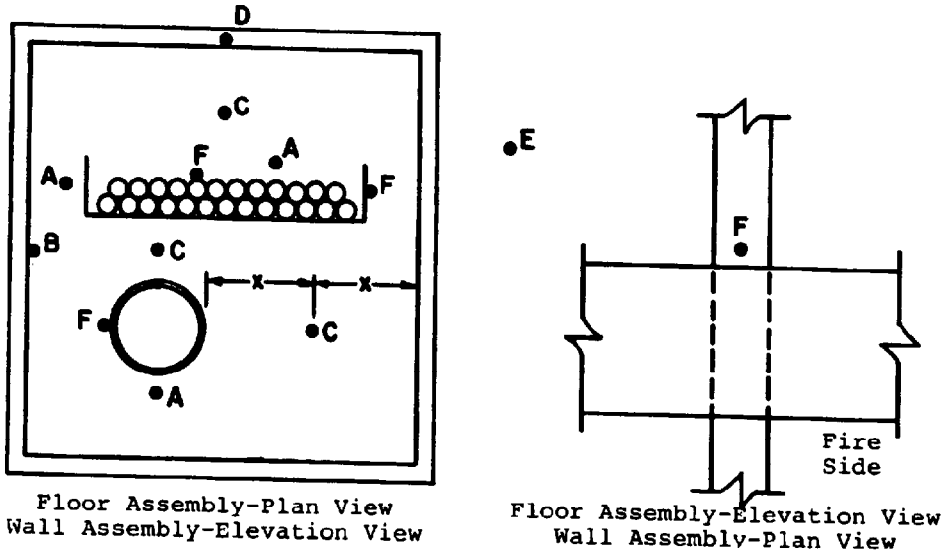

Floor Assembly-Plan View
Wall Assembly-Elevation View

Floor Assembly-Elevation View
Wall Assembly-Plan View

Legend:

A—At a point on the surface of the fire stop 1 in. (25 mm) from one through-penetrating item for each type of penetrating item employed in the field of the fire stop. If the grouping of penetrating items through the test sample prohibits placement of the thermocouple pad, the thermocouple shall not be required.

B—At a point on the fire stop surface at the periphery of the fire stop.

C—At a minimum of three points on the fire stop surface approximately equidistant from a penetrating item or group of penetrating items in the field of the fire stop and the periphery.

D—At one point on any frame that is installed about the perimeter of the opening.

E—At one point on the unexposed surface of the wall or floor that is a minimum of 12 in. (305 mm) from any opening.

F—At one point on each type of through-penetrating item. If the through-penetrating item is insulated or coated on the unexposed side, the thermocouple shall be located on the exterior surface of the insulation or coating. If the coating or insulation does not extend the full length of the penetrating item on the unexposed side, an additional thermocouple shall be installed on the penetrating item 1.0 in. (25.4 mm) beyond the termination of the insulation or coating.

FIG. 2 Temperature Measurement Locations

The thermocouple bead shall be held firmly against the penetrating item. The thermocouple leads shall not be heavier than No. 22 B and S gage (0.025 in.) (0.635 mm) and shall be electrically insulated with heat-resistant and moisture-resistant coverings. The pads as described above shall be held firmly against the penetrating item and shall fit closely about the thermocouples.

6.3.5 Temperature readings shall be taken at intervals not exceeding 15 min until a reading exceeding 212°F (100°C) has been obtained at any one point. Thereafter, at the discretion of the testing body, the readings shall be taken more frequently, but the intervals need not be less than 5 min.

6.4 *Differential Pressure*:

6.4.1 The pressure differential between the exposed and unexposed surfaces of the test assembly, as defined in 3.2.2, shall be measured at two points 0.78 in. (20 mm) from the exposed surface of the test assembly as follows:

6.4.1.1 *Walls*—At two points along the vertical center line. The two points shall be separated by a vertical distance that is equal to or greater than one-half of the height of the test assembly.

6.4.1.2 *Floors*—At approximately the quarter points along the longitudinal center line.

6.4.2 The pressure-measuring probes shall be a Tee-shaped probe or a tube probe and shall be manufactured from stainless steel or other suitable material.

6.4.3 Measure the pressure by means of a manometer or equivalent transducer. The manometer or transducer shall be capable of reading 0.01-in. H_2O (2.5-Pa) increments with a measurement precision of 0.005 in. H_2O (1.25 Pa).

6.4.4 The furnace shall be controlled such that the differential pressure between the exposed and the unexposed surfaces of the test assembly complies with either 6.4.4.1 or 6.4.4.2.

6.4.4.1 *Standard Pressure Condition*—Except for the first 10 min. of the test, the furnace pressure shall be at least 0.01 in. wg (2.5 Pa) greater than the pressure on the unexposed side of the test assembly at the following locations:

(1) Walls—At the lowest elevation of the test specimen (see Note 2).

(2) Floors—At the location of the pressure-measuring probes.

NOTE 2—A supplementary pressure probe, in addition to the two probes specified in 6.4.1.1, may be used to determine compliance with this requirement.

6.4.4.2 *Unique Pressure Condition*—The differential pressure shall be specified by the test sponsor. The furnace shall be controlled such that the specified differential pressure is maintained throughout the duration of the test, excluding the first 10 min., within 20 % of the specified pressure.

7. Test Specimen

7.1 *Construction and Size*:

7.1.1 The construction of the test fire stops shall be of sufficient size and include all conduits, pipes, cables (jacket types, sizes, conductor types, percent fills), required supports, or other through-penetrating items so as to produce a representative fire stop for which evaluation is being sought. Install and test fire stops in each construction type for which ratings are being sought.

7.1.2 Install through-penetrating items so that they extend

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12 in. (300 mm) on the exposed side and 36 in. (900 mm) on the unexposed side unless either or both of these extensions are not typical of actual field installations. In such cases, the installation shall be representative of actual field installations. Support the extended portion of through-penetrating items on the unexposed side so as to minimize relative movement between the through-penetrating item and the restraining frame in which the test assembly is mounted. Cap or otherwise seal the individual ends of through-penetrating items on the exposed side. When the through-penetrating item is a closed system that in actual field practice is not vented or open to the atmosphere, the through-penetrating item shall be capped or sealed on the unexposed side. In such cases, a pressure relief hole shall be provided through the cap or seal on the unexposed side. Otherwise, through-penetrating items shall not be capped or sealed on the unexposed side.

7.1.3 The periphery of the fire stop shall not be closer than 1½ times the thickness of the test assembly or a minimum of 12 in. (300 mm) to the furnace edge, whichever is greater (see Note 3).

NOTE 3—The distance between fire stop periphery and furnace edge may be reduced if the testing agency demonstrates and reports that the edge effects do not affect the results.

8. Protection and Conditioning

8.1 Prior to fire test, condition the floor or wall assembly and fire stops to provide, a moisture condition representative of that existing in similar construction in buildings. For the purposes of standardization, this condition is established at equilibrium resulting from drying in an ambient atmosphere of 50 % relative humidity at 73°F (23°C). However, with some assemblies and fire stops it is difficult or impossible to achieve such uniformity. Therefore, floor or wall assemblies and fire stops are eligible for testing when their dampest portion has achieved a moisture content corresponding to drying to equilibrium with air in the range from 50 to 75 % relative humidity at 73 ± 5°C (23 ± 3°C). If the assembly or fire stops dried in a heated building fail to meet these requirements after a 12-month conditioning period, or if the nature of the construction is such that drying of the assembly or fire stop interior will be prevented by hermetic sealing, these requirements are waived, except as to attainment of the required strength as described in 9.1, and the assembly or fire stop is tested in the condition in which it then exists.

NOTE 4—A method for determining the relative humidity within a hardened concrete specimen with electric sensing elements is described in Appendix I of a paper by C.A. Manzel, "A Method for Determining the Moisture Condition of Hardened Concrete in Terms of Relative Humidity," *Proceedings*, ASTM, Vol 55, 1955, p. 1083. A similar procedure with electric sensing elements can be used to determine the relative humidity within fire test assemblies and fire stops made with other materials.

8.2 Protect the testing equipment, specimen, and assembly undergoing the fire test from any condition of wind or weather that is capable of leading to abnormal results. The ambient air temperature at the beginning of the test shall be within the range from 50 to 90°F (10 to 32°C). The velocity of air across the unexposed surface measured just before the test begins shall not exceed 4.4 ft/s (1.3 m/s) as determined by an anemometer placed at right angles to the unexposed surface. If mechanical ventilation is employed during the test, do not direct an air stream across the surface of the specimen.

9. Conduct of Tests

9.1 *Time of Testing*—Do not test the test specimen until the test assembly has developed sufficient strength to retain the fire stops securely in position.

9.2 *Fire Test*—Continue the test until the evaluation period being sought is reached or until the rating criteria of Section 10 are satisfied.

9.3 *Hose Stream Test*:

9.3.1 Subject a duplicate specimen to a fire-exposure test for a period equal to one half of that indicated as the resistance period in the fire test, but not more than 60 min, immediately after which subject the specimen to the impact, erosion, and cooling effects of a hose stream as described in Table 1 directed first at the middle and then at all parts of the exposed face, with changes in direction being made slowly.

9.3.2 When requested by the test sponsor, and with the advice and consent of the testing body, the hose stream test shall be made on the specimen subjected to the fire test immediately following the fire test.

9.3.3 Deliver the stream through a 2½-in. (63.5-mm) hose and discharge through a National Standard playpipe of corresponding size equipped with a 1⅛-in. discharge tip of the standard-taper, smooth-bore pattern without a shoulder at the orifice. The water pressure and duration of application shall be as specified in Table 1.

9.3.4 The nozzle orifice shall be 20 ft (6.1 m) from the center of the exposed surface of the test specimen if the nozzle is so located that, when directed at the center, its axis is normal to the surface of the test specimen. If otherwise located, its distance from the center shall be less than 20 ft (6.1 m) by an amount equal to 1 ft (300 mm) for each 10° of deviation from the normal.

10. Rating Criteria

10.1 *F Rating*:

10.1.1 A fire stop shall have met the requirements for the *F* rating when it remains in the opening during the fire test and hose stream test and the following conditions are met.

10.1.2 The fire stops shall have withstood the fire test for the rating period by preventing the passage of flame through openings, or the occurrence of flaming on any element of the unexposed side of the fire stops.

TABLE 1 Pressure and Duration—Hose Stream Test[A]

Resistance Period	Water Pressure at Base of Nozzle, psi (kPa)	Duration of Application, s/ft²(m²) of Exposed Area
240 min and over if less than 480 min	45 (310)	3.0 (32)
120 min and over if less than 240 min	30 (210)	1.5 (16)
90 min and over if less than 120 min	30 (210)	0.90 (10)
60 min and over if less than 90 min	30 (210)	0.60 (6)
Less than 60 min if desired	30 (210)	0.60 (6)

[A]When a single fire stop is tested, calculation of the area to be exposed to the hose stream may include more than the outside dimensions of the fire stop if the hose stream uniformly traverses that area. Where multiple test fire stops are tested in the same wall or floor assembly, the rectangular area encompassing all of the fire stops shall be considered as the exposed area since the hose stream must traverse this calculated area during its application.

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10.1.3 During the hose stream test, the fire stop shall not develop any opening that allows a projection of water from the stream beyond the unexposed side.

10.2 *T Rating*:

10.2.1 A fire stop shall have met the requirements for the *T* rating when it remains in the opening during the fire test and hose stream test and the following conditions are met.

10.2.1.1 The transmission of heat through the fire stops during the rating period shall not have been such as to raise the temperature of any thermocouple on the unexposed surface of the fire stop or on any penetrating item more than 325°F (181°C) above its initial temperature. Also, the fire stops shall have withstood the fire test during the rating period by preventing the passage of flame through openings, or the occurrence of flaming on any element of the unexposed side of the fire stops.

10.2.1.2 During the hose stream test, the fire stop shall not develop any opening that allows a projection of water from the stream beyond the unexposed side.

11. Report

11.1 Report results in accordance with the performance in the tests prescribed in this test method. Express the results in time periods of resistance to passage of flame to the nearest integral minute. Reports shall include the following:

11.1.1 Description of the assembly and materials; identify and describe penetrating items of the test fire stop. Drawings depicting geometry, exact size (length, width, thickness), and location of fire stops within the test assembly.

11.1.2 The relative humidities of the test assembly and fire stop materials, if applicable.

11.1.3 The furnace and the unexposed side temperatures for the duration of the standard fire test.

11.1.4 The *F* and *T* ratings for each fire stop in the time period of resistance.

11.1.5 The location of pressure probes and the differential pressures between the exposed and unexposed surfaces of the test assembly measured during the fire test. When the test is conducted with a unique pressure condition in accordance with 6.4.4.2, the report shall state the basis for the specified pressure.

11.1.6 Record observations of significant details of the behavior of the fire stops during the test and after the furnace fire is extinguished. These shall include cracks, deformation, flaming, and smoke issuance. Also, these include continued burning within the fire stop after termination of the fire test.

11.2 When the indicated fire stop rating period is 60 min or over, a correction shall be applied for variation of the furnace exposure from the prescribed, where it will affect the rating, by multiplying the indicated period by two thirds of the difference in area between the curve of average furnace temperature and the standard curve for the first three fourths of the period and dividing the product by the area between the standard curve above a base line of 68°F (20°C) for the same part of the indicated period, the latter area increased by 54°F·h or 30°C·h (3240°F·min or 1800°C·min), to compensate for the thermal lag of the furnace thermocouples during the first part of the test. For fire exposure in the test higher than standard, the indicated rating period shall be increased by the amount of the correction and be similarly decreased for fire exposure below surface. The correction is expressed as follows:

$$C = \frac{2I(A - A_s)}{3(A_s + L)} \quad (1)$$

where:

C = correction in the same units as I,
I = indicated fire-resistance period,
A = area under the curve of indicated average furnace temperature for the first three fourths of the indicated period,
A_s = area under the standard furnace curve for the same part of the indicated period, and
L = lag correction in the same units as A and A_s(54°F·h or 30°C·h; 3240°F·min or 1782°C·min).

12. Precision and Bias

12.1 The precision and bias of this test method have not been determined.

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ANNEXES

(Mandatory Information)

A1. STANDARD TEMPERATURE-TIME CURVE FOR CONTROL OF FIRE TESTS

Time	Temperature,	Area Above 68°F Base		Temperature,	Area Above 20°C Base	
h:min	°F	°F-min	°F-h	°C	°C-min	°C-h
0:00	68	00	0	20	00	0
0:05	1 000	2 330	39	538	1 290	22
0:10	1 300	7 740	129	704	4 300	72
0:15	1 399	14 150	236	760	7 860	131
0:20	1 462	20 970	350	795	11 650	194
0:25	1 510	28 050	468	821	15 590	260
0:30	1 550	35 360	589	843	19 650	328
0:35	1 584	42 860	714	862	23 810	397
0:40	1 613	50 510	842	878	28 060	468
0:45	1 638	58 300	971	892	32 390	540
0:50	1 661	66 200	1 103	905	36 780	613
0:55	1 681	74 220	1 237	916	41 230	687
1:00	1 700	82 330	1 372	927	45 740	762
1:05	1 718	90 540	1 509	937	50 300	838
1:10	1 735	98 830	1 647	946	54 910	915
1:15	1 750	107 200	1 787	955	59 560	993
1:20	1 765	115 650	1 928	963	64 250	1 071
1:25	1 779	124 180	2 070	971	68 990	1 150
1:30	1 792	132 760	2 213	978	73 760	1 229
1:35	1 804	141 420	2 357	985	78 560	1 309
1:40	1 815	150 120	2 502	991	83 400	1 390
1:45	1 826	158 890	2 648	996	88 280	1 471
1:50	1 835	167 700	2 795	1 001	93 170	1 553
1:55	1 843	176 550	2 942	1 006	98 080	1 635
2:00	1 850	185 440	3 091	1 010	103 020	1 717
2:10	1 862	203 330	3 389	1 017	112 960	1 882
2:20	1 875	221 330	3 689	1 024	122 960	2 049
2:30	1 888	239 470	3 991	1 031	133 040	2 217
2:40	1 900	257 720	4 295	1 038	143 180	2 386
2:50	1 912	276 110	4 602	1 045	153 390	2 556
3:00	1 925	294 610	4 910	1 052	163 670	2 728
3:10	1 938	313 250	5 221	1 059	174 030	2 900
3:20	1 950	332 000	5 533	1 066	184 450	3 074
3:30	1 962	350 890	5 848	1 072	194 940	3 249
3:40	1 975	369 890	6 165	1 079	205 500	3 425
3:50	1 988	389 030	6 484	1 086	216 130	3 602
4:00	2 000	408 280	6 805	1 093	226 820	3 780
4:10	2 012	427 670	7 128	1 100	237 590	3 960
4:20	2 025	447 180	7 453	1 107	248 430	4 140
4:30	2 038	466 810	7 780	1 114	259 340	4 322
4:40	2 050	486 560	8 110	1 121	270 310	4 505
4:50	2 062	506 450	8 441	1 128	281 360	4 689
5:00	2 075	526 450	8 774	1 135	292 470	4 874
5:10	2 088	546 580	9 110	1 142	303 660	5 061
5:20	2 100	566 840	9 447	1 149	314 910	5 248
5:30	2 112	587 220	9 787	1 156	326 240	5 437
5:40	2 125	607 730	10 129	1 163	337 630	5 627
5:50	2 138	628 360	10 473	1 170	349 090	5 818
6:00	2 150	649 120	10 819	1 177	360 620	6 010
6:10	2 162	670 000	11 167	1 184	372 230	6 204
6:20	2 175	691 010	11 517	1 191	383 900	6 398
6:30	2 188	712 140	11 869	1 198	395 640	6 594

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A2. REQUIREMENTS FOR THERMOCOUPLE PADS

A2.1 The pads used in measurements of temperature of unexposed surfaces of specimens shall be of suitable inorganic material and shall exhibit the following properties:

A2.1.1 *Length and Width*—2.00 ± 0.04 in. (50.8 ± 1 mm).

A2.1.2 *Thickness*—0.40± 0.05 in. (10 ± 1 mm).

A2.1.3 *Density*—31.2± 0.6 lb/ft^3 (500 ± 10 kg/m^3).

A2.1.4 *Thermal Conductivity at 150°F*—0.380 ± 0.027 Btu·in./h·ft^2·°F (0.055 ± 0.003 W/m·K).

A2.2 The pads shall be capable of being shaped without breaking. The complete pad shall contact the surface against which it is placed.

APPENDIX

(Nonmandatory Information)

X1. DISCUSSION OF SEVERAL ITEMS IN THIS TEST METHOD

X1.1 Introduction

X1.1.1 In writing this standard, various comments and engineering points of view were considered. This test method was written to reflect the broadest possible consensus of these comments.

X1.1.2 This appendix provides a brief discussion of several significant items that were considered. It is intended that the basis for the items included in this test method as well as conflicting points of view, be presented in this discussion.

X1.2 Applicability

X1.2.1 This test method is applicable to through-penetration fire stops of various materials and construction. These fire stops are intended for use in openings in fire resistive walls and floors.

X1.2.2 This test method does not apply to termination devices intended to provide electrical, communication, or other circuitry at the surface of the assembly, and which are evaluated as an integral part of an assembly in accordance with Test Methods E 119.

X1.3 Criteria

X1.3.1 *General*—This fire test method for fire stops is intended to be concerned with evaluating protection provided for openings created in walls or floors that otherwise have a fire resistance rating established in accordance with Test Methods E 119. Presently fire doors and windows, which are similar items, are evaluated by other ASTM standards. Accordingly, the objective of this test method is to assure that the use of such fire stops would not jeopardize the required fire resistance performance of the wall or floor assembly. The rating criteria are accordingly predicated on those conditions relevant to ratings of walls and floors by Test Methods E 119, modified to the extent necessary to take cognizance of the special conditions represented by the occurrence of the fire stops including the penetrating items. In Test Methods E 119, conditions of acceptance include (*1*) passage of flame and hot gases, (*2*) unexposed surface temperature rise, (*3*) ignition of cotton waste, and (*4*) hose stream.

X1.3.2 *Passage of Flame and Hot Gases and Ignition of Cotton Waste*—In Test Methods E 119 one criterion of acceptance of a floor-ceiling or wall is that the assembly shall have withstood the fire endurance test without passage of flame or gases hot enough to ignite cotton waste. The object of this criterion is to minimize the potential for igniting combustible material that might be placed in contact with the unexposed surface. In this test method, the use of cotton waste is excluded and the judgment shall be based only upon visual observation and surface temperatures.

X1.3.3 In Test Methods E 119, visual observation of the passage of flames and hot gases is supplemented with the use of cotton waste. The cotton waste serves as an additional indicator where visual observations are insufficient to determine whether passage of hot gases is occurring. In this test method the cotton waste criterion was excluded for the following reasons: (*1*) the through-penetrating items of a fire stop that continue beyond the wall or floor surface often constitute the combustibles at the unexposed surface, while at the same time minimize the opportunity for other combustibles to come in contact with the wall or floor at the vicinity of the penetration and (2) the through-penetrating items may be of a nature that they inhibit placement of the cotton waste on the protection material surface, while at the same time often being of sufficient temperature that contact with the cotton waste would ignite the cotton waste, thus giving a false indication of fire stop surface ignition.

X1.3.4 *Unexposed Surface Temperatures*—It has been argued that temperatures on the unexposed surface should not be considered in determining the performance of the fire stops, since the fire stops will be installed in such places where they will not be in contact with wood, carpeting, plastic, or other such materials which may ignite at relatively low temperatures. It is further argued a temperature limitation should not be imposed on frames about the opening of fire stop devices or systems since they represent a direct path for heat to flow through to the unexposed surface.

X1.3.5 While these arguments may be valid for some installations, it will be true that the fire stop devices will also be used in areas where they will come in contact with wood, dust, carpeting, paint, wall coverings, or other such materials.

X1.3.6 Further, there are cases where rigorous regulations prohibit combustibles, other than the material that passes

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through the wall or floor, from the area in which the fire stops are located. However, the record clearly establishes that combustible materials such as dust accumulation, workman's clothing items, and miscellaneous building and repair items may well be found in such locations.

X1.3.7 It has been argued that the use of temperature limitation as described in Test Methods E 119 must be retained if the overall character of the fire-resistance rating is to be retained.

X1.3.8 In order to satisfy both positions this test method provides two ratings: a *T* rating incorporating temperature and flame limitation, and an *F* rating predicated only on observation of passage of flame or hot gases.

X1.3.9 The *F* rating is based upon observation of passage of flame. The *T* rating is based upon passage of flame and a maximum individual temperature limitation of 325°F (181°C) above ambient. Therefore, depending upon the construction, the authority having jurisdiction may choose the rating that is most appropriate to fulfill the particular needs of the building.

X1.3.10 Placement of thermocouples as specified by the test method is predicated on obtaining temperatures representative of the various fire-stop items, and the difference in heat transmission through the fire-stop material at various locations.

X1.3.11 A location of approximately 1.0 in. (25 mm) from a penetrating item on the unexposed surface of the fire stop would represent a hot point on fire-stop surface. The distance of 1.0 in. (25 mm) was obtained since one size of standard thermocouple pads is 2.0 by 2.0 in. (50 by 50 mm), and the thermocouple junctions shall be at the center of the pad. This fixes 1.0 in. (25 mm) as the closest permitted spacing from penetrating items.

X1.3.12 A location at a point on the surface at the periphery of the fire-stop material, and at a point approximately equidistant from penetrating items in the field of the fire stop and the periphery would obtain temperature information helpful in evaluating the thermal transmission through the fire stop.

X1.3.13 Also, temperatures of any frame about the opening and the temperatures of penetrating items (that is, cable conductor, conduit) shall be recorded in evaluating the thermal transmission performance of the fire stop.

X1.3.14 The test method indicates that the use of additional thermocouples may be required as determined for individual fire stops.

X1.3.15 *Hose Stream Test*—Passage of the hose stream test was included as an acceptance criterion since it is an indicator of the integrity of the fire stop during fire exposure and the overall reliability of the material to perform its intended function. The hose stream test method as outlined in Test Methods E 119 is considered as applicable to the fire stops.

X1.3.16 Not to conduct a hose stream test without applying any design live load to the test assemblies, would be fire testing the assemblies while ignoring their integrity. It is important that an indication of the integrity of performance be obtained for the fire stops. Failure of the integrity of the fire stops would aid the spread of fire by causing passages for the flames and hot gases.

X1.3.17 However, it was argued that conducting the hose stream test may be difficult to perform at various testing facilities without significant modifications to equipment.

X1.3.18 It was proposed that the hose stream test be included as an option only. Also, it was argued that different hose streams (pressure, spray, durations) be included as an option.

X1.3.19 Although the hose stream tests provide a measure of the structural performance of the fire stop material, it should not be construed as a measure of the load carrying ability of the fire stop tested.

X1.3.20 Also, the hose stream test is not intended to evaluate the structural performance of the floor or wall after the inclusion of the various fire stops.

X1.4 Test Specimen

X1.4.1 The cables, conduits, pipes and other penetrating items used in the fire stops shall be representative of the fire stop for which evaluation is desired. It is intended that the data and information provided by the testing of the fire stops with various penetrating items would be used to determine acceptability of a specific fire stop in the construction.

X1.4.2 Through-penetrating items, as contemplated by this test method, generally represent a small portion of a much larger mechanical, electrical, or similar system. Since this test method is intended to focus on the performance of firestops, standard support and capping provisions are defined for through-penetrating items. Users are cautioned that these standard support and capping provisions are not necessarily representative of field installations nor do they represent worst-case conditions. At the scale contemplated by this test method, it is not feasible to simulate or evaluate all of the performance characteristics associated with these systems that may effect a penetration through a fire-resistive wall or floor. For example, in an actual building fire, significant relative movement may occur between a through-penetrating item and a fire-resistive floor or wall. This test method specifies that, in general, through-penetrating items be supported on the unexposed side by brackets that are attached to the frame in which the test assembly is mounted. Thus, some relative moment may occur due to the deflection of the test assembly. This relative movement is not, however, indicative of that which may occur in actual field installations due to the limited span of the test assembly and other factors. Furthermore, the extension or termination, or both, of these systems will vary considerably. This test method requires that, in general, through-penetrating items be capped or otherwise sealed on the exposed side. This test method also specifies that cables, conduits, pipes, and other through-penetrating items extend 12 in. (300 mm) into the furnace chamber and 36 in. (900 mm) beyond the unexposed surface. From a heat transfer standpoint, previous testing has shown that this arrangement satisfactorily represents continuous cables and conduit as would be encountered in the field. Exceptions for different support and termination conditions have been included for through-penetrating items that will not extend significantly beyond the test assembly in actual field installations. With respect to capping or sealing, an exception has been included for through-penetrating items that will not normally be open to the atmosphere in field installations.

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X1.5 Conduct of Tests

X1.5.1 This test method provides two alternatives for specifying the pressure in the furnace chamber with respect to the unexposed surface. The first, which reflects typical building code provisions that reference this test method, is identified as a *standard pressure condition* and requires that the pressure in the furnace be at least 0.01 in. wg (2.5 Pa) greater than the pressure on the unexposed side of the test assembly at the location of the test specimen (firestop assembly). Other than reporting the actual pressure differentials, no further substantiation is required for tests that are conducted in accordance with the standard pressure condition. The second alternative, which is identified as a *unique pressure condition*, permits the testing of firestop assemblies with a furnace pressure that is less than the standard pressure condition. For tests conducted in accordance with this procedure, the laboratory is required to report the basis for the selected test pressure.

X1.5.2 The issue of pressure differentials that exist in real fires is complex. Normally, a fully-developed fire within an enclosed room will vent through openings, such as windows or open doorways, or both, in the compartment boundaries (walls). A positive pressure in the range of 0.03 to 0.05 in. wg (7.5 to 12.5 Pa) will exist in the upper regions of the fire compartment, due to buoyancy effects, with respect to the atmosphere to which the fire has vented. A negative pressure will exist in the lower regions of the fire compartment. This does not necessarily mean that compartment boundaries in real buildings will be exposed to these pressure differentials. For a given compartment, other pressure differentials may also exist due to the effects of wind, mechanical systems, compartment location within the building, and ambient temperature differences between the inside and outside of the building. As a consequence, during an actual fire, the pressure differential that exists across a given compartment boundary can conceivably be as great as 0.50 in. wg (125 Pa) and either positive or negative. Cooper has published one discussion of this issue (1).[3] Many other excellent references are included in the literature. As a result, the selection of any specific pressure condition for testing purposes is necessarily an arbitrary decision and users should be aware of this shortcoming.

X1.5.3 In studying this issue, the committee has considered a number of other factors. There is, for example, a general consensus that positive pressure testing represents a more severe exposure condition than negative pressure testing. Furthermore, pressure differentials tend to be more important when the test assembly includes joints or openings, or both, which is the case with this test. For some firestop systems, there is evidence that the exact magnitude of the pressure differential does not have a significant impact on performance, provided that the pressure differential is positive (2). Even though this data covers a fairly extensive range of systems and pressure conditions, it is not possible to state that this *rule-of-thumb* applies across the board. And lastly, given the design of many currently available furnaces, testing at significant levels of positive pressure can necessitate complex test equipment modifications (for example, the use of negative pressure chambers on the unexposed surface of the assembly).

X1.5.4 As a result of all of the foregoing, different regulatory authorities have specified different pressure conditions for tests of this nature (3-6). Within the United States, however, model building code provisions that reference this test method specify a minimum positive pressure differential of 0.01 in. wg (2.5 Pa) (3-5). The standard pressure condition is intended to be consistent with these requirements. Users are, however, cautioned that a greater positive pressure differential is specified in Canada in certain instances (6). Since the standard pressure condition specifies a *minimum* positive pressure differential, it is conceivable that a testing program can be carefully designed to satisfy both United States and Canadian building code requirements. As long as the specified pressure differential is positive and at least 0.01 in. wg (2.5 Pa), such tests can be conducted in complete accordance with the standard pressure condition.

X1.5.5 The unique pressure condition alternative is included in recognition of the fact that other regulatory authorities may specify different pressure conditions (including negative pressure differentials). If this alternative is used, 11.1.5 requires that the testing laboratory report the basis for the specified test pressure.

X1.5.6 Within the volume of a furnace, gas temperatures will tend to be reasonably uniform. As a result, a linear static pressure differential relationship will exist between the gases in the furnace and ambient conditions within the laboratory. Higher pressure differentials will exist in the upper portions of the furnace and lower pressure differentials in the lower portions of the furnace. The gradient of this pressure differential relationship can be calculated based upon the average furnace temperature. Even though this gradient will vary with time during the course of a test, an average gradient of approximately 0.01 in. wg/ft of height (8.2 Pa/m) will exist during the majority of a test. The vertical location of the neutral plane (that is, that elevation at which the furnace pressure is equal to the laboratory pressure) will be determined by the operating characteristics of the furnace. As a consequence, for tests involving wall assemblies, the vertical location of the test specimen (firestop assembly) with respect to the neutral plane will determine the applicable pressure differential and test specimens located at different elevations will be exposed to different pressure differentials. This test method therefore requires that the pressure differential be measured at two different elevations for vertical (wall) furnaces (6.4.1.1).

X1.5.7 For tests involving walls, two alternatives can be used to determine whether or not a test specimen (firestop assembly) has been exposed to a minimum positive pressure differential. The elevation of the neutral plane can be determined based upon the measured pressure differentials. The elevation above which the specified positive pressure differential exists can then be calculated based upon an assumed gradient of 0.01 in. wg/ ft of height (8.2 Pa/m). Test specimens located above this elevation will be exposed to the specified minimum positive pressure differential. Test specimens located below this elevation will not. Alternatively, an additional pressure probe can be located at or below the lowest elevation

[3] The boldface numbers in parentheses refer to a list of references at the end of this standard.

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of the test specimen and this probe can be used to determine the minimum pressure differential by direct measurement.

X1.5.8 In the case of floor tests, this degree of complexity is not required since floors will typically be exposed to a uniform pressure differential. For the standard pressure condition, this test method simply requires that the min-imum positive pressure differential of 0.01 in. wg (2.5 Pa) be maintained at the elevation of the required pressure probes.

REFERENCES

(1) Cooper, L. Y., "The Need and Availability of Test Methods for Measuring the Smoke Leakage Characteristics of Door Assemblies," *Fire Safety, Science, and Engineering, ASTM STP 882*, T. Z. Harmathy, Ed., ASTM, 1985, pp. 310–329.

(2) "Investigation of Cable and Cable System Fire Test Parameters, Task B: Firestop Test Method," Report prepared for the Division of Engineering Technology, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, by Underwriters Laboratories Inc., Northbrook, 1985.

(3) "National Building Code, 1990 Edition," Building Officials and Code Administrators International, Inc., Country Club Hills, 1989.

(4) "Standard Building Code, 1991 Edition," Southern Building Code Congress International, Birmingham, 1991.

(5) "Uniform Building Code, 1991 Edition," International Conference of Building Officials, Whittier, 1991.

(6) "National Building Code of Canada, 1985 Edition," National Research Council of Canada, Ottawa, 1985.

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Standard Specification for Polytetrafluoroethylene (PTFE) Plastic-Lined Ferrous Metal Pipe, Fittings, and Flanges[1]

This standard is issued under the fixed designation F 423; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers factory-made polytetrafluoroethylene (PTFE) plastic-lined ferrous metal pipe, fittings, and flanges primarily intended for conveying corrosive fluids. Included are requirements for material, workmanship, dimensions, working pressure and temperature, design, fabrication, test methods, marking, as well as qualification requirements.

NOTE 1—This specification does not include products coated with PTFE.

1.2 This specification covers ANSI Class 150 and 300 PTFE-lined pipe, flanges, and fittings in nominal diameters of ½ to 24 in. Pressure limitations shall be those established by the manufacturer considering both pressure and temperature limitations of the ferrous metal housings and sealing ability of the linear at flanged joints.

1.3 The PTFE-lined flanged pipe and fitting assemblies are limited for use from −20 to 500°F (−29 to 260°C). For use below −20°F (−29°C) consult the manufacturer.

NOTE 2—The temperature limitations are based on noncorrosive test conditions. Use in specific aggressive environments may alter temperature limitations. In such instances, specific temperature limits shall be established by mutual agreement between the purchaser and manufacturer.

1.4 The values given in parentheses are provided for information purposes only.

2. Referenced Documents

2.1 *ASTM Standards:*
A 536 Specification for Ductile Iron Castings[2]
D 792 Test Methods for Specific Gravity (Relative Density) and Density of Plastics by Displacement[3]
D 1457 Specification for Polytetrafluoroethylene (PTFE) Molding and Extrusion Materials[3]
D 1505 Test Method for Density of Plastics by the Density-Gradient Technique[3]
D 1600 Terminology for Abbreviated Terms Relating to Plastics[3,4]
F 412 Terminology Relating to Plastic Piping Systems[4]
2.2 *ANSI/ASME Standards:*
B16.5 Steel Pipe Flanges and Flanged Fittings[5]
B16.9 Factory-Made Wrought Steel Butt Welding Fittings[5]
B16.42 Ductile Iron Pipe Flanges and Flanged Fittings[5]
Section IX of the ASME Boiler and Pressure Vessel Code[6]
2.3 *MSS Standards:*
MSS SP-43 Wrought Stainless Steel Butt-Welding Fittings[7]
2.4 *Federal Standard:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[8]
2.5 *Military Standard:*
MIL-STD-129 Marking for Shipment and Storage[8]

3. Terminology

3.1 *Terminology*—Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise specified. The abbreviation for polytetrafluoroethylene is PTFE.

4. Materials

4.1 *Lining:*
4.1.1 *Material*—The lining shall be made from polytetrafluoroethylene resins conforming to the requirements of Specification D 1457, except that a maximum of 1 % by weight of additives or colorants, or both, is permissible for identification or other purposes. Organic additives or colorants, or both, if used, shall be identified in the manufacturer's specification.
4.1.2 The lining shall be made from virgin resin meeting Specification D 1457 or clean unsintered reworked resin capable of meeting the performance requirements of this specification.
4.1.3 *Mechanical Properties*—When tested in accordance with Specification D 1457 the minimum longitudinal tensile strength and elongation shall be 3000 psi (21 MPa) and 250 % respectively and the transverse minimum values 2500 psi (17 MPa) and 200 %.
4.1.4 *Specific Gravity*—The linings manufactured from PTFE resins meeting Specification D 1457, Types I and IV, shall have a specific gravity from 2.14 to 2.19, and those manufactured from Type III shall have a specific gravity

[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and the direct responsibility of Subcommittee F17.11 on Composite Pipe.
Current edition approved Sept. 10, 1995. Published November 1995. Originally published as F 423 – 75. Last previous edition F 423 – 93.
[2] *Annual Book of ASTM Standards*, Vol 01.02.
[3] *Annual Book of ASTM Standards*, Vol 08.01.
[4] *Annual Book of ASTM Standards*, Vol 08.04.
[5] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.
[6] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.
[7] Available from Manufacturer's Standardization Society of the Valve and Fittings Industry, 5203 Leesburg Pike, Suite 502, Falls Church, VA 22041.
[8] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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TABLE 1 Specifications for Steel Pipe and Fittings

Pipe Section	Material	Specifications	
Piping	carbon steel	ASTM A 53	Welded and Seamless Steel Pipe[8] (Types E and S)
		ASTM A 106	Seamless Carbon Steel Pipe for High-Temperature Service[8]
		ASTM A 135	Electric-Resistance-Welded Steel Pipe[8]
		ASTM A 513	Electric-Resistance Welded Carbon and Alloy Steel Mechanical Tubing[8]
		ASTM A 587	Electric-Welded Low-Carbon Steel Pipe for the Chemical Industry[8]
Flanges	ductile iron	ASTM A 395	Ferritic Ductile Iron Pressure Retaining Castings for Use at Elevated Temperatures[9] (60-40-18)
		ASTM A 536	Ductile Iron Castings
		ANSI B16.42	Ductile Iron Pipe Flanges and Flanged Fittings[4]
	forged steel	ASTM A 105	Forgings, Carbon Steel, for Piping Components[8]
		ASTM A 181	Forgings, Carbon Steel for General Purpose Piping[8]
	cast steel	ASTM A 216	Carbon-Steel Castings Suitable for Fusion Welding for High-Temperature Service[8,9] (Grade WCB)
	steel	ANSI B16.5	Steel Pipe Flanges and Flanged Fittings[4]
Fittings	ductile iron	ASTM A 395	Ferritic Ductile Iron (for Pressure-Retaining Castings for Use at Elevated Temperatures[9] (60-40-18)
		ASTM A 536	Ductile Iron Castings
		ANSI B16.42	Ductile Iron Pipe Flanges and Flanged Fitting[4]
	forged steel	ASTM A 105	Forgings, Carbon Steel, for Piping Components[8]
		ASTM A 181	Forgings, Carbon Steel for General Purpose Piping[8]
	cast steel	ASTM A 216	Carbon-Steel Castings Suitable for Fusion Welding for High-Temperature Service[8,9] (Grade WCB)
		ASTM A 352	Ferritic and Martensitic Steel Castings for Pressure—Containing Parts Suitable for Low-Temperature Service[8,9]
		ASTM A 389	Alloy-Steel Castings Specially Heat Treated for Pressure Containing Parts Suitable for High-Temperature Service[8,9]
	carbon steel	ASTM A 234	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures[8]
	steel	ANSI B16.5	Steel Pipe Flanges and Flanged Fittings[4]

[8] *Annual Book of ASTM Standards*, Vol 01.01.
[9] *Annual Book of ASTM Standards*, Vol 01.02.

from 2.13 to 2.21, when tested in accordance with Test Methods D 792 or D 1505.

4.2 *Pipe and Fittings:*

4.2.1 Mechanical properties of pipe and fitting shall conform to the requirements of the appropriate specification of Table 1 except as they are influenced by accepted methods of processing in the industry, that is, Van Stone flaring, bending, swaging, and welding. The carbon steel pipe and fittings shall be welded or seamless steel, Schedule 40 or Schedule 80, except that Schedule 30 may be used for pipe with 8 and 10-in. nominal size. Schedule 20 may be used for 12-in. nominal size and above with the agreement of the purchaser. Lighter schedules may be used by mutual agreement between the purchaser and the manufacturer.

4.2.2 *Welding*—All fusion welding shall be done by welders or welding operators using welding procedures qualified under the provisions of Section IX of the ASME Boiler and Pressure Vessel Code.

4.2.3 *Finish*—The interior surfaces of all housings shall be clean and free of mold burrs, rust, scale, or other protrusions that may adversely affect the integrity or performance of the lining.

4.3 *Back-Up Gaskets*—Back-up gaskets shall be used to cover the pipe end and gasket face of threaded or slip-on flanges unless a full radius is provided at the end of the pipe and a smooth transition is provided at the junction of the pipe and flange. Gaskets may also be required on fittings to provide accommodation or elimination, or both, of sharp corners that could damage the lining.

5. Requirements

5.1 *Dimensions:*

5.1.1 *Housings*—Housing installation dimensions are as required in the applicable material specification listed in Table 1.

5.1.2 *Wall Thickness*—Pipe and fitting linings shall have a minimum wall thickness and gasket face thickness as follows:

Minimum Linear and Gasket Face Thickness

Nominal Pipe Size, in.	Liner Wall, in. (mm)	Gasket Face Thickness, in. (mm)
1 to 4	0.050 (1.3)	0.040 (1.0)
6 to 14	0.100 (2.5)	0.080 (2.0)
16, 18	0.125 (3.2)	0.100 (2.5)
20, 24	0.150 (3.8)	0.120 (3.0)

5.1.3 *Lining Flare Diameter*—The outside diameter of the PTFE flare covering the gasket face portion of the flange or the full face of the lap-joint stub end shall not be less than the diameter specified in Table 2. The flared portion of the lining shall be concentric with the flared portion of the pipe within 1/16 in. (1.6 mm).

5.1.4 *Tolerances*—Tolerances for pipe, flanges, and fittings shall be as specified in Table 3. Bolt holes in both flanges on a fixed flange spool shall straddle the same center line to facilitate alignment. Finished lined (plastic flare to plastic flare) fabricated fittings shall conform to the nominal face-to-face dimensions as specified in ANSI B16.42 or B16.5 with the applicable tolerances.

TABLE 2 PTFE Flare Diameter

Nominal Pipe Size, in.	Minimum PTFE Flare Diameter, in. (mm)
1/2	1 1/4 (31.8)
3/4	1 9/16 (39.7)
1	1 7/8 (47.6)
1 1/2	2 11/16 (68.3)
2	3 7/16 (87.3)
3	4 5/8 (117.5)
4	5 15/16 (150.8)
6	8 (203.2)
8	10 1/16 (255.6)
10	12 1/4 (311.2)
12	14 3/8 (365.1)
14	15 1/2 (393.7)
16	17 3/4 (450.9)
18	20 1/4 (514.4)
20	22 1/4 (565.2)
24	26 1/4 (666.8)

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TABLE 3 Tolerances for Pipe, Flanges, and Fittings, in. (mm)

Pipe:	
Length	±⅛ (±3.2)
Fixed flange bolt hole alignment	±1/16 (±1.6)
Flange perpendicularity (with pipe centerline)	3/32 in./ft (7.8 mm/m) of diameter
Flanges:	
All dimensions	See ANSI B16.42 or ANSI B16.5
Fittings:	
All dimensions	See ANSI B16.42 or ANSI B16.5

5.2 *Flange Construction:*

5.2.1 Screw-type flanges shall be secured in position to prevent inadvertent turning of the flange.

5.2.2 Socket-type flanges shall be fully backwelded to the pipe housing and the inside surfaces of the socket flanges shall be ground smooth.

5.2.3 Slip-on flanges shall be fully backwelded.

NOTE 3—No welding *shall be done* on lined components in the field unless absolutely necessary and then only under the supervision of experienced and qualified personnel, since excessive heat can cause linear decomposition and failure. It is recommended that lined components be hydrostatically tested as specified in 6.2.1.1 after any welding in the field.

5.2.3.1 Modified slip-on flanges used as lap-joint flanges may be used with flared laps formed by flaring the pipe. The radius of the fillet of the flared lap shall not exceed ⅛ in. (3.8 mm) and the backing flange for the flared metallic lap shall have a ⅛-in. bevel or ⅛-in. corner radius at the bore to provide clearance for the fillet of the flared lap. The outside diameter of the flared lap shall be in accordance with the dimensions of an ANSI B16.9 lap-joint stub.

5.2.4 Lap-joint (or Van Stone) flanged ends may be manufactured by standard forming techniques or by using fully welded Type A MSS SP-43 or ANSI B16.9 lap-joint stub ends. Van Stone flares shall have a fillet radius compatible with the corner radius of the mating flange and shall not contain any cracks or buckles. Van Stone flares and stub ends shall have a radius to provide a smooth transition for the PTFE flare. Only lap joint flanges in accordance with ANSI B16.42 and B16.5 shall be used.

5.3 *Venting*—Each pipe and fitting shall be provided with a venting system that will release any pressure between the liner and the housing.

NOTE 4—A series of 1/16 to 5/32-in. (1.6 to 4.0-mm) diameter holes in the housings, or a helical groove system inside the housing, that connects flange vents, has provided adequate venting.

5.4 *Workmanship:*

5.4.1 Pipe and fitting linings shall show no evidence of pinholes, porosity, or cracks when inspected in accordance with 5.5.2. The linings shall fit snugly inside the pipe and fitting housings. Any bulges or other obvious indication of poor contact with the housing shall be cause for rejection.

5.4.2 The gasket seating surface of the linings shall be free of surface defects that could impair sealing effectiveness. Scratches, dents, nicks, or tool marks on the seating surface shall not be deeper than 10 % of the wall thickness.

5.5 *Performance:*

5.5.1 *Qualification*—Lined pipe and fittings must be capable of meeting the qualification requirements specified in 6.1.

5.5.2 *Inspection*—Each spool and fitting, prior to shipment, shall be hydrostatically or spark tested in accordance with 6.2.1.1 or 6.2.1.2 and shall subsequently be visually inspected to verify conformance to the requirements of 5.4.

6. Test Methods

6.1 *Qualification Tests:*

6.1.1 *Temperature Test*—Cycle representative production samples of lined pipe and fittings in an oven from room temperature to 500°F (260°C) to determine the ability of the lined components to withstand heat aging and temperature cycling. Test a minimum of two pipe spools, tees, and 90° elbows in each size.

6.1.1.1 *Test Method*—Install blind flanges with a center vent hole at the manufacturer's recommended torque value, and affix a thermocouple to the ferrous housing to measure the temperature. Pipe spools shall be at least 3 ft (1 m) long up to the 4-in. size and 10 pipe diameters in sizes 6 in. and larger to a 10-ft (3-m) maximum length. After 1 h in an oven at 500°F (260°C) as indicated by the thermocouple, air cool the lined component to 122°F (50°C) maximum. Repeat this test for a total of three cycles.

6.1.1.2 *Inspection*—Inspect lined pipe and fittings after each cycle for distortion or cracks in the lining. At the completion of the third cycle, subject tested specimens to the hydrostatic or electrostatic test described in 6.2.1.1 or 6.2.1.2.

6.1.2 *Steam-Cold Water Cycling Test*—Subject representative production samples of lined pipe and fittings to steam-cold water cycling to determine the ability of the lined components to withstand rapid temperature changes. Test a minimum of two pipe spools, tees, and 90° elbows in each size.

6.1.2.1 *Test Method*—Assemble lined pipe and fitting with suitable blind flanges having provision for the introduction of steam, air, cold water, and for drainage. Install the flanges using the manufacturer's recommended torque value. Pipe spool length shall be 10 ft (3 m). Mount the sample in such a manner as to permit complete drainage and venting. Then subject it to 100 consecutive steam-cold water cycles, each consisting of the following in the sequence given:

(*1*) Circulate 125 ± 5 psi (862 ± 35 kPa) gage saturated steam through the sample until the ferrous housing skin temperature adjacent to the flange at the outlet end of the sample has been maintained at the maximum stabilized temperature for 10 min.

(*2*) Close off steam.

(*3*) Circulate water at a maximum temperature of 77°F (25°C). Circulate the cooling water until the ferrous housing skin temperature adjacent to the flange at the outlet end of the sample measures 122°F (50°C).

(*4*) Vent and introduce air to purge the sample for a minimum of 1 min, making certain that it is completely drained of water.

6.1.2.2 *Inspection*—There shall be no evidence of leakage from the venting system during the 100 cycles. At the completion of the test, the liner shall evidence no buckling, cracking, or crazing. Formation of water blisters shall not be cause for rejection.

NOTE 5—These surface blisters are formed due to absorption of the steam vapors by the liner and subsequent condensation in the liner. The blisters do not adversely affect liner performance.

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6.1.2.3 Subject the lined pipes or fittings to either the hydrostatic test described in 6.2.1.1 or, after drying, to the electrostatic test described in 6.2.1.2.

6.1.3 *Vacuum Testing*—Test representative production samples of lined pipe and fittings to determine the vacuum ratings of the lined components. Test a minimum of two pipe spools, tees, and 90° elbows in each size. Conduct tests at room temperature, at the manufacturer's maximum recommended service temperature, and at two intermediate temperature levels.

NOTE 6—Vacuum-temperature ratings for pipe and fittings are published in the manufacturers' literature.

NOTE 7—The above vacuum test is performed on pipe and fittings that have not been exposed to prior service. Use in specific environments may alter the vacuum-temperature ratings and these shall be established by mutual agreement between purchaser and manufacturer.

6.1.3.1 *Test Method*—For pipe spools, specimen length shall be at least ten pipe diameters. Install a flange incorporating a sight glass at one end and a blind flange suitable for drawing a vacuum at the other end. Make provision for measuring the ferrous housing temperature. Uniformly heat the specimen externally with the sight glass end visible, and after reaching the desired ferrous housing temperature, begin the test. Hold a selected initial vacuum level for a minimum of 8 h and if no failure occurs, increase the vacuum by 5 in. Hg (17 kPa) up to the 4-in. size and by 2 in. Hg (6.8-kPa) increments for sizes 6 in. and larger. Repeat for 8-h minimum periods until failure or full vacuum is reached. Failure is defined as any buckling or collapse of the liner. If failure occurs at the initial vacuum level selected, test a new specimen at a lower vacuum level to determine the failure threshold. The failure threshold vacuum is defined as 1 in. Hg (3.4 kPa) below that at which failure occurs.

NOTE 8—The external pressure method can be used to simulate higher than full vacuum to establish the failure threshold when full vacuum does not produce failure. With the use of pressure taps, an external pressure is applied between the liner outside diameter and the pipe inside diameter.

6.1.3.2 Set the vacuum ratings 20 % below the failure threshold.

6.1.3.3 At the test completion and after establishing the vacuum rating, place a duplicate specimen in an oven at the test temperature. Apply the rated vacuum to the specimen after the desired skin temperature has been reached. Achieve the rated vacuum within 2 min and apply continuously for 48 h. If no liner buckling or collapse occurs, the rated vacuum shall be considered acceptable.

6.1.4 *Retest*—When a test specimen fails to meet the requirements of either 6.1.1.2, 6.1.2.2, or 6.1.3.3, seek and correct the cause of failure and repeat the specified test, doubling the number of test specimens.

6.2 *Inspection Requirements:*

6.2.1 *Hydrostatic or Electrostatic Testing*—Subject each lined pipe and fitting, prior to shipment, to a hydrostatic test or electrostatic test as specified in 6.2.1.1 or 6.2.1.2. The test to be used shall be at the option of the manufacturer, unless otherwise specified by the purchaser.

6.2.1.1 *Hydrostatic Pressure Test*—The internal test pressure shall be 400 psi (2758 kPa) minimum, and the test shall be conducted at ambient temperature. Fill the pipe or fitting completely with clean water and bleed the system free of all air prior to the application of pressure. Reach full test pressure within 1 min and maintain for 3 min. Observe the pressure gage and the venting system in the test specimen throughout the pressure test for any evidence of leakage, which shall be cause for rejection.

6.2.1.2 *Electrostatic Test*—Conduct the test with a nondestructive high-voltage tester at an output voltage of 10 000 V. A visible or audible spark, or both, that occurs at the probe when electrical contact is made because of a defect in the liner, shall be cause for rejection.

6.2.2 *Final Inspection*—After the requirements of 6.2.1 have been met, visually inspect each lined pipe and fitting prior to shipment to verify conformance to the design and dimensional requirements of this specification and 5.4.

6.2.3 Each spool or fitting shall bear an inspection verification mark on the housing to indicate compliance with the requirements of this specification.

7. Finish

7.1 The outside surface of all lined pipe and fittings shall be coated with a corrosion-resistant primer over a properly prepared surface.

8. Marking

8.1 *Quality of Marking*—The markings shall be applied to the pipe in such a manner that it remains legible (easily read) after installation and inspection have been completed.

8.2 The pipe and fittings shall be marked with the following information:

8.2.1 Nominal pipe size,

8.2.2 Liner material identification (PTFE),

8.2.3 Manufacturer's name (or trademark),

8.2.4 This designation "ASTM F 423," and

8.2.5 Length (on pipe only).

8.3 Other information such as, order numbers, part numbers, item numbers, etc., shall be provided at the request of the purchaser.

8.4 Pipe liner identification shall be provided on a band containing the raised letters "PTFE." The band shall typically be located near the flange.

9. Packaging

9.1 The gasket face of each spool shall be protected by end plates or other suitable protective means.

9.2 Fittings shall have the same protective covers on the gasket faces unless protected by other means, such as individual boxing.

10. Federal Procurement

10.1 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

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NOTE 9—In federal contracts, the contractor is responsible for inspection.

10.2 *Packaging and Marking for U.S. Government Procurement:*

10.2.1 *Packaging*—Unless otherwise specified in the contract, the material shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition, and that will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules.

10.2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE 10—The inclusion of U.S. Government procurement requirements shall not be construed as an indication that the U.S. Government uses or endorses the products described in this document.

11. Quality Assurance

11.1 When the product is marked with this designation, F 423, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

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Standard Specification for Threaded Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80[1]

This standard is issued under the fixed designation F 437; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers chlorinated poly(vinyl chloride) (CPVC) threaded Schedule 80 pipe fittings. Included are requirements for materials, workmanship, dimensions, and burst pressure.

NOTE 1—The CPVC fittings covered by this specification were covered previously in Specification D 2464.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 2—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious safety hazards should a system fail for any reason.

1.3 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values in parentheses are given for information only.

1.5 The following safety hazards caveat pertains only to the test method portion, Section 8, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics for Testing[2]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[2]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D 2749 Symbols for Dimensions of Plastic Pipe Fittings[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings[3]

2.2 *Federal Standard:*

Fed Std. No. 123 Marking for Shipment (Civil Agencies)[4]

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[4]

2.4 *NSF Standard:*

Standard No. 14 for Plastic Piping Components and Related Materials[5]

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions are in accordance with Terminology F 412 and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated. The abbreviation for chlorinated poly(vinyl chloride) is CPVC.

4. Classification

4.1 *General*—This specification covers threaded Schedule 80 CPVC pipe fittings, intended for use with threaded Iron Pipe Size (IPS) outside-diameter plastic pipe.

4.1.1 Fittings covered by this specification are normally molded. In-line fittings, such as couplings, unions, bushings, caps, nipples, etc., shall be molded or machined from extruded stock.

4.1.2 Fittings fabricated by backwelding are not included in this specification.

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[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.10 on Fittings.

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[2] *Annual Book of ASTM Standards,* Vol 08.01.

[3] *Annual Book of ASTM Standards,* Vol 08.04.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[5] Available from the National Sanitation Foundation, P.O. Box 1468, Ann Arbor, MI 48106.

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5. Materials and Manufacture

5.1 This specification covers CPVC pipe fittings made from compounds meeting the requirements of Class 23447 as defined in Specification D 1784.

NOTE 3—Mechanical strength, heat resistance, flammability, and chemical resistance requirements are covered in Specification D 1784.

5.2 *Rework Material*—The manufacturers shall use only their own clean rework fitting material and the fittings produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances*:

6.1.1 The dimensions and tolerances of the fittings shall be as shown in Table 1 and Table 2 when measured in accordance with Test Method D 2122. Minimum dimensions have zero negative tolerances. Bushings shall have thread lengths applicable to the corresponding sizes. Counterbore, which is optional, is not shown in Table 1, and is not included in the center-to-end or end-to-end dimensions.

6.1.2 The maximum angular variation of any opening shall be not more than ½° off the true centerline axis.

6.1.3 *Fittings Not Illustrated*—All fittings, whether illustrated in Table 1 and Table 2 or not, shall have wall thicknesses and thread dimensions conforming to 6.1 and 6.2.

6.2 *Threads*—For all fittings having taper pipe threads, threads shall conform to Specification F 1498 and be gaged in accordance with 8.4.

6.3 *Burst Pressure*:

6.3.1 The minimum burst strength of the fittings shall be not less than that calculated for the size and wall thickness of the pipe with which it is to be used, when calculated from the following equation:

$$S = P(D_o - t)/2t \quad (1)$$

where:

S = hoop stress, psi (or MPa),
P = internal pressure, psi (or MPa),
D_o = average outside diameter, in. (or mm), and
t = minimum wall thickness, in. (or mm).

Fittings tested in accordance with 8.5 shall withstand the minimum burst pressure shown in Table 3.

6.3.2 Pressures shown are minimum burst pressures and do not imply rated working pressures. The burst pressure shall be used only as an indication of quality.

7. Workmanship, Finish, and Appearance

7.1 The fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

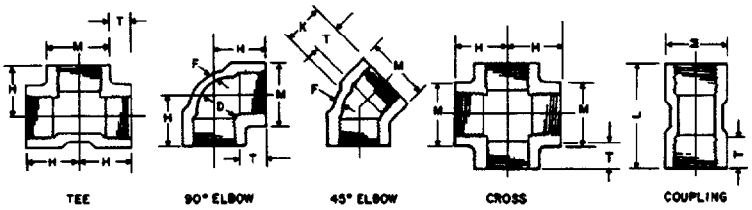
8.1 *Conditioning*—Condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Sampling*—A sufficient quantity of fittings as agreed upon between the seller and the purchaser shall be selected at random from each lot or shipment and tested to determine that the basic design is in conformance with this specification.

NOTE 4—For individual orders or specifications where supplemental

TABLE 1 Dimensions of 90° Ells, Tees, Crosses, 45° Elbows and Couplings (Straight Sizes), in. (mm)[A,B]



Nominal Pipe Size	Center to Thread End, 90° Elbows, Tees, Crosses, *H*, min	Length of Thread, *T*, min	Center to Thread End, 45° Elbow,[C] *K*, min	Inside Diameter of Fitting, *D*, min	Nominal Wall Thickness, *F*, min	Outside Diameter of Hub, *M*, min	Thread End to Thread End of Coupling, *L*, min
1/4	0.812 (20.62)	0.50 (12.70)	0.688 (17.48)	0.258 (6.55)	0.135 (3.43)	0.840 (21.34)	1.063 (27.00)
3/8	0.938 (23.83)	0.50 (12.70)	0.750 (19.05)	0.379 (9.63)	0.144 (3.66)	1.000 (25.40)	1.063 (27.00)
1/2	1.125 (28.58)	0.64 (16.26)	0.750 (19.05)	0.502 (12.75)	0.198 (5.03)	1.280 (32.51)	1.344 (34.14)
3/4	1.250 (31.75)	0.65 (16.51)	1.000 (25.40)	0.698 (17.73)	0.207 (5.25)	1.500 (38.10)	1.500 (38.10)
1	1.500 (28.10)	0.81 (20.51)	1.125 (28.58)	0.911 (23.14)	0.225 (5.72)	1.810 (45.97)	1.688 (42.88)
1¼	1.750 (44.45)	0.85 (21.59)	1.313 (23.35)	1.227 (31.17)	0.261 (6.63)	2.200 (55.88)	1.750 (44.45)
1½	1.938 (49.23)	0.85 (21.59)	1.438 (36.83)	1.446 (36.73)	0.270 (6.85)	2.500 (63.50)	2.000 (50.80)
2	2.250 (57.15)	0.90 (22.86)	1.625 (41.28)	1.881 (47.78)	0.297 (7.54)	3.000 (76.20)	2.063 (52.40)
2½	2.688 (68.28)	1.21 (30.73)	1.938 (49.23)	2.250 (57.15)	0.315 (8.00)	3.560 (90.42)	2.625 (66.68)
3	3.063 (77.80)	1.30 (33.02)	2.125 (53.98)	2.820 (71.63)	0.405 (10.29)	4.300 (109.22)	2.750 (69.85)
4	3.625 (92.08)	1.38 (35.05)	2.625 (66.68)	3.737 (94.92)	0.450 (11.43)	5.430 (137.92)	3.000 (76.20)
6	5.125 (130.18)	1.50 (38.10)	3.250 (82.55)	5.646 (143.41)	0.504 (12.80)	7.625 (193.68)	3.250 (82.55)

[A] The sketches and designs of fittings shown are illustrative only.
[B] Symbols for dimensions are per Symbols D 2749.
[C] This dimension locates the end of the fitting.

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TABLE 2 Dimensions of Plugs and Caps, in.[A,B]

Nominal Pipe Size	Length of Male Thread, *S*, min	Length of Female Thread, *T*, min	Width of Flats,[B] *Q*, min	Nominal Wall Thickness, *F*, min	Height of Head, *R*, min	Cap Height, *W*, min	Outside Diameter of Hub, *M*, min
1/4	0.44 (11.18)	0.50 (12.70)	0.625 (15.88)	0.135 (3.43)	0.188 (4.78)	0.688 (17.48)	0.840 (21.34)
3/8	0.44 (11.18)	0.50 (12.70)	0.750 (19.05)	0.144 (3.66)	0.188 (4.78)	0.688 (17.48)	1.000 (25.40)
1/2	0.53 (13.46)	0.64 (16.26)	0.938 (23.83)	0.198 (5.03)	0.188 (4.73)	0.875 (22.23)	1.280 (32.51)
3/4	0.55 (13.92)	0.65 (16.51)	1.125 (28.53)	0.207 (5.26)	0.219 (5.56)	1.000 (25.40)	1.450 (35.03)
1	0.68 (17.27)	0.81 (20.57)	1.375 (34.93)	0.225 (5.72)	0.219 (5.56)	1.188 (30.18)	1.810 (45.97)
1¼	0.71 (18.03)	0.85 (21.59)	1.750 (44.45)	0.261 (6.63)	0.281 (7.14)	1.250 (31.75)	2.200 (55.88)
1½	0.72 (18.29)	0.85 (21.59)	1.875 (47.63)	0.270 (6.85)	0.313 (7.95)	1.250 (31.75)	2.450 (62.23)
2	0.76 (19.30)	0.90 (22.86)	1.875 (47.63)	0.297 (7.54)	0.313 (7.95)	1.375 (34.93)	3.000 (76.20)
2½	1.14 (28.96)	1.21 (30.25)	1.875 (47.63)	0.369 (8.00)	0.375 (9.53)	1.625 (41.28)	3.560 (90.42)
3	1.20 (30.48)	1.30 (33.02)	2.000 (50.80)	0.405 (10.29)	0.375 (9.53)	1.750 (49.45)	4.250 (107.98)
4	1.30 (33.02)	1.38 (35.05)	2.000 (50.80)	0.450 (11.43)	0.375 (9.53)	2.000 (50.60)	5.350 (125.87)
6	1.44 (36.58)	1.50 (35.10)	2.000 (50.80)	0.504 (12.80)	0.500 (12.10)	2.125 (53.98)	7.625 (193.68)

[A]The sketches and designs of fittings shown are illustrative only.
[B]Symbols for dimensions are per Symbols D 2749.
[C]At the manufacturer's option the head of the plug shall be hexagonal, octagonal, square, or round.

TABLE 3 Burst Pressure Requirements for Water at 73°F (23°C) for CPVC Threaded Pipe Fittings, Schedule 80

Nominal Size, in.	Min Burst Strength[A] Class 23447	
	psi	(MPa)
1/4	3620	(24.96)
3/8	2940	(20.27)
1/2	2720	(18.75)
3/4	2200	(15.17)
1	2020	(13.93)
1 1/4	1600	(11.44)
1 1/2	1510	(10.41)
2	1290	(8.89)
2 1/2	1360	(9.38)
3	1200	(8.27)
4	1040	(7.17)
6	890	(6.14)

[A]This table was calculated for Schedule 80 pipe using the ISO formula and a stress level as follows:

	psi	MPa
Class 23447 (Type IV Grade 1 (CPVC))	6400	44.1

tests are required, only those tests and numbers of tests specifically agreed upon between the purchaser and seller need be conducted.

8.4 *Threads*—All taper pipe threads shall be gaged in accordance with Specification F 1498.

8.5 *Burst Pressure*—Determine the minimum burst pressure with at least five specimens in accordance with Test Method D 1599. Join the fittings to the pipe sufficiently strong and in such a manner that no failures shall occur in the assembly at a pressure less than the pressure requirement given in Table 3. The time of testing each assembly shall be between 60 and 70 s.

9. Retest and Rejection

9.1 If the results of any test(s) do not meet the requirements of this specification, the tests(s) shall be conducted again only by agreement between the purchaser and seller. Under such agreement, minimum requirements shall not be lowered, changed, or modified, nor shall specification limits be changed. If upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

10. Product Marking

10.1 *Quality of Marking*—The markings shall be applied to the fittings in such a manner that they remain legible under normal handling and installation practices.

10.2 *Content of Marking*:

10.2.1 Fittings shall be marked with the following:

10.2.1.1 Manufacturer's name or trademark,

10.2.1.2 Material designation CPVC for CPVC 23447,

10.2.1.3 The seal or mark of the laboratory making the evaluation for potable water contact,

10.2.1.4 Size, and

10.2.1.5 This designation "F 437," with which the fitting complies.

10.3 Where the size of the fitting does not allow complete marking, omit identification marking in the following sequence: size, material designation, F 437, manufacturer's name or trademark.

10.4 Markings or symbols shall be molded, hot-stamped, or applied to fittings by any other suitable method, such as printing.

10.5 Where recessed marking is used, care shall be taken to see that in no case marking causes cracks or reduces the wall thickness below the minimum specified.

11. Quality Assurance

11.1 When the product is marked with this designation, F 437, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this

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specification and has been found to meet the requirements of this specification.

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply *only* to Federal/Military procurement, not domestic sales or transfers.

S1. *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless the purchaser disapproves. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE S1—In U.S. Federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this document.

POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for product to be used to convey or to be in contact with potable water.

S3. Products intended for contact with potable water shall be evaluated, tested and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

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Designation: F 438 – 01

An American National Standard

Standard Specification for Socket-Type Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40[1]

This standard is issued under the fixed designation F 438; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers chlorinated poly(vinyl chloride) (CPVC) Schedule 40 socket-type pipe fittings. Included are requirements for materials, workmanship, dimensions, and burst pressure.

NOTE 1—The CPVC fittings covered by this standard were covered previously in Specification D 2466.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 2—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious saftey hazards should a system fail for any reason.

1.3 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values in parentheses are given for information only.

1.5 The following safety hazards caveat pertains only to the test method portion, Section 8, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics for Testing[2]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[2]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D 2749 Symbols for Dimensions of Plastic Pipe Fittings[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings[3]

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[4]

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[5]

2.4 *NSF Standard:*

Standard No. 14 for Plastic Piping Components and Related Materials[5]

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions are in accordance with Terminology F 412 and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated. The abbreviation for chlorinated poly(vinyl chloride) is CPVC.

4. Classification

4.1 *General*—This specification covers Schedule 40 CPVC pipe fittings, socket-type, intended for use with Iron Pipe Size (IPS) outside-diameter plastic pipe.

4.1.1 Fittings covered by this specification are normally molded. In-line fittings, such as couplings, unions, bushings, caps, nipples, etc., shall be molded or machined from extruded stock.

4.1.2 Fittings fabricated by backwelding are not included in this specification.

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[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.10 on Fittings.

Current edition approved April 10, 2001. Published June 2001. Originally published as part of D 2466 – 74. Last previous edition F 438 – 99.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[5] Available from the National Sanitation Foundation, P.O. Box 1468, Ann Arbor, MI 48106.

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5. Materials and Manufacture

5.1 This specification covers CPVC pipe fittings made from compounds meeting the requirements of Class 23447 as defined in Specification D 1784.

NOTE 3—Mechanical strength, heat resistance, flammability, and chemical resistance requirements are covered in Specification D 1784.

5.2 *Rework Material*—The manufacturers shall use only their own clean rework fitting material and the fittings produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances*:

6.1.1 Fitting sockets, inside diameters (waterways), minimum wall thicknesses, and dimensions shall be as shown in Table 1, Table 2, and Table 3 when measured in accordance with Test Method D 2122.

6.1.2 When multistep reducer bushings are cored out, the inner socket shall be reinforced from the outer wall by a minimum of three ribs extending from the top of the inner socket in the deepest extremity of the coring. The transition from D to DJ (Table 3) shall be straight, tapered as shown, or radiused. A positive taper in the same direction of the taper in the socket on the outside diameter of the bushing is optional.

6.1.3 The maximum angular variation of any opening shall be not more than ½° off the true centerline axis.

6.1.4 The minimum wall thickness of fittings shall be 125 % of the minimum wall thickness of the corresponding size of Schedule 40 pipe for which they are designed to be used, except that for the socket, the wall thickness shall be at least equal to the minimum wall thickness of the corresponding size of Schedule 40 pipe. For any threaded transition fitting the minimum wall thickness of the threaded portion shall be at least equal to the thickness of material under the thread root of threaded Schedule 80 pipe of the same size.

6.1.5 The minimum inside diameter of the fittings shall be not less than the minimum specified inside diameter of the corresponding size of Schedule 40 pipe. Any fitting having a male thread shall have an internal diameter not larger than Schedule 80 pipe of the same size.

6.1.6 Minimum dimensions have zero negative tolerance. Tolerances on other dimensions are shown in Table 1 and Table 3.

6.2 *Threads*—For all fittings having taper pipe threads, threads shall conform to Specification F 1498 and be gaged in accordance with 8.4.

6.3 *Burst Pressure*:

6.3.1 The minimum burst strength of the fittings shall be not less than that calculated for the size and wall thickness of the pipe with which it is to be used, when calculated from the following equation:

$$S = P (D_O - t)/2t \quad (1)$$

where:

S = hoop stress, psi (or MPa),
P = internal pressure, psi (or MPa),
D_O = average outside diameter, in. (or mm), and
t = minimum wall thickness, in. (or mm).

Fittings tested in accordance with 8.5 shall withstand the minimum burst pressure shown in Table 4.

6.3.2 Pressures shown are minimum burst pressures and do not imply rated working pressures. The burst pressure shall be used only as an indication of quality.

7. Workmanship, Finish, and Appearance

7.1 The fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 *Conditioning*—Condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Sampling*—A sufficient quantity of fittings as agreed upon between the seller and the purchaser shall be selected at random from each lot or shipment and tested to determine that the basic design is in conformance with this specification.

NOTE 4—For individual orders or specifications where supplemental tests are required, only those tests and numbers of tests specifically agreed upon between the purchaser and the seller need be conducted.

8.4 *Threads*—All taper pipe threads shall be gaged in accordance with Specification F 1498.

8.5 *Burst Pressure*—Determine the minimum burst pressure in accordance with Test Method D 1599. The time of testing each specimen shall be between 60 and 70 s.

8.5.1 *Apparatus*—Fittings shall be tested while held in a test jig constructed in such a manner as to seal the socket by means of O-rings, or gaskets but not to reinforce or support the fittings, except where contact is necessary because of the shape of the fitting to keep the fitting in the test jig. Such contact shall be held to the minimum. The socket plug portion of the test fixture must extend one third to two thirds of the socket depth. Failure of any part of the test apparatus does not constitute failure of the fittings.

9. Retest and Rejection

9.1 If the results of any test(s) do not meet the requirements of this specification, the tests(s) shall be conducted again only by agreement between the purchaser and seller. Under such agreement, minimum requirements shall not be lowered, changed, or modified, nor shall specification limits be changed. If upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

10. Product Marking

10.1 *Quality of Marking*—The markings shall be applied to the fittings in such a manner that they remain legible under normal handling and installation practices.

10.2 *Content of Marking*:

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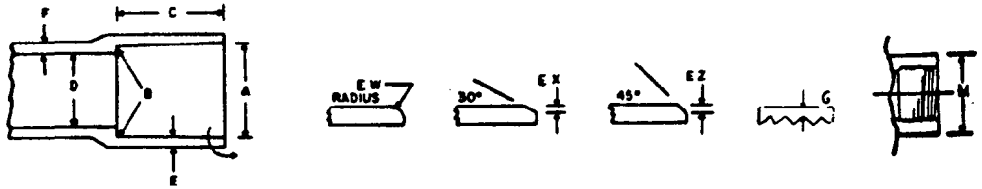
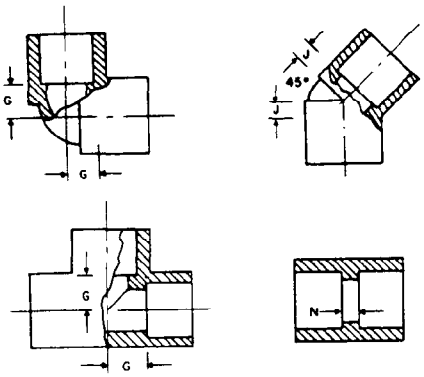
TABLE 1 Tapered Sockets for CPVC Pipe Fittings, Schedule 40, in. (mm)[A]



Nominal Pipe Size	*A* Socket Entrance Diameter			*B* Socket Bottom Diameter			*C*[B] Socket min in. (mm)	*D*[C] Inside Diameter, min in. (mm)	Wall Thickness, min		Outside Diameter of Hub, M, min	Entrance, min	
	Diameter in. (mm)	Tolerance on Diameter in. (mm)	Maximum Out-of-Round in. (mm)	Diameter in. (mm)	Tolerance on Diameter in. (mm)	Maximum Out-of-Round in. (mm)			*E* in. (mm)	*F* in. (mm)		*EW* in. (mm)	*EX, EZ* in. (mm)
¼	0.552 (14.02)	±0.004 (0.10)	0.016 (0.41)	0.536 (13.6)	±0.004 (0.10)	0.016 (0.41)	0.500 (12.70)	0.320 (8.13)	0.088 (2.23)	0.110 (2.79)	0.672	1/64 (0.40)	1/64 (0.40)
⅜	0.687 (17.45)	±0.004 (0.10)	0.016 (0.41)	0.671 (17.04)	±0.004 (0.10)	0.016 (0.41)	0.594 (15.08)	0.449 (11.40)	0.091 (2.31)	0.114 (2.90)	0.821	1/32 (0.79)	1/32 (0.79)
½	0.848 (21.54)	±0.004 (0.10)	0.016 (0.41)	0.836 (21.23)	±0.004 (0.10)	0.016 (0.41)	0.688 (17.48)	0.578 (14.68)	0.109 (2.76)	0.136 (3.45)	0.998	1/32 (0.79)	1/32 (0.79)
¾	1.058 (26.87)	±0.004 (0.10)	0.020 (0.51)	1.046 (26.57)	±0.004 (0.10)	0.020 (0.51)	0.719 (18.26)	0.740 (18.80)	0.113 (2.87)	0.141 (3.58)	1.221	1/32 (0.79)	1/32 (0.79)
1	1.325 (33.66)	±0.005 (0.13)	0.020 (0.51)	1.310 (33.27)	±0.005 (0.13)	0.020 (0.51)	0.875 (22.23)	0.990 (25.15)	0.133 (3.38)	0.166 (4.22)	1.504	1/16 (1.59)	1/16 (1.59)
1¼	1.670 (42.42)	±0.005 (0.13)	0.024 (0.61)	1.655 (42.04)	±0.005 (0.13)	0.024 (0.61)	0.938 (23.83)	1.335 (33.91)	0.140 (3.56)	0.175 (4.45)	1.871	1/16 (1.59)	1/16 (1.59)
1½	1.912 (48.56)	±0.006 (0.15)	0.024 (0.61)	1.894 (48.10)	±0.006 (0.15)	0.024 (0.61)	1.094 (27.79)	1.564 (39.73)	0.145 (3.68)	0.181 (4.60)	2.127	1/16 (1.59)	1/16 (1.59)
2	2.387 (60.63)	±0.006 (0.15)	0.024 (0.61)	2.369 (60.17)	±0.006 (0.15)	0.024 (0.61)	1.156 (29.36)	2.021 (51.33)	0.154 (3.91)	0.193 (4.90)	2.634	1/16 (1.59)	1/16 (1.59)
2½	2.889 (73.38)	±0.007 (0.18)	0.030 (0.76)	2.868 (72.85)	±0.007 (0.18)	0.030 (0.76)	1.750 (44.45)	2.414 (61.32)	0.203 (5.16)	0.254 (6.45)	3.170	3/32 (2.38)	1/8 (3.18)
3	3.516 (89.31)	±0.008 (0.20)	0.030 (0.76)	3.492 (88.70)	±0.008 (0.20)	0.030 (0.76)	1.875 (47.63)	3.008 (76.40)	0.216 (5.49)	0.270 (6.86)	3.841	3/32 (2.38)	1/8 (3.18)
3½	4.016 (102.01)	±0.008 (0.20)	0.030 (0.76)	3.992 (101.40)	±0.008 (0.20)	0.030 (0.76)	2.000 (50.80)	3.486 (88.54)	0.226 (5.74)	0.283 (7.19)	4.374	3/32 (2.38)	1/8 (3.18)
4	4.518 (114.76)	±0.009 (0.23)	0.030 (0.76)	4.491 (114.07)	±0.009 (0.23)	0.030 (0.76)	2.000 (50.80)	3.961 (100.61)	0.237 (6.02)	0.296 (7.52)	4.907	3/32 (2.38)	1/8 (3.18)
5	5.583 (141.81)	±0.010 (0.25)	0.060 (1.52)	5.553 (141.05)	±0.010 (0.25)	0.060 (1.52)	3.000 (76.20)	4.975 (126.37)	0.258 (6.55)	0.323 (8.20)	6.039	3/32 (2.38)	1/8 (3.18)
6	6.647 (168.83)	±0.011 (0.28)	0.060 (1.52)	6.614 (168.00)	±0.011 (0.28)	0.060 (1.52)	3.000 (76.20)	5.986 (152.04)	0.280 (7.11)	0.350 (8.89)	7.203	1/8 (3.18)	3/16 (4.76)

[A] The sketches and designs of fittings are illustrative only.
[B] Socket depth, measured from socket entrance face to socket bottom face.
[C] See 6.1.5.

TABLE 2 Minimum Dimension from Center to End of Sockets (Laying Length) for Couplings, Tees, 90° and 45° Elbows, CPVC Socket-Type Pipe Fittings, Schedule 40, in. (mm)[A]



Nominal Pipe Size	*G*, min in. (mm)	*J*, min in. (mm)	*N*, min in. (mm)
¼	5/16 (7.94)	5/32 (3.97)	1/16 (1.59)
⅜	⅜ (9.53)	3/16 (4.76)	3/32 (2.38)
½	½ (12.70)	¼ (6.35)	3/32 (2.38)
¾	9/16 (14.29)	5/16 (7.94)	3/32 (2.38)
1	11/16 (17.46)	5/16 (7.94)	3/32 (2.38)
1¼	⅞ (22.22)	⅜ (9.53)	3/32 (2.38)
1½	1 (25.40)	7/16 (11.11)	3/32 (2.38)
2	1¼ (31.75)	⅝ (15.88)	3/32 (2.38)
2½	1½ (38.10)	11/16 (17.46)	3/16 (4.76)
3	1 13/16 (46.04)	¾ (19.05)	3/16 (4.76)
3½	2⅛ (53.98)	1 (25.40)	3/16 (4.76)
4	2 5/16 (58.74)	1 (25.40)	3/16 (4.76)
5	3 (76.20)	1⅜ (34.92)	3/16 (4.76)
6	3½ (88.90)	1¾ (44.45)	¼ (6.35)

[A] The sketches and designs of fittings are illustrative only.

10.2.1 Fittings shall be marked with the following:

10.2.1.1 Manufacturer's name or trademark,

10.2.1.2 Material designation CPVC for CPVC 23447,

10.2.1.3 The seal or mark of the laboratory making the evaluation for potable water contact,

10.2.1.4 Size, and

10.2.1.5 This designation F 438, with which the fitting complies.

10.3 Where the size of the fitting does not allow complete marking, omit identification marking in the following sequence: size, material designation, F 438, manufacturer's name or trademark.

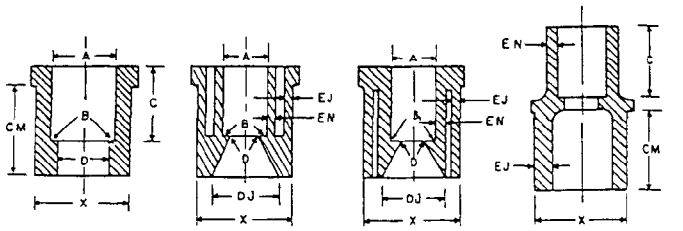
10.4 Markings or symbols shall be molded, hot-stamped, or applied to fittings by any other suitable method, such as printing.

10.5 Where recessed marking is used, care shall be taken to see that in no case marking causes cracks or reduces the wall thickness below the minimum specified.

11. Quality Assurance

11.1 When the product is marked with this designation, F 438, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

TABLE 3 Dimensions of Reducer Bushings, CPVC Socket-Type Pipe Fittings, Schedule 40,[A] in.



Nominal Size	*X*, Outside Diameter	Tolerance on Outside Diameter (includes out-of-round)
⅜ by ¼	0.675	0.016 (0.41)
½ by ⅜, ¼	0.840	0.016 (0.41)
¾ by ½, ⅜, ¼	1.050	0.020 (0.51)
1 by ½, ¾	1.315	0.020 (0.51)
1¼ by ½, ¾, 1	1.660	0.024 (0.61)
1½ by ½, ¾, 1, 1¼	1.900	0.024 (0.61)
2 by ½, ¾, 1, 1¼, 1½	2.375	0.024 (0.61)
2½ by 2	2.875	0.030 (0.76)
3 by 2½, 2	3.500	0.030 (0.76)
3½ by 2½, 2	4.000	0.030 (0.76)
4 by 3½, 3, 2½, 2	4.500	0.030 (0.76)
5 by 4	5.563	0.060 (1.52)
6 by 5	6.625	0.070 (1.78)

[A] The sketches and designs of fittings are illustrative only—per Symbols D 2749.

TABLE 4 Burst Pressure Requirements for Water at 73°F (23°C) for CPVC Socket-Type Pipe Fittings, Schedule 40

Nominal Size, in.	Min Burst Strength,[A] Class 23447	
	psi	(MPa)
¼	2490	(17.17)
⅜	1990	(13.72)
½	1910	(13.17)
¾	1540	(10.62)
1	1440	(9.93)
1¼	1180	(8.14)
1½	1060	(7.31)
2	890	(6.14)
2½	970	(6.69)
3	840	(5.79)
3½	770	(5.31)
4	710	(4.90)
5	620	(4.27)
6	560	(3.86)

[A] This table was calculated for Schedule 40 pipe using the ISO formula and a stress level as follows:

	psi	(MPa)
Class 23447 (Type IV, Grade 1 (CPVC))	6400	(44.1)

12. Keywords

12.1 CPVC; fittings; pressure; Sch 40; sockets; threads

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SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply *only* to Federal/Military procurement, not domestic sales or transfers.

S1. *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless the purchaser disapproves. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE S1.1—In U.S. Federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this document.

POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for product to be used to convey or to be in contact with potable water.

S3. Products intended for contact with potable water shall be evaluated, tested and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

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Designation: F 439 – 01

Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80[1]

This standard is issued under the fixed designation F 439; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers chlorinated poly(vinyl chloride) (CPVC) Schedule 80 pipe fittings. Included are requirements for materials, workmanship, dimensions, and burst pressure.

NOTE 1—The threaded CPVC fittings covered by this specification were covered previously in Specification F 437.

1.2 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this specification.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values in parentheses are given for information only.

1.4 The following safety hazards caveat pertains only to the test method portion, Section 8, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[2]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D 2749 Symbols for Dimensions of Plastic Pipe Fittings[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 437 Specification for Threaded Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80[3]

F 1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings[3]

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[4]

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[4]

2.4 *NSF Standard:*

Standard No. 14 for Plastic Piping Components and Related Materials[5]

Standard No. 61 for Drinking Water System Components—Health Effects[5]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F 412 and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated. The abbreviation for chlorinated poly(vinyl chloride) is CPVC.

4. Classification

4.1 *General*—This specification covers Schedule 80 CPVC pipe fittings, intended for use with Iron Pipe Size (IPS) outside-diameter plastic pipe.

4.1.1 Fittings covered by this specification are normally molded. In-line fittings, such as couplings, unions, bushings, caps, nipples, and so forth, shall be molded or machined from extruded stock.

4.1.2 Fittings fabricated by back welding or butt fusion are not included in this specification.

5. Materials and Manufacture

5.1 This specification covers CPVC pipe fittings made from compounds meeting the requirements of Class 23447 and Class 23448 as defined in Specification D 1784.

NOTE 2—Mechanical strength, heat resistance, flammability, and chemical resistance requirements are covered in Specification D 1784.

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[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.10 on Fittings.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[5] Available from NSF International, P.O. Box 130140, Ann Arbor, MI 48113-0140.

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5.2 *Rework Material*—The manufacturers shall use only their own clean rework fitting material, and the fittings produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances*:

6.1.1 Fitting sockets, inside diameters (waterways), minimum wall thicknesses, and dimensions shall be as shown in Tables 1-5 when measured in accordance with Test Method D 2122.

6.1.2 When multistep reducer bushings are cored out, the inner socket shall be reinforced from the outer wall by a minimum of three ribs extending from the top of the inner socket to the deepest extremity of the coring. The transition from D to DJ (Table 3) shall be straight, tapered as shown, or radiused. A positive taper in the same direction of the taper in the socket on the outside diameter of the bushing is optional.

6.1.3 The maximum angular variation of any opening shall be not more than ½° off the true centerline axis.

6.1.4 The minimum wall thickness of fittings shall be 125 % of the minimum wall thickness of the corresponding size of Schedule 80 pipe for which they are designed to be used, except that for the socket, the wall thickness shall be at least equal to the minimum wall thickness of the corresponding size of Schedule 80 pipe.

6.1.5 The minimum inside diameter of the fittings shall be not less than the minimum specified inside diameter of the corresponding size of Schedule 80 pipe. This is calculated as follows:

$$(\text{minimum OD}) - 2 \times (\text{maximum wall}) = \text{minimum ID} \quad (1)$$

6.1.6 Minimum dimensions have zero negative tolerance. Tolerances on other dimensions are shown in Tables 1 and 3.

6.1.7 *Fitting Not Illustrated*—All fittings, whether illustrated in Tables 1-5 or not, shall maintain the dimensions conforming to 6.1 and 6.2.

6.2 *Threads*—For all fittings having taper pipe threads, threads shall conform to Specification F 1498 and be gaged in accordance with 8.4.

6.3 *Burst Pressure*:

6.3.1 The minimum burst strength of the fittings shall be not less than that calculated for the size and wall thickness of the pipe with which it is to be used, when calculated from the following equation:

$$S = P(D_O - t)/2t \quad (2)$$

where:

S = hoop stress, psi (MPa),
P = internal pressure, psi (MPa),
D_O = average outside diameter, in. (mm), and
t = minimum wall thickness, in. (mm).

Fittings tested in accordance with 8.5 shall withstand the minimum burst pressure shown in Table 6.

6.3.2 Pressures shown are minimum burst pressures and do not imply rated working pressures. The burst pressure shall be used only as an indication of quality.

7. Workmanship, Finish and Appearance

7.1 The fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 *Conditioning*—Condition of test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Sampling*—A sufficient quantity of fittings as agreed upon between the seller and the purchaser shall be selected at random from each lot or shipment and tested to determine that the basic design is in conformance with this specification.

NOTE 3—For individual orders or specifications where supplemental tests are required, only those tests and numbers of tests specifically agreed upon between the purchaser and the seller need be conducted.

8.4 *Threads*—All taper pipe threads shall be gaged in accordance with Specification F 1498.

8.5 *Burst Pressure*—Determine the minimum burst pressure in accordance with Test Method D 1599. The time of testing each specimen shall be between 60 and 70 s.

9. Retest and Rejection

9.1 If the results of any test(s) do not meet the requirements of this specification, the test(s) shall be conducted again only by agreement between the purchaser and the seller. Under such agreement, minimum requirements shall not be lowered, changed, or modified, nor shall specification limits be changed. If upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

10. Marking

10.1 *Quality of Marking*—The markings shall be applied to the fitting in such a manner that they remain legible under normal handling and installation practices.

10.2 *Content of Marking*:

10.2.1 Fittings shall be marked with the following:

10.2.1.1 Manufacturer's name or trademark,

10.2.1.2 Material designation CPVC for CPVC 23447 and designation CPVC 42 for CPVC 23448,

10.2.1.3 The seal or mark of the laboratory making the evaluation for potable water contact,

10.2.1.4 Size, and

10.2.1.5 This designation "F 439," with which the fitting complies.

10.3 Where the size of the fitting does not allow complete marking, omit identification marking in the following sequence: size, material designation, F 439, and the manufacturer's name or trademark.

10.4 Markings or symbols shall be molded, hot-stamped, or applied to fittings by any other suitable method, such as printing.

10.5 Where recessed marking is used, care shall be taken to see that in no case marking causes cracks or reduces the wall thickness below the minimum specified.

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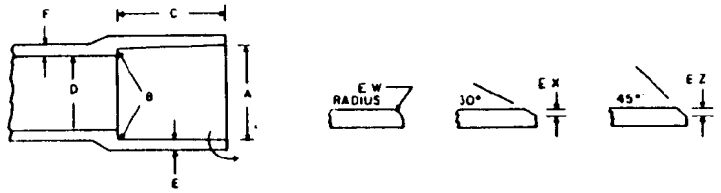
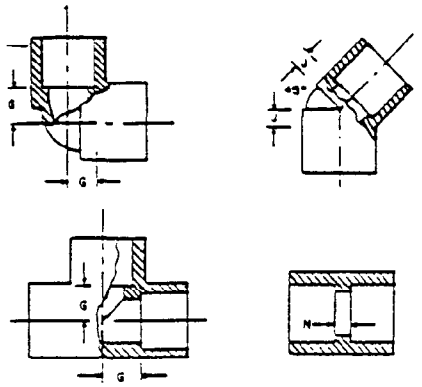
TABLE 1 Tapered Sockets for CPVP Pipe Fittings, Schedule 80, in. (mm)[A]



Nominal Pipe Size	A Socket Entrance Diameter			B Socket Bottom Diameter			C^B Socket Length, min	D^C Inside Diameter, min	Wall Thickness, min		Entrance, min	
	Diameter	Tolerance on Nominal Diameter	Maximum Out-of-Round	Diameter	Tolerance on Nominal Diameter	Maximum Out-of-Round			E	F	EW	EX, EZ
¼	0.552 (14.02)	±0.004 (0.10)	0.016 (0.41)	0.536 (13.61)	±0.004 (0.10)	0.016 (0.41)	0.625 (15.88)	0.258 (6.55)	0.119 (3.02)	0.149 (3.78)	0.02 (0.5)	0.02 (0.5)
⅜	0.687 (17.45)	±0.004 (0.10)	0.016 (0.41)	0.671 (17.04)	±0.004 (0.10)	0.016 (0.41)	0.750 (19.05)	0.379 (9.63)	0.126 (3.20)	0.160 (4.06)	0.03 (0.8)	0.03 (0.8)
½	0.848 (21.54)	±0.004 (0.10)	0.016 (0.41)	0.836 (21.23)	±0.004 (0.10)	0.016 (0.41)	0.875 (22.22)	0.502 (12.75)	0.147 (3.73)	0.185 (4.70)	0.03 (0.8)	0.03 (0.8)
¾	1.058 (26.87)	±0.004 (0.10)	0.020 (0.51)	1.046 (26.57)	±0.004 (0.10)	0.020 (0.51)	1.000 (25.40)	0.698 (17.73)	0.154 (3.91)	0.195 (4.95)	0.03 (0.8)	0.03 (0.8)
1	1.325 (33.66)	±0.005 (0.13)	0.020 (0.51)	1.310 (33.27)	±0.005 (0.13)	0.020 (0.51)	1.125 (28.58)	0.911 (23.14)	0.179 (4.55)	0.225 (5.72)	0.06 (1.5)	0.06 (1.5)
1¼	1.670 (42.42)	±0.005 (0.13)	0.024 (0.61)	1.655 (42.04)	±0.005 (0.13)	0.024 (0.61)	1.250 (31.75)	1.227 (31.17)	0.191 (4.85)	0.240 (6.10)	0.06 (1.5)	0.06 (1.5)
1½	1.912 (48.56)	±0.006 (0.15)	0.024 (0.61)	1.894 (48.11)	±0.006 (0.15)	0.024 (0.61)	1.375 (34.93)	1.446 (36.73)	0.200 (5.08)	0.250 (6.35)	0.06 (1.5)	0.06 (1.5)
2	2.387 (60.63)	±0.006 (0.15)	0.024 (0.61)	2.369 (60.17)	±0.006 (0.15)	0.024 (0.61)	1.500 (38.10)	1.881 (47.78)	0.218 (5.54)	0.275 (6.99)	0.06 (1.5)	0.06 (1.5)
2½	2.889 (73.38)	±0.007 (0.18)	0.030 (0.76)	2.868 (72.85)	±0.007 (0.18)	0.030 (0.76)	1.750 (44.45)	2.250 (57.15)	0.276 (7.01)	0.345 (8.76)	0.09 (2.3)	0.13 (3.3)
3	3.516 (89.31)	±0.008 (0.20)	0.030 (0.76)	3.492 (88.70)	±0.008 (0.20)	0.030 (0.76)	1.875 (47.63)	2.820 (71.63)	0.300 (7.62)	0.375 (9.53)	0.09 (2.3)	0.13 (3.3)
3½	4.016 (102.01)	±0.008 (0.20)	0.030 (0.76)	3.992 (101.40)	±0.008 (0.20)	0.030 (0.76)	2.125 (53.98)	3.280 (83.31)	0.318 (8.08)	0.400 (10.16)	0.09 (2.3)	0.13 (3.3)
4	4.518 (114.76)	±0.009 (0.23)	0.030 (0.76)	4.491 (114.07)	±0.009 (0.23)	0.030 (0.76)	2.250 (57.15)	3.737 (94.92)	0.337 (8.56)	0.420 (10.67)	0.09 (2.3)	0.13 (3.3)
5	5.583 (141.81)	±0.010 (0.25)	0.060 (1.52)	5.553 (141.05)	±0.010 (0.25)	0.060 (1.52)	2.625 (66.68)	4.703 (119.46)	0.375 (9.53)	0.470 (11.94)	0.09 (2.3)	0.13 (3.3)
6	6.647 (168.83)	±0.011 (0.28)	0.060 (1.52)	6.614 (168.00)	±0.011 (0.28)	0.060 (1.52)	3.000 (76.20)	5.646 (143.41)	0.432 (10.97)	0.540 (13.72)	0.13 (3.3)	0.19 (4.8)
8	8.655 (219.84)	±0.015 (0.38)	0.090 (2.29)	8.610	±0.015 (0.38)	0.090 (2.29)	4.000 (101.60)	7.610 (193.29)	0.500 (12.70)	0.625 (15.88)	0.13 (3.3)	0.19 (4.8)

[A] The sketches and designs of fittings are illustrative only.
[B] Socket depth, measured from socket entrance face to socket bottom face.
[C] See 6.1.5.

TABLE 2 Minimum Dimensions from Center to End of Sockets (Laying Length) for Couplings, Tees, 90° and 45° Elbows, CPVC Socket-Type Pipe Fittings, Schedule 80, in. (mm)[A]



Nominal Pipe Size	*G*, min	*J*, min	*N*, min
¼	0.31 (7.9)	0.16 (4.1)	0.06 (1.5)
⅜	0.38 (9.7)	0.19 (4.8)	0.09 (2.3)
½	0.50 (12.7)	0.25 (6.4)	0.09 (2.3)
¾	0.56 (14.2)	0.31 (7.9)	0.09 (2.3)
1	0.69 (17.5)	0.31 (7.9)	0.09 (2.3)
1¼	0.88 (22.4)	0.38 (9.7)	0.09 (2.3)
1½	1.00 (25.4)	0.44 (11.2)	0.09 (2.3)
2	1.25 (31.8)	0.63 (16.0)	0.09 (2.3)
2½	1.50 (38.1)	0.69 (17.5)	0.19 (4.8)
3	1.81 (46.0)	0.75 (19.1)	0.19 (4.8)
3½	2.13 (54.1)	1.00 (25.4)	0.19 (4.8)
4	2.31 (58.7)	1.00 (25.4)	0.19 (4.8)
5	3.00 (76.2)	1.38 (35.1)	0.19 (4.8)
6	3.50 (88.9)	1.75 (44.5)	0.25 (6.4)
8	4.50 (114)	2.00 (50.8)	0.25 (6.4)

[A]The sketches and designs of fittings are illustrative only.

11. Quality Assurance

11.1 When the product is marked with this designation, F 439, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

12. Keywords

12.1 CPVC; fittings; pressure; Schedule 80; sockets; threads

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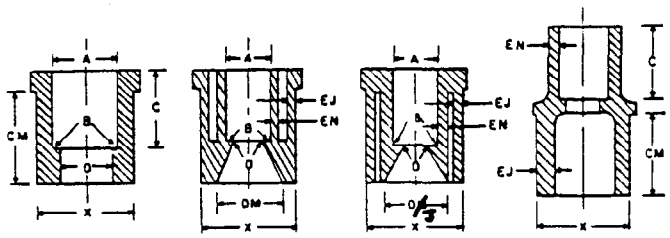
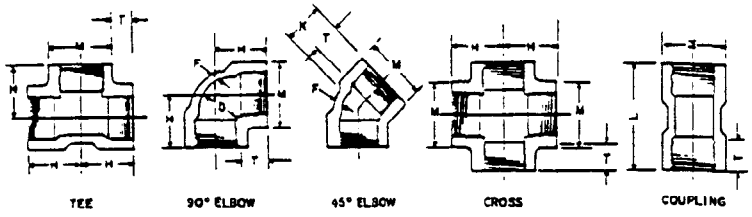
TABLE 3 Symbols for Dimensions of Reducer Bushings, CPVC Socket-Type Pipe Fittings, Schedule 80,[A] in. (mm)



Nominal Size	*X*, Outside Diameter[B]	Tolerance on Outside Diameter	Maximum Out-of-Roundness
⅜ by ¼	0.675 (17.15)	±0.004 (±0.10)	0.016 (0.41)
½ by ⅜, ¼	0.840 (21.34)	±0.004 (±0.10)	0.016 (0.41)
¾ by ½, ⅜, ¼	1.050 (26.67)	±0.004 (±0.10)	0.020 (0.51)
1 by ½, ¾	1.315 (33.40)	±0.005 (±0.13)	0.020 (0.51)
1¼ by ½, ¾, 1	1.660 (42.16)	±0.005 (±0.15)	0.024 (0.61)
1½ by ½, ¾, 1, 1¼	1.900 (48.26)	±0.006 (±0.15)	0.024 (0.61)
2 by ½, ¾, 1, 1¼, 1½	2.375 (60.33)	±0.006 (±0.15)	0.024 (0.61)
2½ by 2	2.875 (73.03)	±0.007 (±0.18)	0.030 (0.76)
3 by 2½, 2	3.500 (88.90)	±0.008 (±0.20)	0.030 (0.76)
3½ by 2½, 2	4.000 (101.60)	±0.008 (±0.20)	0.030 (0.76)
4 by 3½, 3, 2½, 2	4.500 (114.30)	±0.009 (±0.23)	0.030 (0.76)
5 by 4	5.563 (141.30)	±0.010 (±0.25)	0.060 (1.52)
6 by 5	6.625 (168.28)	±0.011 (±0.28)	0.060 (1.78)
8 by 6	8.626 (219.10)	±0.015 (±0.38)	0.090 (2.29)

[A]The sketches and designs of fittings are illustrative only—from Symbols D 2749.
[B]Dimensions not shown in Table 1.

TABLE 4 Dimensions of 90° Ells, Tees, Crosses, 45° Elbows and Couplings (Straight Sizes), in. (mm)[A,B]



Nominal Pipe Size	Center to Thread End, 90° Elbows, Tees, Crosses, *H*, min	Length of Thread, *T*, min	Center to Thread End, 45° Elbow,[C] *K*, min	Inside Diameter of Fitting, *D*, min	Nominal Wall Thickness, *F*, min	Outside Diameter of Hub, *M*, min	Thread End to Thread End of Coupling, *L*, min
¼	0.812 (20.62)	0.50 (12.70)	0.688 (17.48)	0.258 (6.55)	0.135 (3.43)	0.840 (21.34)	1.063 (27.00)
⅜	0.938 (23.83)	0.50 (12.70)	0.750 (19.05)	0.379 (9.63)	0.144 (3.66)	1.000 (25.40)	1.063 (27.00)
½	1.125 (28.58)	0.64 (16.26)	0.750 (19.05)	0.502 (12.75)	0.198 (5.03)	1.280 (32.51)	1.344 (34.14)
¾	1.250 (31.75)	0.65 (16.51)	1.000 (25.40)	0.698 (17.73)	0.207 (5.25)	1.500 (38.10)	1.500 (38.10)
1	1.500 (28.10)	0.81 (20.51)	1.125 (28.58)	0.911 (23.14)	0.225 (5.72)	1.810 (45.97)	1.688 (42.88)
1¼	1.750 (44.45)	0.85 (21.59)	1.313 (23.35)	1.227 (31.17)	0.261 (6.63)	2.200 (55.88)	1.750 (44.45)
1½	1.938 (49.23)	0.85 (21.59)	1.438 (36.83)	1.446 (36.73)	0.270 (6.85)	2.500 (63.50)	2.000 (50.80)
2	2.250 (57.15)	0.90 (22.86)	1.625 (41.28)	1.881 (47.78)	0.297 (7.54)	3.000 (76.20)	2.063 (52.40)
2½	2.688 (68.28)	1.21 (30.73)	1.938 (49.23)	2.250 (57.15)	0.315 (8.00)	3.560 (90.42)	2.625 (66.68)
3	3.063 (77.80)	1.30 (33.02)	2.125 (53.98)	2.820 (71.63)	0.405 (10.29)	4.300 (109.22)	2.750 (69.85)
4	3.625 (92.08)	1.38 (35.05)	2.625 (66.68)	3.737 (94.92)	0.450 (11.43)	5.430 (137.92)	3.000 (76.20)
6	5.125 (130.18)	1.50 (38.10)	3.250 (82.55)	5.646 (143.41)	0.504 (12.80)	7.625 (193.68)	3.250 (82.55)

[A] The sketches and designs of fittings shown are illustrative only.
[B]Symbols for dimensions are in accordance with Symbols D 2749.
[C]This dimension locates the end of the fitting.

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TABLE 5 Dimensions of Threaded Plugs and Caps, in.[A,B]

Nominal Pipe Size	Length of Male Thread, *S*, min	Length of Female Thread, *T*, min	Width of Flats,[B] *Q*, min	Nominal Wall Thickness, *F*, min	Height of Head,[C] *R*, min	Cap Height, *W*, min	Outside Diameter of Hub, *M*, min
¼	0.44 (11.18)	0.50 (12.70)	0.625 (15.88)	0.135 (3.43)	0.188 (4.78)	0.688 (17.48)	0.840 (21.34)
⅜	0.44 (11.18)	0.50 (12.70)	0.750 (19.05)	0.144 (3.66)	0.188 (4.78)	0.688 (17.48)	1.000 (25.40)
½	0.53 (13.46)	0.64 (16.26)	0.938 (23.83)	0.198 (5.03)	0.188 (4.73)	0.875 (22.23)	1.280 (32.51)
¾	0.55 (13.92)	0.65 (16.51)	1.125 (28.53)	0.207 (5.26)	0.219 (5.56)	1.000 (25.40)	1.500 (38.10)
1	0.68 (17.27)	0.81 (20.57)	1.375 (34.93)	0.225 (5.72)	0.219 (5.56)	1.188 (30.18)	1.810 (45.97)
1¼	0.71 (18.03)	0.85 (21.59)	1.750 (44.45)	0.261 (6.63)	0.281 (7.14)	1.250 (31.75)	2.200 (55.88)
1½	0.72 (18.29)	0.85 (21.59)	1.875 (47.63)	0.270 (6.85)	0.313 (7.95)	1.250 (31.75)	2.500 (63.50)
2	0.76 (19.30)	0.90 (22.86)	1.875 (47.63)	0.297 (7.54)	0.313 (7.95)	1.375 (34.93)	3.000 (76.20)
2½	1.14 (28.96)	1.21 (30.25)	1.875 (47.63)	0.369 (8.00)	0.375 (9.53)	1.625 (41.28)	3.560 (90.42)
3	1.20 (30.48)	1.30 (33.02)	2.000 (50.80)	0.405 (10.29)	0.375 (9.53)	1.750 (49.45)	4.300 (109.2)
4	1.30 (33.02)	1.38 (35.05)	2.000 (50.80)	0.450 (11.43)	0.375 (9.53)	2.000 (50.60)	5.430 (137.9)
6	1.44 (36.58)	1.50 (35.10)	2.000 (50.80)	0.504 (12.80)	0.500 (12.10)	2.125 (53.98)	7.625 (193.68)

[A] The sketches and designs of fittings shown are illustrative only.
[B] Symbols for dimensions are in accordance with Symbols D 2749.
[C] At the manufacturer's option, the head of the plug shall be hexagonal, octagonal, square, or round.

TABLE 6 Burst Pressure Requirements for Water at 73°F (23°C) for CPVC Pipe Fittings, Schedule 80

Nominal Size, in.	Minimum Burst Strength[A]	
	Class 23447	
	psi	MPa
¼	3620	24.96
⅜	2940	20.27
½	2720	18.75
¾	2200	15.17
1	2020	13.93
1¼	1660	11.44
1½	1510	10.41
2	1290	8.89
2½	1360	9.38
3	1200	8.27
3½	1110	7.65
4	1040	7.17
5	930	6.41
6	890	6.14
8	790	5.45

[A] This table was calculated for Schedule 80 pipe using the ISO formula and a stress level as follows:

	psi	MPa
Class 23447 (CPVC)	6400	44.1
Class 23448 (CPVC 42)	6400	44.1

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply only to Federal/Military procurement, not domestic sales or transfers.

S1. *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless the purchaser disapproves. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

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NOTE S1.1—In U.S. Federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this document.

POTABLE WATER REQUIREMENT

This requirement applies whenever a regulatory authority or user calls for the product to be used to convey or to be in contact with potable water.

S3. Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

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Standard Specification for Poly(Vinylidene Fluoride) (PVDF) Plastic-Lined Ferrous Metal Pipe and Fittings[1]

This standard is issued under the fixed designation F 491; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers factory-made poly(vinylidene fluoride) (PVDF) plastic-lined ferrous metal pipe and fittings, primarily intended for conveying corrosive liquids and gases. Requirements for materials, workmanship, dimensions, design, construction, working pressures and temperatures, test methods, and markings are included.

NOTE 1—This specification does not include products *coated* with PVDF nor does it define the suitability of PVDF-lined components in chemical environments.

1.2 The ferrous piping products shall meet the requirements of the relevant specification listed in 1.2.1. Nominal sizes from 1 through 10 in. in 150 and 300-psi ratings are covered.

1.2.1 *For Ferrous Pipe:*

Title of Specification	ASTM Designation
Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless (Types E and S)	A 53
Seamless Carbon Steel Pipe for High-Temperature Service	A 106
Electric-Resistance Welded Steel Pipe	A 135
Electric-Welded Low-Carbon Steel Pipe for the Chemical Industry	A 587
Seamless and Welded Austenitic Stainless Steel Pipe	A 312
Electric-Resistance Welded Carbon and Alloy Steel Mechanical Tubing	A 513

1.2.2 *For Ferrous Flanges:*

Title of Specification	ASTM Designation
Forgings, Carbon Steel, for Piping Components	A 105
Forged or Rolled Steel Pipe Flanges, Forged Fittings and Valves and Parts for General Service	A 181
Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service	A 182
Carbon-Steel Castings Suitable for Fusion Welding for High-Temperature Service (Grade WCB)	A 216
Ferritic Ductile Iron Pressure Retaining Castings for Use at Elevated Temperatures (60-40-18)	A 395
Ductile Iron Castings (60-40-18, 64-45-12, 80-55-06)	A 536

1.2.3 *For Ferrous Fittings:*

Title of Specification	ASTM Designation
Forgings, Carbon Steel, for Piping Components	A 105
Forged or Rolled Steel Pipe Flanges, Forged Fittings, and Valves and Parts for General Service	A 181
Carbon Steel Castings Suitable for Fusion Welding for High-Temperature Service (Grade WCB)	A 216
Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures	A 234
Austenitic Steel Castings for High-Temperature Service	A 351
Alloy Steel Castings Specially Heat-Treated for Pressure-Containing Parts Suitable for High-Temperature Service	A 389
Ductile Iron Castings (60-40-18, 64-45-12, 80-55-06)	A 536
Ferritic Ductile Iron Pressure Retaining Castings for Use at Elevated Temperatures (60-40-18)	A 395
Wrought Austenitic Stainless Steel Piping Fittings	A 403

NOTE 2—The PVDF sealing faces may prevent achievement of the full pressure rating of the ferrous housings. For pressure limitations, the manufacturer should be consulted.

1.3 The PVDF-lined flanged pipe and fitting assemblies are limited to use from −18 to 135°C (0 to 275°F). For use below −18°C (0°F) consult the manufacturer. Use in specific aggressive environments may alter the above temperature range. The operating temperature limits shall be established by mutual agreement between the purchaser and the seller.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 3222 Specification for Unmodified Poly(Vinylidene Fluoride) (PVDF) Molding, Extrusion and Coating Materials[3]

F 412 Terminology Relating to Plastic Piping Systems[4]

2.2 *ANSI Standard:*

B16.5 Steel Pipe Flanges and Flanged Fittings[5]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise specified. The abbreviation for poly(vinylidene fluoride) is PVDF.

4. Materials

4.1 *Lining:*

4.1.1 *Material*—The lining shall be made from PVDF resins conforming to the requirements of Specification D 3222, except that a maximum of 1 % by weight of additives or colorants, or both, is permissible. Organic color-

[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.11 on Composite.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.03.

[4] *Annual Book of ASTM Standards*, Vol 08.04.

[5] Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

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ants, if used, shall be identified in the manufacturer's specification.

4.1.2 The PVDF lining shall be made from virgin resin or clean reworked resin.

4.1.3 *Mechanical Properties*—The lining shall have a minimum tensile strength at yield of 5000 psi and a minimum elongation at yield of 8 % when tested in accordance with the requirements of Specification D 3222, except that the test specimens shall be obtained from extruded or molded PVDF liner. The minimum values for tensile strength and elongation shall apply to both the longitudinal and circumferential directions.

4.2 *Ferrous Pipe Fittings:*

4.2.1 The mechanical properties of the pipes and fittings shall conform to the requirements of the appropriate specification of 1.2 except as they are influenced by accepted methods of processing in the industry—for example, Van Stone flaring, bending, swagging, and welding. The carbon steel pipe and wrought fittings shall be welded or seamless steel, Schedule 40 or Schedule 80, except that Schedule 30 pipe may be used in 8 and 10-in. nominal size.

4.2.2 *Finish*—The interior surfaces of all housings shall be clean and free of mold burrs, rust, scale, or other protrusions that may adversely affect the integrity or performance of the lining.

4.3 *Back-Up Gaskets:*

4.3.1 *General*—Back-up gaskets shall be used to cover the pipe end and gasket face of threaded or slip-on flanges unless a full radius is provided at the end of the pipe and flange. Gaskets may also be required on fittings to provide accommodation or elimination, or both, of sharp corners that could damage the lining.

4.3.2 *Material*—Plain gaskets meeting the temperature requirements, or perforated metallic gaskets, may be used.

5. Requirements

5.1 *Dimensions:*

5.1.1 *Housing*—Housing installation dimensions are as required in the specifications listed in 1.2.

5.1.2 *Wall Thickness*—Fitting linings shall have minimum wall thickness of 3/32 in. and a uniform face thickness of not less than 3/32 in. Pipe linings shall have a minimum wall thickness of 0.050 in. and the flared radius and gasket faces shall have a uniform thickness not less than 80 % of the wall thickness.

5.1.3 *PVDF Face Diameter*—The outside diameter of the PVDF covering the gasket face of the flange or the full face of the lap-joint stub end shall not be less than the diameter specified in the following table. They shall be concentric within 1/16 in.

PVDF Face Diameter

Nominal pipe size, in.	Minimum PVDF face diameter, in.
1	1 7/8
1 1/2	2 11/16
2	3 7/16
3	4 5/8
4	5 15/16
6	8
8	10 1/16
10	12 1/4

5.1.4 *Tolerances*—Tolerances for pipe, flanges, and fittings shall be as specified in the following table. Bolt holes in both flanges on a fixed flange spool shall straddle the same center line to facilitate alignment. Finished lined (plastic face to plastic face) fabricated fittings shall conform to the nominal face-to-face, etc. as specified in ANSI B16.5 with the applicable tolerances.

Tolerances for Pipe, Flanges, and Fittings, in.

Pipe	Tolerance
Length	±1/8
Fixed flange bolt hole alignment	±1/16
Flange perpendicularity (with pipe centerline)	3/32 in./ft of diameter
Flanges and Fittings	
All dimensions	in accordance with ANSI B16.5

5.2 *Flange Construction:*

5.2.1 Screw-type flanges shall be secured in position to prevent inadvertent turning of the flange.

5.2.2 Socket-type flanges shall be fully back-welded to the pipe housing and the inside surfaces of the socket flanges shall be welded and ground smooth.

5.2.3 Slip-on flanges shall be fully back-welded.

NOTE 3—No welding shall be done on lined components.

5.2.4 Lap-joint (or Van Stone) flanged ends may be manufactured by standard forming techniques or by using fully welded stub ends or collars. Lap-joints shall not contain any cracks or buckles.

NOTE 4—The use of lap-joint flanges in a piping system may simplify alignment.

5.3 *Venting*—Each pipe and fitting have a liner thickness less than that shown in the following table shall be provided with a venting system that will release any gases between the liner and the housing and will also indicate any leakage through the liner, in the event of liner failure. Such a system may consist of a series of 1/16 to 5/32-in. diameter holes in the housings.

NOTE 5—Vent holes should not be plugged with paint, cement, etc. since this negates the intended purposes listed in 5.3.1.

Minimum Liner Thickness for Non-Vented Piping

Nominal pipe size, in.	Liner thickness, in.
1	0.100
1 1/2	0.120
2	0.130
3	0.150
4	0.160
6	0.180
8	0.180
10	0.180

5.4 *Workmanship:*

5.4.1 Pipe and fitting linings shall show no evidence of pinholes, porosity, or cracks when inspected in accordance with 5.5.2. The linings shall fit snugly inside the pipe and fitting housings. Any bulges or other obvious indication of poor contact with the housing shall be cause for rejection.

5.4.2 The gasket face of the PVDF linings shall be free of surface defects that could impair sealing effectiveness. Scratches, dents, nicks, or tool marks on the gasket surface shall not be deeper than 10 % of the wall thickness.

5.5 *Performance:*

5.5.1 *Qualification*—PVDF-lined pipe and fittings must be capable of meeting the requirements specified in Section 6.

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5.5.2 *Inspection:*

5.5.2.1 Each lined pipe and fitting, prior to shipment, shall be subjected to a hydrostatic test or an electrostatic test, or both, as specified in 7.1 or 7.2. The test or tests to be used shall be at the option of the manufacturer, unless otherwise specified by the purchaser.

5.5.2.2 Each lined pipe and fitting shall subsequently be visually inspected prior to shipment to verify conformance to the design and dimensional requirements of 5.4.

5.5.2.3 Each lined pipe and fitting shall bear an inspection verification impression stamp on the housing to indicate compliance with the requirements of this specification.

6. Qualification Tests

6.1 *Temperature Test:*

6.1.1 Cycle representative production samples of PVDF-lined pipe and fittings in an oven from room temperature to 135 ± 3°C (275 ± 5°F) to determine the ability of the lined components to withstand heat aging and temperature cycling. Test a minimum of two pipe spools, tees, and 90-deg elbows in each size.

6.1.2 Install companion flanges at the manufacturer's recommended torque value, and affix a thermocouple to the ferrous housing to measure the temperature. Pipe spools shall be at least 3 ft long. After 3 h in an oven at 135°C (275°F) as indicated by the thermocouple, air cool the lined components to 50°C (122°F) maximum. Repeat this test for a total of three cycles.

6.1.3 Inspect PVDF-lined pipe and fittings after each cycle for distortion or cracks in the PVDF lining. At the completion of the third cycle, subject specimens to either the hydrostatic or electrostatic test described in 7.1 or 7.2.

6.2 *Steam-Cold Water Cycling Test:*

6.2.1 Subject representative production samples of PVDF-lined pipe and fittings to steam-cold water cycling to determine the ability of the lined components to withstand rapid temperature changes. Test a minimum of two pipe spools, tees, and 90-deg elbows in each size.

6.2.2 Assemble PVDF-lined pipe and fittings with suitable blind flanges having provision for the introduction of steam, air, or cold water, and for drainage. Install the flanges using the manufacturer's recommended torque value. Pipe spool length shall be 10 ft minimum. Mount the test specimens in such a manner as to permit complete drainage and then subject them to 100 steam-cold water cycles, each of which shall consist of the following in the sequence given:

6.2.2.1 Circulate 30 ± 2 psig saturated steam through the specimens until the ferrous housing skin temperature adjacent to the flange at the outlet end of the test specimen has been maintained at the maximum stabilized temperature for 30 min.

6.2.2.2 Close off steam.

6.2.2.3 Vent and introduce air to purge the specimens for a minimum of 1 min.

6.2.2.4 Circulate water at a maximum temperature of 25°C (77°F) until the ferrous housing skin temperature adjacent to the flange at the outlet end of the test specimen measures 50°C (122°F) maximum.

6.2.2.5 Drain, then introduce air to purge the specimens for a minimum of 1 min, making certain that specimens are completely drained.

6.2.3 There shall be no evidence of leakage from the venting system or the flanges during the 100 cycles. At the completion of the test, the liner shall show no evidence of buckling, cracking, or crazing.

6.2.4 At the conclusion of the testing specified in 6.2.2, subject the PVDF-lined pipe or fitting to the hydrostatic test specified in 7.1 or, after drying, to the electrostatic test specified in 7.2.

6.3 *Vacuum Test:*

6.3.1 Test representative production samples of PVDF-lined pipe and fittings to determine the vacuum ratings of the lined components. Test a minimum of two pipe spools, tees, and 90-deg elbows in each size. Conduct tests at room temperature, at the manufacturer's maximum recommended service temperature, and at one intermediate temperature if a full vacuum rating cannot be achieved at the maximum recommended service temperature. Full vacuum is defined as 29.6 in. Hg corrected.

NOTE 5—Vacuum-temperature ratings should be published in the manufacturer's literature.

6.3.2 For pipe spools, specimen length shall be at least 10 pipe diameters. Install a flange incorporating a sight glass at one end and a blind flange suitable for drawing a vacuum at the other end. Make provision for measuring the ferrous housing temperature.

6.3.2.1 Heat the specimens uniformly externally with the sight glass end visible. Begin the test after the desired ferrous housing temperature has been reached. Hold a selected initial vacuum level for 24 h and if no failure occurs, increase the vacuum by 2 in. Hg. Repeat this every 24 h until failure or full vacuum is reached. Failure is defined as any buckling or collapse of the liner. If failure occurs at the initial vacuum level selected, test a new test specimen at a lower vacuum level to determine the failure threshold. The vacuum failure threshold is defined as 1 in. Hg below that at which failure occurs.

NOTE 6—The external pressure method to simulate higher than full vacuum can be used to establish the failure threshold when full vacuum is achievable. With the use of pressure taps, an external pressure is applied between the liner outside diameter and the pipe inside diameter.

6.3.3 The vacuum rating shall be 80 % of the failure threshold value.

6.3.4 At the test completion and after the vacuum rating is established, heat a duplicate specimen to the test temperature. Apply the rated vacuum to the specimen after the desired skin temperature has been reached. Achieve the rated vacuum within 2 min and apply continuously for 48 h. If no liner buckling or collapse occurs, the vacuum rating shall be considered acceptable.

6.4 *Retest*—When a test specimen fails to meet the requirements of 6.1, 6.2, or 6.3, the cause of failure shall be sought and corrected. Repeat the temperature test specified in 6.1, the steam-cold water cycling test specified in 6.2, and the vacuum test specified in 6.3, using double the number of test specimens.

7. Inspection Tests

7.1 *Hydrostatic Pressure Test*—The internal test pressure

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shall be 425 psi minimum. Conduct the test at ambient temperature. Completely fill the pipe and fitting with clean water and bleed the system free of all air prior to the application of pressure. Reach full test pressure within 1 min and maintain for a further 3 min. Observe the pressure gage and the venting system in the test specimen throughout the test for any evidence of leakage, which shall be cause for rejection.

7.2 *Electrostatic Test*—Conduct the test with a nondestructive high-voltage tester at an output voltage of 10 kV. A visible or audible spark (or one that is both), that occurs at the probe when electrical contact is made with the housing because of a defect in the liner, shall be cause for rejection.

8. Finish

8.1 The outside surface of all lined pipe and fittings, other than stainless steel, shall be coated with a corrosion-resistant primer over a properly prepared surface.

9. Marking

9.1 Marking on the pipe and fitting shall include the following:

9.1.1 Nominal pipe size,

9.1.2 Liner material identification ("PVDF"),

9.1.3 Manufacturer's name (or trademark),

9.1.4 This ASTM designation "ASTM F 491,"

9.1.5 Length (on pipe only), and

9.1.6 Other information such as order numbers, part numbers, item numbers, etc., which shall be provided at the purchaser's request.

9.2 Pipe liner identification shall be provided on a band containing the raised letters "PVDF." One band is required on fittings and on pipe lengths up to 6 ft; two bands are required for pipe lengths over 6 ft. The band will typically be located near the flange.

10. Packaging

10.1 The gasket face of each lined pipe and each fitting shall be protected by end plates or other suitable protective means, such as individual boxing.

11. Quality Assurance

11.1 When the product is marked with this designation, F 491, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

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Standard Specification for Propylene and Polypropylene (PP) Plastic-Lined Ferrous Metal Pipe and Fittings[1]

This standard is issued under the fixed designation F 492; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers factory-made propylene and polypropylene (PP) plastic-lined ferrous metal pipe and fittings, primarily intended for conveying corrosive liquids and gases. Requirements for materials, workmanship, dimensions, design, construction, working pressures and temperatures, test methods, and markings are included.

NOTE 1—In this specification, propylene plastics cover those materials defined as both polypropylene plastics and propylene plastics in Definitions D 883. Both materials are identified as "PP" on the product. Note that this is at variance with Abbreviations D 1600, where PP is the abbreviation for polypropylene.

NOTE 2—This specification does not include products *coated* with PP nor does it define the suitability of PP-lined components in chemical environments.

1.2 The ferrous piping products shall meet the requirements of the relevant specifications listed in 1.2.1. Nominal sizes from ½ through 12 in. in Class 125, 150, and 300-psi are covered.

NOTE 3—The PP sealing faces may prevent achievement of the full pressure rating of the ferrous housings. For pressure limitations, the manufacturer should be consulted.

NOTE 4—Flanged fittings are not available in sizes ½ and ¾.

1.2.1 *For Ferrous Pipe:*

Title of Specification	ASTM Designation
Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless (Types E and S)	A 53
Seamless Carbon Steel Pipe for High-Temperature Service	A 106
Electric-Resistance Welded Steel Pipe	A 135
Electric-Welded Low-Carbon Steel Pipe for the Chemical Industry	A 587
Seamless and Welded Austenitic Stainless Steel Pipe	A 312
Electric-Resistance Welded Carbon and Alloy Steel Mechanical Tubing	A 513

1.2.2 *For Ferrous Flanges:*

Title of Specification	ASTM Designation
Gray Iron Castings	A 48
Forgings, Carbon Steel, for Piping Components	A 105
Gray Iron Castings for Valves, Flanges, and Pipe Fittings	A 126
Forgings, Carbon Steel, for General-Purpose Piping	A 181
Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service	A 182
Carbon-Steel Castings Suitable for Fusion Welding for High-Temperature Service (Grade WCB).	A 216
Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F (345°C)	A 278
Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures (60-40-18)	A 395
Ductile Iron Castings (60-40-18, 65-45-12, 80-55-06)	A 536

1.2.3 *For Ferrous Fittings:*

Title of Specification	ASTM Designation
Gray Iron Castings	A 48
Forgings, Carbon Steel, for Piping Components	A 105
Gray Iron Castings for Valves, Flanges, and Pipe Fittings	A 126
Forgings, Carbon Steel, for General-Purpose Piping	A 181
Carbon Steel Castings Suitable for Fusion Welding for High-Temperature Service (Grade WCB)	A 216
Piping Fittings of Wrought Carbon Steel and Alloy for Moderate and Elevated Temperatures Steel Welding Fittings	A 234
Gray Iron Castings for Pressure-Containing Parts for Temperatures up to 650°F (345°C)	A 278
Austenitic Steel Castings for High-Temperature Service	A 351
Alloy Steel Castings Specially Heat-Treated for Pressure-Containing Parts Suitable for High-Temperature Service	A 389
Ductile Iron Castings (60-40-18, 64-45-12, 80-55-06)	A 536
Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures (60-40-18)	A 395
Wrought Austenitic Stainless Steel Piping Fittings	A 403

1.3 The PP-lined flanged pipe and fitting assemblies are limited to use from −18 to 107°C (0 to 225°F). For use below −18°C (0°F) consult the manufacturer. Use in specific aggressive environments may alter the above temperature range. The operating temperature limits shall be established by mutual agreement between the purchaser and the seller.

1.4 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer[2]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 2146 Specification for Propylene Plastic Molding and Extrusion Materials[4]

F 412 Terminology Relating to Plastic Piping Systems[3]

2.2 *ANSI Standards:*

B16.1 Cast Iron Pipe Flanges and Flanged Fittings[5]

[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.11 on Composite.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] *Discontinued*—See *1984 Annual Book of ASTM Standards*, Vol 08.02.

[5] Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

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B16.5 Steel Pipe Flanges and Flanged Fittings[5]
B16.42 Fittings, Flanges and Valves[5]
2.3 *Federal Standard:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[6]
2.4 *Military Standard:*
MIL-STD-129 Marking for Shipment and Storage[6]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated.

4. Materials

4.1 *Lining:*

4.1.1 *Material*—The lining shall be made from PP resins conforming to the requirements of Specification D 2146, except that (*1*) a maximum of 1 % by weight of colorants is permissible for identification, and (*2*) up to 30 % by weight glass fiber filler is permissible to modify physical properties. Organic colorants, if used, shall be identified in the manufacturer's specification.

4.1.2 The PP lining shall be made from virgin resin or clean reworked resin which is not thermally degraded.

4.1.3 Two types of PP resins are covered in this specification. Type I materials are polypropylene homopolymer resins; Type II are propylene copolymer resins.

4.1.4 *Mechanical Properties*—The following table lists minimum tensile strength and minimum elongation at yield for each PP type when tested in accordance with the requirements of Specification D 2146, except that the test specimens shall be obtained from extruded or molded PP liner. The minimum values for tensile strength and elongation shall apply to both the longitudinal and circumferential directions.

Mechanical Properties of PP

PP Type	Minimum Tensile Properties at Yield	
	Strength, psi (MPa)	Elongation, %
Type I (Homopolymer)	4000 (28)	10
Type II (Copolymer)	3000 (21)	10
30 % Glass Fiber Filled	2500 (17)	2

4.1.5 *Flow Rate*—PP resins used to manufacture the PP liner and molded fittings shall have the following flow rate when tested in accordance with Condition L of Test Method D 1238.

Type I—0.2 to 0.6 g/10 min
Type II—0.3 to 0.8 g/10 min
30 % Glass Fiber Filled—3.0 to 6.0 g/10 min

The flow rate of PP linings made from Type I and Type II resins shall not exceed 1.7 g/10 min, or 1.7 times the flow rate of the original resin, whichever is smaller. The melt flow rate of PP linings made from 30 % glass filled materials shall not exceed 7.5 g/10 min, or 1.25 times the melt flow rate of the original resin, whichever is smaller.

[6] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

4.2 *Ferrous Pipe and Fittings:*

4.2.1 The mechanical properties of the pipes and fittings shall conform to the requirements of the appropriate specification of 1.2 except as they are influenced by accepted methods of processing in the industry, for example, Van Stone flaring, bending, swagging, and welding. The carbon steel pipe and wrought fittings shall be welded or seamless steel, Schedule 40 or Schedule 80, except that Schedule 30 pipe may be used in 8, 10, and 12-in. nominal size. Schedule 20 may also be used for 12-in. nominal size with the agreement of the purchaser.

4.2.2 *Finish*—The interior surfaces of all housings shall be clean and free of mold burrs, rust, scale, or other protrusions that may adversely affect the integrity or performance of the lining.

4.3 *Back-Up Gaskets:*

4.3.1 *General*—Back-up gaskets shall be used to cover the pipe end and gasket face of threaded or slip-on flanges unless a full radius or chamfer is provided at the end of the pipe and flange. Gaskets may also be required on fittings to provide accommodation or elimination, or both, of sharp corners that could damage the lining.

4.3.2 *Material*—Plain gaskets meeting the temperature requirements, or perforated metallic gaskets, may be used.

5. Requirements

5.1 *Dimensions:*

5.1.1 *Housings*—Housing installation dimensions are as required in the applicable material specification listed in 1.2.

5.1.2 *Wall Thickness*—Fitting linings shall have a minimum wall thickness of 3/32 in. (24 mm), and shall have a uniform face thickness of not less than 3/32 in. (24 mm). Pipe linings shall have a minimum wall thickness of 0.050 in. (13 mm), and the flared radius and gasket faces shall have a uniform thickness not less than 80 % of the wall thickness. Molded faces shall not be less than 3/32 in. thick.

5.1.3 *PP Face Diameter*—The outside diameter of the PP covering the gasket face of the flange or the full face of the lap-joint stub end shall not be less than the diameter specified in the following table. They shall be concentric within 1/16 in.

Face Diameter

Nominal pipe size, in.	Minimum PP face diameter, in. (mm)
1	1 7/8 (48)
1 1/2	2 11/16 (68)
2	3 7/16 (87)
2 1/2	3 15/16 (100)
3	4 5/8 (119)
4	5 15/16 (151)
6	8 (203)
8	10 1/16 (256)
10	12 1/4 (311)
12	14 3/8 (365)

5.1.4 *Tolerances*—Tolerances for pipe, flanges, and fittings shall be as specified in the following table. Bolt holes in both flanges on a fixed flange spool shall straddle the same center line to facilitate alignment. Finished lined (plastic face to plastic face) fabricated fittings shall conform to the nominal face-to-face, etc., as specified in ANSI B16.1, B16.5, or B16.42 with the applicable tolerances.

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Tolerances for Pipe, Flanges, and Fittings, in.

Pipe	Tolerance
Length	±⅛ (32 mm)
Fixed flange bolt hole alignment	±1/16 (16 mm)
Flange perpendicularity (with pipe centerline)	3/32 in./ft (80 mm/m) of diameter
Flanges and Fittings	
All dimensions	in accordance with ANSI B16.1, B16.5, or B16.42

5.2 *Flange Construction:*

5.2.1 Screw-type flanges shall be secured in position to prevent inadvertent turning of the flange.

5.2.2 Socket-type flanges shall be fully back-welded to the pipe housing and the inside surfaces of the socket flanges shall be welded and ground smooth.

5.2.3 Slip-on flanges shall be fully back-welded.

NOTE 5—No welding shall be done on lined components.

5.2.4 Lap-joint (or Van Stone) flanged ends may be manufactured by standard forming techniques or by using fully welded stub ends or collars. Lap-joints shall not contain any cracks or buckles.

NOTE 6—The use of lap-joint flanges in a piping system may simplify alignment.

5.3 *Workmanship:*

5.3.1 Pipe and fitting linings shall show no evidence of pinholes, porosity, or cracks when inspected in accordance with 5.4.2. The linings shall fit snugly inside the pipe and fitting housings. Any bulges or other obvious indication of poor contact with the housing shall be cause for rejection.

5.3.2 The gasket face portion of the linings shall be free of surface defects that could impair sealing effectiveness. Scratches, dents, nicks, or tool marks on the gasket surface shall not be deeper than 10 % of the wall thickness.

5.4 *Performance:*

5.4.1 *Qualification*—The lined pipes and fittings must be capable of meeting the requirements specified in Section 6.

5.4.2 *Inspection:*

5.4.2.1 Each lined pipe and fitting, prior to shipment, shall be subjected to a hydrostatic test or electrostatic test, or both, as specified in 7.1 or 7.2. The test or tests to be used shall be at the option of the manufacturer, unless otherwise specified by the purchaser.

5.4.2.2 Each lined pipe and fitting shall subsequently be visually inspected prior to shipment to verify conformance to the design and dimensional requirements of 5.3.

5.4.2.3 Each lined pipe and fitting shall bear an inspection verification impression stamp on the housing to indicate compliance with the requirements of this specification.

6. Qualification Tests

6.1 *Temperature Test:*

6.1.1 Cycle representative production samples of the lined pipes and fittings in an oven from room temperature to 225 ± 5°F (107 ± 3°C) to determine the ability of the lined components to withstand heat aging and temperature cycling. Test a minimum of two pipe spools, tees, and 90-deg elbows in each size.

6.1.2 Install companion flanges at the manufacturer's recommended torque value, and affix a thermocouple to the ferrous housing to measure the temperature. Pipe spools shall be at least 3 ft (1 m) long. After 3 h in an oven at 225 ± 5°F (107 ± 3°C) as indicated by the thermocouple, air cool the lined components to 85°F (29°C) maximum. Repeat this test for a total of three cycles.

6.1.3 Inspect the lined pipe and fittings after each cycle for distortion or cracks in the lining. At the completion of the third cycle, subject specimens to either the hydrostatic or electrostatic test described in 7.1 or 7.2.

6.2 *Steam-Cold Water Cycling Test:*

6.2.1 Subject representative production samples of the lined pipe and fittings to steam-cold water cycling to determine the ability of the lined components to withstand rapid temperature changes. Test a minimum of two pipe spools, tees, and 90-deg elbows in each size.

6.2.2 Assemble the lined pipe and fittings with suitable blind flanges having provision for the introduction of steam, air, or cold water, and for drainage. Install the flanges using the manufacturer's recommended torque value. Pipe spool length shall be 10 ft (3 m) minimum. Mount the test specimens in such a manner as to permit complete drainage and then subject them to 100 steam-cold water cycles, each of which shall consist of the following in the sequence given:

6.2.2.1 Circulate 4 ± 1-psig (28 ± 7-kPa) saturated steam through the specimens until the ferrous housing skin temperature adjacent to the flange at the outlet end of the test specimen has been maintained at the maximum stabilized temperature for 30 min.

6.2.2.2 Close off steam.

6.2.2.3 Vent and introduce air to purge the specimens for a minimum of 1 min.

6.2.2.4 Circulate water at a maximum temperature of 77°F (25°C). Circulate the cooling water until the ferrous housing skin temperature adjacent to the flange at the outlet end of the test specimen measures 100°F (38°C) maximum.

6.2.2.5 Drain and introduce air to purge the specimens for a minimum of 1 min, making certain that specimens are completely drained.

6.2.3 There shall be no evidence of leakage from the venting system or the flanges during the 100 cycles. At the completion of the test, the liner shall show no evidence of buckling, cracking, or crazing.

6.2.4 At the conclusion of the testing specified in 6.2.2, subject the lined pipe or fitting to the hydrostatic test specified in 7.1 or, after drying, to the electrostatic test specified in 7.2.

6.3 *Vacuum Test:*

6.3.1 Test representative production samples of the lined pipe and fittings to determine the vacuum ratings of the lined components. Test a minimum of two pipe spools, tees, and 90-deg elbows in each size. Conduct tests at room temperature and at the manufacturer's maximum recommended service temperature.

NOTE 7—Vacuum-temperature ratings should be published in the manufacturer's literature.

6.3.2 For pipe spools, specimen length shall be at least 10 pipe diameters. Install a flange incorporating a sight glass at one end and a blind flange suitable for drawing a vacuum at the other end. Make provisions for measuring the ferrous housing temperature. Heat the specimens uniformly externally with the sight glass end visible, and after the desired ferrous housing temperature is reached, begin the test. Hold a selected initial vacuum level for 24 h and if no failure occurs, increase the vacuum by 2 in. Hg (6.7 kPa). Repeat

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every 24 h until failure or full vacuum is reached. Failure is defined as any buckling or collapse of the liner. Full vacuum is defined as 29.6 in. Hg (100 kPa) corrected. If failure occurs at the initial vacuum level selected, test a new test specimen at a lower vacuum level to determine the failure threshold. The vacuum failure threshold is defined as 1 in. Hg (3.4 kPa) below that at which failure occurs.

NOTE 8—The external pressure method to simulate higher than full vacuum can be used to establish the failure threshold when full vacuum is achievable. With the use of pressure taps, an external pressure is applied between the liner outside diameter and the pipe inside diameter.

6.3.3 The vacuum rating shall be 80 % of the failure threshold value.

6.3.4 At the test completion and after the vacuum rating is established, heat a duplicate specimen to the test temperature. Apply the rated vacuum to the specimen after the desired skin temperature has been reached. Achieve the rated vacuum within 2 min and apply continuously for 48 h. If no liner buckling or collapse occurs, the vacuum rating shall be considered acceptable.

6.4 *Retest*—When a test specimen fails to meet the requirements of 6.1, 6.2, or 6.3, the cause of failure shall be sought and corrected. Repeat the temperature test specified in 6.1, the steam-cold water cycling test specified in 6.2, and the vacuum test specified in 6.3, using double the number of test specimens.

7. Inspection Tests

7.1 *Hydrostatic Pressure Test*—The internal test pressure shall be 250 psi (1.7 MPa) minimum for 125-psi (0.9-MPa) components and 425 psi (2.9 MPa) minimum for 150-psi (0.1-MPa) and 300-psi (2.1-MPa) components. Conduct the test at ambient temperature. Completely fill the pipe and fitting with clean water and bleed the system free of all air prior to the application of pressure. Reach full test pressure within 1 min and maintain for a further 3 min. Observe the pressure gage throughout the test for any evidence of leakage, which shall be cause for rejection.

7.2 *Electrostatic Test*—Conduct the test with a nondestructive high voltage tester at an output voltage of 10 kV. A visible or audible spark, or one that is both, that occurs at the probe when electrical contact is made with the housing because of a defect in the liner shall be cause for rejection.

8. Finish

8.1 The outside surface of all lined pipe and fittings, other than stainless steel, shall be coated with a corrosion-resistant coating over a properly prepared surface.

NOTE 9—Industry practice is to use a paint primer (generally either zinc-rich or epoxy bonded) which permits the user to apply a second layer of paint consistent with his color scheme or identification code, if he so desires.

9. Marking

9.1 Marking on the pipe and fitting shall include the following:

9.1.1 Nominal pipe size,

9.1.2 Liner material identification "PP,"

9.1.3 Manufacturer's name (or trademark),

9.1.4 This ASTM specification "ASTM F 492,"

9.1.5 Length (on pipe only), and

9.1.6 Other information such as order numbers, part numbers, item numbers, etc. shall be provided at the purchaser's request.

9.2 Pipe liner identification shall be provided on a band containing the raised letters "PP." One band is required on fittings and on pipe lengths up to 6 ft; two bands are required for pipe lengths over 6 ft. The band will typically be located near the flange.

10. Packaging

10.1 The gasket face of each lined pipe and each fitting shall be protected by end plates or other suitable protective means, such as individual boxing.

11. Quality Assurance

11.1 When the product is marked with this designation, F 492, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

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GOVERNMENT/MILITARY PROCUREMENT

These requirements apply *only* to federal/military procurement, not domestic sales or transfers.

S1. *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless the purchaser disapproves. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE S1.1—In U.S. federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this specification.

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Standard Specification for Poly(Vinylidene Chloride) (PVDC) Plastic-Lined Ferrous Metal Pipe and Fittings[1]

This standard is issued under the fixed designation F 599; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers factory-made poly(vinylidene chloride) (PVDC) plastic-lined ferrous metal pipe and fittings primarily intended for conveying corrosive liquids and gases. Requirements for materials, workmanship, dimensions, construction, working pressure and temperatures, test methods, and markings are included.

NOTE 1—This specification does not include products *coated* with PVDC nor does it define the suitability of PVDC-lined components in chemical environments.

1.2 The values given in parentheses are provided for information purposes only.

1.3 The ferrous piping products shall meet the requirements of the relevant specifications listed in 1.3.1, 1.3.2, and 1.3.3. Nominal sizes from 1 through 8 in. in 125, 150, and 300 psi ratings are covered.

NOTE 2—The PVDC sealing faces may prevent achievement of the full pressure rating of the ferrous housing. For pressure limitations, the manufacturer should be consulted.

1.3.1 *For Ferrous Pipe:*

Title of Specification	ASTM Designation
Pipe, Steel, Black, and Hot-Dipped, Zinc-Coated, Welded and Seamless	A 53
Seamless Carbon Steel Pipe for High-Temperature Service	A 106
Electric-Resistance-Welded-Carbon and Alloy Steel Mechanical Tubing.	A 513
Electric-Resistance-Welded Steel Pipe	A 135
Electric-Welded Low-Carbon Steel Pipe for the Chemical Industry	A 587

1.3.2 *For Ferrous Flanges:*

Title of Specification	ASTM Designation
Gray Iron Castings	A 48
Forgings, Carbon Steel for Piping Components	A 105
Gray Iron Castings for Valves, Flanges, and Pipe Fittings	A 126
Forgings, Carbon Steel for General Purpose Piping	A 181
Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service	A 182
Carbon-Steel Castings Suitable for Fusion Welding for High-Temperature Service	A 216
Gray Iron Castings for Pressure-Containing Parts for Temperatures up to 650°F (345°C)	A 278
Ferritic Ductile Iron Pressure-Retaining Castings for Use At Elevated Temperatures	A 395
Ductile Iron Castings	A 536

1.3.3 *For Ferrous Fittings:*

Title of Specification	ASTM Designation
Gray Iron Castings	A 48
Forgings, Carbon Steel for Piping Components	A 105
Gray Iron Castings for Valves, Flanges and Pipe Fittings	A 126
Forgings, Carbon Steel, for General Purpose Piping	A 181
Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service	A 182
Carbon-Steel Castings Suitable for Fusion Welding for High-Temperature Service	A 216
Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures	A 234
Gray Iron Castings for Pressure-Containing Parts for Temperatures up to 650°F (345°C)	A 278
Alloy Steel Castings Specially Heat-Treated for Pressure-Containing Parts Suitable for High-Temperature Service	A 389
Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures	A 395
Wrought Austenitic Stainless Steel Piping Fittings	A 403

1.4 The PVDC-lined pipe and fitting assemblies are limited to use from −18 to 79°C (0 to 175°F). For use below −18°C (0°F) consult the manufacturer. Use in specific aggressive environments may alter the above temperature range. The operating temperature range shall be established by mutual agreement between consumer and producer.

NOTE 3—Storage or handling below −7°C (20°F) of uninstalled 4, 6, and 8-in. lined pipe should be avoided.

2. Referenced Documents

2.1 *ASTM Standards:*

D 729 Specification for Vinylidene Chloride Molding Compounds[2]

D 792 Test Methods for Specific Gravity (Relative Density) and Density of Plastics by Displacement[2]

D 1505 Test Method for Density of Plastics by the Density-Gradient Technique[2]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

F 412 Terminology Relating to Plastic Piping Systems[3]

2.2 *ANSI Standards:*

B16.1 Cast Iron Pipe Flanges and Flanged Fittings[4]

B16.5 Steel Pipe Flanges and Flanged Fittings[4]

3. Terminology

3.1 The terminology used is in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise specified.

[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.11 on Composite.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] Available from the American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

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3.2 The abbreviation for poly(vinylidene chloride) is PVDC.

4. Materials

4.1 *Lining:*

4.1.1 *Material*—The lining shall be made from PVDC compounds conforming to the requirements of Specification D 729, except that up to a 20 weight % glass fiber filler is used to modify physical properties, and a maximum of 1 weight % of colorant is permissible for identification. Organic colorants, if used, shall be identified in the manufacturer's specification.

4.1.2 The PVDC shall be virgin compound or clean reworked compound.

4.1.3 *Mechanical Properties*—The minimum tensile strength and minimum elongation at yield when tested in accordance with Specification D 729 shall be 1500 psi (10.34 MPa) and 2 % respectively. The minimum values for tensile strength and elongation shall apply to both the longitudinal and circumferential directions.

4.1.4 *Specific Gravity*—The linings manufactured from PVDC resins with 20 % glass fibers shall have a relative density of 1.8 to 1.9 when tested in accordance with the requirements of Test Methods D 792 and D 1505.

4.2 *Ferrous Pipe and Fittings:*

4.2.1 *Mechanical Properties*—The mechanical properties of the pipe and fittings shall conform to the requirements of the appropriate specification of 1.3 except as they are influenced by accepted methods of processing in the industry, for example, Van Stone flaring, bending, swaging, and welding. The carbon steel pipe and wrought fittings shall be welded or seamless steel, Schedule 40 or Schedule 80, except that Schedule 30 pipe may be used in 8-in. nominal size.

4.2.2 *Finish*—The interior surfaces of all housings shall be clean and free of mold burrs, rust, scale, or other protrusions which may adversely affect integrity or performance of the lining.

4.3 *Back-Up Gaskets:*

4.3.1 *General*—Back-up gaskets shall be used to cover the pipe end and gasket face of threaded or slip-on flanges unless a full radius or chamfer is provided at the end of the pipe and flange. Gaskets may also be required on fittings to provide accommodation or elimination, or both, of sharp corners which could damage the lining.

4.3.2 *Material*—Plain gaskets meeting the temperature requirements, or perforated metallic gaskets, may be used.

5. Requirements

5.1 *Dimensions:*

5.1.1 *Housings*—Housing installation dimensions are as required in the applicable material specification listed in 1.3.

5.1.2 *Wall Thickness*—Fitting linings shall have a minimum wall thickness of 3/32 in. (2.4 mm), and shall have a uniform face thickness of not less than 3/32 in. Pipe linings shall have a minimum wall thickness of 3/32 in., and the flared radius and gasket faces shall have a uniform thickness of not less than 80 % of the wall thickness. Molded faces shall not be less than 3/32 in. thick.

5.1.3 *PVDC Face Diameter*—The outside diameter of the PVDC covering the gasket face of the flange or the full face of the lap-joint stub end shall not be less than the diameter specified in Table 1. They shall be concentric within 1/16 in. (1.6 mm).

5.1.4 *Tolerances*—Tolerance for pipe, flanges, and fittings shall be as specified in Table 2. Bolt holes in both flanges on a fixed spool shall straddle the same center line to facilitate alignment. Finish lined (plastic face to plastic face) fabricated fittings shall conform to the nominal face-to-face, etc., as specified in ANSI B16.1 or B16.5 with the applicable tolerances.

5.2 *Flange Construction:*

5.2.1 Screw-type flanges shall be secured in position to prevent inadvertent turning of the flange.

5.2.2 Socket-type flange shall be fully back-welded to the pipe housing and the inside surfaces of the socket flanges shall be welded and ground smooth.

5.2.3 Slip-on flanges shall be fully back-welded.

NOTE 4—No welding shall be done on lined components.

5.2.4 Lap-joint (or Van Stone) flanged ends may be manufactured by standard forming techniques or by using fully welded stub ends or collars. Lap-joints shall not contain any cracks or buckles.

NOTE 5—The use of lap-joint flanges in a piping system may simplify alignment.

5.3 *Workmanship:*

5.3.1 Pipe and fitting linings shall show no evidence of pinholes, porosity, or cracks when inspected in accordance with 5.4.2. The lining shall fit snugly inside the pipe and fitting housings. Any bulges or other obvious indication of poor contact with the housing shall be cause for rejection.

5.3.2 The gasket face portion of the PVDC linings shall be free of surface defects that could impair sealing effectiveness. Scratches, dents, nicks, or tool marks on the gasket surface shall not be deeper than 10 % of the wall thickness.

5.4 *Performance:*

5.4.1 *Qualification*—PVDC-lined pipe and fittings must be capable of meeting the requirements specified in Section 6.

5.4.2 *Inspection:*

5.4.2.1 Each lined pipe and fitting, prior to shipment, shall be subjected to a hydrostatic test or an electrostatic test,

TABLE 1 PVDC Face Diameter

Nominal Pipe Size, in.	Minimum PVDC Face Diameter, in. (mm)
1	1 7/8 (47.62)
1.5	2 11/16 (68.26)
2	3 7/16 (87.31)
2.5	3 15/16 (104.01)
3	4 5/8 (117.48)
4	5 15/16 (150.81)
6	8 (203.20)
8	10 1/16 (255.59)

TABLE 2 Tolerances for Pipe, Flanges, and Fittings

	Tolerance, in. (mm)
Pipe:	
Length	±1/8 (±3)
Fixed flange bolt hole alignment	±1/16 (±1.6)
Flange perpendicularity (with pipe centerline)	3/32 in./ft (2.38 mm/m) of diameter
Flanges and Fittings:	
All dimensions	per ANSI B16.1 or ANSI B16.5

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or both, as specified in 7.1 or 7.2. The test or tests to be used shall be at the option of the manufacturer, unless otherwise specified by the purchaser.

5.4.2.2 Each lined pipe and fitting shall subsequently be visually inspected prior to shipment to verify conformance to the design and dimensional requirements of 5.3.

5.4.2.3 Each lined pipe and fitting shall bear an inspection verification impression stamp on the housing to indicate compliance with the requirements of this specification.

6. Qualification Tests

6.1 *Temperature Test:*

6.1.1 Representative production samples of PVDC-lined pipe and fittings shall be cycled in an oven from room temperature to 79 ± 3°C (175 ± 5°F) to determine the ability of the lined components to withstand heat aging and temperature cycling. A minimum of two pipe spools, tees, and 90-deg elbows shall be tested in each size.

6.1.2 Install companion flanges at the manufacturer's recommended torque value, and affix a thermocouple to the ferrous housing to measure the temperature. Pipe spools shall be at least 3-ft (0.9-m) long. After 3 h in an oven at 79°C (175°F) as indicated by the thermocouple, air cool the lined components to 29°C (85°F) maximum. Repeat this test for a total of three cycles.

6.1.3 Inspect the PVDC-lined pipe and fittings after each cycle for distortion or cracks in the lining. At the completion of the third cycle, subject specimens to either the hydrostatic or electrostatic test described in 7.1 or 7.2.

6.2 *Thermo Cycling Test:*

6.2.1 Subject representative production samples of PVDC-lined pipe and fittings to hot water-cold water cycling to determine the ability of the lined components to withstand rapid temperature changes. Test a minimum of two pipe spools, tees, and 90-deg elbows in each size.

6.2.2 Assemble the PVDC-lined pipe and fittings with suitable-blind flanges having provision for the introduction of air, hot and cold water, and drainage. Install the flanges using the manufacturer's recommended torque value. Pipe-spool length shall be 10 ft (3 m) minimum. Mount the test specimens in such a manner as to permit complete drainage and then subject them to 100 hot water-cold water cycles, each of which shall consist of the following in the sequence given:

6.2.2.1 Circulate 79 ± 3°C (175 ± 5°F) water through the specimens until the ferrous housing skin temperature adjacent to the flange at the outlet end of the test specimen has been maintained at the maximum stabilized temperature for 30 min.

6.2.2.2 Close off hot water.

6.2.2.3 Drain and introduce air to purge the specimens for a minimum of 1 min.

6.2.2.4 Circulate water at a maximum temperature of 25°C (77°F). Circulate the cooling water until the ferrous housing-skin temperature adjacent to the flange at the outlet end of the test specimen measures 38°C (100°F) maximum.

6.2.2.5 Drain and introduce air to purge the specimens for a minimum of 1 min, making certain that specimens are completely drained.

6.2.3 There shall be no evidence of leakage from the flanges during the 100 cycles. At the completion of the test, the liner shall show no evidence of buckling, cracking, or crazing.

6.2.4 At the conclusion of the testing specified in 6.2.2, the lined pipe or fitting shall be subjected to the hydrostatic test specified in 7.1, or, after drying, to the electrostatic test specified in 7.2.

6.3 *Vacuum Testing:*

6.3.1 Test representative production samples of the PVDC-lined pipe and fittings to determine the vacuum ratings of the lined components. Test a minimum of two pipe spools, tees, and 90-deg elbows in each size. Conduct tests at room temperature and at the manufacturer's-maximum recommended service temperature.

NOTE 6—Vacuum-temperature ratings should be published in the manufacturer's literature.

6.3.2 For pipe spools, specimen length shall be at least ten pipe diameters. Install a flange incorporating a sight glass at one end and a blind flange suitable for drawing a vacuum at the other end. Make provisions for measuring the ferrous housing temperature. Heat the specimens uniformly externally with the sight-glass end visible, and after the specified ferrous housing temperature is reached, begin the test. Hold a selected initial vacuum level for 8 h, and if no failure occurs, increase the vacuum by 2 in. Hg (6.8 kPa). Repeat every 8 h until full vacuum is reached. Failure is defined as any buckling or collapse of the liner. Full vacuum is defined as 29.6 in. Hg (100 kPa) corrected (a gage pressure of −100 kPa). If failure occurs at the initial-vacuum level selected, test a new specimen at a lower-vacuum level to determine the failure threshold. The vacuum-failure threshold is defined as 1 in. Hg (3.4 kPa) below that at which failure occurs.

NOTE 7—The external-pressure method to simulate higher than full vacuum can be used to establish the failure threshold when full vacuum is achievable. With the use of pressure taps, an external pressure is applied between the liner outside diameter and the pipe inside diameter.

6.3.3 The vacuum rating shall be 80 % of the failure threshold value.

6.3.4 At the test (6.3.2) completion, and after the vacuum rating (6.3.3) is established, heat a duplicate specimen to the specified test temperature. Apply the rated vacuum to the specimen after the specified-skin temperature has been reached. Achieve the rated vacuum within 2 min, and apply continuously for 48 h. If no liner buckling or collapse occurs, the vacuum rating shall be considered acceptable.

6.4 *Retest*—When a test specimen fails to meet the requirements of 6.1, 6.2, or 6.3, the cause of failure shall be sought and corrected. Repeat the temperature test specified in 6.1, the hot water-cold water cycling test specified in 6.2, and the vacuum test specified in 6.3, using double the number of test specimens.

7. Inspection Tests

7.1 *Hydrostatic-Pressure Test*—The internal test pressure shall be 250 psi (1720 kPa) minimum for 125-psi (862-kPa) components and 425 psi (2930 kPa) for 150-psi and 300-psi components. Conduct the test at ambient temperature. Completely fill the pipe and fitting with clean water and bleed the system free of all air prior to application of pressure. Reach full test pressure within 1 min and maintain for a further 3 min. Observe the pressure gage and test

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specimen, throughout the test for any evidence of leakage which shall be cause for rejection.

7.2 *Electrostatic Test*—Conduct the test with a nondestructive high-voltage tester at an output voltage of 10 kV. A visible or audible spark, or both, that occurs at the probe when electrical contact is made with the housing because of a defect in the liner, shall be cause for rejection.

8. Finish

8.1 The outside surface of all lined pipe and fittings, other than stainless steel, shall be coated with a corrosion-resistant primer over a properly prepared surface.

9. Marking

9.1 Marking on pipe and fittings shall include the following:

9.1.1 Nominal pipe size,

9.1.2 Liner material identification (PVDC),

9.1.3 Manufacturer's name (or trademark),

9.1.4 This designation "ASTM F 599,"

9.1.5 Length (on pipe only), and

9.1.6. Other information such as order numbers, part numbers, item numbers, etc., at the purchaser's request.

9.2 Pipe-liner identification shall be provided on a band containing the raised letters "PVDC". One band is required on fittings and on pipe lengths up to 6 ft (2 m); two bands are required for pipe lengths over 6 ft. The band will typically be located near the flange.

10. Packaging

10.1 The gasket face of each lined pipe and fitting shall be protected by end plates or other suitable protective means, such as individual boxing.

11. Quality Assurance

11.1 When the product is marked with this designation, F 599, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

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Designation: F 628 – 01

An American National Standard

Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe With a Cellular Core[1]

This standard is issued under the fixed designation F 628; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers coextruded acrylonitrile-butadiene-styrene (ABS) plastic drain, waste, and vent pipe made to Schedule 40 iron pipe sizes (IPS) and produced by the coextrusion process with concentric inner and outer solid ABS layers and the core consisting of closed-cell cellular ABS. Plastic which does not meet the material requirements specified in Section 5 is excluded from single layer and all coextruded layers.

1.2 Fittings suitable for use with pipe meeting the requirements of this specification are given in Annex A1. Fittings meeting the requirement of Specification D 2661 are also acceptable.

1.3 Acrylonitrile-butadiene-styrene plastic which does not meet the definitions of virgin ABS plastic as given in 3.2.4 is excluded, as performance of plastic other than those defined as virgin was not determined. ABS rework plastic which meets the requirements of rework plastic as given in 5.3 is acceptable.

1.4 Reprocessed plastic or recycled plastic as defined in Terminology D 883 is excluded.

1.5 Recommendations for storage, joining, and installation are provided in Appendixes X1, X2, and X3, respectively.

1.6 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.7 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics for Testing[2]

D 883 Terminology Relating to Plastics[2]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 1898 Practice for Sampling of Plastics[2]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D 2235 Specification for Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings[3]

D 2321 Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications[3]

D 2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading[3]

D 2444 Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)[3]

D 2661 Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe and Fittings[3]

D 3311 Specification for Drain, Waste, and Vent (DWV) Plastic Fittings Patterns[3]

D 3965 Specification for Rigid Acrylonitrile-Butadiene-Styrene (ABS) Materials for Pipe and Fittings[4]

E 105 Practice for Probability Sampling of Materials[5]

E 122 Practice for Calculating Sample Size to Estimate, With a Specified Tolerable Error, the Average for a Characteristic of a Lot or Process[5]

F 402 Practice for Safe Handling of Solvent Cements, Primers, and Cleaners Used for Joining Thermoplastic Pipe and Fittings[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings[3]

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[6]

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[6]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise specified. The abbreviation for acrylonitrile-butadiene-styrene plastic is ABS.

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[1] This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.63 on DWV.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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3.1.1 *cellular plastic*—a plastic containing numerous cells, intentionally introduced, interconnecting or not, distributed throughout the mass.

3.1.2 *closed-cell cellular plastic*—cellular plastic in which almost all the cells are noninterconnecting.

3.1.3 *coextruded pipe*—pipe consisting of two or more concentric layers of material bonded together in processing by any combination of temperature, pressure, grafting, crosslinking, or adhesion.

3.1.4 *coextrusion*—a process whereby two or more heated or unheated plastic material streams forced through one or more shaping orifice(s) become one continuously formed piece.

3.1.5 *room temperature*—a temperature in the range from 68 to 85 ± 3.6°F (20 to 30 ± 2°C).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *lot*—a lot shall consist of all pipe produced, of one size, from one extrusion line, during one designated 24-h period.

3.2.2 *recycled plastic*—a plastic prepared from discarded articles that have been cleaned and reground.

3.2.3 *reprocessed plastic*—a thermoplastic prepared from usually melt processed scrap or reject parts by a plastics processor, or from nonstandard or nonuniform virgin material.

3.2.4 *virgin ABS plastic*—plastic in the form of pellets, granules, powder, floc, or liquid that has not been subjected to use or processing other than that required for its initial manufacture.

4. Classification

4.1 Pipe produced in accordance with this specification is intended to provide pipe suitable for the drainage and venting of sewage and certain other liquid wastes.

NOTE 1—Before installing pipe for waste disposal use, the approval of the cognizant building code authority should be obtained as conditions not commonly found in normal use may be encountered and temperatures in excess of 180°F (82°C) may be encountered.

5. Materials

5.1 *Material Specification*—Virgin ABS plastic shall conform to the requirements prescribed in Specification D 3965 with a cell classification of 4-2-2-2-2. The color and form of the material shall be as agreed upon between the seller and the purchaser in accordance with Specification D 3965.

5.2 The ABS plastic shall conform to the following requirements:

5.2.1 *Acrylonitrile-Butadiene-Styrene (ABS) Plastic*—Plastic shall contain a minimum of 15 % acrylonitrile, 6 % butadiene, and 15 % styrene or substituted styrene, or both, of polymers or blends of polymers.

5.2.2 ABS plastic shall contain no more than 10 % of other monomeric or polymeric components plus other necessary compounding ingredients.

5.3 *Rework Material*—The manufacturer shall use only his own clean rework pipe material conforming with these cell class requirements. Use it only in the core layer. The pipe produced shall meet all the requirements of this specification.

6. Requirements

6.1 *General*—The pipe and fittings should be homogeneous throughout and free of visible cracks, holes, foreign inclusions, or other injurious defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

6.1.1 The requirements in this section are intended only for use as quality control tests, not as simulated service tests.

6.2 *Dimension and Tolerance*:

6.2.1 *Outside Diameter*—The outside diameter and tolerances shall meet the requirements of Table 1 when measured in accordance with Test Method D 2122. The tolerances for out-of-roundness shall apply to pipe prior to shipment.

6.2.2 *Wall Thickness*—The wall thickness and tolerances shall meet the requirements of Table 2 when measured in accordance with Test Method D 2122.

6.2.3 *Length*—The pipe shall be in either 10 or 20-ft (3.05 or 6.1-m) lengths, unless otherwise specified. The allowable tolerance on length shall be +½, –0 in. (+12, –0 mm).

6.3 *Performance Requirements*:

6.3.1 *Pipe Stiffness*—The minimum pipe stiffness values at 5 % deflection when measured in accordance with Test Method D 2412, shall equal or exceed the values in Table 3. The rate of crosshead motion shall be 0.20 to 0.25 in./min (5.1 to 6.3 mm/min). Three specimens shall be tested. If all three meet this requirement, the sample meets this requirement. If one or two fail, additional testing shall be conducted in accordance with 6.3.1.1. If all three fail, the sample does not meet the requirement.

6.3.1.1 *Pipe Stiffness and Lower Confidence Limit*—In the event that one or two of the specimens tested in 6.3.1 fail to meet the minimum requirement, the average pipe stiffness of eleven specimens shall meet or exceed the minimum requirement given in Table 3. The 99 % lower confidence limit (LCL)

TABLE 1 Outside Diameters and Tolerances for ABS Schedule 40 Plastic Drain, Waste, and Vent Pipe Produced by the Coextrusion Process with Concentric Inner and Outer Solid ABS-Layers and the Core Consisting of Closed-Cell Cellular ABS

Nominal Pipe Size, in.	Outside Diameter		
	Average, in. (mm)	Tolerance on Average, in. (mm)	Out-of-Roundness Maximum Diameter Minus Minimum Diameter, in. (mm)[A]
1¼	1.660 (42.16)	+0.010, –0.000 (+0.25, –0.00)	0.024 (0.60)
1½	1.900 (48.26)	+0.010, –0.000 (+0.25, –0.00)	0.024 (0.60)
2	2.375 (60.32)	+0.010, –0.000 (+0.25, –0.00)	0.024 (0.60)
3	3.500 (88.90)	+0.015, –0.000 (+0.38, –0.00)	0.030 (0.76)
4	4.500 (114.30)	+0.015, –0.000 (+0.38, –0.00)	0.100 (2.54)
6	6.625 (168.28)	+0.011, –0.011 (+0.28, –0.28)	0.100 (2.54)

[A] Measured at time of manufacturing.

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TABLE 2 Wall Thickness and Tolerance for ABS Schedule 40 Plastic Drain, Waste, and Vent Pipe Produced by the Coextrusion Process with Concentric Inner and Outer Solid ABS Layers and the Core Consisting of Closed-Cell Cellular ABS

Nominal Pipe Size, in.	Wall Thickness[A]	
	Minimum Total Wall, in. (mm)	Tolerance, in. (mm)
1¼	0.140 (3.56)	+0.020 (+0.50)
1½	0.145 (3.68)	+0.020 (+0.50)
2	0.154 (3.91)	+0.020 (+0.50)
3	0.216 (5.42)	+0.026 (+0.66)
4	0.237 (6.02)	+0.028 (+0.71)
6	0.280 (7.11)	+0.034 (+0.86)

[A] The minimum is the lowest wall thickness of the pipe at any cross section.

TABLE 3 Pipe Stiffness of ABS Schedule 40 Plastic Drain, Waste, and Vent Pipe Produced by the Coextrusion Process with Concentric Inner and Outer Solid ABS Layers and the Core Consisting of Closed-Cell Cellular ABS

Nominal Pipe Size, in.	Minimum Pipe Stiffness at 5 % Deflection	
	psi	(MPa)
1¼	600	(4.13)
1½	535	(3.69)
2	300	(2.06)
3	280	(1.93)
4	175	(1.21)
6	75	(0.52)

shall be within 15 % of the average value. The LCL shall be calculated using the Student's "*t*" distribution, with *N*-1 degrees of freedom, where *N* is the number of specimens. The critical *t* value shall be used to at least three significant digits. Alternatively, if the LCL exceeds the minimum pipe stiffness requirement in Table 3, but is not within 15 % of the average, the sample meets the requirements of the Pipe Stiffness testing. The eleven specimens include the three tested under 6.3.1, and an additional eight with rotation by 35°, as specified in Test Method D 2412, continuing throughout the remaining specimens.

6.3.1.2 The LCL based on testing eleven specimens is calculated as follows:

$$\text{LCL} = (\text{avg PS}) - \{2.76(\text{std. dev.})/\sqrt{(N)}\}$$

where:

$$(\text{avg PS}) = [\Sigma(\text{PS}_i)]/(11) \quad (1)$$

$$(\text{std. dev.}) = \left[\frac{\Sigma\,\text{PS}^2 - (\Sigma\text{PS})^2/N}{N-1}\right]^{1/2}$$

$$N = 11.$$

6.3.1.3 The 15 % requirement is calculated as follows:

$$(\text{avg} - \text{LCL})/(\text{avg}) \times 100 \leq 15\ \%$$

NOTE 2—For quality control testing, a single specimen may be used with the thinnest wall at the top.

NOTE 3—The 5 % deflection criterion, which was arbitrarily selected for testing convenience, should not be considered as a limitation with respect to in-use deflection. The engineer is responsible for establishing the acceptable deflection limit.

NOTE 4—The strength and load-carrying capabilities of plastic pipe are measured and reported as pipe stiffness, which is determined in accordance with Test Method D 2412. The term "crush strength" is not applicable to plastic piping because the values obtained can be significantly different, depending on the bedding, loading, or testing technique used, and the term derives from rigid pipe and refers to its ultimate strength at rupture.

6.3.2 *Pipe Flattening*—There shall be no evidence of rupture when pipe is deflected 25 % of the initial inside diameter when tested in accordance with Test Method D 2412. Three specimens shall be tested; all shall meet the requirements. Failure shall be a crack or break extending entirely through the pipe wall visible to the unaided eye.

6.3.3 *Impact Strength*—The minimum impact resistance, when tested at the time of manufacture, shall comply with Table 4. Test in accordance with Test Method D2444 using Tup A and Holder B. Use 12–lb (5 kg) tup for testing pipe sizes 4 in. and smaller and a 20–lb (10–kg) tup for sizes larger than 4 in.

6.3.3.1 Test 10 specimens. When 9 or 10 specimens pass, accept the lot. When 2 or more specimens fail, test 10 additional specimens. When 17 of 20 specimens tested pass, accept the lot. When 4 or more of 20 specimens fail, test 20 additional specimens. When 32 of 40 specimens pass, accept the lot. When 9 or more of 40 specimens fail, the lot does not meet the requirements of this specification.

6.3.3.2 Failure of the test specimen shall be shattering or any crack or break extending entirely through the pipe wall and visible to the unaided eye.

6.3.4 *Bond*—The bond between layers shall be strong and uniform. It shall not be possible to separate any two layers with a probe or point of a knife blade so that the layers separate cleanly, or so the probe or knife blade moves freely between the layers; nor shall separation of bond occur between layers during testing performed under the requirements of this specification.

6.3.5 *Pigments or Screening Agents*—The ABS compound used in the outer layer shall contain pigments or screening agents to provide protection against UV radiation.

6.4 *Other Requirements*:

6.4.1 *Inspection*—Inspection shall be made prior to installation of all pipe. Pipe that does not meet the requirements of 6.1 shall be returned to the seller.

6.4.2 *Joining*—Coextruded ABS Schedule 40 drain, waste, and vent pipe with a cellular core are joined using molded

TABLE 4 Impact Resistance of ABS Schedule 40 Plastic Drain, Waste, and Vent Pipe Produced by the Coextrusion Process and Concentric Inner and Outer Solid ABS Layers and the Core Consisting of Closed-Cell Cellular ABS

Nominal Pipe Size, in.	Minimum Impact Resistance, ft·lbf (J)
	At 32°F (0°C)
1¼	15 (20)
1½	20 (27)
2	30 (41)
3	40 (54)
4	40 (54)
6	40 (54)

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fittings meeting the requirements of Specifications D 2661 and D 3311 or the requirements for fittings listed in the Annex of this specification.

6.4.3 *Solvent Cement*—In the assembly of solvent cement joints, the safety requirements of Practice F 402 shall be followed using solvent cement meeting the requirements of Specification D 2235.

7. Sampling and Conditioning

7.1 *Sampling*—For the purpose of testing, the lot shall consist of all pipe produced of one size, from one extrusion line, during one designated 24-h period. The number of specimens designated for each test shall be taken from pipe selected at random from each lot in accordance with the random sampling plan of Practice D 1898.

NOTE 5—Also see Practices E 105 and E 122.

7.2 *Number of Test for Quality Control*— When evaluating a product against this specification, the following minimum number of specimens shall be tested for each lot.

7.2.1 *Outside Diameter*—One specimen per extrusion line.

7.2.2 *Wall Thickness*—One specimen per extrusion line.

7.2.3 *Length*—One specimen per extrusion line.

7.2.4 *Pipe Stiffness*—A minimum of three specimens per extrusion line.

7.2.5 *Pipe Flattening*—A minimum of three specimens per extrusion line.

7.2.6 *Impact Strength*—A minimum of 10 specimens and a maximum of 40.

7.2.7 *Bond*—One specimen per extrusion line.

7.3 *Conditioning* :

7.3.1 For referee testing at 73°F, condition the specimens prior to the test at 73.4 ± 3.6° (23 ± 2°C) and 50 ± 5 % relative humditity in accordance with Practice D 618, Procedure A.

7.3.2 For routine quality control testing at 73°F, condition the specimens at the tempertaure and humidity of the manufacturers testing facility for not less than 1 h or until the specimens are at the room temperature.

7.3.3 For referee testing at 32°F, condition the specimens at 32 ± 3.6°F (0 ± 2°C) for at least 2 h, or in ice water for at least 1 h.

7.4 *Test Conditions*:

7.4.1 For referee purposes, conduct tests in the standard laboratory atmosphere of 73.4 ± 3.6 F° (23 ± 2°C) and 50 ± 5 % relative humidity.

7.4.2 For routine quality control testing, conduct tests at the temperature and humditiy of the manufacturers testing area.

7.4.3 For testing at 32°F, complete the test as soon as possible after removal from the conditioning atmosphere, but in any case within 15 s.

7.5 *Test Methods*—Only ASTM test methods specified shall be used.

8. Retest and Rejection

8.1 If the results of any test(s) do not meet the requirements of this specification, the test(s) shall be conducted again only by agreement between the purchaser and the seller. Under such agreement, minimum requirements shalll not be lowered, changed, or modified, nor shall specification limits be changed. If, upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

9. Product Marking

9.1 *Quality of Marking*—The marking shall be applied to the pipe in such a manner that it remains legible (easily read) after installation and inspection.

9.2 *Content of Marking*—The pipe shall be marked in letters not less than 3/16in. (5 mm) high, in a contrasting color, spaced at intervals of not more than 5 ft. (1.5 m), with the following information:

9.2.1 Manufacturer's name (or trademark).

9.2.2 This designation "ASTM F 628".

9.2.3 The wording "COEXTRUDED ABS CELLULAR CORE DWV".

9.2.4 Nominal pipe size (for example: 2 in. (51 mm)).

9.2.5 Manufacturer's code for resin manufacture, lot number, and date of manufacture.

10. Quality Assurance

10.1 When the product is marked with this designation, F 628, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

11. Keywords

11.1 ABS; cellular; DWV; fittings; pipe; plastic; thermoplastic; Schedule 40

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SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply *only* to federal/military procurement, not domestic sales or transfers.

S1. *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE S1.1—In U.S. Federal Government contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the material shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of U.S. Federal Government procurement requirements should not be construed as an indication that the U.S. Federal Government uses or endorses the products described in this specification.

ANNEX

(Mandatory Information)

A1. ABS FITTINGS

A1.1 The pattern, dimension, and laying length of fittings shall meet the requirements of Specification D 3311 and Table A1.1 when determined in accordance with Test Method D 2122.

A1.2 Fittings produced by any molding process shall be made of virgin ABS plastic which shall conform to the requirements prescribed in Specification D 3965 with a cell classification of 3-2-2-2-2. The color and form of the material shall be as agreed upon between the seller and the purchaser in accordance with Specification D 3965.

A1.3 *Rework Material*—The manufacturer shall use only his own clean rework pipe material conforming with these cell class requirements. Use it only in the core layer. The pipe produced shall meet all the requirements of this specification.

A1.4 The spigot dimensions of the fittings shall meet the requirements of Table 1 of this specification.

A1.5 For all fittings having taper pipe threads, threads shall conform to and be gaged in accordance with Specification F 1498.

A1.6 Individual fittings assembled shall withstand a minimum load of 750 lbf/ft (11 kN/m) of centerline length without visible evidence of failure when tested in accordance with Test Method D 2412.

A1.7 Individual fittings assembled shall meet a minimum impact of 20 ft·lbf (27 J) when tested in accordance with Test Method D 2444 at 73°F (23°C) using a 12-lb (5-kg) Tup C and Holder B.

A1.8 Solvent cement meeting the requirements of Specification D 2235 shall be used to join pipe and fittings.

A1.9 Fittings shall be marked on the body or hub with the manufacturer's name or trademark, this designation, "ASTM F 628", and the symbol "ABS".

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TABLE A1.1 Dimensions and Tolerances for ABS Schedule 40 Drain, Waste, and Vent Fittings

Nominal Pipe Size, in.	Socket Entrance Diameter			Socket Bottom Diameter			Socket Depth, min	Wall Thickness[A]		Internal Threads	
	Average[B]	Tolerance on Diameter	Out-of-Roundness (maximum minus minimum)	Average[B]	Tolerance on Diameter	Out-of-Roundness (maximum minus minimum)		Average, min	Minimum After Core Shift	Outside Diameter of Hub M, min	Thread Length, min
	in. (mm)										
1¼	1.670 (42.42)	+0.010 (0.25) −0.005 (0.13)	0.024 (0.61)	1.655 (42.04)	±0.005 (0.13)	0.024 (0.61)	0.687 (17.45)	0.156 (3.96)	0.140 (3.56)	1.871 (47.52)	0.687 (17.4)
1½	1.910 (48.51)	+0.010 (0.25) −0.005 (0.13)	0.024 (0.61)	1.895 (48.13)	±0.005 (0.13)	0.024 (0.61)	0.687 (17.45)	0.156 (3.96)	0.140 (3.56)	2.127 (54.03)	0.687 (17.4)
2	2.385 (60.58)	+0.010 (0.25) −0.005 (0.13)	0.024 (0.61)	2.370 (60.19)	±0.005 (0.13)	0.024 (0.61)	0.750 (19.05)	0.156 (3.96)	0.140 (3.56)	2.634 (66.90)	0.750 (19.0)
3	3.515 (89.28)	+0.010 (0.25) −0.005 (0.13)	0.030 (0.76)	3.495 (88.73)	+0.005 (0.13) −0.010 (0.25)	0.030 (0.76)	1.500 (38.1)	0.218 (5.54)	0.196 (4.98)	3.841 (97.56)	1.187 (30.15)
4	4.515 (114.68)	+0.010 (0.25) −0.005 (0.13)	0.030 (0.76)	4.495 (114.17)	+0.005 (0.13) −0.010 (0.25)	0.030 (0.76)	1.750 (44.45)	0.250 (6.35)	0.225 (5.72)	4.907 (124.64)	1.281 (32.54)
6	6.647 (168.83)	±0.011 (0.28)	0.060 (1.52)	6.614 (167.99)	±0.011 (0.28)	0.060 (1.52)	3.000 (76.20)	0.281 (7.14)	0.253 (6.43)	7.203 (182.96)	1.500 (38.10)

[A] The average wall thickness is the minimum wall thickness plus the opposite wall thickness divided by 2. The average shall equal or exceed that shown in the table. The minimum wall thickness, due to core shift, shall equal or exceed the value shown in the table. The minimum wall thickness is determined by allowing a 10 % variation due to core shift.

[B] The average is the maximum plus the minimum diameters divided by 2.

APPENDIXES

(Nonmandatory Information)

X1. STORAGE

X1.1 *Outside Storage*—Plastic pipe should be stored on a flat surface or supported in a manner that will prevent sagging or bending. Do not store pipe in direct sunlight forlong periods.

X1.2 Inventories of plastic pipe should be used on a first-in-first-out basis.

X2. JOINING

X2.1 *Field Inspection*—Prior to use, all pipe should be carefully inspected for cuts, gouges, deep scratches, damaged ends, and other major imperfections. Defective pipe should be rejected and damaged sections should be cut out.

X2.2 *Pipe Fit*—Pipe is manufactured to close tolerances to ensure satisfactory "interference" fit between the pipe and the fittings socket during assembly. Use only combinations of pipe and fittings that give interference fits. Pipe that is a loose fit in the socket may not properly bond. The allowable tolerance assures a forced fit and when solvent cement is applied, the pipe and fitting will readily mate, thus assuring proper adhesion. The pipe should enter the dry fitting socket to between one half and two thirds of the fitting socket depth.

X2.3 *Cutting*—Pipe can be easily cut with an ordinary hacksaw or carpenter's saw. Fine-tooth blades with little or no set should be used for best results. The pipe should be cut square and all burrs removed with a sharp knife, a fine-tooth file, or other suitable tool such as chamfering tool or reamer. A miter box is recommended to ensure square cut ends. Standard steel pipe or tubing cutters are not recommended for cutting ABS pipe since they may cause excessive heat and pressure, which can result in cracked or irregular pipe ends. There are special plastic pipe cutters available with extra wide rollers and thin cutting wheels that have been especially designed for cutting plastic pipe, and their use is recommended.

X2.4 *Cleaning*—Remove burrs from inside and outside pipe edges. Wipe off all dust, dirt, and moisture from surfaces to be cemented with a clean dry rag or a paper towel. At no time should pipe or fittings be assembled that are wet or damp. Pipe and fittings must be dry before assembly to obtain good joints.

X2.5 *Safety Requirements for Solvent Cement and Primers*—Follow Practice F 402.

X2.6 *Solvent Cement*—Use only solvent cement designed for ABS. Use a solvent cement meeting the requirements of Specification D 2235.

X2.6.1 *Application of Cement*—Using the applicator supplied with the can of solvent cement, or a brush or roller with a width of about one half the pipe diameter for pipe sizes above 2 in. (51 mm), apply a moderate even coating of cement in the fitting socket to cover only the surfaces to be joined. Heavy or excessive application of solvent cement may become an obstruction in the pipe and prevent satisfactory joining. Quickly apply a heavy coat of solvent cement to the outside of the pipe. Make sure that the coated distance on the pipe is equal to the depth of the fitting socket.

X2.7 *Assembly*—Make the joint as quickly as possible after application of the solvent cement and before the solvent cement dries. Should the solvent cement dry partially before the joint is made up, reapply solvent cement before assembling. Insert the pipe into the fitting socket, making sure that the pipe is inserted to the full depth of the fitting socket. Hold joint together firmly for about 30 s for small diameter pipe and 60 s for diameters above 6 in. (152 mm) to avoid push-out. Remove excessive solvent cement from the exterior of the joint with a clean, dry cloth.

X2.8 *Set Time*—Do not attempt to disturb the pipe and fitting joint until after the solvent cement has set or damage to the joint and loss of fit may result. Reasonable handling of assembly is permissible within 2 min after joining. Allow 15 min for the joint to develop good handling strength and the joint will withstand the stresses of normal installation. A badly misaligned installation will cause excessive stresses in the joint, pipe, and fittings and constitutes a plumbing code violation and should be avoided. The recommendation of the solvent cement manufacturer should be followed for best results.

X2.9 *Cure Time*—Joint strength development is very rapid during periods of high ambient temperatures, low relative humidity, and using interference-type fittings. Joint strength development is not as rapid during periods of low ambient temperatures, high relative humidity, and using loose fits. Therefore, the recommendations of the solvent cement manufacturer should be followed for best results prior to leak testing.

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X3. INSTALLATION

X3.1 *Underground Installation*—Underground installations of pipe shall be in accordance with the excavation, bedding and backfill provisions of the Plumbing Code having jurisdiction, except maximum aggregate size shall be limited to ½ in. (13 mm) for angular and ¾ in. (19 mm) for rounded particles. For special conditions consult Practice D 2321.

X3.2 *DWV Installation*—Pipe should be installed in conformance with governing building codes. In areas not governed by codes, pipe should be installed in accordance with accepted engineering practices.

X3.3 *Installation Under Freezing Conditions*—Plastic pipe has decreased resistance to impact under freezing conditions. Increased care should be exercised if installation is likely to occur under these conditions, particularly during handling, transportation, installation, and backfilling. Where possible, installation should be avoided during freezing conditions. Allowance shall be made for expansion that will occur when the temperature of the pipe is raised.

X3.4 *Alignment and Grade*—Align all piping system components properly without strain. Do not bend or pull pipe into position after being solvent cemented. The grade of horizontal drainage and vent piping shall be as specified in the applicable code.

X3.5 *Supports and Spacing*—Hangers and straps should not compress, distort, cut, or abrade the piping and should allow free movement of pipe. Support all piping at intervals of not more than 4 ft (1.2 m) at end of branches and at changes of direction or elevation. Supports should allow free movement. Maintain vertical piping in straight alignment with supports at each floor level or at 10-ft (3.1-m) intervals, whichever is less. Support trap arms in excess of 3 ft (0.9 m) in length as close as possible to the trap. Securely fasten closed flanges with corrosion-resistant fasteners to the floor with the top surface ¼ in. (6.4 mm) above the finish floor level. Stabilize closet bends or stubs against all horizontal or vertical movement. Protect pipe exposed to damage by sharp surfaces with gromets or sleeves of rubber or plastic.

X3.6 *Threaded Connections*—Do not cut threads on pipe. Molded threads on adapter fittings for transition to threaded construction is necessary except in the case of cleanout plugs. The joint between the pipe and transition fittings should be of the solvent cement type. Only approved thread tape or thread lubricant specifically intended for use with ABS plastic pipe should be used. Conventional pipe thread compound, putty, linseed oil base products, and unknown mixtures should be avoided.

X3.7 *Thread Tightness*—Where a threaded joint is made, obtain tightness by a maximum hand tightening plus additional tightening with a strap wrench, not to exceed one full turn.

X3.8 *Connection to Nonplastic Pipe*—When connecting plastic pipe to other types of piping, use only approved types of fittings and adapters designed for the specific transition.

X3.9 *Connections to Traps*—Connect traps by means of approved threaded trap adapters.

X3.10 *Connection to Closet Flanges*—Install screw-type closet flanges in the drainage system by means of a threaded connection.

X3.11 *Transition to Bell-and-Spigot Pipe*—Make connections or transition to bell-and-spigot cast iron soil pipe and fittings, and to bell-and-spigot pipe and fittings of other materials with approved mechanical compression joints designed for this use, or caulk joints made in an approved manner.

X3.12 *Building Drains Under Floor Slabs*—Make trench bottoms smooth and of uniform grade with either undisturbed soil or a layer of selected and compacted-backfill so that no settlement will be encountered. Bottom of pipe must rest on this material throughout the entire length.

X3.13 *Thermal Expansion*—Allow for thermal expansion and movement in all piping installations by the use of approved methods. Support but do not rigidly restrain piping at branches or changes of direction. Do not anchor pipe rigidly in walls. Holes through framing members should be adequately sized to allow for free movement. Thermal expansion for installations subject to temperature changes may be determined from Table X3.1. The linear expansion shown is independent of the diameter of the pipe. Buried piping or piping installed in the crawl space under a building is normally subject to less than the ambient temperature changes.

X3.14 *Exposed Piping*—Provide adequate support where

TABLE X3.1 Thermal Expansion Table of ABS Schedule 40 Drain, Waste, and Vent Pipe Produced by the Coextrusion Process with Concentric Inner and Outer Solid ABS Layers and the Core Consisting of Closed-Cell Cellular ABS

Length, ft	Temperature Change, °F[A]						
	40	50	60	70	80	90	100
	Length of Change, in.[B]						
20	0.5	0.7	0.8	0.9	1.0	1.2	1.3
40	1.1	1.3	1.6	1.9	2.0	2.4	2.7
60	1.6	2.0	2.4	2.8	3.2	3.6	4.0
80	2.1	2.7	3.2	3.8	4.3	4.8	5.4
100	2.7	3.4	4.0	4.7	5.4	6.0	6.7

Length, m	Temperature Change, °C			
	20	30	40	50
	Length of Change, mm			
10	20	30	40	50
20	40	60	80	100
30	60	90	120	150

[A] Example of Temperature Change:

Highest Temperature Expected	100°F
Lowest Temperature Expected	50°F
Total variation	50°F

[B] For a length of run of 60 ft (20 m) the chart indicates that the installation should provide for a linear expansion of 2 in. (51 mm).

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piping is exposed to wind, snow, and ice loading. Plumbing vents exposed to sunlight should be protected by water-base synthetic latex paints. Where surface temperatures exceed 165°F (74°C), piping shall be protected by means of shielding or some type of lightweight insulation. Exposure to sunlight during normal construction periods is not harmful. It is good practice to store pipe and fittings under suitable cover prior to installation.

X3.15 *Antifreeze Protection*—When necessary to protect traps and fixtures from freezing, do not use alcohol or petroleum products. Use only approved plastic pipe antifreeze packaged for this purpose or one of the following solutions:

X3.15.1 Sixty percent, by mass, of glycerin in water.

X3.15.2 Twenty-two percent, by mass, of magnesium chloride in water. Strong solutions of common table salt (sodium chloride) may also be used.

X3.16 *Commercial and Industrial Applications:*

X3.16.1 The DWV pipe will accommodate temperature of 180°F (82°C) encountered in household applications, but the nature of some applications is to run to higher temperatures; for example, commercial dishwashers, require special consideration.

X3.16.2 Waste disposal lines where concentrated agents and certain chemicals that are routinely present and that may be aggressive to ABS should only be installed with the specific approval of the cognizant building code authority. Service station bay area floor drains require special consideration.

X3.17 *Fire-Rated Construction*—When the piping is to be installed within or penetrating fire-rated constructions, the cognizant building code authorities should be consulted for approved methods of construction of fire barriers.

NOTE X3.1—Fire barriers are either mechanical devices that close off penetration openings or intumescent materials that expand with heat to form a char that make a flame and water-resistant seal.

X3.17.1 All fire barriers should bear the seal of approval and classification of the approving laboratory recognized as qualified to perform such evaluations, for example, UL.

NOTE X3.2—Use fire barrier products meeting this requirement.[7]

[7] Fire barrier products that have been found satisfactory for this purpose are: "Flamarest," available from Avco Systems Division, Lowell Industrial Park, Lowell, MA 01851; "Flameseal," available from Nelson Electric, P.O. Box 726, Tulsa, OK 74101; "Firebarrier," available from 3M, Electrical Products Division, 225-4N 3M Center, St. Paul, MN 55144 and "Fire Stop Foam," available from Dow Corning, Dept. A 6009, Midland, MI 48686.

X4. PREFABRICATED PLUMBING TREES

X4.1 When prefabricated plumbing trees are assembled, it is important that the recommendation of Appendix X2 on joining and Appendix X3 on installation, where applicable, be followed for satisfactory results.

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Standard Specification for Perfluoro (Alkoxyalkane) Copolymer (PFA) Plastic-Lined Ferrous Metal Pipe and Fittings[1]

This standard is issued under the fixed designation F 781; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers factory-made perfluoro (alkoxyalkane) copolymer (PFA) plastic-lined ferrous metal pipe and fittings, primarily intended for conveying corrosive liquids and gases. Requirements for materials, workmanship, dimensions, design, construction, working pressures and temperatures, test methods, and markings are included.

1.2 The values given in parentheses are provided for information purposes only.

NOTE 1—This specification does not include products coated with PFA nor does it define the suitability of PFA-lined components in chemical environments.

1.3 The ferrous piping products shall meet the requirements of the relevant specification listed in 1.3.1 through 1.3.4. Nominal sizes from 1 through 12 in. in 150 and 300 psi (1.0 to 2.0 MPa) ratings are covered.

NOTE 2—The PFA sealing faces may prevent achievement of the full pressure rating of the ferrous housings. For pressure limitations, the manufacturer should be consulted.

1.3.1 *For Ferrous Pipe:*[2,3]

Title of Specification	ASTM Designation
Pipe, Steel, Black, and Hot-Dipped, Zinc-Coated Welded and Seamless	A 53
Seamless Carbon Steel Pipe and High-Temperature Service	A 106
Electric-Resistance-Welded Steel Pipe	A 135
Electric-Welded Low-Carbon Steel Pipe for the Chemical Industry	A 587
Seamless and Welded Austenitic Stainless Steel Pipe	A 312

1.3.2 *For Ferrous Flanges:*[2,3]

Title of Specification	ASTM Designation
Forgings, Carbon Steel, for Piping Components	A 105
Forged or Rolled Steel Pipe Flanges, Forged Fittings and Valves and Parts for General Service	A 181
Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service	A 182
Carbon-Steel Castings Suitable for Fusion Welding for High-Temperature Service	A 216
Ferritic Ductile Iron for Pressure Retaining Castings for Use at Elevated Temperatures	A 395
Ductile Iron Castings	A 536

1.3.3 *For Ferrous Fittings:*[2,3]

Title of Specification	ASTM Designation
Forgings, Carbon Steel, for Piping Components	A 105
Forged or Rolled Steel Pipe Flanges, Forged Fittings, and Valves and Parts for General Service	A 181
Carbon Steel Castings Suitable for Fusion Welding for High-Temperature Service	A 216
Piping Fittings Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures	A 234
Austenitic Steel Castings for High-Temperature Service	A 351
Alloy Steel Castings Specially Heat-Treated for Pressure Containing Parts Suitable for High-Temperature Service	A 389
Ferritic Ductile Iron for Pressure Retaining Castings for Use at Elevated Temperatures	A 395
Ductile Iron Castings	A 536
Ductile Iron for Pressure Containing Castings for Use at Elevated Temperatures	A 403

1.4 The PFA-lined flanged pipe and fitting assemblies are limited to use from −20 to 500°F (−29 to 260°C). For use below −29°C (−20°F) consult the manufacturer.

NOTE 3—The above temperature limitations are based on noncorrosive test conditions. Use in specific aggressive environments may alter the above temperatures, and these limits shall be established by mutual agreement between the purchaser and manufacturer.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1600 Terminology for Abbreviated Terms Relating to Plastics[4]

D 3307 Specification for PFA-Fluorocarbon Molding and Extrusion Materials[5]

F 412 Terminology Relating to Plastic Piping Systems[6]

2.2 *ANSI Standard:*

B 16.5 Steel Pipe Flanges and Flanged Fittings[7]

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[8]

2.4 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[8]

3. Terminology

3.1 The terminology used is in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600 unless otherwise specified.

3.2 The abbreviation for perfluoro (alkoxyalkane) copolymer is PFA.

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[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.11 on Composite.

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[2] *Annual Book of ASTM Standards*, Vol 01.01.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 08.01.

[5] *Annual Book of ASTM Standards*, Vol 08.03.

[6] *Annual Book of ASTM Standards*, Vol 08.04.

[7] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

[8] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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TABLE 1 Face Diameter

Nominal Pipe Size, in.	Minimum PFA Face Diameter, in. (mm)
1	1⅞ (48)
1.5	2¹¹⁄₁₆ (68)
2	3⁷⁄₁₆ (87)
3	4⅝ (117)
4	5¹⁵⁄₁₆ (151)
6	8 (203)
8	10¹⁄₁₆ (256)
10	12¼ (311)
12	14⅜ (365)

4. Materials

4.1 *Lining:*

4.1.1 *Material*—The lining shall be made from PFA resins conforming to the requirements of Type II materials as defined in Specification D 3307 except that a maximum of 1 % by weight of additives or colorants, or both, is permissible. Organic colorants, if used, shall be identified in the manufacturer's specification.

4.1.2 *Mechanical Properties*—The minimum tensile strength and minimum elongation at yield when tested in accordance with the requirements of Specification D 3307 shall be 3800 psi (26 MPa) and 300 % respectively.

4.1.3 *Flow Rate*—PFA resins used to manufacture the liner and molded fittings shall have a maximum flow rate of 3.0 g/10 min when tested in accordance with Specification D 3307.

4.2 *Ferrous Pipe and Fittings:*

4.2.1 The mechanical properties of the pipes and fittings shall conform to the requirements of the appropriate specification of 1.3 except as they are influenced by accepted methods of processing in the industry, for example, Van Stone flaring, bending, swagging, and welding. The carbon steel pipe and wrought fittings shall be welded or seamless steel. Schedule 40 or Schedule 80, except that Schedule 30 pipe may be used in 8, 10, and 12-in. nominal size. Schedule 20 may also be used for 12-in. nominal size with the agreement of the purchaser.

4.2.2 *Finish*—The interior surfaces of all housings shall be clean and free of mold burrs, rust, scale, or other protrusions, that may adversely affect the integrity or performance of the lining.

4.3 *Back-Up Gaskets:*

4.3.1 *General*—Back-up gaskets shall be used to cover the pipe and gasket face of threaded or slip-on flanges unless a full radius is provided at the end of the pipe and flange. Gaskets may also be required on fittings to provide accommodation, or elimination, or both, of sharp corners that could damage the lining.

4.3.2 *Material*—Plain gaskets meeting the temperature requirements, or perforated metallic gaskets, may be used.

TABLE 2 Tolerances for Pipe, Flanges, and Fittings

Pipe	Tolerance, in. (mm)
Length	±⅛ (±3.2)
Fixed flange bolt hole alignment	±¹⁄₁₆ (±1.6)
Flange perpendicularity (with pipe centerline)	³⁄₃₂ in./ft. of diameter (7.8 mm/m of diameter
Flanges and Fittings	
All dimensions	per ANSI B16.5

5. Requirements

5.1 *Dimensions:*

5.1.1 *Housings*—Housing installation dimensions are as required in the applicable material specification listed in 1.3.

5.1.2 *Wall Thickness*—Fitting linings shall have a minimum wall thickness of ³⁄₃₂ in. (2.38 mm), and shall have a uniform face thickness of not less than ³⁄₃₂ in. (2.38 mm). Pipe linings shall have a minimum wall thickness of 0.050 in. (1.27 mm), and the flared radius and gasket faces shall have a uniform thickness not less than 80 % of the wall thickness.

5.1.3 *PFA Face Diameter*—The outside diameter of the PFA covering the gasket face of the flange or the full face of the lap-joint stub end shall not be less than the diameter specified in Table 1 and they shall be concentric within ¹⁄₁₆ in. (1.6 mm).

5.1.4 *Tolerances*—Tolerances for pipe, flanges, and fittings shall be as specified in Table 2. Bolt holes in both flanges on a fixed-flange spool shall straddle the same center line to facilitate alignment. Finished lined (plastic face to plastic face) fabricated fittings shall conform to the nominal face-to-face, etc. as specified in ANSI B16.5 with the applicable tolerances.

5.2 *Flange Construction:*

5.2.1 Screw-type flanges shall be secured in position to prevent inadvertent turning of the flange.

5.2.2 Socket-type flanges shall be fully back-welded to the pipe housing and the inside surfaces of the socket flanges shall be welded and ground smooth.

5.2.3 Slip-on flanges shall be fully backwelded.

NOTE 4—No welding shall be done on lined components.

5.2.4 Lap-joint (or Van Stone) flanged ends may be manufactured by standard forming techniques or by using fully welded stub ends or collars. Lap-joints shall not contain any cracks or buckles.

NOTE 5—The use of lap-joint flanges in a piping system may simplify alignment.

5.3 *Venting*—Each pipe and fittings shall be provided with a venting system that will release any gases between the linear and the housing (this system will also indiate any leakage through the liner). Two systems that provide adequate venting are a series of ¹⁄₁₆ to ⁵⁄₃₂-in. (1.6 to 4-mm) diameter holes in the housings or a helical groove system inside the housing that connects flange vents.

NOTE 6—Vent holes should not be plugged with paint, cement, etc., since this negates the intended purpose listed in 5.3.

5.4 *Workmanship:*

5.4.1 Pipe and fitting linings shall show no evidence of pinholes, porosity, or cracks when inspected in accordance with 5.5.2. The linings shall fit snugly inside the pipe and fitting housings. Any bulges or other obvious indication of poor contact with the housing shall be cause for rejection.

5.4.2 The gasket face of the PFA-linings shall be free of surface defects that could impair sealing effectiveness. Scratches, dents, nicks, or tool marks on the gasket surface shall not be deeper than 10 % of the wall thickness.

5.5 *Performance:*

5.5.1 *Qualification*—PFA-lined pipe and fittings must be capable of meeting the requirements specified in Section 6.

5.5.2 *Inspection:*

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5.5.2.1 Each lined pipe and fitting, prior to shipment, shall be subjected to a hydrostatic test or an electrostatic test, or both, as specified in 7.1 or 7.2. The test or tests to be used shall be at the option of the manufacturer, unless otherwise specified by the purchaser.

5.5.2.2 Each lined pipe and fitting shall subsequently be visually inspected prior to shipment to verify conformance to the design and dimensional requirements of 5.4.

5.5.2.3 Each lined pipe and fitting shall bear an inspection verification impression stamp on the housing to indicate compliance with the requirements of this specification.

6. Qualification Tests

6.1 *Temperature Tests:*

6.1.1 Cycle representative production samples of PFA-lined pipe and fittings in an oven from room temperature to 500 ± 5°F (260 ± 3°C) to determine the ability of the lined components to withstand heat aging and temperature cycling. Test a minimum of two pipe spools, tees, and 90° elbows in each size.

6.1.2 Install companion flanges at the manufacturer's recommended torque value, and affix a thermocouple to the ferrous housing to measure the temperature. Pipe spools shall be at least 3 ft (0.9 m) long. After 3 h in an oven at 500°F (265°C) as indicated by the thermocouple, air-cool the lined components to 122°F (50°C) maximum. Repeat this test for a total of three cycles.

6.1.3 Inspect PFA-lined pipe and fittings after each cycle for distortion or cracks in the PFA lining. At the completion of the third cycle, subject-specimens to either the hydrostatic or electrostatic test described in 7.1 or 7.2.

6.2 *Steam-Cold Water Cycling Test:*

6.2.1 Subject representative production samples of PFA-lined pipe and fittings to steam-cold water cycling to determine the ability of the lined components to withstand rapid temperature changes. Test a minimum of two pipe spools, tees, and 90° elbows in each size.

6.2.2 Assemble PFA-lined pipe and fittings with suitable blind flanges having provision for the introduction of steam, air, or cold water and for drainage. Install the flanges using the manufacturer's recommended torque value. Pipe spool length shall be 10 ft (3.05 m) minimum. Mount the test specimens in such a manner as to permit complete drainage and then subject them to 100 steam-cold water cycles, each of which shall consist of the following in the sequence given:

6.2.2.1 Circulate saturated steam at a gage pressure of 125 ± 5 psi (862 ± 35 kPa) through the specimens until the ferrous housing skin temperature adjacent to the flange at the outlet end of the test specimen has been maintained at the maximum stabilized temperature for 30 min.

6.2.2.2 Close off steam. Vent and introduce air to purge the specimens for a minimum of 1 min.

6.2.2.3 Circulate water at a maximum temperature of 77°F (25°C) until the ferrous housing skin temperature adjacent to the flange at the outlet end of the test specimen measures 122°F (50°C) maximum.

6.2.2.4 Drain, then introduce air to purge the specimens for a minimum of 1 min, making certain that specimens are completely drained.

6.2.3 There shall be no evidence of leakage from the venting system or the flanges during the 100 cycles. At the completion of the test, the linear shall show no evidence of buckling, cracking, or crazing. Formation of water blisters shall not be cause for rejection.

NOTE 7—These surface blisters extend only partially into the wall thickness and are formed due to absorption of steam by the PFA liner and subsequent condensation in the liner. The blisters do not adversely affect PFA liner performance.

6.2.4 At the conclusion of the testing specified in 6.2.2, subject the PFA-lined pipe or fitting to the hydrostatic test specified in 7.1 or, after drying, to the electrostatic test specified in 6.2.

6.3 *Vacuum Testing:*

6.3.1 Test representative production samples of PFA-lined pipe and fittings to determine the vacuum ratings of the lined components. Test a minimum of two pipe spools, tees, and 90° elbows in each size. Conduct tests at room temperature and at the manufacturer's maximum recommended service temperature, and at one intermediate temperature if a full vacuum rating cannot be achieved at the maximum recommended service temperature. Full vacuum is defined as 29.6 in. Hg (100 kPa) corrected.

NOTE 8—Vacuum-temperature ratings are published in the manufacturer's literature.

6.3.2 For pipe spools, specimen length shall be at least ten pipe diameters. Install a flange incorporating a sight glass at one end and a blind flange suitable for drawing a vacuum at the other end. Provide for measuring the ferrous housing temperature.

6.3.3 Heat the specimens uniformly and externally with the sight glass end visible, and after the desired ferrous housing temperature is reached, begin the test. Hold a selected initial vacuum level for 24 h and if no failure occurs, increase the vacuum by 2 in. Hg (6.8 kPa). Repeat this every 4–6 h until failure or full vacuum is reached. Failure is defined as any buckling or collapse of the liner.

6.3.4 If failure occurs at the initial vacuum level selected, test a new test specimen at a lower vacuum level to determine the failure threshold. The vacuum failure threshold is defined as 1 in. Hg (3.4 kPa) below that at which failure occurs.

NOTE 9—The external pressure method to simulate higher than full vacuum can be used to establish the failure threshold when full vacuum is achievable. With the use of pressure taps, an external pressure is applied between the liner outside and the pipe inside diameter.

6.3.5 The vacuum rating shall be 80 % of the failure threshold value.

6.3.6 At the test completion and after the vacuum rating is established, heat a duplicate specimen to the test temperature. Apply the rated vacuum to the specimen after the desired skin temperature has been reached. Achieve the rated vacuum within 2 min and apply continuously for 48 h. If no liner buckling or collapse occurs, the vacuum rating shall be considered acceptable.

6.4 *Retest*—When a test specimen fails to meet the requirements of 6.1, 6.2, or 6.3, the cause of failure shall be sought and corrected. Then repeat the temperature test specified in 6.1 and the steam-cold water cycling test specified in 6.2 and vacuum test specified in 6.3, using double the number of test specimens.

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7. Inspection Tests

7.1 *Hydrostatic Pressure Test*—The internal test pressure shall be 425 psi (2.93 MPa) minimum. Conduct the test at ambient temperature. Fill the pipe and fitting completely with clean water and bleed the system free of all air pior to the application of pressure. Reach full test pressure within 1 min and maintain for a further 3 min. Observe the pressure gage and the venting system in the test specimen throughout the test for any evidence of leakage, which shall be cause for rejection.

7.2 *Electrostatic Test*—Conduct the test with a non-destructive high-voltage tester at an output voltage of 10 000 V. A visible or audible spark, or both, that occurs at the probe when electrical contact is made with the housing because of a defect in the liner, shall be cause for rejection.

8. Finish

8.1 The outside surface all lined pipe and fittings, other than stainless steel, shall be coated with a corrosion-resistant primer over a properly prepared surface.

9. Marking

9.1 The markings shall be applied to the pipe in such a manner that they remain legible (easily read) after installation and inspection.

9.2 Marking on the pipe and fitting shall include the following:

9.2.1 Nominal pipe size,

9.2.2 Liner material identification (PFA),

9.2.3 Manufacturer's name (or trademark),

9.2.4 This designation "ASTM F 781", and

9.2.5 Length (on pipe only).

9.2.6 Other information such, as order numbers, part numbers, item numbers, etc., shall be provided at the purchaser's request.

9.3 Pipe liner indentification shall be provided on a band containing the raised letters "PFA".

10. Packaging

10.1 The gasket face of each lined pipe and each fitting shall be protected by end plates or other suitable protective means, such as, individual boxing.

11. Federal Procurement

11.1 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

NOTE 10—In Federal contracts, the contractor is responsible for inspection.

11.2 *Packaging and Marking for U.S. Government Procurement:*

11.2.1 *Packaging*—Unless otherwise specified in the contract, the material shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition, and which will be acceptable to the carrier at lowest rates. Containers and packaging shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

11.2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE 11—The inclusion of U.S. Government procurement requirements shall not be construed as an indication that the U.S. Government uses or endorses the products described in this document.

12. Quality Assurance

12.1 When the product is marked with this designation, F 781, the manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

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Standard Specification for Thermosetting Resin Fiberglass Pipe and Fittings to be Used for Marine Applications[1]

This standard is issued under the fixed designation F 1173; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers machine made reinforced thermosetting epoxy resin pipe and fittings nominal pipe size (NPS) 1 through 48 in. in diameter to be used in marine piping systems in which resistance to corrosion, aging, and deterioration from seawater, gas, chemicals, and sea environment is required.

1.2 When invoked by military or other procurement activities, MIL-P-24608 (SH) shall apply.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The dimensionless designator NPS has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.5 The specific maximum temperature and pressure covered by this specification is 240°F (115.6°C) and 225 psi (15.5 bar).

1.6 The following safety hazards caveat pertains to the test methods portion, Section 11, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 257 Test Methods for dc Resistance or Conductance of Insulating Materials[2]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[3]

D 883 Terminology Relating to Plastics[3]

D 1141 Specification for Substitute Ocean Water[4]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[5]

D 1600 Terminology of Abbreviated Terms Relating to Plastics[3]

D 1898 Practice for Sampling of Plastics[3]

D 2105 Test Method for Longitudinal Tensile Properties of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube[5]

D 2310 Classification for Machine-Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[5]

D 2924 Test Method for External Pressure Resistance of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[5]

D 2925 Test Method for Beam Deflection of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Under Full Bore Flow[5]

D 2996 Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe[5]

D 2997 Specification for Centrifugally Cast "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe[5]

D 3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[5]

D 4024 Specification for Machine Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Flanges[5]

D 4496 Test Method for dc Resistance or Conductance of Moderately Conductive Materials[6]

E 162 Test Method for Surface Flammability of Materials Using a Radiant Heat Source[7]

E 662 Test Method for Specific Optical Density of Smoke Generated by Solid Materials[7]

E 800 Guide for Measurement of Gases Present or Generated During Fires[7]

F 412 Terminology Relating to Plastic Piping Systems[5]

2.2 *ANSI Standards:*[8]

B16.1 Cast Iron Pipe Flanges and Flanged Fittings

B16.5 Steel Pipe Flanges, Flanges, Flanged Fittings

2.3 *ISO Standards:*[8]

13 Grey Iron Pipe, Special Castings and Grey Iron Parts for Pressure Main Lines

559 Welded or Seamless Steel Tubes for Water, Sewage and Gas

2.4 *Other Documents:*

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[1] This specification is under the jurisdiction of ASTM Committee F-25 on Shipbuilding and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

Current edition approved Feb. 15, 1995. Published April 1995. Originally published as F 1173 – 88. Last previous edition F 1173 – 88 (1993)[ε1].

[2] *Annual Book of ASTM Standards*, Vol 10.01.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 11.02.

[5] *Annual Book of ASTM Standards*, Vol 08.04.

[6] *Annual Book of ASTM Standards*, Vol 10.02.

[7] *Annual Book of ASTM Standards*, Vol 04.08.

[8] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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National Sanitation Foundation Standard 14[9]
MIL-P-24608 (SH) Pipe, Fittings, and Adhesive Kits, Glass Reinforced Thermosetting Epoxy Resin for Shipboard Piping Systems[10]
IMO Assembly Resolution A.753(18)[10]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminologies D 883 or F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise indicated.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *maximum operating pressure*—the highest pressure that can exist in a system or subsystem under normal operating conditions. This pressure is determined by such influences as pump or compressor shut-off pressures, pressure regulating valve lockup (no flow) pressure, and maximum chosen pressure at the system source.

3.2.2 *representative piping system*—a system composed of a single manufacturer's pipes, fittings, joints, and adhesives that would normally be used by a customer or installer. If the system is conductive, any devices normally supplied by the manufacturer (either as electromechanical attachments or integrated into the composite structure) for electrical continuity or grounding are to be included as well.

4. Classification

4.1 *General:*

4.1.1 Pipe meeting this specification is classified by type, grade, and class similar to Classification D 2310.

4.1.2 Fittings meeting this specification are also classified by types (method of manufacture), grades (generic type of resin), and classes (joining system).

4.1.3 Joints meeting this specification are classified only as being conductive or non-conductive.

4.2 *Types:*

4.2.1 *Type I*—Filament-wound (pipe and fittings).

4.2.2 *Type II*—Centrifugally cast (pipe and fittings).

4.2.3 *Type III*—Molded (fittings only).

4.3 *Grades:*

4.3.1 *Grade I*—Epoxy/Epoxy Vinyl Ester resin (pipe and fittings).

4.3.2 *Grade II*—Polyester Resins (pipe and fittings).

4.3.3 *Grade III*—Customer Specified Thermosetting resin (pipe and fittings).

4.4 *Classes:*

4.4.1 *Pipe and Fittings Only:*

4.4.1.1 *Class A*—No liner.

4.4.1.2 *Class B*—Liner, reinforced.

4.4.1.3 *Class C*—Conductive, no liner.

4.4.1.4 *Class D*—Reinforced with conductive outer layer.

4.4.2 *Joining System:*

4.4.2.1 *Class E*—Non-conductive joint.

4.4.2.2 *Class F*—Conductive joint.

4.5 *Piping Systems*, including pipes, joints, and fittings, along with any applicable fire protection coatings or coverings shall meet at least one of the following three levels of full scale fire endurance.

4.5.1 *Level 1*—Piping systems must satisfy the acceptance criteria defined in Annex A4 and pass the fire endurance test method specified in Annex A4 for a duration of a minimum of one h.

4.5.2 *Level 2*—Piping systems must satisfy the acceptance criteria defined in Annex A4 and pass the fire endurance test method specified in Annex A4 for a duration of a minimum of 30 min.

4.5.3 *Level 3*—Piping systems must satisfy the acceptance criteria defined in Annex A5 and pass the fire endurance test method specified in Annex A5 for a duration of a minimum of 30 min.

4.5.4 Piping and insulation systems should not drip during full scale evaluations for levels 1, 2, or 3.

5. Ordering Information

5.1 When ordering pipe and fittings under this specification, the following should be specified:

5.1.1 Designation and date of this specification.

5.1.2 Type.

5.1.3 Grade.

5.1.4 Class.

5.1.5 NPS.

5.1.6 Manufacturer's identification (for example, part number, product's name, etc.).

5.1.7 Specific customer requirements, if any.

6. Materials and Manufacture

6.1 *Materials:*

6.1.1 *General*—The resins, reinforcements, colorants, fillers, and other materials, when combined as a composite structure, shall produce a pipe that shall meet the performance requirements of this specification.

6.1.2 *Joining Systems*—The joining system used shall be rated for the same design conditions as the pipe and fittings. This includes design for internal pressure, tensile strength, bending strength, electrical resistance, etc., as called for in Section 7.

6.2 *Manufacture:*

6.2.1 Pipe manufactured by the filament winding process shall be in accordance with Specification D 2996.

6.2.2 Pipe manufactured by the centrifugal casting process shall be in accordance with Specification D 2997.

6.2.3 Fittings shall be manufactured by the filament wound, molded, or centrifugally cast process, using thermosetting resin and glass reinforcement.

7. Performance Requirements

7.1 *General:*

7.1.1 The requirements of this section apply to all piping and piping systems independent of service or location.

7.1.2 The specification of the piping shall meet the performance guidelines that follow.

7.1.3 The structural wall of the piping system shall have sufficient strength to take account of the most severe coincident conditions of pressure, temperature, the weight of the piping itself, and any static and dynamic loads imposed by the design or environment. Once the structural wall

[9] Available from the National Sanitation Foundation, 3475 Plymouth Rd., P.O. Box 1460, Ann Arbor, MI 48106.

[10] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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thickness is calculated, the corrosion liner is added to obtain the pipe's total wall thickness.

7.1.4 For the purpose of assuring adequate robustness for all piping systems, including open-ended piping, all pipe, fittings, and joints shall have a minimum structural wall thickness able to withstand loads due to transportation, handling, installation, personnel traffic, etc. This may require the pipe, fittings, and joints to have additional structural thickness than otherwise required by service considerations.

7.1.5 The performance requirements for any component of a piping system such as fittings and joints are the same as those requirements for the piping system they are installed in.

7.2 *Hydrostatic Strength:*

7.2.1 A piping system shall be designed for a maximum operating pressure not less than the maximum working pressure to be expected under operating conditions nor less than the highest set pressure of any safety valve or pressure relief device on the system, if fitted.

7.2.2 The maximum operating pressure for a pipe system shall be determined by dividing the short-term hydrostatic test failure pressure by a minimum safety factor of 4 or the long-term hydrostatic (>100,000 hours) test failure pressure by a minimum safety factor of 2.5, whichever is the lesser of the two. Special design cases, such as where pressure surges can not be accurately estimated or where dynamic loads cannot be accurately accounted for, may warrant safety factors in excess of these values, in some cases as great as 10:1. Either the short-term or the long-term hydrostatic test pressures, whichever is used, shall be verified experimentally or by a combination of testing and calculations to the satisfaction of the approving authority. In all designs, the maximum allowable internal pressure shall be based on the weakest part of the system, be it the pipe, fittings, and flanges or the joining method used.

7.2.2.1 The maximum operating pressure shall be based on the structural wall thickness, not the total wall thickness.

7.3 *External Pressure:*

7.3.1 External pressure shall be taken into account in the design of the piping system for any installation which may be subject to vacuum conditions inside the pipe or a pressure head acting on the outside of the pipe.

7.3.2 A piping system shall be designed for a maximum allowable external pressure not less than the sum of the maximum potential pressure head outside the pipe plus the design vacuum pressure. The maximum allowable external pressure for a piping system shall be determined by dividing the collapse test pressure by a minimum safety factor of 3. Special design cases, such as where pressure surges cannot be accurately estimated or where dynamic loads cannot be accurately accounted for, may warrant safety factors in excess of these values, in some cases as great as 10:1. The collapse test pressure shall be verified experimentally or by a combination of testing and calculation methods to the satisfaction of the approving authority.

7.3.2.1 The maximum allowable external pressure shall be based on the structural wall thickness, not the total wall thickness.

7.4 *Longitudinal Tensile Properties:*

7.4.1 The sum of the longitudinal stresses due to pressure, weight and other dynamic and sustained loads shall not exceed the maximum allowable stress in the longitudinal direction. Forces due to thermal expansion, contraction, and external loads, such as wind loads, seismic loads, etc., shall be considered when determining longitudinal stresses in the system. Internal shock, or pressure surge, commonly known as water hammer, shall also be considered when determining the stresses in the system.

7.4.2 The sum of the longitudinal stresses shall not exceed half of the nominal circumferential stress derived from the nominal internal pressure determined according to 2.2, unless the maximum allowable longitudinal stress is verified experimentally or by a combination of testing and calculation methods to the satisfaction of the approving authority.

7.4.2.1 The maximum allowable maximum longitudinal stress shall be based on the structural wall thickness, not the total wall thickness.

7.5 *Bending Strength:*

7.5.1 A piping system shall be designed for a maximum allowable bending stress not less than the sum of all bending stress due to dead weight, expansion loads, external loads, and any other static or dynamic loads imposed on the piping system.

7.5.2.1 The maximum allowable maximum bending stress shall be based on the structural wall thickness, not the total wall thickness.

7.6 *Beam Stiffness:*

7.6.1 The piping system shall be supported properly to limit the vertical deflection in any part of the piping system to 0.5 in. (12.7 mm).

7.6.2 The calculation of support spacing shall take into account the dead weight of the pipe and its fluid contents as well as any other static external loads.

7.6.2.1 The maximum allowable maximum support spacing shall be based on the structural wall thickness, not the total wall thickness.

7.7 *Temperature:*

7.7.1 The piping system shall meet the design requirements of these guidelines over the range of service temperatures it will experience.

7.7.2 The maximum working temperature should be at least 36°F (20°C) less than the minimum heat distortion temperature (determined according to ISO 75 method A, or equivalent) of the resin or plastic material. The minimum heat distortion temperature should not be less than 176°F (80°C).

7.7.3 Where high or low temperature services are encountered, special attention should be paid to material properties. Material properties such as strength, modulus, etc., will change with temperature, therefore, they shall be modified according to the pipe system's design temperature.

7.8 *Impact Resistance:*

7.8.1 A piping system shall have a minimum resistance to impact to the satisfaction of the approving authority. The impact resistance needs to satisfy all impact loading due to transportation and installation, not just under normal operation.

7.9 *Ageing:*

7.9.1 Before selection of a piping system material, the manufacturer shall confirm that the environmental effects including, but not limited to, ultraviolet rays, saltwater

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exposure, oil and grease exposure, temperature, and humidity, will not degrade the mechanical, electrical, or physical properties of the piping system material below the values necessary to meet these guidelines.

7.10 *Fatigue:*

7.10.1 In the cases where design loadings incorporate a significant cyclic or fluctuating component, fatigue shall be considered in the material selection process and taken into account in the installation design.

7.10.2 In addressing material fatigue, the designer may rely on experience with similar materials in similar service or only laboratory evaluation with mechanical test specimens. However, the designer is cautioned that small changes in the material composition may significantly affect fatigue behavior.

7.11 *Erosion Resistance:*

7.11.1 In the cases where fluid in the system has high flow velocities, abrasive characteristics, or where there are flow path discontinuities producing excessive turbulence, the possible effect of erosion shall be considered. If erosion can not be avoided then adequate measures shall be taken such as special liners, change of materials, etc.

7.12 *Fluid Absorption:*

7.12.1 Absorption of fluid by the piping system material shall not cause a reduction of mechanical, electrical, or physical properties of the material below that required by these guidelines.

7.13 *Material Compatibility:*

7.13.1 The piping material shall be compatible with the fluid being carried or in which it is immersed such that its design strength does not degenerate below that recognized by these guidelines. Where the reaction between the pipe material and the fluid is unknown, the compatibility should be demonstrated to the satisfaction of the approving authority.

7.14 *Potable Water Usage:*

7.14.1 The material, including pipe, fittings, and joints shall have no adverse effect on the health of personnel when used for potable water service. The material used for such purposes shall be to the satisfaction of the authority.

7.15 *Electrical Resistance*—Classes C and D pipe and fittings, and F joints and representative systems assembled from such components shall have a resistance per unit length not to exceed 1×10^5 Ω/meter (3.281×10^5 Ω/foot) when tested in accordance with 11.12.

7.16 *Static Charge Shielding*—Classes C and D pipe and fittings and F joints shall have a maximum resulting voltage not to exceed 100 V induced on the exterior surface of the pipe when tested in accordance with 11.13.

7.17 *Grounding Resistance*—Resistance to ground should not exceed 1×10^6 Ω when tested in accordance with 11.14.

7.18 *Flame Spread*—Piping shall have a flame spread index of 25 or less when tested in accordance with 11.9. Nominal 6-inch pipe should be cut into three 2-inch by 18-inch sections, measured along its chord and axially, respectively (19.5°) to approximate the flat 6 inch by 18 inch panel required in Test Method E 162. Edges of each of these sections should be cut so that they are completely flush (0.001″ gap maximum) to each other along the entire length of the sections. Where protective coatings or coverings are used, they shall also be tested while coated on or attached to the pipe sections. The outer surface should be orthogonal to the fire direction. The IMD Assembly Resolution A.753(18) is an alternative test method.

7.19 *Smoke Generation*—The maximum specific optical density under uncorrected flaming and nonflaming conditions for pipe should be 200 when tested in accordance with 11.10. 3 in. by 3 in., measured axially and along its chord (29° segment), square pieces should be cut from 12 in. pipe. Where protective coatings or coverings are used, they shall also be tested while coated or attached to the pipe sections. The outer surface should be orthogonal to the fire direction.

7.20 *Toxic Products of Combustion*—The following gases should have concentrations less than or equal to the limits listed in Table 1 when measured in accordance with Guide E 800 or equivalent during smoke generation (test 3). Samples should be drawn from the smoke chamber either at the point of maximum smoke concentration, or at the end of the test. The point of maximum smoke concentration, or at the end of the test. The point of maximum smoke concentration is explained in Guide E 800. For purposes of sampling, it may be defined as the point in time up to two minutes after the smoke concentration begins to decline or flatten out in a straight line. Burning of the pipe samples shall be done with Test Method E 662.

8. Other Requirements

8.1 *Flanges*—Fiberglass flanges for merchant vessels shall conform to Specification D 4024, ANSI B16.1, and ANSI B16.5.

8.2 *Potable Water Piping Systems*—Fiberglass pipe and fittings to be used on potable water systems must conform with National Sanitation Foundation Standard 14.

8.3 *Conductive Systems and Components:*

8.3.1 Conductive pipes, fittings, and joints meeting this specification and systems constructed thereof are preferred to be homogeneously conductive throughout.

8.3.2 Conductivity may be achieved through the use of conductive layers. In this case, the following applies:

8.3.2.1 Two conductive layers, as a minimum, are required—one on the interior and one on the exterior.

8.3.2.2 Conductive connections between the layers are required to equalize potential between the layers. The resistance of these connections shall meet the requirements of 7.15 and 7.17.

8.3.2.3 Test points must be included that are easily accessible on the exterior surface to permit measurement of the interior layer's resistance per unit length after installation. These test points must be electrically isolated from the exterior conductive layer.

8.3.2.4 The internal and external conductive layers, con-

TABLE 1 Gas Concentrations

Gas	Maximum Concentration (PPM)
CO	500
CO_2	15,000
HCl	20
HF	8
HCN	10
SO_2	10
NO_x	5
NH_3	200
$COCl_2$	1
H_2S	15

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ductive connections, and test points shall be suitable for the system's intended service and have a lifetime expectation no less than the non-conductive materials of the system.

9. Dimensions and Tolerances

9.1 Dimensions and tolerances of pipe and fittings shall meet the requirements of Annex A6, unless otherwise agreed upon by the buyer and seller.

10. Workmanship, Finish, and Appearance

10.1 The pipe and fittings shall be free from defects including indentations, delaminations, bubbles, pinholes, foreign inclusions, cracks, porosity, and resin-starved areas which, due to their nature, degree, or extent, detrimentally affect the strength, serviceability, and conductivity (as applicable) of the pipe and fittings. The pipe and fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties. The pipe and fittings shall be smooth and uniform. All pipe and fittings ends shall be cut at right angles to the axis of the pipe and any sharp edges removed. The bore of each fitting shall have a smooth uniform surface, and protrusion exceeding 1/16 in. (1.6 mm) of material into the internal fittings flow area shall be removed and blended with adjacent smooth surfaces.

11. Test Methods

11.1 *Conditioning*—Condition test specimens at 73 ± 4°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 48 h prior to testing, in accordance with Procedure A of Practice D 618, for those tests in which conditioning is required and in all cases of disagreement.

11.2 *Test Conditions*—Conduct tests at ambient temperature and humidity, unless otherwise specified in the test method or in this specification.

11.3 *Sampling*—To determine conformance of the material to the hydrostatic strength requirements of 7.2, take samples of pipe at random on a monthly basis or on each production run, whichever is the most frequent. The rate of sampling for the other tests listed shall be in accordance with accepted statistical practice.

11.4 *Dimensions and Tolerances*—Determine wall thickness, length, diameter, and liner thickness in accordance with Practice D 3567.

11.5 *Hydrostatic Strength*—Determine hydrostatic strength in accordance with Test Method D 1599 (free ends test).

11.6 *Impact Resistance*—Determine impact resistance in accordance with the recommended test method in Annex A1.

11.7 *Beam Stiffness*—Test the pipe samples at a minimum temperature of 240°F (116°C) in accordance with Test Method D 2925. After determining *EI* from the test results, calculate the permissible simple span for 1/2 in. (25 mm) deflection. The calculated span after 1000 h at 240°F (116°C) shall not be less than those given by the manufacturer's literature, assuming the pipe to be full of water.

11.8 *External Pressure Resistance*—Test the pipe samples at 240°F (116°C) in accordance with Test Method D 2924. The failure pressure for the manufacturer's minimum wall thickness shall not be less than three times the rate of external pressure resistance published by the manufacturer's product specifications. Calculate the failure pressure for all pipe sizes of identical construction using the following equation:

$$P = \frac{8K't^3}{(OD - t)^3}$$

where:

P = pressure at collapse or leak, psi (kPa),
K' = KE, psi (kPa),
K = buckling scaling constant determined by Test Method D 2924,
E = circumferential modulus of elasticity as defined in Test Method D 2924,
t = minimum reinforced wall thickness, in. (mm), and
OD = outside diameter of pipe, in. (mm).

11.9 *Flame Spread*—Test samples cut from pipe in accordance with 7.18 and tested per Test Method E 162 or equivalent.

11.10 *Smoke Generation*—Test samples cut from pipe in accordance with 7.19 and tested per Test Method E 662 or equivalent.

11.11 *Toxic Products of Combustion*—Determine the toxic products of combustion during smoke generation test 3 of Test Method E 800 or equivalent.

11.12 *Electrical Resistance Per Unit Length*—Determine electrical resistance in accordance with the recommended test method in Annex A3.

11.13 *Static Charge Shielding Capability*—Determine static charge shielding capability in accordance with the recommended test method in Annex A2.

11.14 *Grounding Resistance*—Determine grounding resistance in accordance with the recommended test method in Annex A2.

11.15 *Longitudinal Tensile Properties*—Determine longitudinal tensile properties in accordance with Test Method D 2105.

12. Inspection and Sampling

12.1 Inspection and sampling of the material shall be in accordance with Practice D 1898 and agreed upon between the purchaser and the supplier as part of the purchase contract.

13. Certification

13.1 *General:*

13.1.1 A producer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. A report of the test results shall be furnished.

13.2 If the supplier has in his possession bonafide test certification data acceptable to the purchaser, the purchaser may extend initial approval under 13.1 of this specification.

14. Product Marking

14.1 Pipe and fittings shall be marked with the name, brand or trademark of the manufacturer, NPS, weight (type, grade, and class), specification designation, and date and any other information that may be desired for a specific material.

15. Keywords

15.1 epoxy resin fittings; epoxy resin pipe; marine piping; nominal pipe size; thermoset epoxy resin pipe

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ANNEXES

(Mandatory Information)

A1. TEST METHOD FOR IMPACT RESISTANCE OF FIBERGLASS PIPE AND FITTINGS BY MEANS OF A FALLING STEEL BALL

A1.1 Scope

A1.1.1 This test method covers the determination of the energy required to produce failure in fiberglass pipe and fittings under specified conditions of impact by means of a falling steel ball. Balls of differing diameter and weight may be used.

A1.2 Significance

A1.2.1 The testing procedures in this test method are applicable over a range of impact energies and ball diameters. The specific ball weight and diameter must be selected for each size and type of product.

A1.2.2 This test method is intended to represent service conditions wherein the product may be subjected to damage from impact by falling objects such as tools. Low-velocity impact, such as that caused by dropping a full length of pipe or fitting for a small distance onto a support surface, may not be accurately represented by this test method.

A1.3 Apparatus

A1.3.1 *General*—One type of impact tester is illustrated in Fig. A1.1.

A1.3.2 *Steel Ball*—Two different balls may be used. The ball designated A is 2.30 in. (58.4 mm) in diameter with a weight of 29.15 oz (826.5 g). The ball designated B has a diameter of 3.00 in. (76.2 mm) and a weight of 63.5 oz (1800 g). Other ball sizes may be used upon agreement between the buyer and the seller.

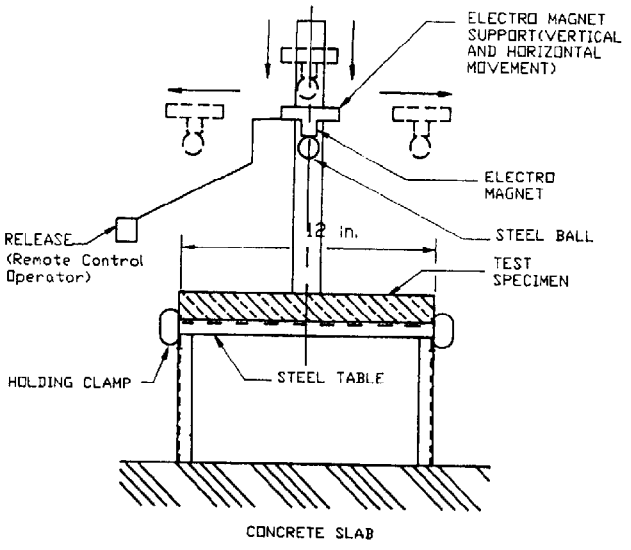

FIG. A1.1 Test Apparatus

A1.3.3 *Support Surface*—The test stand from which the ball is dropped shall be resting firmly on a concrete slab floor.

A1.3.4 *Vertical Drop*—A plump bob shall be used to ensure that the ball will drop squarely on the test specimen when released.

A1.3.5 Drop heights in increments of 1, 2, or 3 in. (25.4, 51, or 76 mm) are normally used. Means shall be provided to hold the ball at the appropriate drop heights above the test specimen as measured from the bottom of the ball to the surface of the specimen, to release the ball in a reproducible manner and to allow the ball to fall freely. Mechanical means may be used to catch the rebounding ball, or it may be caught by hand.

A1.3.6 *Specimen Holder:*

A1.3.6.1 For testing pipe, the specimen shall rest for its full length on a flat steel plate at least 0.5 in. (13 mm) thick.

A1.3.6.2 For testing fittings, a steel saddle plate curved to fit the part may be required to produce line bearing, as, for example, when the ball is being dropped onto the outer radius of a 90° elbow.

A1.3.6.3 Means shall be provided to clamp the specimen firmly into proper position at each end.

A1.4 Test Specimens

A1.4.1 The test specimens of pipe shall be equal in length to the nominal diameter but not less than 12-in. (305-mm) long. If impact resistance can vary along the pipe length, select test specimens from at least three widely spaced locations.

A1.4.2 Fittings shall be tested as a single unassembled unit.

A1.5 Number of Specimens

A1.5.1 The approximate starting point can usually be determined on one preliminary specimen.

A1.5.2 Sufficient specimens shall be used thereafter to produce a minimum of four drops at each of three different drop heights. Usable data are obtained only when, at a given drop height, at least one drop causes a failure and at least one drop does not cause a failure. If usable data are obtained at only one or two of the selected drop heights, reduce the drop height increments and continue testing within the range of heights yielding usable data.

A1.6 Conditioning

A1.6.1 The test specimens shall be conditioned at 73° + 4°F (23° + 3°C) for a minimum of 8 h prior to testing for those tests in which conditioning is required.

A1.6.2 Tests made at other temperatures shall be made in an enclosure maintained at the test temperature.

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A1.7 Procedure

A1.7.1 Measure the dimensions of the test specimens in accordance with Practice D 3567. Include measurements of liner thickness and external coating thickness if applicable.

A1.7.2 Mount the specimen so the ball will strike no less than 3 in. (76 mm) from its end. The point of impact shall be at the top of the vertical diameter. Mark the point of impact and drop height on the outside of the specimen with a marking pen.

A1.7.3 Make preliminary tests to determine the approximate height of fall to produce failure in the particular pipe or fitting being tested. At this point it will usually not be necessary to cut the specimen in order to examine the inside surface.

A1.7.4 Select a ball weight and size that will produce failures between NPS 6 and 60. Using additional specimens test at three different drop heights that bracket the approximate height determined previously.

A1.7.5 Pipe less than NPS 2 in diameter are impacted twice at diametrically opposite points. Pipe NPS 2 or more in diameter can be impacted at each cross section a minimum of four times equally spaced around the circumference, using equal drop heights. As permitted by specimen diameter, additional drop points may be used with a circumferential spacing of 3 in. (76 mm). With a specimen 12 in. (305 mm) in length, drops may be made at three different cross sections (at the quarter points).

A1.7.6 For testing fittings, use diametrically opposite drop points or points in a line separated by a minimum of 3 in. (76 mm), depending on specimen geometry. For example, a 90° elbow may be laid on its side and tested at diametrically opposite points every 3 in. (76 mm) along its length, or it may be supported on a curved saddle plate and tested at points every 3 in. (76 mm) along its outer radius.

A1.7.6.1 Impact resistance of certain fittings will be a function of the fitting geometry at the point of impact. For example, testing on a 90° elbow may be limited to drops only on the outside radius when the test results reveal this as the critical area.

A1.7.7 A minimum of four impacts at each of three different drop heights which produce usable data are required (see A5.2).

A1.7.8 After a specimen has been impacted in as many places as permitted herein, cut the specimen lengthwise along its axis to examine the inside surface for failure. If a leakage test is to be performed on the impacted specimen, this can be carried out using water or air prior to cutting. The test pressure shall be 1½ times the rated pressure for the part.

A1.7.9 Swab the inside surface with fluorescent dye and use an ultraviolet light to detect failure. As an alternative, it may be possible to use other dyes or inks to high-light cracks.

A1.8 Definition of Failure

A1.8.1 Failure in the test specimen shall be shattering or any crack or split on the inside that was created by the impact which, when highlighted with dyes or inks, can be seen by the naked eye.

A1.8.2 Leaking of the specimen as a result of impact shall also be defined as failure. Because of difficulty in observing damage on the inside, failure in an unlined pipe or fitting will normally be defined as leakage in a pressure test.

A1.8.3 Damage to an external coating is not considered failure unless agreed upon between the buyer and the seller.

A1.9 Determination of Average and Standard Deviation

A1.9.1 Calculate the percentage of failures at each drop height.

A1.9.2 Plot the percentage of failures versus drop height on probability paper and draw a best-fit line representing the trend of the data. Read off the mean drop height, h_{50}, and drop height standard deviation $h_{50} - h_{15.9\%}$.

A1.9.3 Calculate the impact resistance as ball weight in pounds (newtons) times drop height in feet (meters). Calculate the standard deviation of impact resistance as ball weight times drop height standard deviation.

A1.10 Report

A1.10.1 Report the following information:

A1.10.1.1 Complete identification of the pipe or fitting tested including manufacturer's name and code, NPS, and average wall, liner, and coating thicknesses.

A1.10.1.2 Location of test specimens along pipe length, if applicable.

A1.10.1.3 Atmosphere in which the test was made and conditioning procedure.

A1.10.1.4 Ball diameter and weight.

A1.10.1.5 Average impact resistance in ft·lbf (N·m).

A1.10.1.6 Standard deviation in ft·lbf (N·m).

A1.10.1.7 Point of impact on fittings.

A1.10.1.8 Mode of failure (visible crack or leak) and appearance of impact area.

A1.10.1.9 Results of pressure test if applicable.

A1.10.1.10 Date of test.

A2. TEST METHOD FOR DETERMINING THE STATIC CHARGE SHIELDING CAPABILITY AND SYSTEM RESISTANCE OF REINFORCED THERMOSETTING RESIN PIPE, FITTINGS, AND JOINTS AFTER EXPOSURE TO VARIOUS CHEMICAL ENVIRONMENTS

A2.1 Scope

A2.1.1 This test method determines the static charge, if any, present on the exterior surface of a grounded fiberglass pipe, fitting, or joint when a charge is applied to the interior surface. It is also used to measure the resistance of the associated grounding techniques and to determine the effect of typical chemical exposures on the shielding capability of the pipe and grounding system.

A2.2 Summary of Test Methods

A2.2.1 *Grounding Resistance*—The test method consists of electrically isolating the pipe, fitting, or joint, then grounding the system using its associated grounding technique, and measuring the resistance of the system from an interior surface to a common ground.

A2.2.2 *Static Charge Shielding Capability*—This test method consists of applying a static charge to the interior

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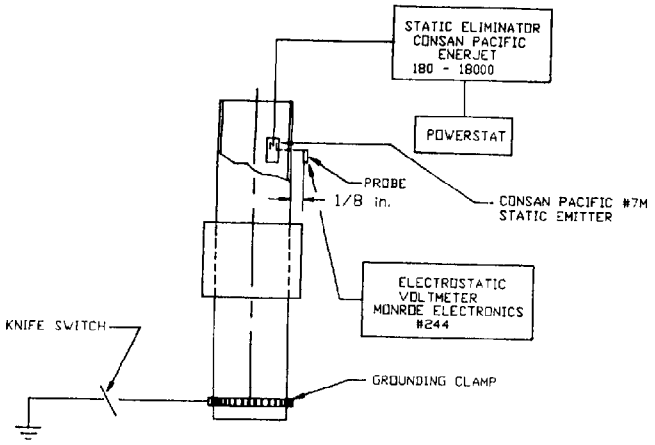

FIG. A2.1 Test Setup

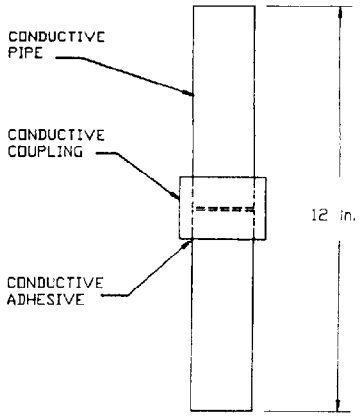

FIG. A2.2 Test Specimens

surface of a grounded reinforced thermosetting resin pipe, fitting, or joint and then measuring the resulting voltage, if any, induced on the exterior surface.

A2.3 Test Equipment (see Fig. A2.1)

A2.3.1 *Static Generator*—An instrument capable of producing clouds of either negative or positive charges having a controlled voltage of 0 to 1000 V.[11]

A2.3.2 *Electrostatic Voltmeter*—An electrostatic voltmeter having a range of 0 to +3000 V and an accuracy of 0.1 %.[12]

A2.3.3 *Exposure Tank*—An exposure tank of nonmetallic construction and resistant to the test environment. It shall be maintained at a temperature of 60 to 80°F (15.6° to 26.7°C) throughout the duration of the test.

A2.3.4 *Oven*—An oven capable of being controlled to a temperature of 150° + 10°F (65.6° + 10°C).

A2.3.5 *Megohmmeter*—A megohmmeter having an accuracy of ±2 %.

A2.4 Test Specimens (see Fig. A2.2)

A2.4.1 *Specimen Size:*

A2.4.1.1 *Diameter*—Unless otherwise specified, the nominal diameter of the pipe, fitting, or joint tested shall be 2 in. (Fig. A2.2).

A2.4.1.2 *Length*—The length of the specimen shall be a minimum of seven times the nominal diameter of the pipe. To achieve this length, additional sections of conductive pipe shall be added as necessary, using the manufacturer's normally recommended assembly methods. If the additional sections are needed, resistance measurements shall be taken across the joints to ensure that the resistance per unit length does not exceed 1×10^5 ohms per meter (3.281×10^5 ohms per foot). The procedures in Annex A3 shall be used.

A2.5 Conditioning

A2.5.1 No special conditioning of the samples prior to initiation of the test is required.

[11] A Static Eliminator has been found to meet these requirements.

[12] An instrument manufactured by Monroe Electronics, Model No. 244, has been found to meet this requirement.

A2.6 Procedure

A2.6.1 Apply a suitable paint-on electrode around the interior circumference of the specimen on the end to which the grounding system will be installed. The distance of the electrode from the end of the specimen shall be greater than or equal to twice the specimen thickness. The width of the electrode shall be greater than four times the specimen wall thickness. Dimensional tolerances of the electrode with and its distance to the end shall not exceed ±10 % separately or combined. Allow the electrode to dry, then install the grounding clamp of the ground system on the exterior of the specimen at one end in accordance with the manufacturer's instructions. Any surface preparation shall not exceed that normally required when assembling a piping system using a fitting. If it is desired to compute surface or volume resistivity, then the procedures in Test Methods D 257 and D 4496 shall be adhered to.

A2.6.2 Position the specimen vertically on a nonconducting surface. Ground the specimen through the grounding system, and using the megohmmeter measure the resistance of the ground system from ground to a position on the interior surface of the electrode. The power applied should neither exceed 1W, nor should the electrification time exceed one min unless otherwise specified. Record the reading of the megohmmeter and its accuracy at that range.

A2.6.3 Thoroughly remove the electrode, then lower the static emitter into the interior of the pipe, fitting, or joint so that it is equidistant from each end. The emitter must be located as close to the interior surface of the pipe, fitting, or joint as possible.

A2.6.4 Approximately ⅛ in. (3.2 mm) from the exterior surface of the pipe, fitting or joint, and opposite the static emitter, position the probe from the electrostatic voltmeter. Fig. A2.1 shows a typical test setup.

A2.6.5 With the specimen ungrounded, turn the static eliminator on and adjust its output via a powerstat to obtain a voltage reading of 2500 permissible deviation (for example, +10 V) on the electrostatic voltmeter.

A2.6.6 Ground the test specimen by closing a switch connecting the test specimen to ground and record the residual voltage.

A2.6.7 If the effect of a chemical on the shielding charac-

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teristics of the pipe, fitting, or joint and grounding technique is being studied, place the test specimen in a test tank so that it is completely immersed in the test fluid after initial measurement. Maintain the temperature of the bath at 60° to 80°F (15.6° to 26.7°C) throughout the duration of the test. Suggested test environments include but are not limited to (*1*) salt water per Specification D 1141, (*2*) gasoline, (*3*) Bunker C, and (*4*) 1 % sulfuric acid.

A2.6.8 At the end of 1, 3, 6, and 12 months, remove the test specimen from the bath and rinse thoroughly with tap water if the specimen has been exposed to a water-soluble product or a hydrocarbon solvent if the specimen has been exposed to a petroleum product.

A2.6.9 Wipe dry and place the test specimen in an oven at 150 + 10°F for a period of 2 h.

A2.6.10 At the end of 2 h, remove the specimen from the oven and allow it to cool to 70° to 80°F (21.1° to 26.7°C) in a 50 ± 5 % relative humidity environment for 60 ± 5 min before retesting.

A2.6.11 Repeat A2.6.1 through A2.6.6.

A2.6.12 Note the appearance of the test specimens and the condition of the grounding clamp.

A2.7 Report

A2.7.1 Report the following information:

A2.7.1.1 Manufacturer of pipe, fitting, or joint.

A2.7.1.2 Designation of product being tested.

A2.7.1.3 Description of the test sample including diameter of pipe, fitting, or joint and lengths of pipe extenders (when needed).

A2.7.1.4 Description of grounding details.

A2.7.1.5 Initial resistance reading of grounding system and accuracy and those before and after exposure periods of 1, 3, 6, and 12 months when the exposure periods are used.

A2.7.1.6 Test media.

A2.7.1.7 Initial exterior voltage readings before and after grounding and the exterior voltage reading before and after grounding following exposure periods of 1, 3, 6, and 12 months when the exposure periods are used.

A2.7.1.8 Appearance of test specimen.

A2.7.1.9 Date of test.

A3. TEST METHOD FOR DETERMINING THE ELECTRICAL RESISTANCE PER UNIT LENGTH OF FIBERGLASS PIPE, FITTINGS, AND JOINTS AND REPRESENTATIVE PIPING SYSTEMS AFTER EXPOSURE TO VARIOUS CHEMICAL ENVIRONMENTS

A3.1 Scope

A3.1.1 This test method covers the determination of the electrical resistance per unit length of conductive pipe, fittings, and joints in air before and after exposure to various chemical environments and the electrical resistance per unit length in air of a representative piping system assembled from such components. The components and systems are hereafter referred to in this Annex as the specimen.

A3.2 Summary of Test Method

A3.2.1 In this test method, the length of the potential current path is measured and then a potential difference of 1500 V is applied across the test specimen and a resistor of known value, which are connected in series. The voltage drop across the test specimen is then accurately measured and the resistance of the specimen calculated followed by calculation of resistance per unit length. Figure A3.1 shows a drawing of a typical test setup.

A3.3 Significance

A3.3.1 This test method is suitable for measuring resistance between 2 and 1×10^{10} Ω using an applied voltage of 1500 V.

A3.4 Test Equipment

A3.4.1 *Exposure Tank*—An exposure tank of nonmetallic construction and resistant to the environment being tested. It shall be maintained at a temperature of 60° to 80°F (15.6° to 26.7°C) throughout the duration of the test.

A3.4.2 *Oven*—An oven capable of being controlled to a temperature of 150° ± 10°F (66.6 ± 10°C).

A3.4.3 *Voltmeter*—A voltmeter capable of measuring dc voltages between 0.0001 and 1500 V with a resolution of 0.005 %.[13]

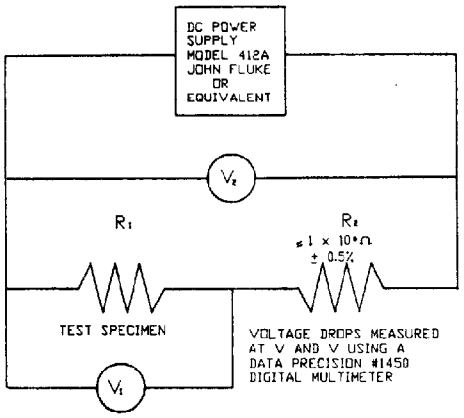

FIG. A3.1 Test Setup for Determining the Electrical Resistance of Fiberglass Pipe and Fittings

A3.4.4 *dc Power Supply*—A constant voltage dc power supply capable of supplying 1500 V at a current of 0.5 mA.

A3.4.5 *A 1 × 10⁶* ± 0.5 % × 1 watt resistor.

A3.5 Test Specimens

A3.5.1 *Pipe, Fittings, and Joints:*

A3.5.1.1 *Diameter*—Unless otherwise specified, the nominal diameter of the pipe, fitting, or joint tested shall be 2 in.

A3.5.1.2 *Length*—The length of the specimen shall be six times the nominal diameter of the product plus two times the width of the grounding clamps. To achieve this length,

[13] A Data Precision Model No. 1450 Digital Multimeter has been found satisfactory for this purpose.

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additional sections of conductive pipe shall be added using the manufacturer's normally recommended assembly methods.

A3.5.2 *Representative Piping Systems:*

A3.5.2.1 *Diameter*—Unless otherwise specified the nominal diameter of the system tested shall be 2 inches.

A3.5.2.2 *Length*—The minimum length shall meet the requirements of A3.5.1.2.

A3.6 Conditioning

A3.6.1 No special conditioning of the specimens prior to initiation of the test is required.

A3.7 Procedure

A3.7.1 *Potential current path selection:*

A3.7.1.1 *Pipes, straight joints, adapters, couplings, plugs, caps, and bushings*—The path length shall be parallel to the centerline axis of the component and shall encompass the length of the component.

A3.7.1.2 *Elbows*—Two path lengths shall be established, one on the outer and one on the inner radius of curvature.

A3.7.1.3 *Crosses*—Six path lengths shall be established, one parallel to each of the longitudinal centerline axes and one along the shortest path from adjacent openings through each 90° bend.

A3.7.1.4 *Tees*—One path shall parallel the centerline axis opposite the interior opening. Two additional paths shall also be established, one along the shortest path from adjacent openings through each 90° bend.

A3.7.1.5 *Laterals*—Three paths shall be established, one parallel to the longitudinal centerline axis, one along the shortest distance between adjacent openings through the oblique angle, and one along the shortest distance between adjacent openings through the obtuse angle.

A3.7.1.6 *Representative piping systems*—The path length shall encompass the longest possible length that parallels the centerline axis of the system.

A3.7.1.7 If extenders are used, both lengths shall incorporate that portion of the extenders needed to meet specimen length requirements.

A3.7.1.8 For components and systems achieving conductivity through use of conductive layers, the resistance per unit length will be measured as follows:

(*a*) Separately through each conductive layer using the path selection criteria in paragraphs A3.7.1.1 through A3.7.1.7.

(*b*) Through the conductive connections between layers. The path length shall consist of the distance between the clamps plus the thickness of the non-conductive portion of the pipe, fitting, or joint. The path shall be measured from the interior of one end through the joint to the exterior of the opposite end.

(*c*) From the exterior part of the test point separately to the interior of each end of the pipe, joint, or fitting.

A3.7.2 *Sample Preparation*—Install the grounding clamps for each potential current path of interest in accordance with the manufacturer's recommendations. In the case of pipes having conductive layers, the recommendations will include methods/equipment that accommodate the separate resistance measurements of inner and outer conductive layers, conductive connections between layers, and resistance of interior layer test points. The surface preparation in any case shall not exceed that normally required when assembling a piping system using a fitting. The distance between the clamps should be six times the nominal diameter of the pipe, fitting, or joint when testing individual components and systems. If a specimen ends with an open flange, the grounding clamp will be installed on the face of the flange.

A3.7.3 Measure the lengths of the potential current paths of interest for test specimen including extenders (if used) and the thickness of any exposed flange faces.

A3.7.4 Isolate the test specimen from ground.

A3.7.5 Connect a $1 \times 10^6\ \Omega - 1$ W resistor in series with the test specimen.

A3.7.6 Apply a dc voltage of 1500 ± 0.1 V across the test specimen and resistor.

A3.7.7 Measure the voltage drop, V_1, across the test specimen. If immersion is not required, calculate the resistance in accordance with A3.7.14.

A3.7.8 If immersion is requested by the purchaser, place the specimens in the test tank so that they are completely immersed in the test fluid. Maintain the temperature of the bath at 60° to 80°F (15.5° to 26.7°C) throughout the duration of the test. Suggested test environments are: (1) Salt water per Specification D 1141, (2) Gasoline, (3) Bunker C, and (4) 1 % sulfuric acid.

A3.7.9 At the end of 1, 3, 6, and 12 months, remove the test specimens from the bath and rinse thoroughly with tap water if the test specimens have been exposed to a water soluble product or a hydrocarbon solvent if the specimens have been exposed to a petroleum product.

A3.7.10 Place the test specimens in an oven at 150° ± 10°F (66.6° ± 10°C) for a period of 2 h.

A3.7.11 At the end of 2 h, remove the specimens from the oven and allow them to cool to 70° to 80°F (21.1° to 26.7°C) in a 50 ± 5 % relative humidity environment for 60 ± 5 min before retesting.

A3.7.12 Remeasure the voltage drop across the specimens in accordance with A3.7.5 through A3.7.7.

A3.7.13 Note the appearance of the test specimens and the conditions of the clamps.

A3.7.14 Using the information obtained, calculate the resistance of the test specimen before and after exposure using the following equation:

$$\frac{V_1}{R_1} = \frac{V_2}{R_1 + R_2}$$

where:

V_1 = voltage drop across specimen,
R_1 = resistance of test specimen,
V_2 = line voltage (1500 V), and
R_2 = value of known resistor ($1 \times 10^6\ \Omega$).

A3.7.15 Calculate the resistance per unit length for each of the potential current paths of interest on the specimen and its associated resistance.

A3.8 Report

A3.8.1 Report the following information:

A3.8.1.1 Manufacturer of the specimen.

A3.8.1.2 Designation of product being tested.

A3.8.1.3 Description of the specimen including the diameter and length for a pipe, fitting, or joint (including the

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lengths of extensions, if applicable) or a dimensioned sketch for a representative piping system. In both cases, placement of the grounding clamps and the potential current paths and their lengths shall be identified.

A3.8.1.4 Description of grounding clamps and grounding procedure.

A3.8.1.5 Test media.

A3.8.1.6 Initial resistance per unit length between clamps for each potential current path and resistance per unit length for each potential current path at 1, 3, 6, and 12 months if immersion testing was conducted.

A3.8.1.7 Appearance of test specimen if immersion testing was conducted.

A3.8.1.8 Date of test.

A4. TEST METHOD FOR FIRE ENDURANCE EVALUATION OF PLASTIC PIPING IN THE DRY CONDITION

A4.1 Scope

A4.1.1 This test method covers the determination of the fire endurance of thermosetting resin fiberglass pipe, fittings, and joints to be used in marine applications when empty. This test procedure is based on the IMO Assembly Resolution A.753(18) which is an alternative to this test. SI units shall be used in referee decisions.

A4.2 Significance

A4.2.1 This testing procedure in this test method is applicable over a range of temperatures up to 2012°F (1100°C). This temperature rise occurs in less than 1 hour, simulating a fully developed liquid hydrocarbon fire. This test is valid for pipe 1 in. to 48 in. nominal diameters for pressures up to 225 psi.

A4.3 Test Equipment

A4.3.1 *Furnace*—Test furnace with the capability to increase its temperature to 2012°F (1100°C) within 1 h while meeting the accuracy in A4.6.4.1. Furnace shall have a temperature gauge capable of measuring temperature ±2 %.

A4.3.2 *Thermocouples*—Two thermocouples capable of measuring up to 2012°F (1100°C).

A4.3.3 Nitrogen tank with regulator.

A4.4 Test Specimen

A4.4.1 The test specimen should be prepared with the joints, fittings, and fire protection coverings intended for use in the proposed application.

A4.4.2 The number of specimens shall be sufficient to test typical joints and fittings including joints between non-metal and metal pipes and fittings to be used.

A4.4.3 The ends of the specimen shall be closed with one end allowing pressurized nitrogen to be connected.

A4.4.4 The pipe ends and closures may be outside the furnace.

A4.4.5 The general orientation of the specimen should be horizontal and it should be supported by one fixed support with the remaining supports allowing free movement.

A4.4.6 The free length between supports should not be less than 8 times the pipe diameter.

A4.4.7 Full scale fire test shall be performed on 1, 2, 4, and 8 inch pipe systems. Above 8-inch, every third size of the manufacturer's product line shall be tested.

TABLE A4.1 Time/Mean Temperature Ramp of Furnace

Time	Mean Temperature
at the end of: 5 minutes:	≥945°C
at the end of: 10 minutes:	≥1033°C
at the end of: 15 minutes:	≥1071°C
at the end of: 30 minutes:	≥1098°C
at the end of: 60 minutes:	≥1100°C

A4.5 Test Conditions

A4.5.1 *Fire-Protective Coatings:*

A4.5.1.1 If the fire protective coating contains, or is liable to absorb, moisture the specimen should not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature of 50 % relative humidity at 70 ± 10°F (20 ± 5°C).

A4.5.1.2 Accelerated conditioning is permissible provided the method does not alter the properties of component materials.

A4.5.1.3 Special samples shall be used for moisture content determination and conditioned with the test specimen. These samples should be so constructed as to represent the loss of water vapor from the specimen by having similar thickness and exposed faces.

A4.5.2 A nitrogen pressure inside the test specimen should be maintained automatically at 0.7 ± 0.1 bar during the test. Means should be provided to record the pressure inside the pipe and the nitrogen flow into and out of the specimen in order to indicate leakage.

A4.5.3 *Flame Temperature:*

A4.5.3.1 The exterior flame temperature shall be measured by means of two thermocouples mounted not more than 1 in. (2.5 cm) from the pipe near the center span of the assembly.

A4.5.3.2 The thermocouples shall be mounted on the horizontal plane at the level of the pipe.

A4.5.3.3 The test temperature shall be taken as the average of the two thermocouple readings.

A4.6 Procedure

A4.6.1 Measure the dimensions of the specimen in accordance with Practice D 3567. Include measurements of liner thickness and external coatings, if applicable.

A4.6.2 Place specimen in the furnace.

A4.6.3 Pressurize specimen with nitrogen maintaining the pressure in accordance with A4.5.2.

A4.6.4 Time/mean temperature ramp of furnace according to Table A4.1 is started.

A4.6.4.1 The accuracy of the furnace control should be as follows:

(*a*) During the first 10 min. of the test the area under the curve of mean furnace temperature vs. time should not vary by more than ±15 % of the area under the standard curve.

(*b*) During the first half hour of the test the area under the curve of mean furnace temperature vs. time should not vary by more than ±10 % of the area under the standard curve.

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(*c*) For any ten minute period after the first half hour of the test the area under the curve of mean furnace temperature vs. time should not vary by more than ±5 % of the area under the standard curve.

(*d*) At any time after the first 10 min of the test the mean furnace temperature should not differ from the standard curve by more than ±100°C.

A4.6.5 The mean temperature and exterior flame temperature shall be recorded a minimum of once every 30 s.

A4.7 Acceptance Criteria

A4.7.1 No nitrogen leakage from the sample should occur during the test.

A4.7.2 *Hydrostatic Pressure:*

A4.7.2.1 After termination of the furnace test, the specimen together with fire protection coating, if any, should be allowed to cool in still air to ambient temperature and then test to the rated pressure of the pipe.

A4.7.2.2 The pressure should be held for a minimum of 15 min without leakage.

A4.7.2.3 Where practicable, the hydrostatic test should be conducted on bare pipe, that is pipe without any covering, including fire protection. This is to make any leakage readily apparent.

A4.8 Report

A4.8.1 Report the following information:

A4.8.1.1 Complete identification of the pipe or fitting tested including manufacturer's name and code.

A4.8.1.2 Description of fire-protective coating if applicable.

A4.8.1.3 Diameter of pipe, fitting or joint.

A4.8.1.4 Endurance time.

A4.8.1.5 Appearance of test specimen.

A4.8.1.6 Date of test.

A5. TEST METHOD FOR FIRE ENDURANCE TESTING OF WATER-FILLED PLASTIC PIPING

A5.1 Scope

A5.1.1 This test method covers the determination of the fire endurance of thermosetting resin fiberglass pipe, fittings and joints to be used in marine applications when in the wet condition. This test procedure is based on the IMO Assembly Resolution A.753(18) which is an alternative to this test. SI units shall be used in referee decisions.

A5.2 Summary of Test Method

A5.2.1 This test method subjects a pipe sample to a constant 36,011 Btu/(hr-ft·2) (113.6 kW/m·2) net flux to determine a pipe systems fire-endurance.

A5.3 Significance

A5.3.1 This test is valid for pipe 1 in. to 48 in. nominal diameters for pressures up to 225 psi. It will give a purchaser of fiberglass pipe the ability to determine the fire resistance of a fiberglass piping system when filled with water.

A5.4 Test Equipment

A5.4.1 *Sivert No. 2942 burner* or equivalent which produces an air mixed flame.

A5.4.1.1 The inner diameter of the burner heads should be 1.5 in. (29 mm) (see Fig. A5.1).

A5.4.1.2 The burner heads should be mounted in the same plane and supplied with gas from a manifold.

A5.4.1.3 If necessary, each burner should be equipped with a valve in order to adjust the flame height.

A5.4.1.4 The height of the burner stand should also be adjustable.

A5.4.1.5 It should be mounted centrally below the test pipe with the rows of burners parallel to the pipe's axis.

A5.4.1.6 The distance between the burner heads and the pipe should be maintained at 5 ± 3/8 in. (12.5 ± 1.0 cm) during the test.

A5.4.1.7 The free length of the pipe between its supports should be 31.5 ± 2 in. (0.80 ± 0.05 m).

A5.4.2 *Thermocouples*—Two thermocouples capable of

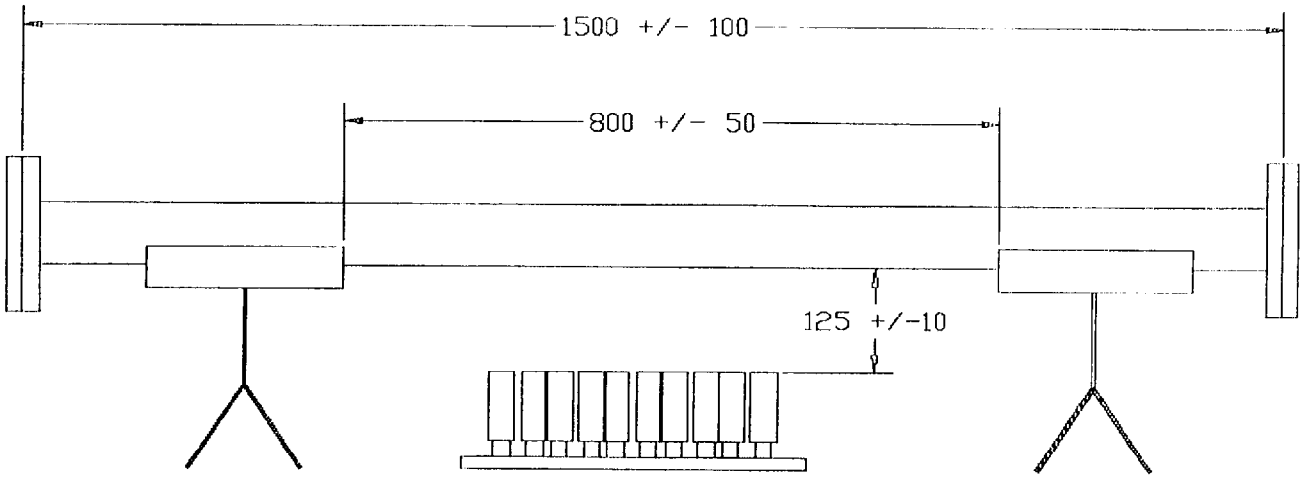

FIG. A5.1 Stand with Mounted Sample

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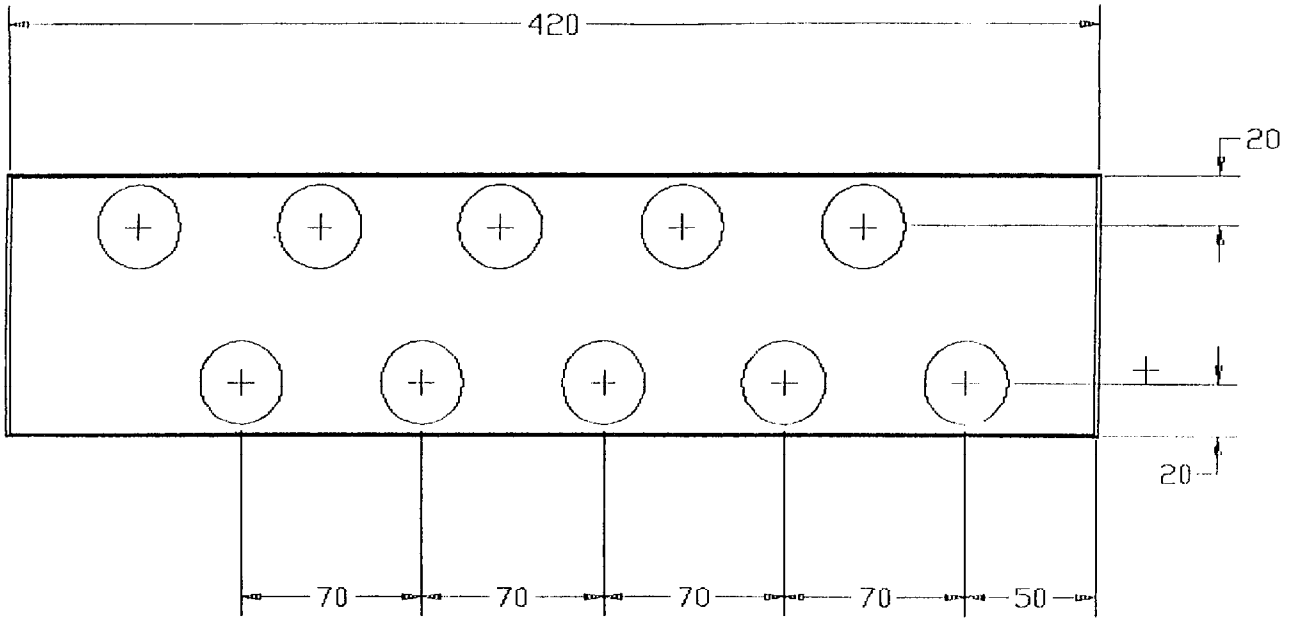

FIG. A5.2 Top View Burner Assembly

measuring up to 2012°F (1100°C).

A5.4.3 *Deaerated water.*

A5.4.4 *Thermometer*—To measure internal water temperature.

A5.4.5 *Pressure Gauge*—Capable of reading up to 5 bars (±5 %).

A5.4.6 *V-Shaped Pipe Supports.*

A5.5 Test Specimen

A5.5.1 *Specimen Length:*

A5.5.1.1 The test specimen should have a length of 59 in. (1.5 m).

A5.5.2 Test specimen should be pipe with permanent joints or fittings intended for use in marine applications.

A5.5.3 All joint types should be tested as they are the primary point of failure.

A5.5.4 The number of pipe specimens should be sufficient to test all typical joints and fittings.

A5.5.5 The ends of each specimen must be closed.

A5.5.6 One end should allow pressurized water to be connected.

A5.5.7 A pressure relief valve should be connected to one of the end closures of each specimen.

A5.6 Test Conditions

A5.6.1 *Fire-Protective Coatings:*

A5.6.1.1 If the fire-protective coating or covering contains, or is liable to absorb, moisture, the test specimen should not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature of 50 % relative humidity at 70 ± 10°F (20 ± 5°C).

A5.6.1.2 Accelerated conditioning is permissible provided the method does not alter the properties of component materials.

A5.6.1.3 Special samples shall be used for moisture content determination and conditioned with the test specimen. These samples should be so constructed as to represent the loss of water vapor from the specimen by having similar thickness and exposed faces.

A5.6.2 The test should be carried out in a sheltered test site in order to prevent any draft influencing the test.

A5.6.3 Each pipe specimen should be completely filled with deaerated water and vented to exclude air bubbles.

A5.6.3.1 The water temperature should not be less than 59°F (15°C) at the start and should be measured continuously during the test.

A5.6.3.2 The water inside the sample should be stagnant and the pressure maintained at 3 ± 0.5 bar during the test.

A5.6.4 *Flame Temperature:*

A5.6.4.1 The exterior flame temperature shall be measured by means of two thermocouples mounted not more than 1 in. (2.5 cm) from the pipe near the center span of the assembly.

A5.6.4.2 The thermocouples shall be mounted on the horizontal plane at the level of the pipe.

A5.6.4.3 The test temperature shall be taken as the average of the two thermocouple readings.

A5.7 Procedure

A5.7.1 Measure the dimensions of the specimen in accordance with Practice D 3567. Include measurements of liner thickness and external coatings, if applicable.

A5.7.2 Place specimen on two V-shaped supports. The supports may consist of two stands as shown in Fig. A5.1.

A5.7.3 Pressurize specimen with water maintaining conditions in accordance with A6.3.

A5.7.4 *Burner Configuration for Constant Heat Flux:*

A5.7.4.1 For piping 6 ins. and less in diameter, the fire source should consist of two rows of 5 burners as shown in Fig. A5.2.

A5.7.4.2 A constant heat flux averaging 36,011 Btu/(hr-ft·2) (113.6 kW/m·2) (±10 %) should be maintained 5 ± 3/8 in. (12.5 ± 1.0 cm) above the centerline of the array.

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(*a*) This flux corresponds to a pre-mix flame of propane with a fuel flow rate of 11.02 lb/hr (5 kg/hr) for a total heat release of 221,780 btu/hr (65 kW).

(*b*) The gas consumption should be measured with an accuracy of at least ±3 % in order to maintain a constant heat flux.

A5.7.4.3 For piping greater than 6 in. in diameter, one additional row of burners should be included for each 2 inch increase in pipe diameter.

(*a*) A constant heat flux averaging 36,011 Btu/(hr-ft·2) 113.6 kW/m·2 (±10 %) should still be maintained at the 5 ± 3/8 in. (12.5 ± 1.0 cm) height above the centerline of the burner array.

(*b*) The fuel flow should be increased as required to maintain the designated heat flux.

A5.7.5 Begin heat flux.

A5.7.6 Record test temperature, water temperature, water pressure at least once every 30 s.

A5.8 Acceptance Criteria

A5.8.1 No leakage from the sample(s) should occur except that slight weeping from the wall may be accepted.

A5.8.2 *Hydrostatic Pressure:*

A5.8.2.1 After termination of the burner regulation test, the test sample, together with the fire protection coating, if any, should be allowed to cool to ambient temperature and then tested to the rated pressure of the pipe.

A5.8.2.2 The pressure should be held for a minimum of 15 min and produce a leakage of less than 0.05 gpm (0.2 liters/min).

A5.8.2.3 Where practical, the hydrostatic test should be conducted on bare pipe that has had all of its coverings, including fire protection insulation removed, so that leakage will be readily apparent.

A5.9 Report

A5.9.1 Report the following information:

A5.9.1.1 Complete identification of the pipe, fitting or joint tested including manufacturer's name and code.

A5.9.1.2 Description of fire-protective coating if applicable.

A5.9.1.3 Diameter of pipe, fitting or joint.

A5.9.1.4 Endurance time.

A5.9.1.5 Appearance of test specimen.

A5.9.1.6 Date of test.

A6. DIMENSIONS AND TOLERANCES

A6.1 For Pipe

A6.1.1 *Diameter*—Pipe meeting this specification shall conform to the requirements in Table A6.1 or Table A6.2. Dimensions shall be determined in accordance with 11.4.

A6.1.2 *Wall Thickness*—The minimum wall thickness of pipe furnished under this specification shall not, at any point, be less than:

A6.1.2.1 Eighty-five percent of the nominal wall thickness published in the manufacturer's literature current at the time of purchase when measured in accordance with 11.4.

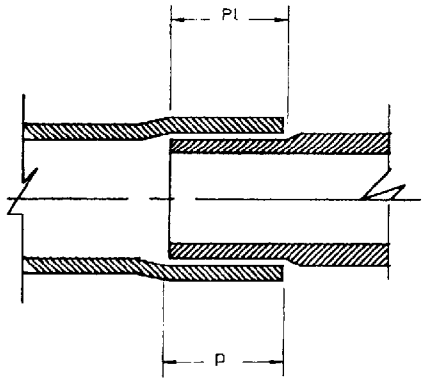
A6.1.2.2 The wall thickness determined using hydrostatic design basis in accordance with 7.2.

A6.1.3 *Liner thickness*—Except for unlined products, all pipe shall have a minimum liner thickness of 0.010 in. (0.254 mm) when measured in accordance with 11.4.

A6.1.4 *Length*—Pipe shall be in lengths as specified by

TABLE A6.1 Dimensions for Outside Diameter (OD) Series Pipe

Steel NPS	Outside Diameter	
	in., min	mm, min
1	1.31	33.4
1½	1.90	48.3
2	2.37	60.3
3	3.50	88.9
4	4.50	114.3
6	6.625	168.3
8	8.625	219.1
10	10.75	273.1
12	12.75	323.9
14	14.00	355.6
16	16.00	406.4
18	18.04	458.1
20	20.04	509.0
22	22.04	559.8
24	24.05	610.9
26	26.04	661.5
28	28.04	712.2
30	30.04	762.9
32	32.04	813.8
34	34.04	864.7
36	36.04	915.5



NPS	Minimum Socket Length, P in. (mm)	Minimum Spigot Length, P1 in. (mm)	Spigot Diameter	
			Minimum in. (mm)	Maximum in. (mm)
1	1.063 (27)	1.125 (29)	1.277 (32.4)	1.293 (32.8)
1½	1.250 (32)	1.125 (35)	1.876 (47.4)	1.883 (47.8)
2	1.813 (46)	2.000 (51)	2.330 (59.2)	2.346 (59.6)
3	1.813 (46)	2.000 (51)	3.450 (87.6)	3.466 (88.0)
4	1.813 (46)	2.000 (51)	4.430 (112.5)	4.446 (112.9)
6	2.250 (57)	2.375 (60)	6.544 (166.2)	6.560 (166.6)
8	2.500 (64)	2.625 (67)	8.544 (217.0)	8.560 (217.4)
10	2.750 (70)	2.875 (73)	10.680 (271.3)	10.696 (271.7)
12	3.000 (76)	3.125 (79)	12.684 (322.2)	12.700 (322.6)
14	3.500 (88)	3.625 (92)	13.945 (354.2)	13.970 (354.8)
16	4.000 (102)	4.125 (105)	15.909 (404.1)	15.925 (404.5)

NOTE 1—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

FIG. A6.1 Standard Straight-Taper and Straight-to-Straight Joints

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TABLE A6.2 Dimensions for Inside Diameter (ID) Series Pipe

Steel NPS	Inside Diameter	
	in.	mm
1	1.00 ± 0.06	25.4 ± 1.52
1½	1.50 ± 0.06	38.1 ± 1.52
2	2.00 ± 0.06	50.8 ± 1.52
3	3.00 ± 0.12	76.2 ± 3.05
4	4.00 ± 0.12	101.6 ± 3.05
6	6.00 ± 0.25	152.4 ± 6.35
8	8.00 ± 0.25	203.2 ± 6.35
10	10.00 ± 0.25	254.0 ± 6.35
12	12.00 ± 0.25	304.8 ± 6.35
14	14.00 ± 0.25	355.6 ± 6.35
16	16.00 ± 0.25	406.4 ± 6.35
18	18.00 ± 0.25	457.2 ± 6.35
20	20.00 ± 0.25	508.0 ± 6.35
22	22.00 ± 0.25	558.8 ± 6.35
24	24.00 ± 0.25	609.6 ± 6.35
26	26.00 ± 0.25	660.4 ± 6.35
28	28.00 ± 0.25	711.2 ± 6.35
30	30.00 ± 0.25	762.0 ± 6.35
32	32.00 ± 0.25	812.8 ± 6.35
34	34.00 ± 0.25	863.6 ± 6.35
36	36.00 ± 0.25	914.4 ± 6.35

the purchase order when measured in accordance with 11.4.

A6.2 For Fittings

A6.2.1 *Wall thickness*—The minimum wall thickness of fittings furnished under this specification shall not, at any point, be less than the pipe nominal wall thickness published in the manufacturer's literature current at the time of purchase when measured in accordance with 11.4.

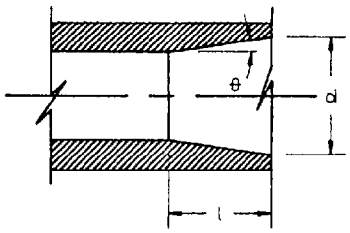
A6.2.2 Except for unlined products, the fittings shall have a minimum liner of 0.010 inches (0.254 mm) when measured in accordance with 11.4.

A6.2.3 *Length*—Lengths and tolerances are specified in Figs. A6.1 through A6.16.

NOTE 1—Outside diameters other than those listed in Table A6.1 or inside diameters as listed in Table A6.2 shall be permitted upon agreement between the manufacturer and the purchaser.

NOTE 2—Outside diameters approximate those for iron pipe size, ISO International Standard 559-1978, and for cast iron pipes, ISO International Standard 13-1978, as follows:

NOTE 3—Tolerances for 1 to 16 NPS in accordance with Specification D 2996 Figures. Tolerances for 18 to 36 NPS are ±1 % of the pipe outside diameter in accordance with ISO 559-1978.



NPS	Socket Entrance Diameter, min, d, in. (mm)	Minimum Effective Bond Length, min, L, in. (mm)	Taper Angle Range ° (Degrees)
1	1.335 (34)	0.750 (19)	1 to 3
1½	1.910 (76)	0.750 (19)	1 to 3
2	2.375 (60)	1.000 (25)	1 to 2
3	3.500 (89)	1.125 (29)	1 to 2
4	4.500 (114)	1.250 (32)	1 to 2
6	6.600 (168)	1.500 (38)	1 to 2
8	8.635 (219)	2.000 (51)	1 to 2
10	10.700 (272)	2.125 (54)	1 to 2
12	12.670 (322)	2.250 (57)	1 to 2
14	14.400 (366)	2.500 (64)	1 to 2
16	16.460 (418)	2.500 (64)	1 to 2

NOTE 1—*Standard tapered socket.* In all cases, the base angle for bells (sockets) shall be the same as the angle for the pipe spigots (male tapers). The tolerances shall be set to ensure there is no gap between the end of the spigot and the bottom of the bell. The minor I.D. (diameter at the bottom) of the tapered socket shall always be less than the end dimension (the diameter at the end) of the pipe spigot to ensure that the spigot does not insert beyond the tapered portion of the bell. The insertion of the spigot into the bell shall be at least equal to the minimum allowable effective bond length (EBL) shown for Fig. A6.2. The minimum effective bond length is the minimum insertion length where the tapered spigot surfaces are in contact with the tapered bell surfaces. The tolerances shall be set to ensure that the effective bond length is at least equal to the values in Fig. A6.2. Angle tolerance for male tapers (spigots) and for female tapers (bells) shall not vary more than 0.25° i.e. the most extreme mismatch in a bonded joint must never exceed 0.5°. For all bonded joints, the angle for the spigot shall be equal to or less than the bell angle (preventing a gap between the end of the spigot and the bottom of the bell).

NOTE 2—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

FIG. A6.2 Standard Taper-to-Taper Joint

A6.2.4 The lengths and tolerances of fittings not covered in Annex A6 must be agreed upon by the purchaser and the supplier.

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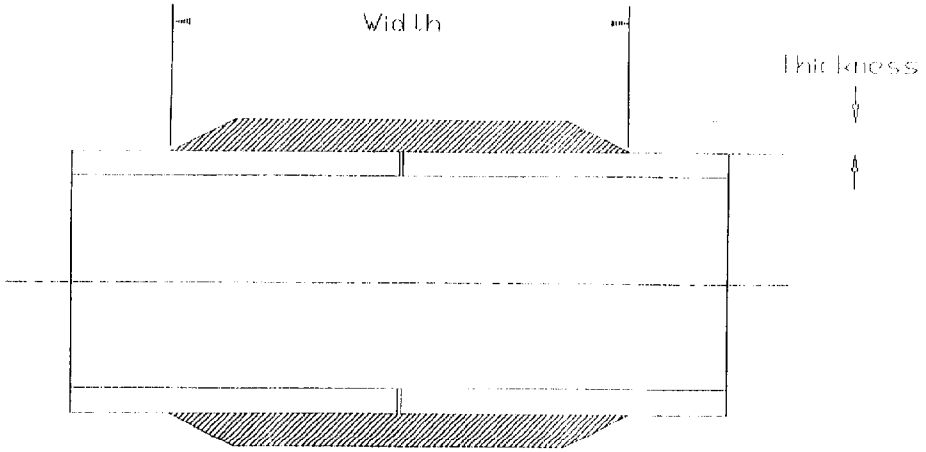
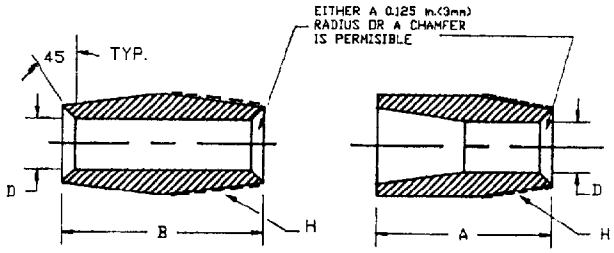
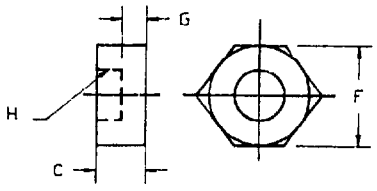


NPS	Width, min, in.	Thickness, min, in.
2	3	0.125
3	3	0.125
4	3	0.125
6	4	0.175
8	4	0.175
10	6	0.2
12	6	0.25
14	8	0.25
16	19	0.25

FIG. A6.3 Standard Butt-And-Wrap





NPS	Overall Length, min			Minimum Internal Diameter D, in. (mm)	Width[A] Across Hex Flats F, in. (mm)	Minimum Thickness G, in. (mm)	Pipe Thread (IPS) H, in. (mm)	Taper[B] Angle Degrees °
	A, in. (mm)	B, in. (mm)	C, in. (mm)					
1	3.250 (83)	2.375 (60)	1.500 (38)	0.875 (22)	1.688 (43)	0.438 (11)	NPT	1 to 3
1½	3.250 (83)	2.500 (64)	1.750 (44)	1.500 (38)	2.438 (62)	0.500 (13)	NPT	1 to 3
2	4.000 (102)	3.500 (89)	2.000 (51)	1.890 (48)	3.000 (76)	0.563 (14)	NPT	1 to 2

[A] Width across hex flats tolerance +0.000 and −0.063 in. [+0.000 and −0.005 mm].

NOTE 1—Machining of threads shall be accordance with ANSI B2.1 for NPT threads.
NOTE 2—For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.

FIG. A6.4 (A) Standard Adapter, Tapered Spigot × Male Pipe Thread; (B) Standard Adapter Tapered × Male Pipe Thread; and (C) Hexagonal Threaded Cap

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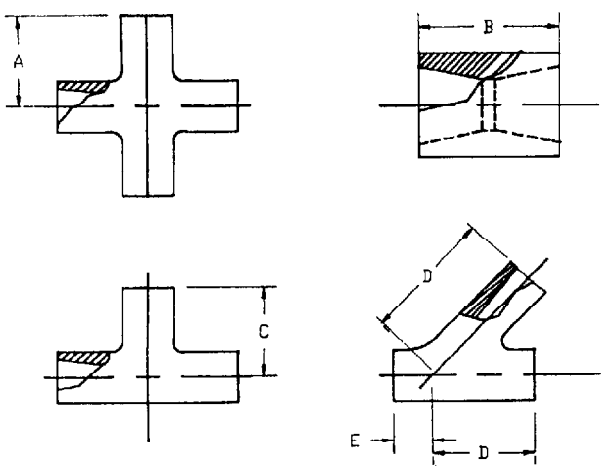
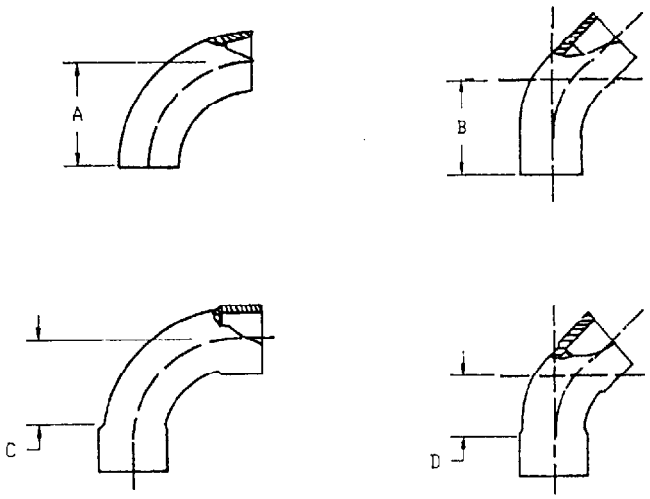


NPS	A, min, in. (mm)	B, min, in. (mm)	C, min, In. (mm)	D, min, in. (mm)	E, min, in. (mm)
1	2.500 (64)	2.500 (64)	2.500 (64)	3.625 (92)	2.250 (57)
1½	3.125 (79)	3.000 (76)	3.125 (79)	5.000 (127)	3.000 (76)
2	3.125 (79)	4.625 (117)	3.125 (79)	6.375 (162)	2.500 (64)
3	4.375 (111)	4.750 (121)	4.375 (111)	7.500 (191)	4.000 (102)
4	4.875 (124)	5.000 (127)	4.875 (124)	8.750 (222)	4.125 (105)
6	5.875 (149)	6.750 (171)	5.875 (149)	12.250 (311)	5.500 (140)
8	11.375 (289)	9.750 (248)	11.375 (289)	16.000 (406)	7.125 (181)
10	12.875 (327)	10.250 (260)	12.875 (327)	19.375 (492)	8.500 (216)
12	13.750 (349)	10.750 (273)	13.750 (349)	24.500 (622)	11.500 (292)
14	15.750 (400)	12.250 (311)	15.750 (400)	32.250 (819)	15.500 (394)
16	16.750 (425)	12.750 (324)	16.750 (425)	35.500 (902)	17.500 (445)

NOTE 1—For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.
NOTE 2—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

FIG. A6.5 Taper-to-taper (A) Cross, (B) Coupling, (C) Tee, and (D) 45° Lateral



NPS	A, min, in. (mm)[A]	B, min, in. (mm)[A]	C, min, in. (mm)	D, min, in. (mm)
1	2.500 (64)	2.125 (54)	2.562 (65)	0.875 (22)
1½	3.125 (79)	2.625 (67)	3.188 (81)	0.125 (29)
2	3.125 (79)	2.375 (60)	3.000 (76)	1.375 (35)
3	4.375 (111)	3.505 (89)	4.500 (114)	2.000 (51)
4	4.875 (124)	3.625 (92)	6.000 (152)	2.500 (64)
6	5.875 (149)	4.125 (105)	9.000 (229)	3.750 (95)
8	11.375 (289)	7.875 (200)	12.000 (305)	5.000 (127)
10	12.875 (327)	8.375 (213)	15.000 (381)	6.250 (155)
12	13.750 (349)	9.250 (235)	18.000 (457)	7.500 (151)
14	15.750 (400)	10.000 (254)	14.125 (359)	4.750 (120)
16	17.000 (432)	10.625 (270)	15.125 (397)	5.375 (136)

[A] For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.

NOTE 1—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

FIG. A6.6 Taper-to-Taper and Butt-Weld: (A) 90° Elbows and (B) 45° elbows; Straight-Taper and Straight-to-Straight (C) 90° Elbows and (D) 45° elbows

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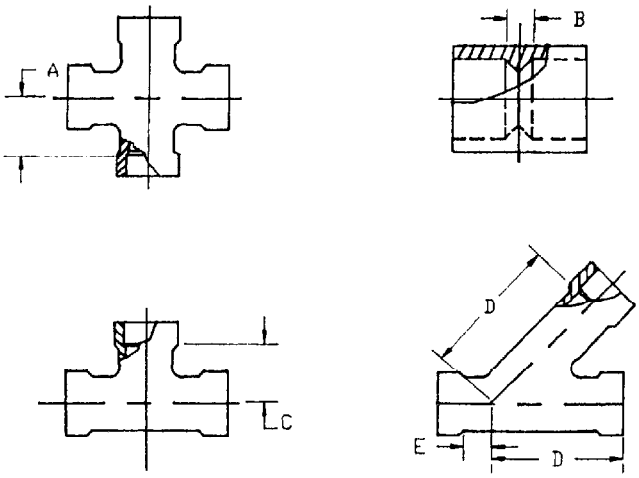

NPS	A, min, in. (mm)	B, min, in. (mm)	C, min, in. (mm)	D, min, in. (mm)	E, min, in. (mm)
1	1.063 (27)	0.375 (10)	0.063 (27)	3.000 (76)	1.000 (25)
1½	1.188 (30)	0.375 (10)	1.188 (30)	4.000 (102)	1.500 (38)
2	2.500 (64)	0.375 (10)	2.500 (64)	8.000 (203)	2.500 (64)
3	3.375 (86)	0.375 (10)	3.375 (86)	10.000 (254)	3.000 (76)
4	4.125 (105)	0.375 (10)	4.125 (105)	12.000 (305)	3.000 (76)
6	5.125 (143)	0.375 (10)	5.625 (143)	14.500 (368)	3.500 (89)
8	7.000 (178)	0.375 (10)	7.000 (178)	17.500 (445)	4.500 (114)
10	8.500 (216)	0.375 (10)	8.500 (216)	20.500 (521)	5.000 (127)
12	10.000 (254)	0.375 (10)	10.000 (254)	24.500 (622)	5.500 (140)
14	10.500 (267)	0.750 (19)	10.500 (267)	24.500 (622)	5.500 (140)
16	11.500 (292)	0.750 (19)	11.500 (292)	24.500 (622)	5.500 (140)

NOTE 1—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

FIG. A6.7 Straight-Taper and Straight-to-Straight (A) Cross, (B) Coupling, (C) Tee, and (D) & (E) 45° Lateral

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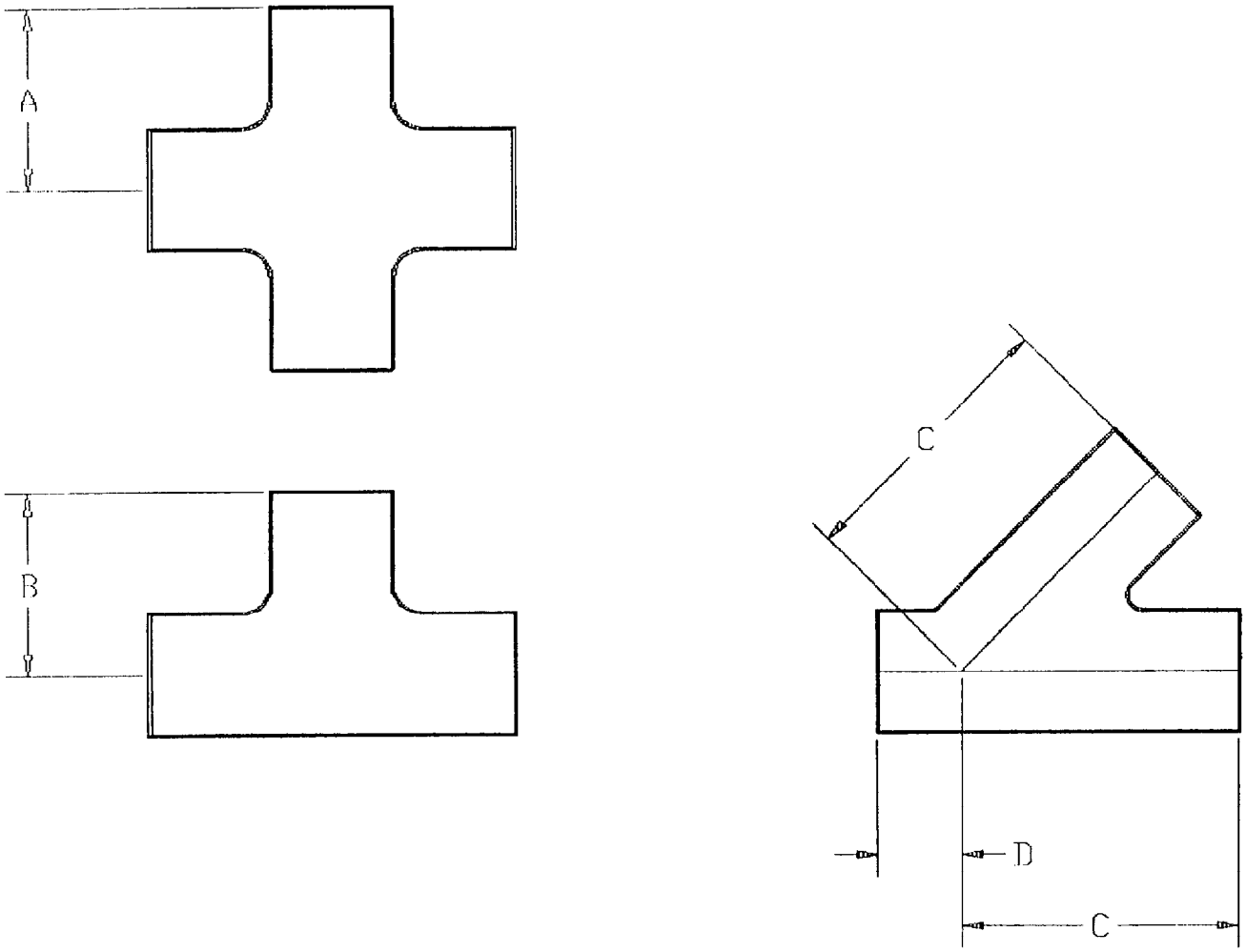

NPS	A, min, in.	B, min, in.	C, min, in.	D, min, in.
2	5	5	9	5
3	6	6	11	5
4	7	7	13	5
6	9	9	15	7
8	11	11	19	9
10	13	13	23	09
12	15	15	25	11
14	17	17	29	11
16	19	19	31	13

FIG. A6.8 Plain End (A) Cross, (B) Tee, and (C) & (D) 45° Lateral

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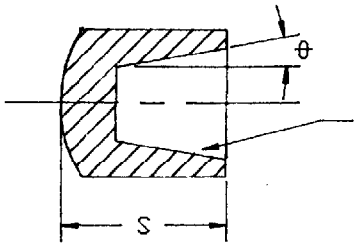
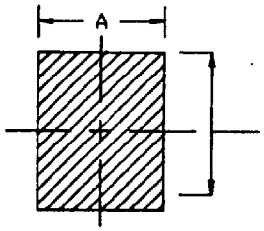


NPS	Cap Length, S, min, in. (mm)
1	2.250 (57)
1½	2.375 (60)
2	2.500 (64)
3	3.000 (76)
4	3.500 (89)
6	4.625 (117)
8	6.500 (165)
10	7.000 (178)
12	8.750 (222)
14	10.500 (267)
16	11.500 (292)

NOTE 1—For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.

FIG. A6.9 End Cap: Taper-to-Taper



NPS	Plug Length, A, in. (mm)
1	1.188 (30)
1½	1.375 (35)
2	1.937 (49)
3	1.937 (49)
4	1.937 (49)
6	2.375 (60)
8	2.625 (67)
10	2.875 (73)
12	3.125 (79)
14	3.625 (92)
16	4.125 (105)

NOTE 1—For straight taper socket dimensions, see Fig. 1.

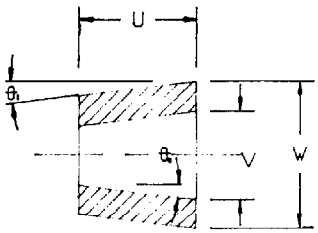
FIG. A6.10 Pipe Cap Fitting Plug: Straight-Taper

NPS	A, min, in. (mm)	B, min, in. (mm)[A]
1½ by 1	$A = 2.5 \times$ (Outside Diameter − Inside Diameter)	1.250 (32)
2 by 1		2.500 (64)
2 by 1½		1.250 (32)
3 by 1½		3.000 (76)
3 by 2		2.120 (54)
4 by 2		3.000 (76)
4 by 3		2.880 (73)
6 by 3		3.810 (94)
6 by 4		3.690 (94)
8 by 4		5.440 (138)
8 by 6		3.880 (98)
10 by 6		4.620 (117)
10 by 8		4.120 (105)
12 by 8		5.880 (149)
12 by 10		5.380 (137)
14 by 10		16.620 (422)
14 by 12		16.620 (422)
16 by 12		18.620 (473)
16 by 14		18.880 (479)

[A] For straight taper joint, only.

NOTE 1—For tapered socket dimensions, see Fig. A6.2 and note 1, Fig. A6.2.
NOTE 2—Fiberglass fittings and pipe can be connected by flanges or mechanical couplings, or both (that is, grooved or compression type).

FIG. A6.11 Taper Body Reducer: (A) Taper by Taper and Plain end; (B) Straight-Taper and Straight by Straight



NPS	Bushing Length, min, U, in. (mm)
1½ by 1	1.125 (29)
2 by 1	1.375 (35)
2 by 1½	1.375 (35)
3 by 2	1.880 (41)
4 by 3	1.960 (67)
6 by 4	2.250 (57)
8 by 6	2.750 (70)
10 by 8	3.750 (95)
12 by 10	4.250 (108)
14 by 12	5.250 (133)
16 by 14	5.750 (146)

NOTE 1—For tapered socket dimensions, see Fig A6.2 and note 1, Fig. A6.2. For external taper, see note 1, Fig. A6.2 (reference spigot design).

FIG. A6.12 Concentric Reducer Bushing: Taper-to-Taper

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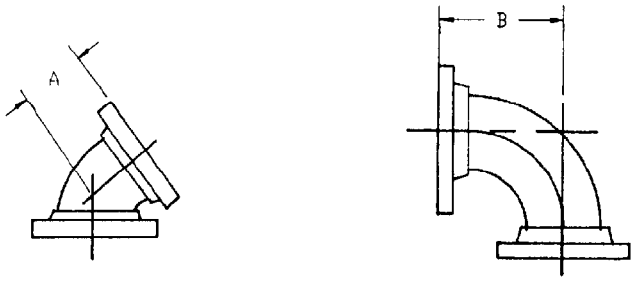
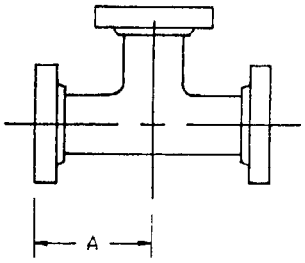


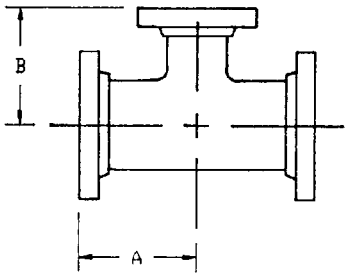
NPS	A, min, in. (mm)	B, min, in. (mm)
18	17.250 (438)	27.000 (432)
20	19.000 (483)	30.000 (762)
22	20.875 (530)	33.750 (857)
24	22.750 (578)	36.000 (914)
26	24.500 (622)	39.750 (1010)
28	26.375 (670)	42.750 (1086)
30	26.500 (673)	45.000 (1143)
32	30.000 (762)	48.750 (1238)
34	31.875 (810)	51.750 (1314)
36	29.000 (737)	54.000 (1372)

FIG. A6.13 (A) 45 Degree Flanged Elbow (B) 90 Degree Flanged Elbow



NPS	Center to Contact Surface "A", min, in. (mm)
18	22.500 (572)
20	24.750 (629)
22	27.000 (686)
24	29.250 (743)
26	31.500 (800)
28	33.750 (857)
30	35.500 (902)
32	38.250 (972)
34	40.500 (1029)
36	40.500 (1029)

FIG. A6.14 Tee Flanged



NPS	Center to Contact Surface		NPS	Center to Contact Surface	
	Main, A, min. in. (mm)	Branch, B, min, in. (mm)		Main A, min, in. (mm)	Branch, B, min, in. (mm)
18 by 18 by 8	22.500 (572)	17.026 (389)	28 by 28 by 22	33.750 (857)	30.000 (762)
10	22.500 (572)	18.026 (465)	24	33.750 (857)	31.250 (794)
12	22.500 (572)	18.067 (478)	26	33.750 (857)	32.500 (826)
14	22.500 (572)	20.005 (510)	30 by 30 by 18	35.500 (902)	28.500 (724)
16	22.500 (572)	21.005 (535)	20	35.500 (902)	29.750 (756)
20 by 20 by 10	24.750 (629)	19.026 (491)	22	36.000 (914)	31.000 (787)
12	24.750 (629)	19.067 (503)	24	35.500 (902)	32.250 (819)
14	24.750 (629)	21.005 (510)	26	36.000 (914)	33.500 (851)
16	24.750 (629)	22.005 (560)	28	36.000 (914)	34.750 (883)
18	24.750 (629)	23.500 (597)	32 by 32 by 20	38.250 (972)	30.750 (781)
24 by 24 by 12	29.250 (743)	22.026 (567)	22	38.250 (972)	32.000 (813)
14	29.250 (743)	23.005 (586)	24	38.250 (972)	33.250 (845)
16	29.250 (743)	24.005 (611)	26	38.250 (972)	34.500 (876)
18	29.250 (743)	25.500 (648)	28	38.250 (972)	35.750 (908)
20	29.250 (743)	25.500 (648)	34 by 34 by 22	40.500 (1029)	33.000 (838)
22	29.250 (743)	26.750 (679)	24	40.500 (1029)	34.250 (870)
26 by 26 by 14	31.500 (800)	24.000 (610)	26	40.500 (1029)	35.500 (902)
16	31.500 (800)	25.000 (635)	28	40.500 (1029)	36.750 (933)
18	31.500 (800)	26.500 (673)	30	40.500 (1029)	38.000 (965)
20	31.500 (800)	27.750 (705)	32	40.500 (1029)	39.250 (997)
22	31.500 (800)	29.000 (737)	36 by 36 by 24	40.500 (1029)	35.250 (895)
24	31.500 (800)	30.250 (768)	26	42.750 (1086)	36.500 (927)
28 by 28 by 16	33.750 (857)	26.000 (660)	28	42.750 (1086)	37.750 (959)
18	33.750 (857)	27.500 (699)	30	40.500 (1029)	39.000 (991)
20	33.750 (857)	28.750 (730)	32	42.750 (1086)	40.250 (1022)

FIG. A6.15 Reducer Tee Flanged

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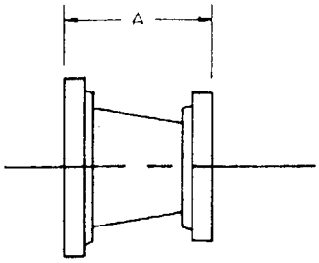

NPS	Center to Contact Surface "A", min, in. (mm)
18 by 14	19.000 (483)
16	19.000 (483)
20 by 16	20.000 (508)
18	20.000 (508)
22 by 18	22.000 (559)
20	22.000 (559)
24 by 20	24.000 (610)
22	24.000 (610)
26 by 22	26.000 (660)
24	26.000 (660)
28 by 24	28.000 (711)
26	28.000 (711)
30 by 26	30.000 (762)
28	30.000 (762)
32 by 28	32.000 (813)
30	32.000 (813)
34 by 30	34.000 (864)
32	34.000 (864)
36 by 30	35.000 (889)
32	36.000 (914)

FIG. A6.16 Reducer Flanged

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American Water Works Association
6666 W. Quincy Ave., Denver, CO 80235 (303) 794-7711

Erratum to ANSI/AWWA C110/A21.10-98 Standard for Ductile-Iron and Gray-Iron Fittings, 3 In. Through 48 In. (76mm Through 1,219 mm) For Water

(October 1999)

Correction to figure and table:

P.9, Fig. 1, The arrow head for the "F" dimension needs to be raised so that it touches the dimension line extending between the minimum internal diameters of the gland and the ball socket. (See following Figure)

P.10, Table 1, Bolt lengths for the 42- and 48-inch sizes should read 6½ inches not 6 inches. (See following Table)

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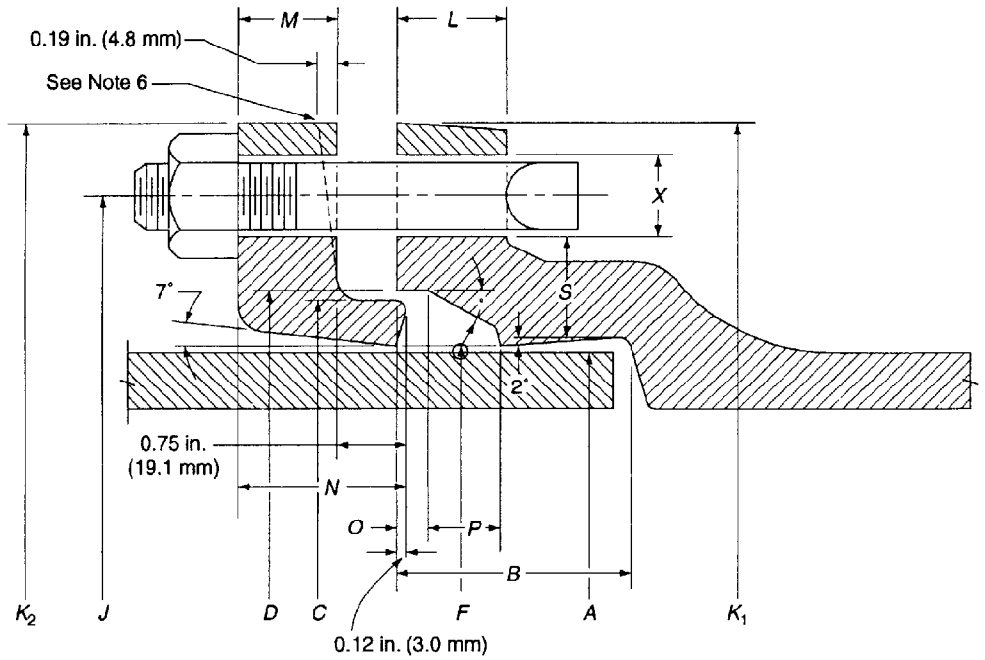

NOTES:

1. The nominal thickness *S* shall not be less than the nominal thickness of the fitting of which it is a part.
2. The diameter of cored holes may be tapered an additional 0.06 in. (1.5 mm).
3. Dimension *A* in Table 1 is the outside diameter of the plain end of the fitting.
4. In the event of an ovalness to the outside diameter of the plain end, the mean diameter measured by a circumferential tape shall not be less than the minimum diameter shown in Table 1. The minor axis shall not be less than the foregoing minimum diameter plus an additional minus tolerance of 0.04 in. (1.0 mm) for sizes 8–12 in. (203–305 mm), 0.07 in. (1.8 mm) for sizes 14–24 in. (356–610 mm), and 0.10 in. (2.5 mm) for sizes 30–48 in. (762–1,219 mm).
5. K_1 and K_2 are the dimensions across the centerline of the bolt holes. The gray-iron gland and bell flange may be round or polygon in shape for all sizes or square for 3-in. (76-mm) and 4-in. (100-mm) sizes. Ductile-iron glands may be other shapes as long as the gland meets the performance requirements specified in Sec. 4.5, ANSI/AWWA C111/A21.11.
6. Gland thickness *M* for sizes 14–48 in. (356–1,219 mm) may be tapered as shown, at the option of the manufacturer.
7. For ductile-iron glands, the gland thickness *M* listed above is not applicable. Designs incorporating reduced metal-section thicknesses are permitted provided tests with these glands meet the performance requirements of Sec. 4.5, ANSI/AWWA C111/A21.11. Conformance with *N* dimensions shown in Table 1 is required at the bolt holes for all glands, gray iron or ductile iron, to ensure interchangeability of joint parts.

Figure 1 Mechanical-joint dimensions for sizes 3 to 48 in. (76 to 1,219 mm) (see Table 1)

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STD.AWWA C110/A21.10-ENGL 1998 ■ 0783350 0509679 468 ■

Table 1 Mechanical-joint dimensions—in.*

Size	A Plain End	B	C	D	F	φ	X +0.06 −0.00	J ±0.06	K_1	K_2	L	M‡	N	O	P	S	Bolts† No.	Bolts† Size	Bolts† Length
3	3.96±0.06	2.50	4.84±0.04	4.94+0.06 −0.04	4.06+0.07 −0.03	28°	¾	6.19	7.69+0.24 −0.12	7.69+0.24 −0.12	0.94+0.13 −0.60	0.62 −0.06	1.37 −0.06	0.31	0.63	0.52 −0.10	4	⅝	3
4	4.80±0.06	2.50	5.92±0.40	6.02+0.06 −0.04	4.90+0.07 −0.03	28°	⅞	7.50	9.12+0.24 −0.12	9.12+0.24 −0.12	1.00+0.13 −0.06	0.75 −0.06	1.50 −0.06	0.31	0.75	0.65 −0.10	4	¾	3½
6	6.90±0.06	2.50	8.02±0.04	8.12+0.06 −0.04	7.00+0.07 −0.03	28°	⅞	9.50	11.12+0.24 −0.12	11.12+0.24 −0.12	1.06+0.13 −0.06	0.88 −0.06	1.63 −0.06	0.31	0.75	0.70 −0.10	6	¾	3½
8	9.05±0.06	2.50	10.17±0.04	10.27+0.06 −0.04	9.15+0.07 −0.03	28°	⅞	11.75	13.37+0.24 −0.12	13.37+0.24 −0.12	1.12+0.13 −0.08	1.00 −0.08	1.75 −0.80	0.31	0.75	0.75 −0.12	6	¾	4
10	11.10±0.06	2.50	12.22+0.06 −0.04	12.34+0.06 −0.04	11.20+0.07 −0.03	28°	⅞	14.00	15.69+0.24 −0.12	15.62+0.24 −0.12	1.19+0.13 −0.08	1.00 −0.08	1.75 −0.08	0.31	0.75	0.80 −0.12	8	¾	4
12	13.20±0.06	2.50	14.32+0.06 −0.04	14.44+0.06 −0.04	13.30+0.07 −0.03	28°	⅞	16.25	17.94+0.24 −0.12	17.88+0.24 −0.12	1.25+0.13 −0.08	1.00 −0.08	1.75 −0.08	0.31	0.75	0.85 −0.12	8	¾	4
14	15.30+0.05 −0.08	3.50	16.40+0.07 −0.05	16.54+0.07 −0.05	15.44+0.06 −0.07	28°	⅞	18.75	20.31+0.30 −0.12	20.25+0.30 −0.12	1.31+0.19 −0.12	1.25 −0.12	2.00 −0.12	0.31	0.75	0.89 −0.12	10	¾	4½
16	17.40+0.05 −0.08	3.50	18.50+0.07 −0.05	18.64+0.07 −0.05	17.54+0.06 −0.07	28°	⅞	21.00	22.56+0.30 −0.12	22.50+0.30 −0.12	1.38+0.19 −0.12	1.31 −0.12	2.06 −0.12	0.31	0.75	0.97 −0.12	12	¾	4½
18	19.50+0.05 −0.08	3.50	20.60+0.07 −0.05	20.74+0.07 −0.05	19.64+0.06 −0.07	28°	⅞	23.25	24.83+0.30 −0.15	24.75+0.30 −0.15	1.44+0.19 −0.12	1.38 −0.12	2.13 −0.12	0.31	0.75	1.05 −0.15	12	¾	4½
20	21.60+0.05 −0.08	3.50	22.70+0.07 −0.05	22.84+0.07 −0.05	21.74+0.06 −0.07	28°	⅞	25.50	27.08+0.30 −0.15	27.00+0.30 −0.15	1.50+0.19 −0.12	1.44 −0.12	2.19 −0.12	0.31	0.75	1.12 −0.15	14	¾	4½
24	25.80+0.05 −0.08	3.50	26.90+0.07 −0.05	27.04+0.07 −0.05	25.94+0.06 −0.07	28°	⅞	30.00	31.58+0.30 −0.15	31.50+0.30 −0.15	1.62+0.19 −0.12	1.56 −0.12	2.31 −0.12	0.31	0.75	1.22 −0.15	16	¾	5
30	32.00+0.08 −0.06	4.00	33.29+0.08 −0.06	33.46+0.08 −0.06	32.17+0.08 −0.06	20°	1⅛	36.88	39.12+1.00 −0.18	39.12+0.36 −0.18	1.81+0.25 −0.12	2.00 −0.12	2.75 −0.12	0.38	1.00	1.50 −0.15	20	1	6
36	38.30+0.08 −0.06	4.00	39.59+0.08 −0.06	39.76+0.08 −0.06	38.47+0.08 −0.06	20°	1⅛	43.75	46.00+1.00 −0.18	46.00+0.36 −0.18	2.00+0.25 −0.12	2.00 −0.12	2.75 −0.12	0.38	1.00	1.80 −0.15	24	1	6
42	44.50+0.08 −0.06	4.00	45.79+0.08 −0.06	45.96+0.08 −0.06	44.67+0.08 −0.06	20°	1⅜	50.62	53.12+1.00 −0.18	53.12+0.36 −0.18	2.00+0.25 −0.12	2.00 −0.12	2.75 −0.12	0.38	1.00	1.95 −0.15	28	1¼	6½
48	50.80+0.08 −0.06	4.00	52.09+0.08 −0.06	52.26+0.08 −0.06	50.97+0.08 −0.06	20°	1⅜	57.50	60.00+1.00 −0.18	60.00+0.36 −0.18	2.00+0.25 −0.12	2.00 −0.12	2.75 −0.12	0.38	1.00	2.20 −0.15	32	1¼	6½

*Dimension details of bell are shown in Figure 1.

†Bolt lengths shown for the 8-in. through 16-in. sizes are ½ in. longer than ANSI/AWWA C153/A21.53-88 bolts for use with ANSI/AWWA C153/A21.53 fittings for these sizes. These longer ANSI/AWWA C111/A21.11 bolts, shown in the table above, may also be furnished with compact fittings in sizes 8–16 in. with the bolt thread length as shown in Figure 3 and Figure 4 of ANSI/AWWA C111/A21.11.

‡For ductile-iron glands, the flange thickness *M* listed above is not applicable. Designs incorporating reduced metal-section thicknesses are permitted provided tests with these glands meet the performance requirements of Sec. 4.5 of ANSI/AWWA C111/A21.11. Conformance with *N* dimensions shown in Table 1 is required for all glands, gray iron or ductile iron, to ensure interchangeability of joint parts.

NOTE: Metric conversions: Dimension: in. × 25.4 = mm.

STD.AWWA C110/A21.10-ENGL 1998 ■ 0783350 0506077 428 ■

American Water Works Association
ANSI/AWWA C110/A21.10-98
(Revision of ANSI/AWWA C110/A21.10-93)

AMERICAN NATIONAL STANDARD

FOR

DUCTILE-IRON AND GRAY-IRON FITTINGS, 3 IN. THROUGH 48 IN. (76 mm THROUGH 1,219 mm), FOR WATER

AMERICAN NATIONAL STANDARD

Administrative Secretariat
AMERICAN WATER WORKS ASSOCIATION

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AMERICAN WATER WORKS ASSOCIATION

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Foreword

This foreword is for information only and is not a part of ANSI/AWWA C110/A21.10.

I. Introduction.

I.A. *Background.* American National Standards Committee A21 on Cast-Iron Pipe and Fittings was organized in 1926 under the sponsorship of the American Gas Association (A.G.A.), the American Society for Testing and Materials (ASTM), the American Water Works Association (AWWA), and the New England Water Works Association (NEWWA). Between 1972 and 1984, the cosecretariats were A.G.A., AWWA, and NEWWA, with AWWA serving as administrative secretariat. In 1984, the committee became an AWWA committee with the name AWWA Standards Committee A21 on Ductile Iron Pipe and Fittings. In 1988, NEWWA withdrew as a separate secretariat; however, it continues to maintain its representation on the A21 Committee. In 1997, A.G.A. withdrew as cosecretariat.

The present scope of Committee A21 activity is the preparation of standards for cast-iron and ductile-iron pressure pipe for gas, water, and other liquids, and fittings for use with such pipe. These standards include design, dimensions, materials, coatings, linings, joints, accessories, and methods of inspection and testing.

The work of Committee A21 is conducted by subcommittees. The scope of Subcommittee 3, Fittings, includes the periodic review of all current A21 standards for fittings and the preparation of revisions and new standards, when needed, for fittings to be used with cast-iron and ductile-iron pressure pipe included in A21 standards.

I.B. *History.* The evolution of AWWA and ANSI standards for fittings is presented in this foreword to provide information relating to systems having aged cast-iron pipe and fittings still in service.

The earliest record of an AWWA standard for cast-iron pipe is contained in the *Report of Proceedings of the Tenth Annual Meeting of the American Water Works Association* (1890). In 1902, NEWWA adopted a more detailed standard titled "Standard Specification for Cast Iron Pipe and Special Castings."

The next AWWA standard for pipe and fittings, AWWA 7C.1-1908, was approved May 12, 1908. A second edition, AWWA C100-52T, was approved by AWWA Dec. 31, 1952, and by NEWWA Jan. 23, 1953. The third edition, AWWA C100-54T, was approved by AWWA Oct. 25, 1954, and finally issued as AWWA C100-55, having been advanced from tentative to standard without change June 17, 1955. AWWA C100-55 covered fittings in the size range 4 to 60 in. (102 to 1,500 mm).* The fittings were all bell and spigot (caulked joint) of the so-called long-radius design. The outside diameter (OD) for spigots varied with wall thicknesses, which were designated classes A, B, C, and D. Fittings 4 to 12 in. (102 to 305 mm) were made to class D patterns, having only one OD and pressure rating. Fittings 14 to 24 in. (356 to 610 mm) in size were furnished in classes B and D, and fittings 30 to 60 in. (762 to 1,500 mm) in size were furnished in classes A, B, C, and D. All fittings made in accordance with AWWA 7C.1-1908 and C100-55 had the class identification cast on the fitting.

*Metric conversions given in this standard are direct conversions of US customary units and are not those specified in the International Organization for Standardization (ISO) standards.

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ASA* A21.10-1952 (AWWA C110-52) was approved by ASA Sept. 30, 1952, following approval by AWWA May 4, 1951. The standard covered 3- to 12-in. (76- to 305-mm) fittings of the so-called short-body design, which were the subject of extensive research and tests by Committee A21. The rated pressure given by the standard was 250 psi (1,724 kPa) plus water hammer. The standard provided a safety factor of 2.5 plus water hammer based on burst tests. Hydraulic losses were determined and compared with those found with long-radius fittings manufactured in accordance with AWWA Standards. The minimum grade of cast iron in the standard was 25,000 psi (172.4 MPa) tensile strength.

ASA A21.10-1964 (AWWA C110-64) was approved by ASA Jan. 9, 1964. The revision covered 2- to 48-in. (50- to 1,219-mm) fittings. The design of the 14- to 48-in. (356- to 1,219-mm) fittings in the revision was based on an exhaustive series of burst tests. The minimum grade of cast iron (25,000 psi [172.4 MPa] tensile strength) was retained, and higher grades up to 35,000 psi (241.3 MPa) tensile strength were used to secure higher pressure ratings without radically changing the thicknesses. Ductile iron, grade 80-60-03, was also added in the 14- to 48-in. (356- to 1,219-mm) sizes with a rated working pressure of 250 psi (1,724 kPa), having the same wall thicknesses as 150-psi (1,034-kPa)-rated gray-iron fittings. The minimum safety factor based on burst tests of representative fittings of the weakest type was three times the rated working pressure. Tables for flanged fittings and mechanical-joint fittings were added for the first time.

ANSI A21.10-1971 (AWWA C110-71) was approved by ANSI July 14, 1971. Ductile-iron fittings were added in sizes 3 to 12 in. (76 to 305 mm) and were rated for 350 psi (2,413 kPa) working pressure. The grade of ductile iron was changed to 70-50-05 to provide greater toughness. The safety factor against bursting was three times the rated working pressure. If required by the purchaser on special order, fittings were required to withstand a hydrostatic proof test not to exceed one and one half times the rated working pressure without leaks or permanent distortions.

ANSI A21.10a-1972 (AWWA C110a-72) was approved Dec. 17, 1972, as a supplement to ANSI A21.10-1971. The pressure rating for 14- to 24-in. (356- to 610-mm) ductile-iron fittings was increased to 350 psi (2,413 kPa).

ANSI/AWWA C110-77 (ANSI A21.10) was approved by ANSI Apr. 7, 1977. The major change in this revision was the discontinuance of bell-and-spigot fittings (caulked joints) and 2- and 2¼-in. (50- and 56-mm) fittings in the standard. These actions were taken because the use of caulked joints had steadily declined until their use had become a rarity and the 2- and 2¼-in. (50- and 56-mm) sizes were no longer manufactured in the United States. (Bell-and-spigot fittings are still available from some foundries on special order.) With the elimination of 2- and 2¼-in. (50- and 56-mm) sizes, the standard included 3- to 48-in. (76- to 1,219-mm) mechanical-joint and flanged fittings only.

Another change made in the 1977 edition was in bolt lengths for flanged fittings to comply with ANSI/AWWA C115/A21.15-75, Standard for Flanged Cast-Iron and Ductile-Iron Pipe With Threaded Flanges. Appendix A was added to the standard to cover bolts, gaskets, and the installation of flanged fittings. Appendix B was added as a listing of available special fittings that are not a part of the standard. These include

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reducing bends, Y-branches, blind flanges, reducing tees, bullhead tees, flared fittings, side-outlet tees and elbows, and wall pipe.

The following note introduced in the 1977 edition cautioned about using mechanical-joint fittings with aged existing cast-iron pipe:

NOTE: Care should be used when connecting mechanical-joint fittings to aged existing cast-iron pipe. The outside diameter of aged pipe should be measured prior to cutting since some of the older pipe was manufactured to a larger diameter than is presently specified in A21 standards. Mechanical-joint sleeves or bell-and-spigot (caulked-joint) sleeves are available to provide transition from existing cast-iron pipe; however, they must be specified on the purchase order. Center to bottom-of-socket dimensions (dimension *A* in Table 3 and dimension *J* in Table 4 of this standard) for A21.10 mechanical-joint fittings are the same as the center to bottom-of-socket dimensions for bell-and-spigot (caulked-joint) fittings specified in the 1971 and previous editions of A21.10. The following standards contain reference dimensions useful in classifying existing cast-iron pipe:

AWWA 7C.1-1908 (AWWA C100-55), Standard Specifications for Cast Iron Pressure Fittings, Table 1.

ASA A21.2-1953 (AWWA C102-53), American Standard for Cast Iron Pit Cast Pipe for Water or Other Liquids, Tables 2.1 and 2.2.

ANSI A21.6-1975 (AWWA C106-75), American National Standard for Cast-Iron Pipe Centrifugally Cast in Metal Molds for Water or Other Liquids, Tables 6.4, 6.5, and 6.6.

ANSI A21.8-1975 (AWWA C108-75), American National Standard for Cast Iron Pipe Centrifugally Cast in Sand-Lined Molds for Water or Other Liquids, Tables 8.4, 8.5, and 8.6.

ANSI/AWWA C151/A21.51-86, American National Standard for Ductile Iron Pipe Centrifugally Cast in Metal Molds or Sand-Lined Molds for Water or Other Liquids, Tables 51.4 and 51.5.

ANSI/AWWA C110/A21.10-82, as approved by ANSI Aug. 24, 1982, introduced no major revisions.

ANSI/AWWA C153/A21.53-84 (First Edition), American National Standard for Ductile-Iron Compact Fittings, 3 In. through 12 In. (76 mm through 305 mm), for Water and Other Liquids, was approved by ANSI Feb. 4, 1985. This standard, developed by Standards Committee A21, Subcommittee 3, Fittings, presents compact fittings designed to use the attendant strength of ductile iron.

ANSI/AWWA C110/A21.10-87 was approved by ANSI Oct. 30, 1987. The major revisions included new sections on rejection of fittings and determination of rejection, and ductile-iron grade 60-42-10 was added. Cast marking of the country where cast was added; Sec. 10-4.3, Joint Accessories, was added; and 14-in. through 48-in. (356-mm through 1,219-mm) solid sleeves made with B-pattern equipment were added.

ANSI/AWWA C110/A21.10-93 was approved by ANSI Aug. 10, 1993. Major revisions in this edition of the standard included the addition of a section on health effects and permeation, allowance for reduced metal-section thicknesses for ductile-iron glands, addition of a precautionary note on the use of flange gaskets thinner than ⅛ in. (3.2 mm) in appendix A, addition of flanged-joint bolt tightening sequence to appendix A, and the addition of a section on ring gaskets in appendix A.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF) to develop voluntary third-party consensus standards and a certification program for all direct and indirect drinking water additives. Other

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members of the original consortium included the American Water Works Association Research Foundation (AWWARF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.* Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.
2. Specific policies of the state or local agency.
3. Two standards developed under the direction of NSF, ANSI†/NSF‡ 60, Drinking Water Treatment Chemicals—Health Effects, and ANSI/NSF 61, Drinking Water System Components—Health Effects.
4. Other references, including AWWA standards, *Food Chemicals Codex*, *Water Chemicals Codex*,§ and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with ANSI/NSF 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Appendix A, "Toxicology Review and Evaluation Procedures," to ANSI/NSF 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Appendix A procedures may not always be identical, depending on the certifier.

ANSI/AWWA C110/A21.10 does not address additives requirements. Thus, users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.
2. Determine the status of certifications by all parties offering to certify products for contact with, or treatment of, drinking water.
3. Determine current information on product certification.

II. Special Issues.

II.A. *Advisory Information on Product Application.* Unless otherwise provided in the purchaser's specifications, all fittings and accessories shall comply with this standard. Fittings and accessories not complying with this standard shall be replaced by the manufacturer at the agreed point of delivery. The manufacturer shall not be liable for shortages or damaged fittings after the fitting is accepted at the agreed

*Persons in Canada, Mexico, and non-North American countries should contact the appropriate authority having jurisdiction.

†American National Standards Institute, 11 W. 42nd St., New York, NY 10036.

‡NSF International, 3475 Plymouth Rd., Ann Arbor, MI 48106.

§Both publications available from National Academy of Sciences, 2102 Constitution Ave. N.W., Washington, DC 20418.

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point of delivery, except as recorded on the delivery receipt or similar document by the carrier's agent.

III. Use of This Standard.

AWWA has no responsibility for the suitability or compatibility of the provisions of this standard to any intended application by any user. Accordingly, each user of this standard is responsible for determining that the standard's provisions are suitable for and compatible with that user's intended application.

III.A. *Purchaser Options and Alternatives.* This standard includes certain options that, if desired, must be specified in the purchaser's specifications. It is also necessary that such options be included on the purchase order. Also, a number of items must be specified to describe completely the fittings required. The following list summarizes the details and available options, and references the sections of the standard where they are found.

1. Size, joint type, pressure rating (Sec. 1.1 and tables).
2. Joint requirements (Sec. 4.2.1 and 4.2.2).
3. Type of iron (Sec. 4.2.4).
4. End combinations (Sec. 4.2.5).
5. Certification by manufacturer (Sec. 5.1.3).
6. Inspection by purchaser (Sec. 5.2).
7. Elimination of cement-mortar lining (Sec. 4.3.2). Experience has indicated that the petroleum asphaltic inside coating is not complete protection against loss in pipe capacity caused by tuberculation. Cement-mortar linings are recommended for most waters.
8. Special coatings and linings (Sec. 4.3.3).
9. Acceptance tests (Sec. 5.4).
10. Special tests (Sec. 5.6).
11. Special flange bolt-hole orientation (Sec. 4.4.3).

III.B. *Special Service Requirements.* The following special service requirements should be noted:

1. The fittings for which this standard is intended are those normally used for water. Fittings for other services may require special consideration by the purchaser.
2. The method of installation of fittings depends on the type of joint and should be made in accordance with applicable parts of ANSI/AWWA C111/A21.11, Rubber-Gasket Joints for Ductile-Iron and Gray-Iron Pressure Pipe and Fittings; ANSI/AWWA C600, Installation of Ductile-Iron Water Mains and Their Appurtenances; and recommendations of manufacturers regarding their product.
3. Attention is directed to an apparent conflict between this standard and ASME/ANSI B16.1, Cast Iron Pipe Flanges and Flanged Fittings, with regard to pressure ratings for flanged fittings.

In ANSI/AWWA C110/A21.10, flanged joint fittings are rated for 150 or 250 psi (1,034 or 1,724 kPa) working pressure, depending on the material, that is, gray iron or ductile iron; the wall thickness of gray iron; and the size of the fitting. The ratings of these fittings were established on the basis of hydrostatic testing of fittings to bursting and provide for a factor of safety of at least 3.0 at the rated working pressure and at ambient temperature. ANSI/AWWA C110/A21.10 flanges that are adequate for water service of 250 psi (1,724 kPa) working pressure have facing and drilling identical to ASME/ANSI B16.1 class 125 flanges, and match class 125 B16.1 flanges, that for service at –20° to 150°F (–28.9° to 65.6°C) are rated for only 150 to 200 psi (1,034 to 1,724 kPa), depending on the flange size and the class or grade of iron.

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ASME/ANSI B16.1 covers both separate flanges and flanged fittings of gray iron for service at both ambient and elevated temperatures. The pressure-temperature ratings of these flanges, as set forth in ASME/ANSI B16.1 and stated on the flyleaf of that standard, are not based on burst strength, but have evolved over an extended period of time of satisfactory performance in a wide range of general service conditions. These ratings encompass pressure combined with elevated temperature, stresses imposed by piping, thermal stresses due to temperature variations, and many other conditions causing stress in the flange or fitting.

ASME/ANSI B16.1 also contains the design of a class 250 flange, which is much heavier, has a larger bolt circle, and uses larger-sized bolts than the B16.1 class 125 flange and the flanges covered in ANSI/AWWA C115/A21.15 and this standard. ASME/ANSI B16.1 class 250 flanges will not connect to the B16.1 class 125 flange, the ANSI/AWWA C115/A21.15 flange, or the ANSI/AWWA C110/A21.10 flange.

4. Although this standard does not detail the orientation of bolt holes in the flanges of the mechanical joint, it is at times convenient or necessary to have the bolt holes specially oriented. The normal but not universal practice is to have the bolt holes straddle the vertical centerline of the fittings, valves, and hydrants. (The vertical centerline of a fitting is determined when the fitting is in the position to change the direction of fluid flowing in a horizontal plane. With standard base bends and standard base tees, the vertical centerline is determined when the fitting is in a position to change the fluid flowing in a vertical plane.) If special orientation is known to be necessary, it should be stated on the purchase order.

III.C. *Modification to Standard.* Any modification to the provisions, definitions, or terminology in this standard must be provided in the purchaser's specifications.

IV. Major Revisions. The major revisions made to this standard in this edition are as follows:

1. The format has been changed to AWWA standard style.
2. Section I.A, Background, was revised to recognize the withdrawal of the American Gas Association as cosecretariat of the A21 Committee.
3. The acceptance clause (Sec. I.C) has been revised to approved wording.
4. The advisory information paragraph (Sec. II.A) was revised and moved from the body of the standard into the foreword.
5. The scope of the standard has been limited to water service and all references to gas and other liquids have been eliminated.
6. The scope was amended to recognize 350-psi (2,413-kPa) ratings for 12-in. (305-mm) and smaller flanged ductile-iron fittings when used with special gaskets.
7. Cement-mortar linings (Sec. 4.3.2) was revised to reflect the optional status of seal coat in the latest revision of ANSI/AWWA C104/A21.4.
8. Special coatings and linings (Sec. 4.3.3) was revised to include asphaltic material as a special lining.
9. Table 1 was revised in accordance with the 1995 revision of ANSI/AWWA C111/A21.11. Revisions include plus tolerances on the K_1, K_2, and L dimensions; longer bolt lengths for the 42- and 48-in. (1,067- and 1,219-mm) sizes; and the footnote on ductile-iron glands.
10. Tables 16 through 19 on flanged fittings were revised to show the use of ductile iron for 3- to 12-in. (76- to 305-mm) flanged fittings with the same dimensions as gray-iron fittings. Explanatory footnotes were also added.
11. The gaskets section of appendix A was revised to describe the rubber material as being synthetic.

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V. Comments. If you have any comments or questions about this standard, please call the AWWA Volunteer and Technical Support Group, (303) 794-7711 ext. 6283, FAX (303) 795-1440, or write to the department at 6666 W. Quincy Ave., Denver, CO 80235.

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American Water Works Association

ANSI/AWWA C110/A21.10-98
(Revision of ANSI/AWWA C110/A21.10-93)

AMERICAN NATIONAL STANDARD FOR

DUCTILE-IRON AND GRAY-IRON FITTINGS, 3 IN. THROUGH 48 IN. (76 mm THROUGH 1,219 mm), FOR WATER

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard covers 3- to 48-in. (76- to 1,219-mm) gray-iron and/or ductile-iron fittings to be used with ductile-iron pipe for water. Requirements for fittings with mechanical joints and flanged joints are listed in Tables 1 through 20 at the end of this standard. This standard may also be used for fittings with push-on joints or such other joints as may be agreed on at the time of purchase.

For the 3- to 24-in. (76- to 610-mm) size range, ductile-iron mechanical-joint fittings and ductile-iron push-on-joint fittings are rated for 350 psi (2,413 kPa) working pressure. Ductile-iron flange-joint fittings are rated for 250-psi (1,724-kPa) working pressure; however, 12-in. (305-mm) and smaller sizes may be rated for 350 psi (2,413 kPa) with the use of special gaskets. Gray-iron fittings having all types of joints covered by this standard are rated for 150- or 250-psi (1,034- or 1,724-kPa) working pressures, as shown in the tables.

For the 30- to 48-in. (762- to 1,219-mm) size range, fittings with all types of joints covered by this standard are shown in the tables with rated working pressures of 150 or 250 psi (1,034 or 1,724 kPa), depending on the type of iron as shown in the tables.

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Sec. 1.2 Purpose

The main purpose of this standard is to provide the minimum requirements for ductile-iron and gray-iron fittings, 3 in. through 48 in. (76 mm through 1,219 mm), for water.

Sec. 1.3 Application

This standard can be referenced in specifications for ductile-iron and gray-iron fittings, 3 in. through 48 in. (76 mm through 1,219 mm), for water. The stipulations of this standard apply when this document has been referenced and then only to ductile-iron and gray-iron fittings, 3 in. through 48 in. (76 mm through 1,219 mm), for water.

SECTION 2: DEFINITIONS

The following definitions shall apply in this standard:

1. *Ductile iron:* A cast ferrous material in which a major part of the carbon content occurs as free graphite in a substantially nodular or spheroidal form.
2. *Flange joint:* The flanged and bolted joint as detailed in Figure 14 and Table 14.
3. *Gray iron:* The cast ferrous material in which a major part of the carbon content occurs as free graphite in the form of flakes interspersed throughout the metal.
4. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.
5. *Mechanical joint:* The gasketed and bolted joint as detailed in the latest revision of ANSI/AWWA C111/A21.11.
6. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.
7. *Push-on joint:* The single rubber-gasket joint as set forth in the latest revision of ANSI/AWWA C111/A21.11.

SECTION 3: REFERENCES

This standard references the following documents. In their latest editions, they form a part of this standard to the extent specified within the standard. In any case of conflict, the requirements of this standard shall prevail.

ASME*/ANSI† B16.1—Cast Iron Pipe Flanges and Flanged Fittings.

ASTM‡ A48—Standard Specification for Gray Iron Casting.

*American Society of Mechanical Engineers, United Engineering Center, 345 E. 47th St., New York, NY 10017.

†American National Standards Institute, 11 W. 42nd St., New York, NY 10036.

‡American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

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ASTM A438—Standard Test Method for Transverse Testing of Gray Cast Iron.

ASTM A536—Standard Specification for Ductile Iron Castings.

ANSI/AWWA C104/A21.4—American National Standard for Cement-Mortar Lining for Ductile-Iron Pressure Pipe and Fittings for Water.

ANSI/AWWA C111/A21.11—American National Standard for Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings.

ANSI/AWWA C153/A21.53—American National Standard for Ductile-Iron Compact Fittings, 3 In. Through 24 In. (76 mm Through 610 mm) and 54 In. Through 64 In. (1,400 mm Through 1,600 mm), for Water Service.

ANSI/AWWA C600—Standard for Installation of Ductile-Iron Water Mains and Their Appurtenances.

SECTION 4: REQUIREMENTS

Sec. 4.1 Permeation

The selection of materials is critical for water service and distribution piping in locations where there is likelihood the pipe will be exposed to significant concentrations of pollutants composed of low molecular weight petroleum products or organic solvents or their vapors. Research has documented that pipe materials such as polyethylene, polybutylene, polyvinyl chloride, and asbestos cement, and elastomers, such as used in jointing gaskets and packing glands, may be subject to permeation by lower molecular weight organic solvents or petroleum products. If a water pipe must pass through such a contaminated area or an area subject to contamination, consult with the manufacturer regarding permeation of pipe walls, jointing materials, and so forth, *before* selecting materials for use in that area.

Sec. 4.2 General Requirements

4.2.1 *Mechanical joint and flange joint.* Fittings with mechanical joints and flange joints shall conform to the dimensions and weights shown in the tables in this standard unless otherwise agreed on at the time of purchase. The mechanical joint shall also conform to ANSI/AWWA C111/A21.11. Either ductile-iron or gray-iron glands may be used unless otherwise specified by the purchaser.

Split glands and glands in segments and other variations shall be allowed, provided they meet the performance requirements of ANSI/AWWA C111/A21.11.

4.2.2 *Push-on joint.* Fittings with push-on joints shall have weights and dimensions of the bell, socket, and plain end in accordance with the manufacturer's standard design. The manufacturer shall furnish drawings of the joint and gasket if requested by the purchaser. Performance requirements and special requirements for push-on joints shall conform to the requirements for the push-on joint in ANSI/AWWA C111/A21.11.

4.2.3 *Joint accessories.* Unless otherwise specified by the purchaser, gaskets, glands, bolts, and nuts shall be furnished with mechanical joints; and gaskets and lubricant shall be furnished with push-on joints; all in sufficient quantity for assembly of each joint.

4.2.4 *Type of iron.* Fittings shall be cast from gray iron or ductile iron and have pressure ratings as shown in the tables. When both materials are shown in the tables, either may be furnished at the manufacturer's option unless otherwise

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specified by the purchaser. All fittings shall be capable of withstanding, without bursting, hydrostatic tests of three times the rated water working pressure.

4.2.5 *Other joint designs or dimensions.* Standard fittings shall be furnished with the end combinations shown in the tables. When fittings of other designs or dimensions are purchased under this standard, the purchaser must specify the fitting design. Plain ends of mechanical-joint fittings may be furnished with bevels for assembly with push-on joint bells.

NOTE: Bell fittings without plain ends are most readily available.

Sec. 4.3 Coatings and Linings

4.3.1 *Outside coating.* The outside coating shall be a petroleum asphaltic coating approximately 1 mil (25 μm) thick. The coating shall be applied to the outside of all fittings unless otherwise specified by the purchaser. The finished coating shall be continuous, smooth, neither brittle when cold nor sticky when exposed to the sun, and strongly adherent to the fitting.

4.3.2 *Cement-mortar linings.* The lining for use under normal conditions shall be a cement-mortar lining in accordance with the latest revision of ANSI/AWWA C104/A21.4, unless otherwise specified.* Cement-mortar linings are not normally furnished in sleeves, plugs, or caps.

4.3.3 *Special coatings and linings.* For special conditions, other types of coatings and linings may be available. Special coatings and linings shall be specified by the purchaser. One special lining for fittings that are not cement-mortar lined is an asphaltic material as thick as practicable, at least 1 mil (25 μm), that conforms to all appropriate requirements for seal coat, as described in the latest revision of ANSI/AWWA C104/A21.4.

Sec. 4.4 Special Requirements for Flanged Fittings

4.4.1 *Flanges.* Flanges shall conform to the dimensions shown in Table 14, which are adequate for the pressure ratings given in Sec. 4.2.2 of ANSI/AWWA C111/A21.11.

NOTE: The bolt circle and bolt holes of these flanges match those of ASME/ANSI B16.1 and can be joined with these class 125 flanges. Flanges of ANSI/AWWA C110/A21.10 fittings cannot be joined with class 250 B16.1 flanges.

4.4.2 *Facing.* Flanges shall be flat-faced without projection or raised-face and shall be furnished smooth or with shallow serrations. Flanges may be back-faced or spot-faced for compliance with the flange thickness tolerance set forth in this standard. Bearing surfaces for bolting shall be parallel to the flange face within 3°.

4.4.3 *Bolt holes.* Bolt holes shall be in accordance with the dimensions shown in Table 14. Bolt holes shall be equally spaced and shall straddle the centerlines of the flange as shown in Figure 14.

4.4.3.1. Misalignment of corresponding bolt holes of two opposing flanges shall not exceed 0.12 in. (3.0 mm).

4.4.3.2. If bolt-hole orientation other than provided for in this standard is required by the purchaser, the special orientation shall be specified in the purchaser's specification.

*Experience indicates that the petroleum asphaltic inside coating is not complete protection against loss in pipe capacity caused by tuberculation. Cement-mortar linings are recommended for most waters.

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4.4.4 *Laying-length dimensions.* Face-to-face dimensions shall conform to a tolerance of ±0.06 in. (±1.5 mm) for sizes 3 to 10 in. (76 to 254 mm) and ±0.12 in. (±3.0 mm) for sizes 12 to 48 in. (305 to 1,219 mm). Center-to-face tolerances shall be one half those of face-to-face tolerances. The largest opening shall govern the tolerance for all openings.

SECTION 5: VERIFICATION

Sec. 5.1 Inspection and Certification by Manufacturer

5.1.1 *Quality control and inspection practice.* The manufacturer shall establish the necessary quality control and inspection practice to ensure compliance with this standard. All fittings shall be clean and sound without defects that could impair their service.

5.1.2 *Repairs of defects.* Repairing defects by welding or other methods shall not be allowed if such repairs could adversely affect the serviceability of the fitting or its capability to meet the strength requirements of this standard.

5.1.3 *Certification by manufacturer.* If required by the purchaser, the manufacturer shall furnish a sworn statement that the inspection and all the specified tests have been made and the results thereof comply with the requirements of this standard.

5.1.4 *Manufacturer's records.* The results of the specified tests (Sec. 5.4, 5.5, 5.6, and 5.9 if applicable) shall be recorded and retained for one year and shall be available to the purchaser at the manufacturer's plant.

Sec. 5.2 Inspection by Purchaser

5.2.1 *Purchaser's obligations.* If the purchaser desires to inspect fittings at the manufacturer's plant, it shall be stated in the purchaser's specifications and the conditions described under which the inspection shall be made (such as time and extent of the inspection).

5.2.2 *Manufacturer's obligations.* The purchaser's representative shall have free access to those areas of the manufacturer's plant as are necessary to determine compliance with this standard. The manufacturer shall make available for the use by the purchaser's representative such gauges as are necessary for inspection. The manufacturer shall provide the purchaser's representative with assistance as necessary for the handling of fittings.

Sec. 5.3 Tolerances or Permitted Variations

5.3.1 *Dimensions.* Fittings shall be measured with suitable gauges at sufficiently frequent intervals to ensure that the dimensions comply with the requirements of this standard. The smallest inside diameter (ID) of the sockets and the outside diameter (OD) of the plain ends shall be tested with circular gauges. Other socket dimensions shall be measured as appropriate.

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5.3.2 *Thickness.* Minus tolerances for metal thicknesses, except those shown in Tables 1 and 2, shall not exceed the following:

Fitting Size*	Minus Tolerance	
in.	*in.*	*(mm)*
3–6	0.10	(2.5)
8–20	0.12	(3.0)
24–48	0.15	(3.8)

*Metric conversion for dimension: in. × 25.4 = mm.

An additional tolerance shall be permitted over areas not exceeding 8 in. (200 mm) in any direction as follows: for 3- to 12-in. (76- to 305-mm) fittings, 0.02 in. (0.5 mm); for 14- to 48-in. (356- to 1,219-mm) fittings, 0.03 in. (0.8 mm).

5.3.3 *Weight.* The weight of any fitting shall not be less than the nominal tabulated weight by more than 10 percent for fittings 12 in. (305 mm) or smaller in diameter or by more than 8 percent for fittings larger than 12 in. (305 mm) in diameter. The nominal tabulated weight is the weight of the fitting before the application of any lining or coating other than the standard coatings.

Sec. 5.4 Acceptance Tests

5.4.1 *Physical test—gray-iron fittings.* The standard acceptance test for the physical characteristics of gray-iron fittings shall be one of the following:

1. Transverse test conducted in accordance with ASTM A438.
2. Tensile test conducted in accordance with ASTM A48.
3. Transverse or tensile tests conducted on coupons obtained from a part of the castings' runner-bar system or the casting. The diameter of the runner bar or the thickness of the casting where the test coupon or bar is selected must be similar to that required of ASTM A438 or A48 test bars.

5.4.1.1 Choice of test. Unless specified by the purchaser, selection of the test bar coupon and test method (either the transverse test or tensile test, as the acceptance test) shall be at the option of the manufacturer. The acceptance values for tensile and transverse tests shall be as shown in the following table.

Iron Strength		Fitting Size	Bar Diam.		Span†		Min. Breaking Load		Min. Tensile Strength‡	
psi (1,000s)	*(MPa)*	*in.**	*in.*	*(mm)*	*in.*	*(mm)*	*lb*	*(kg)*	*psi (1,000s)*	*(MPa)*
25	(172)	3–14	1.20	(30.5)	18	(457)	2,000	(907)	25	(172)
30	(207)	14–24	1.20	(30.5)	18	(457)	2,200	(998)	30	(207)
30	(207)	20–48	2.00	(50.8)	24	(610)	7,600	(3,447)	30	(207)
35	(241)	16–24	1.20	(30.5)	18	(457)	2,400	(1,089)	35	(241)
35	(241)	20–36	2.00	(50.8)	24	(610)	8,300	(3,765)	35	(241)

*Metric conversion for dimension: in. × 25.4 = mm.

†ASTM A438.

‡ASTM A48.

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For 20-in. (508-mm) and 24-in. (610-mm) fittings with a body thickness greater than 1 in. (25.4 mm), a 2-in. (50.8-mm) test bar shall be used.

5.4.2 *Physical test—ductile-iron fittings.* The standard acceptance test for the physical characteristics of ductile-iron fittings shall be a tensile test on coupons cast from the same iron as the fittings.

Except as otherwise provided herein, coupons shall be cast and the test made in accordance with ASTM A536. The test coupon shall be obtained, at the manufacturer's option, from one of the following: (1) the ASTM A536 keel block, modified keel block, or Y-block separately cast coupon; (2) the castings' runner-bar system, provided that the diameter of the runner bar at the location the coupon is selected is similar to the respective ASTM A536 coupon; or (3) the casting.

5.4.2.1 Acceptance value. The standard grade of iron shall be 70-50-05, with acceptance values as follows: minimum tensile strength, 70,000 psi (483 MPa); minimum yield strength, 50,000 psi (345 MPa); minimum elongation, 5 percent.

Another permissible acceptance value shall be the 60-42-10 grade of iron, with acceptance values as follows: minimum tensile strength, 60,000 psi (414 MPa); minimum yield strength, 42,000 psi (290 MPa); and minimum elongation, 10 percent; provided the manufacturer of fittings produced from this grade can furnish records to demonstrate that such fittings meet the performance test requirements of this standard.

5.4.3 *Sampling.* At least one sample shall be taken during each period of approximately 3 h, while the melting unit is operated continuously.

Sec. 5.5 Chemical Limitations

5.5.1 *Gray-iron fittings.* Analyses of the iron in gray-iron fittings shall be made at sufficiently frequent intervals to ensure compliance with the following limits: phosphorus, 0.90 percent maximum; sulfur, 0.15 percent maximum.

Control of the other chemical constituents shall be maintained to meet the physical property requirements of this standard. Samples for chemical analyses shall be representative and shall be obtained from either acceptance-test specimens or specimens cast for this purpose.

5.5.2 *Ductile-iron fittings.* Analyses of the iron shall be made at sufficiently frequent intervals to ensure compliance with the following limit: phosphorus, 0.08 percent maximum. Control of other chemical constituents shall be maintained to meet the physical property requirements of this standard.

Samples for chemical analyses shall be representative and shall be obtained from either an acceptance-test specimen or specimens cast for this purpose.

Sec. 5.6 Additional Tests Required by the Purchaser

If tests other than those provided in this standard are required by the purchaser, such tests shall be specified by the purchaser. Although it is not customary to make hydrostatic proof tests of fittings at the foundry, such tests may be made on special order at additional cost. If proof tests at the foundry are required by the purchaser for an order of fittings, the fittings shall withstand, without leaks or permanent distortion, hydrostatic test pressures not to exceed one and one half times the rated water working pressures.

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Sec. 5.7 Defective Specimens and Retests

When any physical test specimen shows defective machining or lack of continuity of metal, it shall be discarded and replaced by another specimen cast in the same sampling period as the specimen that failed.

Sec. 5.8 Rejection of Fittings

If the test results of any sound specimen fail to meet the applicable requirements of Sec. 5.4, or the chemical analyses do not conform to the limitations of Sec. 5.5 where applicable, the fittings represented by these tests and/or analyses shall be rejected, except as provided in Sec. 5.9.

Sec. 5.9 Determining Rejection

The manufacturer may limit the amount of rejection by making additional acceptance tests until the rejected lot is bracketed, in order of manufacture, by an acceptable test at each end of the interval in question.

SECTION 6: DELIVERY

Sec. 6.1 Marking

Fittings shall have distinctly cast on them the pressure rating, nominal diameters of openings, manufacturer's identification, country where cast, and the number of degrees or fraction of the circle on all bends. Ductile-iron fittings shall have the letters "DI" or "Ductile" cast on them. Cast letters and figures shall be on the outside body of the fitting and shall have dimensions no smaller than the following:

Fitting Size*	Height of Letters		Relief	
in.	*in.*	*(mm)*	*in.*	*(mm)*
Less than 8	As large as practical		As large as practical	
8–10	¾	(19)	3/32	(2.5)
12–48	1¼	(32)	3/32	(2.5)

*Metric conversion for dimension: in. × 25.4 = mm.

Sec. 6.2 Packing and Shipping

This standard has no applicable information for this section.

Sec. 6.3 Affidavit of Compliance

This standard has no applicable information for this section.

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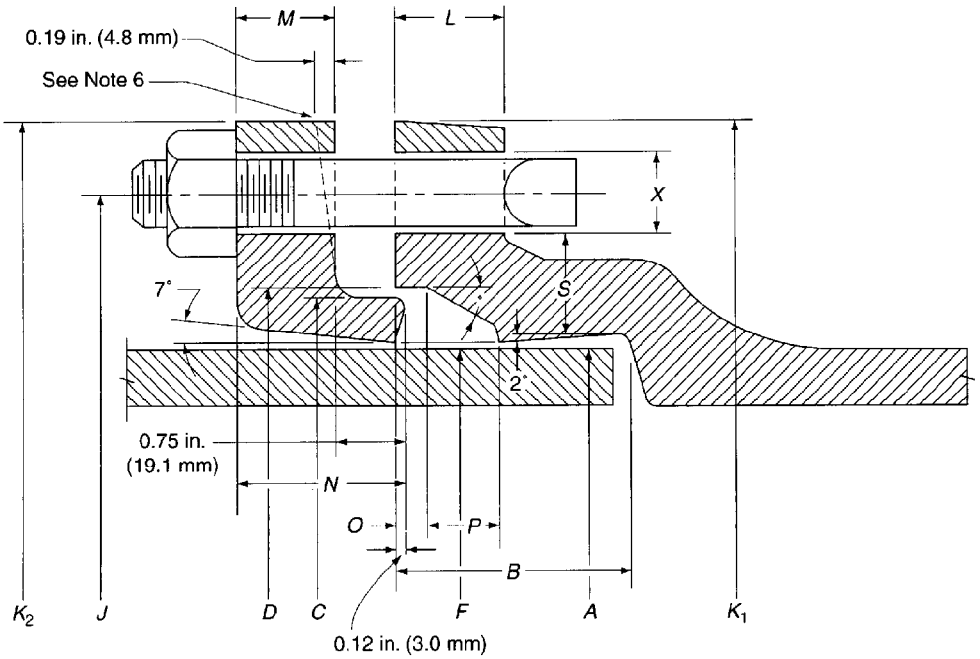

NOTES:

1. The nominal thickness *S* shall not be less than the nominal thickness of the fitting of which it is a part.
2. The diameter of cored holes may be tapered an additional 0.06 in. (1.5 mm).
3. Dimension *A* in Table 1 is the outside diameter of the plain end of the fitting.
4. In the event of an ovalness to the outside diameter of the plain end, the mean diameter measured by a circumferential tape shall not be less than the minimum diameter shown in Table 1. The minor axis shall not be less than the foregoing minimum diameter plus an additional minus tolerance of 0.04 in. (1.0 mm) for sizes 8–12 in. (203–305 mm), 0.07 in. (1.8 mm) for sizes 14–24 in. (356–610 mm), and 0.10 in. (2.5 mm) for sizes 30–48 in. (762–1,219 mm).
5. K_1 and K_2 are the dimensions across the centerline of the bolt holes. The gray-iron gland and bell flange may be round or polygon in shape for all sizes or square for 3-in. (76-mm) and 4-in. (100-mm) sizes. Ductile-iron glands may be other shapes as long as the gland meets the performance requirements specified in Sec. 4.5, ANSI/AWWA C111/A21.11.
6. Gland thickness *M* for sizes 14–48 in. (356–1,219 mm) may be tapered as shown, at the option of the manufacturer.
7. For ductile-iron glands, the gland thickness *M* listed above is not applicable. Designs incorporating reduced metal-section thicknesses are permitted provided tests with these glands meet the performance requirements of Sec. 4.5, ANSI/AWWA C111/A21.11. Conformance with *N* dimensions shown in Table 1 is required at the bolt holes for all glands, gray iron or ductile iron, to ensure interchangeability of joint parts.

Figure 1 Mechanical-joint dimensions for sizes 3 to 48 in. (76 to 1,219 mm) (see Table 1)

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Table 1 Mechanical-joint dimensions—in.*

Size	A Plain End	B	C	D	F	ϕ	X +0.06 −0.00	J ±0.06	K_1	K_2	L	M‡	N	O	P	S	Bolts† No.	Bolts† Size	Bolts† Length
3	3.96±0.06	2.50	4.84±0.04	4.94+0.06 −0.04	4.06+0.07 −0.03	28°	¾	6.19	7.69+0.24 −0.12	7.69+0.24 −0.12	0.94+0.13 −0.60	0.62 −0.06	1.37 −0.06	0.31	0.63	0.52 −0.10	4	⅝	3
4	4.80±0.06	2.50	5.92±0.40	6.02+0.06 −0.04	4.90+0.07 −0.03	28°	⅞	7.50	9.12+0.24 −0.12	9.12+0.24 −0.12	1.00+0.13 −0.06	0.75 −0.06	1.50 −0.06	0.31	0.75	0.65 −0.10	4	¾	3½
6	6.90±0.06	2.50	8.02±0.04	8.12+0.06 −0.04	7.00+0.07 −0.03	28°	⅞	9.50	11.12+0.24 −0.12	11.12+0.24 −0.12	1.06+0.13 −0.06	0.88 −0.06	1.63 −0.06	0.31	0.75	0.70 −0.10	6	¾	3½
8	9.05±0.06	2.50	10.17±0.04	10.27+0.06 −0.04	9.15+0.07 −0.03	28°	⅞	11.75	13.37+0.24 −0.12	13.37+0.24 −0.12	1.12+0.13 −0.08	1.00 −0.08	1.75 −0.80	0.31	0.75	0.75 −0.12	6	¾	4
10	11.10±0.06	2.50	12.22+0.06 −0.04	12.34+0.06 −0.04	11.20+0.07 −0.03	28°	⅞	14.00	15.69+0.24 −0.12	15.62+0.24 −0.12	1.19+0.13 −0.08	1.00 −0.08	1.75 −0.08	0.31	0.75	0.80 −0.12	8	¾	4
12	13.20±0.06	2.50	14.32+0.06 −0.04	14.44+0.06 −0.04	13.30+0.07 −0.03	28°	⅞	16.25	17.94+0.24 −0.12	17.88+0.24 −0.12	1.25+0.13 −0.08	1.00 −0.08	1.75 −0.08	0.31	0.75	0.85 −0.12	8	¾	4
14	15.30+0.05 −0.08	3.50	16.40+0.07 −0.05	16.54+0.07 −0.05	15.44+0.06 −0.07	28°	⅞	18.75	20.31+0.30 −0.12	20.25+0.30 −0.12	1.31+0.19 −0.12	1.25 −0.12	2.00 −0.12	0.31	0.75	0.89 −0.12	10	¾	4½
16	17.40+0.05 −0.08	3.50	18.50+0.07 −0.05	18.64+0.07 −0.05	17.54+0.06 −0.07	28°	⅞	21.00	22.56+0.30 −0.12	22.50+0.30 −0.12	1.38+0.19 −0.12	1.31 −0.12	2.06 −0.12	0.31	0.75	0.97 −0.12	12	¾	4½
18	19.50+0.05 −0.08	3.50	20.60+0.07 −0.05	20.74+0.07 −0.05	19.64+0.06 −0.07	28°	⅞	23.25	24.83+0.30 −0.15	24.75+0.30 −0.15	1.44+0.19 −0.12	1.38 −0.12	2.13 −0.12	0.31	0.75	1.05 −0.15	12	¾	4½
20	21.60+0.05 −0.08	3.50	22.70+0.07 −0.05	22.84+0.07 −0.05	21.74+0.06 −0.07	28°	⅞	25.50	27.08+0.30 −0.15	27.00+0.30 −0.15	1.50+0.19 −0.12	1.44 −0.12	2.19 −0.12	0.31	0.75	1.12 −0.15	14	¾	4½
24	25.80+0.05 −0.08	3.50	26.90+0.07 −0.05	27.04+0.07 −0.05	25.94+0.06 −0.07	28°	⅞	30.00	31.58+0.30 −0.15	31.50+0.30 −0.15	1.62+0.19 −0.12	1.56 −0.12	2.31 −0.12	0.31	0.75	1.22 −0.15	16	¾	5
30	32.00+0.08 −0.06	4.00	33.29+0.08 −0.06	33.46+0.08 −0.06	32.17+0.08 −0.06	20°	1⅛	36.88	39.12+1.00 −0.18	39.12+0.36 −0.18	1.81+0.25 −0.12	2.00 −0.12	2.75 −0.12	0.38	1.00	1.50 −0.15	20	1	6
36	38.30+0.08 −0.06	4.00	39.59+0.08 −0.06	39.76+0.08 −0.06	38.47+0.08 −0.06	20°	1⅛	43.75	46.00+1.00 −0.18	46.00+0.36 −0.18	2.00+0.25 −0.12	2.00 −0.12	2.75 −0.12	0.38	1.00	1.80 −0.15	24	1	6
42	44.50+0.08 −0.06	4.00	45.79+0.08 −0.06	45.96+0.08 −0.06	44.67+0.08 −0.06	20°	1⅜	50.62	53.12+1.00 −0.18	53.12+0.36 −0.18	2.00+0.25 −0.12	2.00 −0.12	2.75 −0.12	0.38	1.00	1.95 −0.15	28	1¼	6
48	50.80+0.08 −0.06	4.00	52.09+0.08 −0.06	52.26+0.08 −0.06	50.97+0.08 −0.06	20°	1⅜	57.50	60.00+1.00 −0.18	60.00+0.36 −0.18	2.00+0.25 −0.12	2.00 −0.12	2.75 −0.12	0.38	1.00	2.20 −0.15	32	1¼	6

*Dimension details of bell are shown in Figure 1.

†Bolt lengths shown for the 8-in. through 16-in. sizes are ½ in. longer than ANSI/AWWA C153/A21.53-88 bolts for use with ANSI/AWWA C153/A21.53 fittings for these sizes. These longer ANSI/AWWA C111/A21.11 bolts, shown in the table above, may also be furnished with compact fittings in sizes 8–16 in. with the bolt thread length as shown in Figure 3 and Figure 4 of ANSI/AWWA C111/A21.11.

‡For ductile-iron glands, the flange thickness *M* listed above is not applicable. Designs incorporating reduced metal-section thicknesses are permitted provided tests with these glands meet the performance requirements of Sec. 4.5 of ANSI/AWWA C111/A21.11. Conformance with *N* dimensions shown in Table 1 is required for all glands, gray iron or ductile iron, to ensure interchangeability of joint parts.

NOTE: Metric conversions: Dimension: in. × 25.4 = mm.

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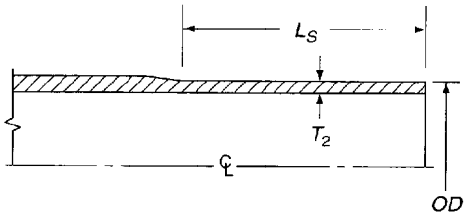


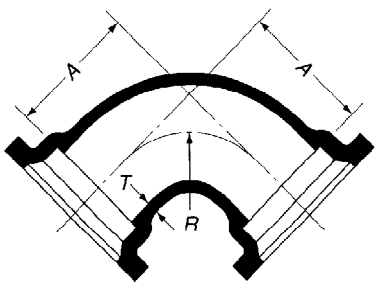
NOTES:

1. All sizes of fittings with plain ends have 8 in. (203 mm) of added laying length as compared with the laying length of standard all-bell fittings.
2. In Figure 2, dimension L_S is the minimum length of the plain end that must be gauged to ensure that the outside diameter is within the dimensions and tolerances specified in Table 2.
3. Metric conversions:
   Iron strength: psi (1,000s) × 6.89 = MPa;
   Pressure rating: psi × 0.00689 = MPa;
   Dimension: in. × 25.4 = mm;
   Weight: lb × 0.4536 = kg

Figure 2 Mechanical-joint plain-end dimensions and tolerances (see Table 2)

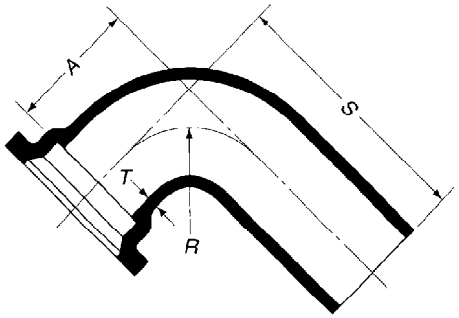
Table 2 Plain-end dimensions and tolerances for mechanical-joint fittings

Size *in.*	*OD* *in.*	T_2 *in.*	L_S *in.*
3	3.96±0.06	0.48–0.10	5.5
4	4.80±0.06	0.47–0.10	5.5
6	6.90±0.06	0.50–0.10	5.5
8	9.05±0.06	0.54–0.12	5.5
10	11.10±0.06	0.60–0.12	5.5
12	13.20±0.06	0.68–0.12	5.5
14	15.30+0.05 −0.08	0.66–0.12	8.0
16	17.40+0.05 −0.08	0.70–0.12	8.0
18	19.50+0.05 −0.08	0.75–0.12	8.0
20	21.60+0.05 −0.08	0.80–0.12	8.0
24	25.80+0.05 −0.08	0.80–0.15	8.0
30	32.00+0.08 −0.06	1.03–0.15	8.0
36	38.30+0.08 −0.06	1.15–0.15	8.0
42	44.50+0.08 −0.06	1.28–0.15	8.0
48	50.80+0.08 −0.06	1.42–0.15	8.0

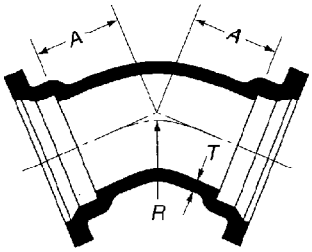


MJ and MJ

¼ Bend (90°)

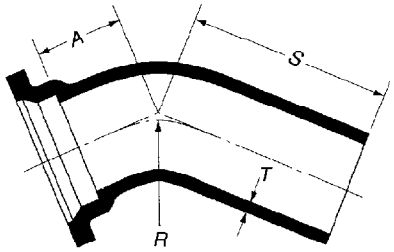


MJ and PE

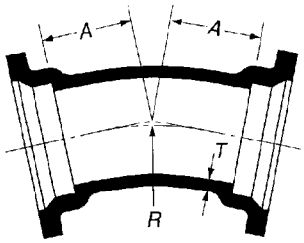


MJ and MJ

⅛ Bend (45°)

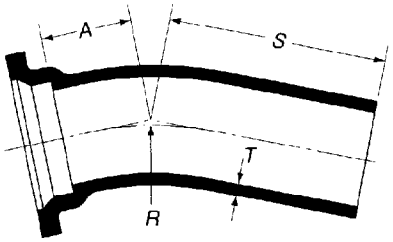


MJ and PE

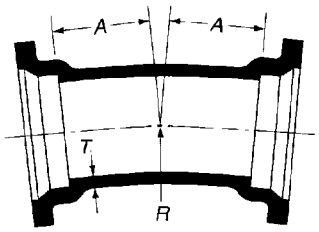


MJ and MJ

1/16 Bend (22½°)

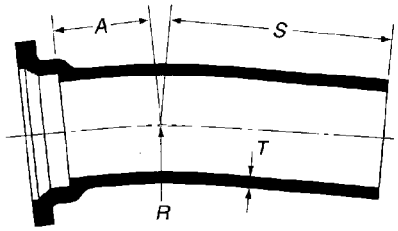


MJ and PE



MJ and MJ

1/32 Bend (11¼°)



MJ and PE

Figure 3 Mechanical-joint bends (see Table 3)

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Table 3 Mechanical-joint bends

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1,000s)*	Dimensions—*in.**				Weight—*lb*†	
			T	*A*	*S*	*R*	MJ & MJ	MJ & PE
			¼ Bends (90°)					
3	250	25	0.48	5.5	13.5	4.0	35	35
3	350	DI‡	0.48	5.5	13.5	4.0	35	35
4	250	25	0.52	6.5	14.5	4.5	55	50
4	350	DI	0.52	6.5	14.5	4.5	55	50
6	250	25	0.55	8.0	16.0	6.0	85	80
6	350	DI	0.55	8.0	16.0	6.0	85	80
8	250	25	0.60	9.0	17.0	7.0	125	120
8	350	DI	0.60	9.0	17.0	7.0	125	120
10	250	25	0.68	11.0	19.0	9.0	190	190
10	350	DI	0.68	11.0	19.0	9.0	190	190
12	250	25	0.75	12.0	20.0	10.0	255	255
12	350	DI	0.75	12.0	20.0	10.0	255	255
14	150	25	0.66	14.0	22.0	11.5	340	325
14	250	25	0.82	14.0	22.0	11.5	380	365
14	350	DI	0.66	14.0	22.0	11.5	340	325
16	150	30	0.70	15.0	23.0	12.5	430	410
16	250	30	0.89	15.0	23.0	12.5	490	470
16	350	DI	0.70	15.0	23.0	12.5	430	410
18	150	30	0.75	16.5	24.5	14.0	545	520
18	250	30	0.96	16.5	24.5	14.0	625	600
18	350	DI	0.75	16.5	24.5	14.0	545	520
20	150	30	0.80	18.0	26.0	15.5	680	650
20	250	30	1.03	18.0	26.0	15.5	790	755
20	350	DI	0.80	18.0	26.0	15.5	680	650
24	150	30	0.89	22.0	30.0	18.5	1,025	985
24	250	30	1.16	22.0	30.0	18.5	1,215	1,175
24	350	DI	0.89	22.0	30.0	18.5	1,025	985
30	150	30	1.03	25.0	33.0	21.5	1,690	1,585
30	250	30	1.37	25.0	33.0	21.5	2,030	1,920
30	250	DI	1.03	25.0	33.0	21.5	1,690	1,585
36	150	30	1.15	28.0	36.0	24.5	2,475	2,310
36	250	30	1.58	28.0	36.0	24.5	3,045	2,880
36	250	DI	1.15	28.0	36.0	24.5	2,475	2,310
42	150	30	1.28	31.0	39.0	27.5	3,410	3,200
42	250	30	1.78	31.0	39.0	27.5	4,255	4,050
42	250	DI	1.28	31.0	39.0	27.5	3,410	3,200
48	150	30	1.42	34.0	42.0	30.5	4,595	4,330
48	250	30	1.96	34.0	42.0	30.5	4,595	4,330
48	250	DI	1.42	34.0	42.0	30.5	4,595	4,330

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Dimension details of mechanical-joint bells are shown in Table 1; dimension details of plain ends are shown in Table 2.

†Weight does not include accessory weights.

‡Ductile iron.

Table continued next page.

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Table 3 Mechanical-joint bends (continued)

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1,000s)*	Dimensions—*in.**				Weight—*lb*†	
			T	*A*	*S*	*R*	MJ & MJ	MJ & PE
			⅛ Bends (45°)					
3	250	25	0.48	3.0	11.0	3.62	30	30
3	350	DI‡	0.48	3.0	11.0	3.62	30	30
4	250	25	0.52	4.0	12.0	4.81	50	45
4	350	DI	0.52	4.0	12.0	4.81	50	45
6	250	25	0.55	5.0	13.0	7.25	75	70
6	350	DI	0.55	5.0	13.0	7.25	75	70
8	250	25	0.60	5.5	13.5	8.44	110	105
8	350	DI	0.60	5.5	13.5	8.44	110	105
10	250	25	0.68	6.5	14.5	10.88	155	155
10	350	DI	0.68	6.5	14.5	10.88	155	155
12	250	25	0.75	7.5	15.5	13.25	215	215
12	350	DI	0.75	7.5	15.5	13.25	215	215
14	150	25	0.66	7.5	15.5	12.06	270	255
14	250	25	0.82	7.5	15.5	12.06	300	280
14	350	DI	0.66	7.5	15.5	12.06	270	255
16	150	30	0.70	8.0	16.0	13.25	340	320
16	250	30	0.89	8.0	16.0	13.25	380	360
16	350	DI	0.70	8.0	16.0	13.25	340	320
18	150	30	0.75	8.5	16.5	14.50	420	395
18	250	30	0.96	8.5	16.5	14.50	470	445
18	350	DI	0.75	8.5	16.5	14.50	420	395
20	150	30	0.80	9.5	17.5	16.88	530	500
20	250	30	1.03	9.5	17.5	16.88	595	565
20	350	DI	0.80	9.5	17.5	16.88	530	500
24	150	30	0.89	11.0	19.0	18.12	755	715
24	250	30	1.16	11.0	19.0	18.12	865	825
24	350	DI	0.89	11.0	19.0	18.12	755	715
30	150	30	1.03	15.0	23.0	27.75	1,380	1,275
30	250	30	1.37	15.0	23.0	27.75	1,620	1,510
30	250	DI	1.03	15.0	23.0	27.75	1,380	1,275
36	150	30	1.15	18.0	26.0	35.00	2,095	1,930
36	250	30	1.58	18.0	26.0	35.00	2,525	2,360
36	250	DI	1.15	18.0	26.0	35.00	2,095	1,930
42	150	30	1.28	21.0	29.0	42.25	2,955	2,745
42	250	30	1.78	21.0	29.0	42.25	3,635	3,425
42	250	DI	1.28	21.0	29.0	42.25	2,955	2,745
48	150	30	1.42	24.0	32.0	49.50	4,080	3,815
48	250	30	1.96	24.0	32.0	49.50	5,040	4,770
48	250	DI	1.42	24.0	32.0	49.50	4,080	3,815

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Dimension details of mechanical-joint bells are shown in Table 1; dimension details of plain ends are shown in Table 2.

†Weight does not include accessory weights.

‡Ductile iron.

Table continued next page.

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Table 3 Mechanical-joint bends (continued)

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1,000s)*	Dimensions—*in.**				Weight—*lb*†	
			T	*A*	*S*	*R*	MJ & MJ	MJ & PE
			1/16 Bends (22½°)					
3	250	25	0.48	3.0	11.0	7.56	30	30
3	350	DI‡	0.48	3.0	11.0	7.56	30	30
4	250	25	0.52	4.0	12.0	10.06	50	45
4	350	DI	0.52	4.0	12.0	10.06	50	45
6	250	25	0.55	5.0	13.0	15.06	75	70
6	350	DI	0.55	5.0	13.0	15.06	75	70
8	250	25	0.60	5.5	13.5	17.62	110	105
8	350	DI	0.60	5.5	13.5	17.62	110	105
10	250	25	0.68	6.5	14.5	22.62	160	160
10	350	DI	0.68	6.5	14.5	22.62	160	160
12	250	25	0.75	7.5	15.5	27.62	220	220
12	350	DI	0.75	7.5	15.5	27.62	220	220
14	150	25	0.66	7.5	15.5	25.12	275	260
14	250	25	0.82	7.5	15.5	25.12	300	285
14	350	DI	0.66	7.5	15.5	25.12	275	260
16	150	30	0.70	8.0	16.0	27.62	345	325
16	250	30	0.89	8.0	16.0	27.62	385	365
16	350	DI	0.70	8.0	16.0	27.62	345	325
18	150	30	0.75	8.5	16.5	30.19	430	405
18	250	30	0.96	8.5	16.5	30.19	480	455
18	350	DI	0.75	8.5	16.5	30.19	430	405
20	150	30	0.80	9.5	17.5	35.19	535	505
20	250	30	1.03	9.5	17.5	35.19	605	575
20	350	DI	0.80	9.5	17.5	35.19	535	505
24	150	30	0.89	11.0	19.0	37.69	765	725
24	250	30	1.16	11.0	19.0	37.69	880	840
24	350	DI	0.89	11.0	19.0	37.69	765	725
30	150	30	1.03	15.0	23.0	57.81	1,400	1,295
30	250	30	1.37	15.0	23.0	57.81	1,650	1,540
30	250	DI	1.03	15.0	23.0	57.81	1,400	1,295
36	150	30	1.15	18.0	26.0	72.88	2,135	1,970
36	250	30	1.58	18.0	26.0	72.88	2,580	2,410
36	250	DI	1.15	18.0	26.0	72.88	2,135	1,970
42	150	30	1.28	21.0	29.0	88.00	3,020	2,810
42	250	30	1.78	21.0	29.0	88.00	3,720	3,510
42	250	DI	1.28	21.0	29.0	88.00	3,020	2,810
48	150	30	1.42	24.0	32.0	103.06	4,170	3,905
48	250	30	1.96	24.0	32.0	103.06	5,160	4,895
48	250	DI	1.42	24.0	32.0	103.06	4,170	3,905

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Dimension details of mechanical-joint bells are shown in Table 1; dimension details of plain ends are shown in Table 2.

†Weight does not include accessory weights.

‡Ductile iron.

Table continued next page.

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Table 3 Mechanical-joint bends (continued)

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1,000s)*	Dimensions—*in.**				Weight—*lb*†	
			T	*A*	*S*	*R*	MJ & MJ	MJ & PE
			1/32 Bends (11¼°)					
3	250	25	0.48	3.0	11.0	15.25	30	30
3	350	DI‡	0.48	3.0	11.0	15.25	30	30
4	250	25	0.52	4.0	12.0	20.31	50	45
4	350	DI	0.52	4.0	12.0	20.31	50	45
6	250	25	0.55	5.0	13.0	30.50	75	70
6	350	DI	0.55	5.0	13.0	30.50	75	70
8	250	25	0.60	5.5	13.5	35.50	110	105
8	350	DI	0.60	5.5	13.5	35.50	110	105
10	250	25	0.68	6.5	14.5	45.69	160	160
10	350	DI	0.68	6.5	14.5	45.69	160	160
12	250	25	0.75	7.5	15.5	55.81	220	220
12	350	DI	0.75	7.5	15.5	55.81	220	220
14	150	25	0.66	7.5	15.5	50.75	275	260
14	250	25	0.82	7.5	15.5	50.75	305	285
14	350	DI	0.66	7.5	15.5	50.75	275	260
16	150	30	0.70	8.0	16.0	55.81	345	325
16	250	30	0.89	8.0	16.0	55.81	385	365
16	350	DI	0.70	8.0	16.0	55.81	345	325
18	150	30	0.75	8.5	16.5	60.94	430	405
18	250	30	0.96	8.5	16.5	60.94	480	455
18	350	DI	0.75	8.5	16.5	60.94	430	405
20	150	30	0.80	9.5	17.5	71.06	540	510
20	250	30	1.03	9.5	17.5	71.06	610	575
20	350	DI	0.80	9.5	17.5	71.06	540	510
24	150	30	0.89	11.0	19.0	76.12	770	730
24	250	30	1.16	11.0	19.0	76.12	885	845
24	350	DI	0.89	11.0	19.0	76.12	770	730
30	150	30	1.03	15.0	23.0	116.75	1,410	1,305
30	250	30	1.37	15.0	23.0	116.75	1,655	1,550
30	250	DI	1.03	15.0	23.0	116.75	1,410	1,305
36	150	30	1.15	18.0	26.0	147.25	2,145	1,980
36	250	30	1.58	18.0	26.0	147.25	2,545	2,425
36	250	DI	1.15	18.0	26.0	147.25	2,145	1,980
42	150	30	1.28	21.0	29.0	177.69	3,035	2,825
42	250	30	1.78	21.0	29.0	177.69	3,740	3,535
42	250	DI	1.28	21.0	29.0	177.69	3,035	2,825
48	150	30	1.42	24.0	32.0	208.12	4,190	3,925
48	250	30	1.96	24.0	32.0	208.12	5,195	4,925
48	250	DI	1.42	24.0	32.0	208.12	4,190	3,925

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Dimension details of mechanical-joint bells are shown in Table 1; dimension details of plain ends are shown in Table 2.

†Weight does not include accessory weights.

‡Ductile iron.

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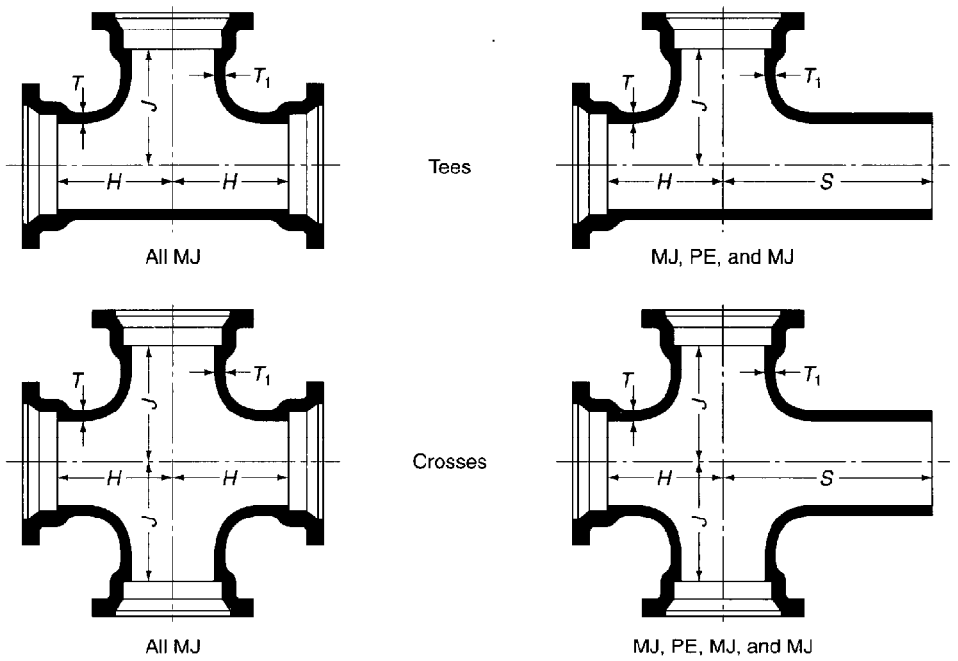

Figure 4 Mechanical-joint tees and crosses (see Table 4)

Table 4 Mechanical-joint tees and crosses

Size *in.*		Pressure Rating *psi*	Iron Strength *psi* (*1,000s*)	Dimensions—*in.**					Weight—*lb*†			
									Tee		Cross	
Run	Branch			T	T_1	H	J	S	All MJ	MJ, PE, & MJ	All MJ	MJ, PE, MJ, & MJ
3	3	250	25	0.48	0.48	5.5	5.5	13.5	55	55	70	70
3	3	350	DI‡	0.48	0.48	5.5	5.5	13.5	55	55	70	70
4	3	250	25	0.52	0.48	6.5	6.5	14.5	75	70	90	85
4	3	350	DI	0.52	0.48	6.5	6.5	14.5	75	70	90	85
4	4	250	25	0.52	0.52	6.5	6.5	14.5	80	75	105	100
4	4	350	DI	0.52	0.52	6.5	6.5	14.5	80	75	105	100
6	3	250	25	0.55	0.48	8.0	8.0	16.0	110	105	125	120
6	3	350	DI	0.55	0.48	8.0	8.0	16.0	110	105	125	120
6	4	250	25	0.55	0.52	8.0	8.0	16.0	115	110	140	135
6	4	350	DI	0.55	0.52	8.0	8.0	16.0	115	110	140	135
6	6	250	25	0.55	0.55	8.0	8.0	16.0	125	120	160	155
6	6	350	DI	0.55	0.55	8.0	8.0	16.0	125	120	160	155

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Dimension details of mechanical-joint bells are shown in Table 1; dimension details of plain ends are shown in Table 2.

†Weight does not include accessory weights.

‡Ductile iron.

Table continued next page.

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Table 4 Mechanical-joint tees and crosses (continued)

Size *in.*		Pressure Rating *psi*	Iron Strength *psi* (*1,000s*)	Dimensions—*in.**					Weight—*lb*†			
									Tee		Cross	
Run	Branch			*T*	T_1	*H*	*J*	*S*	All MJ	MJ, PE, & MJ	All MJ	MJ, PE, MJ, & MJ
8	4	250	25	0.60	0.52	9.0	9.0	17.0	165	160	185	180
8	4	350	DI‡	0.60	0.52	9.0	9.0	17.0	165	160	185	180
8	6	250	25	0.60	0.55	9.0	9.0	17.0	175	170	205	200
8	6	350	DI	0.60	0.55	9.0	9.0	17.0	175	170	205	200
8	8	250	25	0.60	0.60	9.0	9.0	17.0	185	180	235	230
8	8	350	DI	0.60	0.60	9.0	9.0	17.0	185	180	235	230
10	4	250	25	0.68	0.52	11.0	11.0	19.0	235	235	260	260
10	4	350	DI	0.68	0.52	11.0	11.0	19.0	235	235	260	260
10	6	250	25	0.68	0.55	11.0	11.0	19.0	250	250	285	285
10	6	350	DI	0.68	0.55	11.0	11.0	19.0	250	250	285	285
10	8	250	25	0.68	0.60	11.0	11.0	19.0	260	260	310	310
10	8	350	DI	0.68	0.60	11.0	11.0	19.0	260	260	310	310
10	10	250	25	0.80	0.80	11.0	11.0	19.0	310	310	380	380
10	10	350	DI	0.80	0.80	11.0	11.0	19.0	310	310	380	380
12	4	250	25	0.75	0.52	12.0	12.0	20.0	315	315	340	340
12	4	350	DI	0.75	0.52	12.0	12.0	20.0	315	315	340	340
12	6	250	25	0.75	0.55	12.0	12.0	20.0	325	325	360	360
12	6	350	DI	0.75	0.55	12.0	12.0	20.0	325	325	360	360
12	8	250	25	0.75	0.60	12.0	12.0	20.0	340	340	385	385
12	8	350	DI	0.75	0.60	12.0	12.0	20.0	340	340	385	385
12	10	250	25	0.87	0.80	12.0	12.0	20.0	390	390	460	460
12	10	350	DI	0.87	0.80	12.0	12.0	20.0	390	390	460	460
12	12	250	25	0.87	0.87	12.0	12.0	20.0	410	410	495	495
12	12	250	DI	0.87	0.87	12.0	12.0	20.0	410	410	495	495
14	6	150	25	0.66	0.55	14.0	14.0	22.0	435	420	475	460
14	6	250	25	0.82	0.55	14.0	14.0	22.0	485	470	525	505
14	6	350	DI	0.66	0.55	14.0	14.0	22.0	435	420	475	460
14	8	150	25	0.66	0.60	14.0	14.0	22.0	450	435	500	485
14	8	250	25	0.82	0.60	14.0	14.0	22.0	500	480	550	535
14	8	350	DI	0.66	0.60	14.0	14.0	22.0	450	435	500	485
14	10	150	25	0.66	0.68	14.0	14.0	22.0	465	435	540	525
14	10	250	25	0.82	0.68	14.0	14.0	22.0	515	500	585	570
14	10	350	DI	0.66	0.68	14.0	14.0	22.0	465	450	540	525
14	12	150	25	0.82	0.75	14.0	14.0	22.0	540	525	630	615
14	12	250	30	0.82	0.75	14.0	14.0	22.0	540	525	630	615
14	12	350	DI	0.66	0.75	14.0	14.0	22.0	495	475	585	570
14	14	150	25	0.82	0.82	14.0	14.0	22.0	585	570	710	695
14	14	250	30	0.82	0.82	14.0	14.0	22.0	585	570	710	695
14	14	350	DI	0.66	0.66	14.0	14.0	22.0	520	500	635	620
16	6	150	30	0.70	0.55	15.0	15.0	23.0	540	520	575	555
16	6	250	30	0.89	0.55	15.0	15.0	23.0	615	590	650	630
16	6	350	DI	0.70	0.55	15.0	15.0	23.0	540	520	575	555
16	8	150	30	0.70	0.60	15.0	15.0	23.0	550	530	605	585
16	8	250	30	0.89	0.60	15.0	15.0	23.0	625	605	675	655
16	8	350	DI	0.70	0.60	15.0	15.0	23.0	550	530	605	585

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Dimension details of mechanical-joint bells are shown in Table 1; dimension details of plain ends are shown in Table 2.

†Weight does not include accessory weights.

‡Ductile iron.

Table continued next page.

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Table 4 Mechanical-joint tees and crosses (continued)

Size *in.*		Pressure Rating	Iron Strength	Dimensions—*in.**					Weight—*lb*†			
									Tee		Cross	
Run	Branch	*psi*	*psi* (*1,000s*)	*T*	T_1	*H*	*J*	*S*	All MJ	MJ, PE, & MJ	All MJ	MJ, PE, MJ, & MJ
16	10	150	30	0.70	0.68	15.0	15.0	23.0	570	550	645	625
16	10	250	30	0.89	0.68	15.0	15.0	23.0	645	620	710	690
16	10	350	DI‡	0.70	0.68	15.0	15.0	23.0	570	550	645	625
16	12	150	30	0.70	0.75	15.0	15.0	23.0	590	570	685	665
16	12	250	30	0.89	0.75	15.0	15.0	23.0	660	640	745	725
16	12	350	DI	0.70	0.75	15.0	15.0	23.0	590	570	685	665
16	14	150	30	0.89	0.82	15.0	15.0	23.0	710	690	830	810
16	14	250	35	0.89	0.82	15.0	15.0	23.0	710	690	830	810
16	14	350	DI	0.70	0.66	15.0	15.0	23.0	620	600	735	715
16	16	150	30	0.89	0.89	15.0	15.0	23.0	740	720	895	875
16	16	250	35	0.89	0.89	15.0	15.0	23.0	740	720	895	875
16	16	350	DI	0.70	0.70	15.0	15.0	23.0	650	625	790	770
18	6	150	30	0.75	0.55	13.0	15.5	21.0	590	565	625	600
18	6	250	30	0.96	0.55	13.0	15.5	21.0	670	645	705	680
18	6	350	DI	0.75	0.55	13.0	15.5	21.0	590	565	625	600
18	8	150	30	0.75	0.60	13.0	15.5	21.0	605	580	655	630
18	8	250	30	0.96	0.60	13.0	15.5	21.0	685	655	730	705
18	8	350	DI	0.75	0.60	13.0	15.5	21.0	605	580	655	630
18	10	150	30	0.75	0.68	13.0	15.5	21.0	620	595	685	660
18	10	250	30	0.96	0.68	13.0	15.5	21.0	700	670	760	735
18	10	350	DI	0.75	0.68	13.0	15.5	21.0	620	595	685	660
18	12	150	30	0.75	0.75	13.0	15.5	21.0	640	615	725	700
18	12	250	30	0.96	0.75	13.0	15.5	21.0	715	690	790	765
18	12	350	DI	0.75	0.75	13.0	15.5	21.0	640	615	725	700
18	14	150	30	0.75	0.66	16.5	16.5	24.5	755	730	870	845
18	14	250	30	0.96	0.82	16.5	16.5	24.5	865	840	990	965
18	14	350	DI	0.75	0.66	16.5	16.5	24.5	755	730	870	845
18	16	150	30	0.96	0.89	16.5	16.5	24.5	905	880	1,060	1,035
18	16	250	35	0.96	0.89	16.5	16.5	24.5	905	880	1,060	1,035
18	16	350	DI	0.75	0.70	16.5	16.5	24.5	785	760	930	905
18	18	150	30	0.96	0.96	16.5	16.5	24.5	945	920	1,130	1,105
18	18	250	35	0.96	0.96	16.5	16.5	24.5	945	920	1,130	1,105
18	18	350	DI	0.75	0.75	16.5	16.5	24.5	820	795	995	965
20	6	150	30	0.80	0.55	14.0	17.0	22.0	725	695	760	730
20	6	250	30	1.03	0.55	14.0	17.0	22.0	830	800	865	835
20	6	350	DI	0.80	0.55	14.0	17.0	22.0	725	695	760	730
20	8	150	30	0.80	0.60	14.0	17.0	22.0	735	705	790	760
20	8	250	30	1.03	0.60	14.0	17.0	22.0	845	810	890	860
20	8	350	DI	0.80	0.60	14.0	17.0	22.0	735	705	790	760
20	10	150	30	0.80	0.68	14.0	17.0	22.0	755	725	820	790
20	10	250	30	1.03	0.68	14.0	17.0	22.0	860	825	920	890
20	10	350	DI	0.80	0.68	14.0	17.0	22.0	755	725	820	790
20	12	150	30	0.80	0.75	14.0	17.0	22.0	775	745	860	830
20	12	250	30	1.03	0.75	14.0	17.0	22.0	875	840	955	920
20	12	350	DI	0.80	0.75	14.0	17.0	22.0	775	745	860	830

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Dimension details of mechanical-joint bells are shown in Table 1; dimension details of plain ends are shown in Table 2.

†Weight does not include accessory weights.

‡Ductile iron.

Table continued next page.

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Table 4 Mechanical-joint tees and crosses (continued)

Size *in.*		Pressure Rating *psi*	Iron Strength *psi* (*1,000s*)	Dimensions—*in.**					Weight—*lb*†			
									Tee		Cross	
Run	Branch			*T*	T_1	*H*	*J*	*S*	All MJ	MJ, PE, & MJ	All MJ	MJ, PE, MJ, & MJ
20	14	150	30	0.80	0.66	14.0	17.0	22.0	795	765	905	875
20	14	250	35	1.03	0.82	14.0	17.0	22.0	910	875	1,025	990
20	14	350	DI‡	0.80	0.66	14.0	17.0	22.0	795	765	905	875
20	16	150	30	0.80	0.70	18.0	18.0	26.0	945	915	1,085	1,055
20	16	250	35	1.03	0.89	18.0	18.0	26.0	1,095	1,060	1,245	1,215
20	16	350	DI	0.80	0.70	18.0	18.0	26.0	945	915	1,085	1,055
20	18	150	35	1.03	0.96	18.0	18.0	26.0	1,140	1,110	1,330	1,300
20	18	350	DI	0.80	0.75	18.0	18.0	26.0	985	950	1,155	1,120
20	20	150	35	1.03	1.03	18.0	18.0	26.0	1,185	1,155	1,415	1,385
20	20	350	DI	0.80	0.80	18.0	18.0	26.0	1,020	990	1,230	1,200
24	6	150	30	0.89	0.55	15.0	19.0	23.0	985	945	1,025	985
24	6	250	30	1.16	0.55	15.0	19.0	23.0	1,145	1,105	1,180	1,140
24	6	350	DI	0.89	0.55	15.0	19.0	23.0	985	945	1,025	985
24	8	150	30	0.89	0.60	15.0	19.0	23.0	1,000	960	1,045	1,005
24	8	250	30	1.16	0.60	15.0	19.0	23.0	1,160	1,115	1,200	1,160
24	8	350	DI	0.89	0.60	15.0	19.0	23.0	1,000	960	1,045	1,005
24	10	150	30	0.89	0.68	15.0	19.0	23.0	1,025	1,980	1,085	1,015
24	10	250	30	1.16	0.68	15.0	19.0	23.0	1,170	1,130	1,230	1,190
24	10	350	DI	0.89	0.68	15.0	19.0	23.0	1,020	980	1,085	1,045
24	12	150	30	0.89	0.75	15.0	19.0	23.0	1,030	990	1,110	1,070
24	12	250	30	1.16	0.75	15.0	19.0	23.0	1,185	1,145	1,260	1,220
24	12	350	DI	0.89	0.75	15.0	19.0	23.0	1,030	990	1,110	1,070
24	14	150	30	0.89	0.66	15.0	19.0	23.0	1,055	1,015	1,155	1,115
24	14	250	30	1.16	0.82	15.0	19.0	23.0	1,220	1,180	1,325	1,285
24	14	350	DI	0.89	0.66	15.0	19.0	23.0	1,055	1,015	1,155	1,115
24	16	150	30	0.89	0.70	15.0	19.0	23.0	1,075	1,035	1,200	1,160
24	16	250	35	1.16	0.89	15.0	19.0	23.0	1,245	1,200	1,375	1,335
24	16	350	DI	0.89	0.70	15.0	19.0	23.0	1,075	1,035	1,200	1,160
24	18	150	30	0.89	0.75	22.0	22.0	30.0	1,400	1,360	1,590	1,550
24	18	250	35	1.16	0.96	22.0	22.0	30.0	1,660	1,615	1,865	1,820
24	18	350	DI	0.89	0.75	22.0	22.0	30.0	1,400	1,360	1,590	1,550
24	20	150	35	1.16	1.03	22.0	22.0	30.0	1,720	1,680	1,965	1,925
24	20	350	DI	0.89	0.80	22.0	22.0	30.0	1,450	1,410	1,675	1,630
24	24	150	35	1.16	1.16	22.0	22.0	30.0	1,815	1,775	2,155	2,115
24	24	350	DI	0.89	0.89	22.0	22.0	30.0	1,535	1,490	1,835	1,795
30	6	150	30	1.03	0.55	18.0	23.0	26.0	1,730	1,615	1,770	1,655
30	6	250	30	1.37	0.55	18.0	23.0	26.0	2,050	1,935	2,085	1,970
30	6	250	DI	1.03	055	18.0	23.0	26.0	1,730	1,615	1,770	1,655
30	8	150	30	1.03	0.60	18.0	23.0	26.0	1,745	1,630	1,795	1,680
30	8	250	30	1.37	0.60	18.0	23.0	26.0	2,060	1,945	2,110	1,990
30	8	250	DI	1.03	0.60	18.0	23.0	26.0	1,745	1,630	1,795	1,680
30	10	150	30	1.03	0.68	18.0	23.0	26.0	1,760	1,645	1,830	1,715
30	10	250	30	1.37	0.68	18.0	23.0	26.0	2,075	1,960	2,135	2,020
30	10	250	DI	1.03	0.68	18.0	23.0	26.0	1,760	1,645	1,830	1,715
30	12	150	30	1.03	0.75	18.0	23.0	26.0	1,780	1,665	1,865	1,750
30	12	250	30	1.37	0.75	18.0	23.0	26.0	2,090	1,970	2,165	2,045
30	12	250	DI	1.03	0.75	18.0	23.0	26.0	1,780	1,665	1,865	1,750

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Dimension details of mechanical-joint bells are shown in Table 1; dimension details of plain ends are shown in Table 2.

†Weight does not include accessory weights.

‡Ductile iron.

Table continued next page.

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Table 4 Mechanical-joint tees and crosses (continued)

Size *in.*		Pressure Rating *psi*	Iron Strength *psi* (*1,000s*)	Dimensions—*in.**					Weight—*lb*†			
									Tee		Cross	
Run	Branch			*T*	T_1	*H*	*J*	*S*	All MJ	MJ, PE, & MJ	All MJ	MJ, PE, MJ, & MJ
30	14	150	30	1.03	0.66	18.0	23.0	26.0	1,800	1,685	1,905	1,790
30	14	250	30	1.37	0.82	18.0	23.0	26.0	2,120	2,005	2,230	2,115
30	14	250	DI‡	1.03	0.66	18.0	23.0	26.0	1,800	1,685	1,905	1,790
30	16	150	30	1.03	0.70	18.0	23.0	26.0	1,820	1,705	1,950	1,835
30	16	250	30	1.37	0.89	18.0	23.0	26.0	2,145	2,030	2,280	2,165
30	16	250	DI	1.03	0.70	18.0	23.0	26.0	1,820	1,705	1,950	1,835
30	18	150	30	1.03	0.75	18.0	23.0	26.0	1,845	1,730	2,000	1,885
30	18	250	35	1.37	0.96	18.0	23.0	26.0	2,170	2,055	2,330	2,215
30	18	250	DI	1.03	0.75	18.0	23.0	26.0	1,845	1,730	2,000	1,885
30	20	150	30	1.03	0.80	18.0	23.0	26.0	1,875	1,760	2,060	1,945
30	20	250	35	1.37	1.03	18.0	23.0	26.0	2,205	2,090	2,395	2,280
30	20	250	DI	1.03	0.80	18.0	23.0	26.0	1,875	1,760	2,060	1,945
30	24	150	35	1.37	1.16	25.0	25.0	33.0	2,880	2,765	3,180	3,065
30	24	250	DI	1.03	0.89	25.0	25.0	33.0	2,400	2,280	2,675	2,560
30	30	150	35	1.37	1.37	25.0	25.0	33.0	3,105	2,990	3,640	3,520
30	30	250	DI	1.03	1.03	25.0	25.0	33.0	2,595	2,480	3,075	2,955
36	8	150	30	1.15	0.60	20.0	26.0	28.0	2,520	2,345	2,565	2,390
36	8	250	30	1.58	0.60	20.0	26.0	28.0	3,050	2,870	3,095	2,915
36	8	250	DI	1.15	0.60	20.0	26.0	28.0	2,520	2,345	2,565	2,390
36	10	150	30	1.15	0.68	20.0	26.0	28.0	2,535	2,360	2,600	2,425
36	10	250	30	1.58	0.68	20.0	26.0	28.0	3,065	2,885	3,120	2,940
36	10	250	DI	1.15	0.68	20.0	26.0	28.0	2,535	2,360	2,600	2,425
36	12	150	30	1.15	0.75	20.0	26.0	28.0	2,550	2,375	2,630	2,455
36	12	250	30	1.58	0.75	20.0	26.0	28.0	3,075	2,895	3,140	2,906
36	12	250	DI	1.15	0.75	20.0	26.0	28.0	2,550	2,375	2,630	2,455
36	14	150	30	1.15	0.66	20.0	26.0	28.0	2,570	2,395	2,665	2,490
36	14	250	30	1.58	0.82	20.0	26.0	28.0	3,105	2,925	3,205	3,025
36	14	250	DI	1.15	0.66	20.0	26.0	28.0	2,570	2,395	2,665	2,490
36	16	150	30	1.15	0.70	20.0	26.0	28.0	2,585	2,410	2,705	2,530
36	16	250	30	1.58	0.89	20.0	26.0	28.0	3,125	2,945	3,245	3,065
36	16	250	DI	1.15	0.70	20.0	26.0	28.0	2,585	2,410	2,705	2,530
36	18	150	30	1.15	0.75	20.0	26.0	28.0	2,610	2,435	2,750	2,575
36	18	250	30	1.58	0.96	20.0	26.0	28.0	3,150	2,970	3,290	3,110
36	18	250	DI	1.15	0.75	20.0	26.0	28.0	2,610	2,435	2,750	2,575
36	20	150	30	1.15	0.80	20.0	26.0	28.0	2,635	2,460	2,805	2,630
36	20	250	35	1.58	1.03	20.0	26.0	28.0	3,175	2,995	3,345	3,165
36	20	250	DI	1.15	0.80	20.0	26.0	28.0	2,635	2,460	2,805	2,630
36	24	150	30	1.15	0.89	20.0	26.0	28.0	2,690	2,515	2,910	2,735
36	24	250	35	1.58	1.16	20.0	26.0	28.0	3,230	3,050	3,450	3,270
36	24	250	DI	1.15	0.89	20.0	26.0	28.0	2,690	2,515	2,910	2,735
36	30	150	35	1.58	1.37	28.0	28.0	36.0	4,345	4,170	4,790	4,615
36	30	250	DI	1.15	1.03	28.0	28.0	36.0	3,545	3,365	3,965	3,790
36	36	150	35	1.58	1.58	28.0	28.0	36.0	4,590	4,410	5,280	5,105
36	36	250	DI	1.15	1.15	28.0	28.0	36.0	3,745	3,565	4,370	4,190
42	12	150	30	1.28	0.75	23.0	30.0	31.0	3,555	3,335	3,640	3,420
42	12	250	30	1.78	0.75	23.0	30.0	31.0	4,385	4,160	4,450	4,225
42	12	250	DI	1.28	0.75	23.0	30.0	31.0	3,555	3,335	3,640	3,420

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Dimension details of mechanical-joint bells are shown in Table 1; dimension details of plain ends are shown in Table 2.

†Weight does not include accessory weights.

‡Ductile iron.

Table continued next page.

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Table 4 Mechanical-joint tees and crosses (continued)

Size *in.*		Pressure Rating	Iron Strength	Dimensions—*in.**					Weight—*lb*†			
									Tee		Cross	
Run	Branch	*psi*	*psi* (*1,000s*)	*T*	T_1	*H*	*J*	*S*	All MJ	MJ, PE, & MJ	All MJ	MJ, PE, MJ, & MJ
42	14	150	30	1.28	0.66	23.0	30.0	31.0	3,575	3,355	3,675	3,455
42	14	250	30	1.78	0.82	23.0	30.0	31.0	4,415	4,190	4,515	4,290
42	14	250	DI‡	1.28	0.66	23.0	30.0	31.0	3,575	3,355	3,675	3,455
42	16	150	30	1.28	0.70	23.0	30.0	31.0	3,595	3,375	3,715	3,495
42	16	250	30	1.78	0.89	23.0	30.0	31.0	4,435	4,210	4,550	4,325
42	16	250	DI	1.28	0.70	23.0	30.0	31.0	3,595	3,375	3,715	3,495
42	18	150	30	1.28	0.75	23.0	30.0	31.0	3,615	3,395	3,755	3,535
42	18	250	30	1.78	0.96	23.0	30.0	31.0	4,455	4,230	4.595	4,370
42	18	250	DI	1.28	0.75	23.0	30.0	31.0	3,615	3,395	3,755	3,535
42	20	150	30	1.28	0.80	23.0	30.0	31.0	3,640	3,420	3,810	3,590
42	20	250	30	1.78	1.03	23.0	30.0	31.0	4,480	4,255	4,645	4,420
42	20	250	DI	1.28	0.80	23.0	30.0	31.0	3,640	3,420	3,810	3,590
42	24	150	30	1.78	1.16	23.0	30.0	31.0	4,530	4,305	4,745	4,520
42	24	250	DI	1.28	0.89	23.0	30.0	31.0	3,690	3,470	3,910	3,690
42	30	150	30	1.78	1.37	31.0	31.0	39.0	5,800	5,575	6,210	5,985
42	30	250	DI	1.28	1.03	31.0	31.0	39.0	4,650	4,425	5,040	4,815
42	36	150	DI	1.28	1.15	31.0	31.0	39.0	4,880	4,655	5,425	5,200
42	36	250	DI	1.78	1.58	31.0	31.0	39.0	6,075	5,850	6,655	6,430
42	42	150	DI	1.28	1.28	31.0	31.0	39.0	5,085	4,860	5,840	5,615
42	42	250	DI	1.78	1.78	31.0	31.0	39.0	6,320	6,095	7,145	6,920
48	12	150	30	1.42	0.75	26.0	34.0	34.0	4,870	4,580	4,955	4,665
48	12	250	30	1.96	0.75	26.0	34.0	34.0	6,025	5,735	6,095	5,805
48	12	250	DI	1.42	0.75	26.0	34.0	34.0	4,870	4,580	4,955	4,665
48	14	150	30	1.42	0.66	26.0	34.0	34.0	4,885	4,595	4,985	4,695
48	14	250	30	1.96	0.82	26.0	34.0	34.0	6,055	5,770	6,155	5,865
48	14	250	DI	1.42	0.66	26.0	34.0	34.0	4,885	4,595	4,985	4,695
48	16	150	30	1.42	0.70	26.0	34.0	34.0	4,905	4,615	5,025	4,735
48	16	250	30	1.96	0.89	26.0	34.0	34.0	6,075	5,785	6,195	5,905
48	16	250	DI	1.42	0.70	26.0	34.0	34.0	4,905	4,615	5,025	4,735
48	18	150	30	1.42	0.75	26.0	34.0	34.0	4,925	4,635	5,065	4,775
48	18	250	30	1.96	0.96	26.0	34.0	34.0	6,095	5,804	6,235	5,945
48	18	250	DI	1.42	0.75	26.0	34.0	34.0	4,925	4,635	5,065	4,775
48	20	150	30	1.42	0.80	26.0	34.0	34.0	4,950	4,660	5,115	4,825
48	20	250	30	1.96	1.03	26.0	34.0	34.0	6,120	5,830	6,285	5,995
48	20	250	DI	1.42	0.80	26.0	34.0	34.0	4,950	4,660	5,115	4,825
48	24	150	30	1.42	0.89	26.0	34.0	34.0	4,995	4,705	5,210	4,920
48	24	250	30	1.96	1.16	26.0	34.0	34.0	6,165	5,880	6,375	6,085
48	24	250	DI	1.42	0.89	26.0	34.0	34.0	4,995	4,705	5,210	4,920
48	30	150	30	1.96	1.37	26.0	34.0	34.0	6,315	6,025	6,670	6,385
48	30	250	DI	1.42	1.03	26.0	34.0	34.0	5,140	4,855	5,495	5,210
48	36	150	30	1.96	1.58	34.0	34.0	42.0	7,835	7,545	8,360	8,075
48	36	250	DI	1.42	1.15	34.0	34.0	42.0	6,280	5,995	6,790	6,500
48	42	150	DI	1.42	1.28	34.0	34.0	42.0	6,510	6,225	7,150	6,860
48	42	250	DI	1.96	1.78	34.0	34.0	42.0	8,130	7,845	8,815	8,530
48	48	150	DI	1.42	1.42	34.0	34.0	42.0	6,765	6,475	7,655	7,370
48	48	250	DI	1.96	1.96	34.0	34.0	42.0	8,420	8,135	9,380	9,095

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Dimension details of mechanical-joint bells are shown in Table 1; dimension details of plain ends are shown in Table 2.

†Weight does not include accessory weights.

‡Ductile iron.

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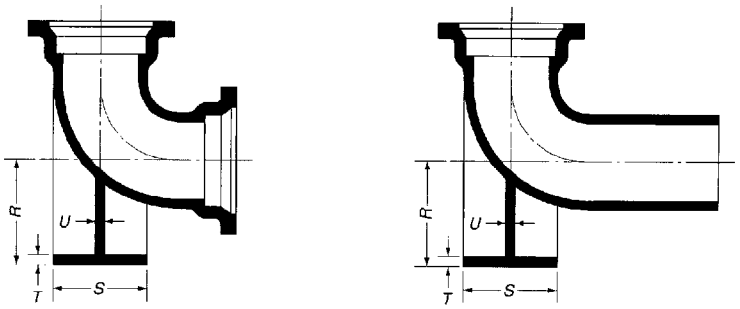

For other dimensions of base bends, see Table 3.

Figure 5 Mechanical-joint base bends (see Table 5)

Table 5 Mechanical-joint base bends

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1,000s)*	Dimensions—*in.*				Weight—*lb**		Base Only
			R†	S Diam.	T	U	MJ & MJ	MJ & PE	
3	250	25	4.88	5.00	0.56	0.50	45	45	10
3	350	DI‡	4.88	5.00	0.56	0.50	45	45	10
4	250	25	5.50	6.00	0.62	0.50	65	60	10
4	350	DI	5.50	6.00	0.62	0.50	65	60	10
6	250	25	7.00	7.00	0.69	0.62	105	100	20
6	350	DI	7.00	7.00	0.69	0.62	105	100	20
8	250	25	8.38	9.00	0.94	0.88	165	160	40
8	350	DI	8.38	9.00	0.94	0.88	165	160	40
10	250	25	9.75	9.00	0.94	0.88	235	235	45
10	350	DI	9.75	9.00	0.94	0.88	235	235	45
12	250	25	11.25	11.00	1.00	1.00	320	320	65
12	350	DI	11.25	11.00	1.00	1.00	320	320	65
14	150	25	12.50	11.00	1.00	1.00	410	395	70
14	250	25	12.50	11.00	1.00	1.00	450	435	70
14	350	DI	12.50	11.00	1.00	1.00	410	395	70
16	150	30	13.75	11.00	1.00	1.00	505	485	75
16	250	30	13.75	11.00	1.00	1.00	565	545	75
16	350	DI	13.75	11.00	1.00	1.00	505	485	75
18	150	30	15.00	13.50	1.12	1.12	660	635	115
18	250	30	15.00	13.50	1.12	1.12	740	715	115
18	350	DI	15.00	13.50	1.12	1.12	660	635	115
20	150	30	16.00	13.50	1.12	1.12	800	770	120
20	250	30	16.00	13.50	1.12	1.12	910	875	120
20	350	DI	16.00	13.50	1.12	1.12	800	770	120
24	150	30	18.50	13.50	1.12	1.12	1,155	1,115	130
24	250	30	18.50	13.50	1.12	1.12	1,345	1,305	130
24	350	DI	18.50	13.50	1.12	1.12	1,155	1,115	130
30	150	30	23.00	16.00	1.19	1.15	1,880	1,775	190
30	250	30	23.00	16.00	1.19	1.15	2,220	2,110	190
30	250	DI	23.00	16.00	1.19	1.15	1,880	1,775	190
36	150	30	26.00	19.00	1.25	1.15	2,725	2,560	250
36	250	30	26.00	19.00	1.25	1.15	3,295	3,130	250
36	250	DI	26.00	19.00	1.25	1.15	2,725	2,560	250
42	150	30	30.00	23.50	1.44	1.28	3,820	3,610	410
42	250	30	30.00	23.50	1.44	1.28	4,665	4,460	410
42	250	DI	30.00	23.50	1.44	1.28	3,820	3,610	410
48	150	30	34.00	25.00	1.56	1.42	5,110	4,845	515
48	250	30	34.00	25.00	1.56	1.42	6,260	5,990	515
48	250	DI	34.00	25.00	1.56	1.42	5,110	4,845	515

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Weight does not include accessory weights.

†Dimension R is a finished dimension; unfinished bases will be ⅛ in. (3 mm) longer; for base drilling see Table 15.

‡Ductile iron.

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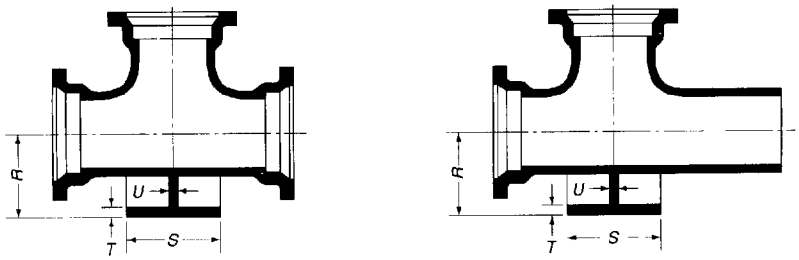

For other dimensions of base tees, see Table 4.

Figure 6 Mechanical-joint base tees (see Table 6)

Table 6 Mechanical-joint base tees

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1,000s)*	Dimensions—*in.*				Weight—*lb**		Base Only
			R†	*S* Diam.	*T*	*U*	All MJ	MJ, PE, & MJ	
3	250	25	4.88	5.00	0.56	0.50	60	60	5
3	350	DI‡	4.88	5.00	0.56	0.50	60	60	5
4	250	25	5.50	6.00	0.62	0.50	90	85	10
4	350	DI	5.50	6.00	0.62	0.50	90	85	10
6	250	25	7.00	7.00	0.69	0.62	140	135	15
6	350	DI	7.00	7.00	0.69	0.62	140	135	15
8	250	25	8.38	9.00	0.94	0.88	215	210	30
8	350	DI	8.38	9.00	0.94	0.88	215	210	30
10	250	25	9.75	9.00	0.94	0.88	340	340	30
10	350	DI	9.75	9.00	0.94	0.88	340	340	30
12	250	25	11.25	11.00	1.00	1.00	455	455	45
12	350	DI	11.25	11.00	1.00	1.00	455	455	45
14	150	25	12.50	11.00	1.00	1.00	635	620	50
14	250	30	12.50	11.00	1.00	1.00	635	620	50
14	350	DI	12.50	11.00	1.00	1.00	570	550	50
16	150	30	13.75	11.00	1.00	1.00	790	770	50
16	250	35	13.75	11.00	1.00	1.00	790	770	50
16	350	DI	13.75	11.00	1.00	1.00	700	675	50
18	150	30	15.00	13.50	1.12	1.12	1,020	995	75
18	250	35	15.00	13.50	1.12	1.12	1,020	995	75
18	350	DI	15.00	13.50	1.12	1.12	895	870	75
20	150	35	16.00	13.50	1.12	1.12	1,260	1,230	75
20	350	DI	16.00	13.50	1.12	1.12	1,095	1,065	75
24	150	35	18.50	13.50	1.12	1.12	1,895	1,855	80
24	350	DI	18.50	13.50	1.12	1.12	1,615	1,570	80
30	150	35	23.00	16.00	1.19	1.15	3,225	3,110	120
30	250	DI	23.00	16.00	1.19	1.15	2,715	2,600	120
36	150	35	26.00	19.00	1.25	1.15	4,750	4,570	160
36	250	DI	26.00	19.00	1.25	1.15	3,905	3,725	160
42	150	DI	30.00	23.50	1.44	1.28	5,355	5,130	270
42	250	DI	30.00	23.50	1.44	1.28	6,590	6,365	270
48	150	DI	34.00	25.00	1.56	1.42	7,100	6,810	335
48	250	DI	34.00	25.00	1.56	1.42	8,755	8,470	335

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Weight does not include accessory weights.

†Dimension *R* is a finished dimension; unfinished bases will be ⅛ in. (3 mm) longer; for base drilling see Table 15.

‡Ductile iron.

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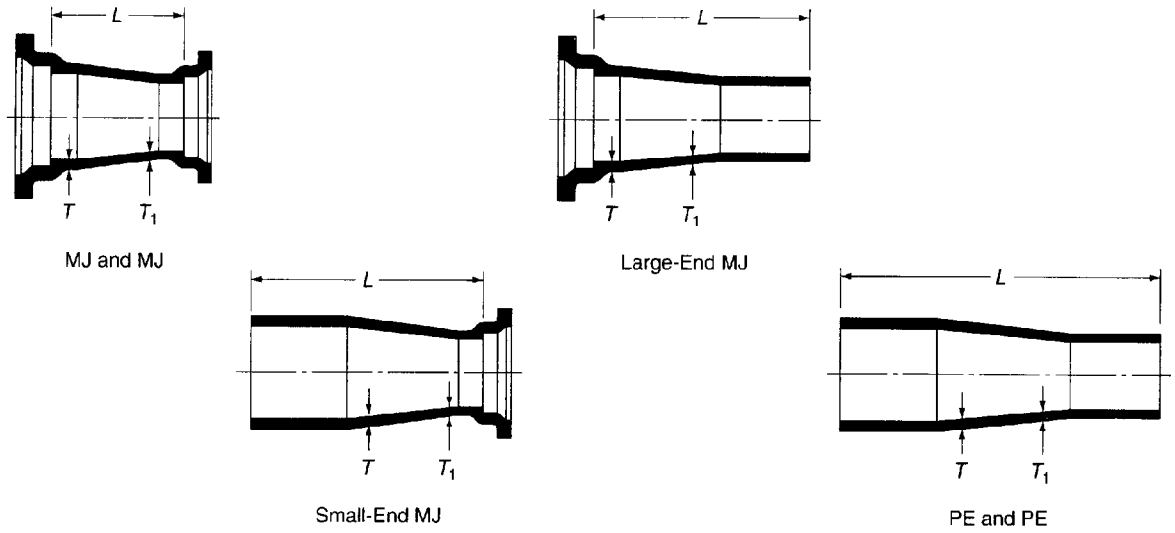

Figure 7 Mechanical-joint reducers (see Table 7)

Table 7 Mechanical-joint reducers*

Size in.				Thickness in.		MJ & MJ		Small-End MJ		Large-End MJ		PE to PE	
Large End	Small End	Pressure Rating psi	Iron Strength psi (1,000s)	T Large End	T_1 Small End	L in.	Weight† lb	L in.	Weight† lb	L in.	Weight† lb	L in.	Weight† lb
4	3	250	25	0.52	0.48	7	40	15	35	15	40	23	35
4	3	350	DI‡	0.52	0.48	7	40	15	35	15	40	23	35
6	3	250	25	0.55	0.48	9	55	17	50	17	55	25	50
6	3	350	DI	0.55	0.48	9	55	17	50	17	55	25	50
6	4	250	25	0.55	0.52	9	60	17	60	17	60	25	55
6	4	350	DI	0.55	0.52	9	60	17	60	17	60	25	55
8	4	250	25	0.60	0.52	11	80	19	80	19	80	27	75
8	4	350	DI	0.60	0.52	11	80	19	80	19	80	27	75
8	6	250	25	0.60	0.55	11	95	19	90	19	90	27	85
8	6	350	DI	0.60	0.55	11	95	19	90	19	90	27	85
10	4	250	25	0.68	0.52	12	105	20	100	20	100	28	100
10	4	350	DI	0.68	0.52	12	105	20	100	20	100	28	100
10	6	250	25	0.68	0.55	12	115	20	115	20	115	28	115
10	6	350	DI	0.68	0.55	12	115	20	115	20	115	28	115
10	8	250	25	0.68	0.60	12	135	20	130	20	130	28	130
10	8	350	DI	0.68	0.60	12	135	20	130	20	130	28	130
12	4	250	25	0.75	0.52	14	135	22	130	22	130	30	130
12	4	350	DI	0.75	0.52	14	135	22	130	22	130	30	130
12	6	250	25	0.75	0.55	14	150	22	150	22	145	30	145
12	6	350	DI	0.75	0.55	14	150	22	150	22	145	30	145

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*For dimension details of mechanical-joint bells, see Table 1; for dimension details of plain ends, see Table 2. Eccentric reducers with the same dimensions and weights given for concentric reducers are available from most manufacturers if specified on the purchase order.

†Weight does not include accessory weights.

‡Ductile iron.

Table continued next page.

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Table 7 Mechanical-joint reducers* (continued)

Size in.				Thickness in.		MJ & MJ		Small-End MJ		Large-End MJ		PE to PE	
Large End	Small End	Pressure Rating psi	Iron Strength psi (1,000s)	T Large End	T_1 Small End	L in.	Weight† lb	L in.	Weight† lb	L in.	Weight† lb	L in.	Weight† lb
12	8	250	25	0.75	0.60	14	165	22	165	22	165	30	165
12	8	350	DI‡	0.75	0.60	14	165	22	165	22	165	30	165
12	10	250	25	0.75	0.68	14	190	22	190	22	185	30	185
12	10	350	DI	0.75	0.68	14	190	22	190	22	185	30	185
14	6	150	25	0.66	0.55	16	190	24	175	24	185	32	170
14	6	250	25	0.82	0.55	16	200	24	185	24	200	32	185
14	6	350	DI	0.66	0.55	16	190	24	175	24	185	32	170
14	8	150	25	0.66	0.60	16	210	24	190	24	205	32	190
14	8	250	25	0.82	0.60	16	220	24	205	24	220	32	205
14	8	350	DI	0.66	0.60	16	210	24	190	24	205	32	190
14	10	150	25	0.66	0.68	16	230	24	215	24	230	32	215
14	10	250	25	0.82	0.68	16	245	24	230	24	245	32	230
14	10	350	DI	0.66	0.68	16	230	24	215	24	230	32	215
14	12	150	25	0.66	0.75	16	255	24	240	24	255	32	240
14	12	250	25	0.82	0.75	16	270	24	255	24	275	32	260
14	12	350	DI	0.66	0.75	16	255	24	240	24	255	32	240
16	6	150	30	0.70	0.55	18	230	26	210	26	230	34	210
16	6	250	30	0.89	0.55	18	250	26	230	26	250	34	230
16	6	350	DI	0.70	0.55	18	230	26	210	26	230	34	210
16	8	150	30	0.70	0.60	18	250	26	230	26	250	34	230
16	8	250	30	0.89	0.60	18	270	26	250	26	270	34	250
16	8	350	DI	0.70	0.60	18	250	26	230	26	250	34	230
16	10	150	30	0.70	0.68	18	280	26	255	26	275	34	255
16	10	250	30	0.89	0.68	18	300	26	280	26	300	34	280
16	10	350	DI	0.70	0.68	18	280	26	255	26	275	34	255
16	12	150	30	0.70	0.75	18	305	26	285	26	305	34	285
16	12	250	30	0.89	0.75	18	325	26	305	26	330	34	310
16	12	350	DI	0.70	0.75	18	305	26	285	26	305	34	285
16	14	150	30	0.70	0.66	18	335	26	310	26	315	34	295
16	14	250	30	0.89	0.82	18	370	26	350	26	355	34	335
16	14	350	DI	0.70	0.66	18	335	26	310	26	315	34	295
18	8	150	30	0.75	0.60	19	295	27	270	27	295	35	270
18	8	250	30	0.96	0.60	19	320	27	295	27	320	35	295
18	8	350	DI	0.75	0.60	19	295	27	270	27	295	35	270
18	10	150	30	0.75	0.68	19	325	27	300	27	320	35	295
18	10	250	30	0.96	0.68	19	350	27	325	27	350	35	325
18	10	350	DI	0.75	0.68	19	325	27	300	27	320	35	295
18	12	150	30	0.75	0.75	19	350	27	325	27	350	35	325
18	12	250	30	0.96	0.75	19	380	27	355	27	385	35	360
18	12	350	DI	0.75	0.75	19	350	27	325	27	350	35	325
18	14	150	30	0.75	0.66	19	380	27	355	27	365	35	340
18	14	250	30	0.96	0.82	19	425	27	400	27	410	35	385
18	14	350	DI	0.75	0.66	19	380	27	355	27	365	35	340
18	16	150	30	0.75	0.70	19	415	27	390	27	395	35	370
18	16	250	30	0.96	0.89	19	465	27	440	27	445	35	420
18	16	350	DI	0.75	0.70	19	415	27	390	27	395	35	370
20	10	150	30	0.80	0.68	20	375	28	345	28	375	36	345
20	10	250	30	1.03	0.68	20	410	28	380	28	410	36	380
20	10	350	DI	0.80	0.68	20	375	28	345	28	375	36	345

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*For dimension details of mechanical-joint bells, see Table 1; for dimension details of plain ends, see Table 2. Eccentric reducers with the same dimensions and weights given for concentric reducers are available from most manufacturers if specified on the purchase order.

†Weight does not include accessory weights.

‡Ductile iron.

Table continued next page.

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Table 7 Mechanical-joint reducers* (continued)

Size *in.*				Thickness *in.*		MJ & MJ		Small-End MJ		Large-End MJ		PE to PE	
Large End	Small End	Pressure Rating *psi*	Iron Strength *psi (1,000s)*	*T* Large End	T_1 Small End	*L* *in.*	Weight† *lb*	*L* *in.*	Weight† *lb*	*L* *in.*	Weight† *lb*	*L* *in.*	Weight† *lb*
20	12	150	30	0.80	0.75	20	405	28	375	28	405	36	375
20	12	250	30	1.03	0.75	20	440	28	410	28	445	36	415
20	12	350	DI‡	0.80	0.75	20	405	28	375	28	405	36	375
20	14	150	30	0.80	0.66	20	430	28	400	28	415	36	385
20	14	250	30	1.03	0.82	20	485	28	455	28	470	36	440
20	14	350	DI	0.80	0.66	20	430	28	400	28	415	36	385
20	16	150	30	0.80	0.70	20	470	28	435	28	445	36	415
20	16	250	30	1.03	0.89	20	530	28	500	28	510	36	475
20	16	350	DI	0.80	0.70	20	470	28	435	28	445	36	415
20	18	150	30	0.80	0.75	20	510	28	475	28	485	36	455
20	18	250	30	1.03	0.96	20	575	28	545	28	550	36	520
20	18	350	DI	0.80	0.75	20	510	28	475	28	485	36	455
24	12	150	30	0.89	0.75	24	550	32	510	32	550	40	510
24	12	250	30	1.16	0.75	24	610	32	570	32	615	40	575
24	12	350	DI	0.89	0.75	24	550	32	510	32	550	40	510
24	14	150	30	0.89	0.66	24	575	32	535	32	560	40	520
24	14	250	30	1.16	0.82	24	660	32	620	32	645	40	605
24	14	350	DI	0.89	0.66	24	575	32	535	32	560	40	520
24	16	150	30	0.89	0.70	24	615	32	575	32	595	40	555
24	16	250	30	1.16	0.89	24	705	32	665	32	685	40	645
24	16	350	DI	0.89	0.70	24	615	32	575	32	595	40	555
24	18	150	30	0.89	0.75	24	660	32	620	32	635	40	595
24	18	250	30	1.16	0.96	24	760	32	720	32	735	40	695
24	18	350	DI	0.89	0.75	24	660	32	620	32	635	40	595
24	20	150	30	0.89	0.80	24	705	32	665	32	675	40	635
24	20	250	30	1.16	1.03	24	815	32	775	32	785	40	745
24	20	350	DI	0.89	0.80	24	705	32	665	32	675	40	635
30	18	150	30	1.03	0.75	30	990	38	885	38	965	46	860
30	18	250	30	1.37	0.96	30	1,160	38	1,050	38	1,130	46	1,025
30	18	250	DI	1.03	0.75	30	990	38	885	38	965	46	860
30	20	150	30	1.03	0.80	30	1,050	38	945	38	1,020	46	915
30	20	250	30	1.37	1.03	30	1,225	38	1,120	38	1,195	46	1,090
30	20	250	DI	1.03	0.80	30	1,050	38	945	38	1,020	46	915
30	24	150	30	1.03	0.89	30	1,165	38	1,060	38	1,125	46	1,020
30	24	250	30	1.37	1.16	30	1,360	38	1,255	38	1,320	46	1,215
30	24	250	DI	1.03	0.89	30	1,165	38	1,060	38	1,125	46	1,020
36	20	150	30	1.15	0.80	36	1,450	44	1,285	44	1,420	52	1,255
36	20	250	30	1.58	1.03	36	1,730	44	1,560	44	1,695	52	1,530
36	20	250	DI	1.15	0.80	36	1,450	44	1,285	44	1,420	52	1,255
36	24	150	30	1.15	0.89	36	1,580	44	1,410	44	1,535	52	1,370
36	24	250	30	1.58	1.16	36	1,885	44	1,720	44	1,845	52	1,680
36	24	250	DI	1.15	0.89	36	1,580	44	1,410	44	1,535	52	1,370
36	30	150	30	1.15	1.03	36	1,855	44	1,690	44	1,750	52	1,585
36	30	250	30	1.58	1.37	36	2,225	44	2,060	44	2,120	52	1,950
36	30	250	DI	1.15	1.03	36	1,855	44	1,690	44	1,750	52	1,585
42	20	150	30	1.28	0.80	42	1,915	50	1,705	50	1,880	58	1,670
42	20	250	30	1.78	1.03	42	2,320	50	2,110	50	2,285	58	2,080
42	20	250	DI	1.28	0.80	42	1,915	50	1,705	50	1,880	58	1,670

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*For dimension details of mechanical-joint bells, see Table 1; for dimension details of plain ends, see Table 2. Eccentric reducers with the same dimensions and weights given for concentric reducers are available from most manufacturers if specified on the purchase order.

†Weight does not include accessory weights.

‡Ductile iron.

Table continued next page.

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Table 7 Mechanical-joint reducers* (continued)

Size *in.*				Thickness *in.*		MJ & MJ		Small-End MJ		Large-End MJ		PE to PE	
Large End	Small End	Pressure Rating *psi*	Iron Strength *psi (1,000s)*	*T* Large End	T_1 Small End	*L* *in.*	Weight† *lb*	*L* *in.*	Weight† *lb*	*L* *in.*	Weight† *lb*	*L* *in.*	Weight† *lb*
42	24	150	30	1.28	0.89	42	2,060	50	1,855	50	2,020	58	1,810
42	24	250	30	1.78	1.16	42	2,495	50	2,285	50	2,455	58	2,245
42	24	250	DI‡	1.28	0.89	42	2,060	50	1,855	50	2,020	58	1,810
42	30	150	30	1.28	1.03	42	2,370	50	2,165	50	2,265	58	2,055
42	30	250	30	1.78	1.37	42	2,885	50	2,675	50	2,780	58	2,570
42	30	250	DI	1.28	1.03	42	2,370	50	2,165	50	2,265	58	2,055
42	36	150	30	1.28	1.15	42	2,695	50	2,485	50	2,530	58	2,320
42	36	250	30	1.78	1.58	42	3,310	50	3,100	50	3,145	58	2,935
42	36	250	DI	1.28	1.15	42	2,695	50	2,485	50	2,530	58	2,320
48	30	150	30	1.42	1.03	48	3,005	56	2,740	56	2,900	64	2,635
48	30	250	30	1.96	1.37	48	3,680	56	3,410	56	3,570	64	3,305
48	30	250	DI	1.42	1.03	48	3,005	56	2,740	56	2,900	64	2,635
48	36	150	30	1.42	1.15	48	3,370	56	3,100	56	3,205	64	2,940
48	36	250	30	1.96	1.58	48	4,160	56	3,890	56	3,990	64	3,725
48	36	250	DI	1.42	1.15	48	3,370	56	3,100	56	3,205	64	2,940
48	42	150	30	1.42	1.28	48	3,750	56	3,480	56	3,540	64	3,275
48	42	250	30	1.96	1.78	48	4,655	56	4,390	56	4,445	64	4,180
48	42	250	DI	1.42	1.28	48	3,750	56	3,480	56	3,540	64	3,275

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*For dimension details of mechanical-joint bells, see Table 1; for dimension details of plain ends, see Table 2. Eccentric reducers with the same dimensions and weights given for concentric reducers are available from most manufacturers if specified on the purchase order.

†Weight does not include accessory weights.

‡Ductile iron.

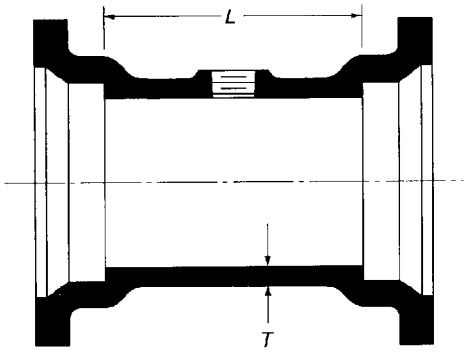

Figure 8 Mechanical-joint tapped tees (see Table 8)

Table 8 Mechanical-joint tapped tees*

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1,000s)*	*T* *in.*	*L* *in.*	Max. Tap in Boss *in.*	Weight† *lb*
3	250	25	0.48	8	2½	35
3	350	DI‡	0.48	8	2½	35
4	250	25	0.52	8	2½	45
4	350	DI	0.52	8	2½	45
6	250	25	0.55	8	2½	70
6	350	DI	0.55	8	2½	70
8	250	25	0.60	8	2½	95
8	350	DI	0.60	8	2½	95
10	250	25	0.68	8	2½	130
10	350	DI	0.68	8	2½	130
12	250	25	0.75	8	2½	165
12	250	DI	0.75	8	2½	165

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Two bosses can be used to make a tapped cross. For dimension details of mechanical-joint bells, see Table 1.

†Weight does not include accessory weights.

‡Ductile iron.

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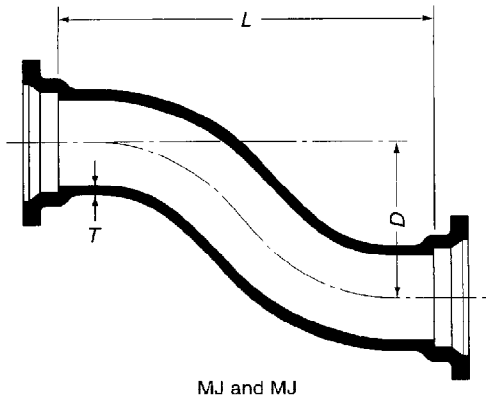
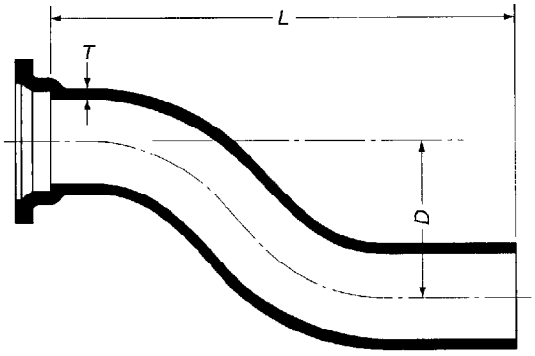


MJ and MJ



MJ and PE

Figure 9 Mechanical-joint offsets (see Table 9)

Table 9 Mechanical-joint offsets*

Size in.	PR† psi	Iron Strength psi (1,000s)	D in.	T in.	MJ & MJ L in.	MJ & MJ Wgt.‡ lb	MJ & PE L in.	MJ & PE Wgt.‡ lb
3	250	25	5	0.48	19	50	27	50
3	350	DI§	5	0.48	19	50	27	50
3	250	25	12	0.48	22	60	30	60
3	350	DI	12	0.48	22	60	30	60
3	250	25	18	0.48	30	75	38	75
3	350	DI	18	0.48	30	75	38	75
4	250	25	6	0.52	19	75	27	70
4	350	DI	6	0.52	19	75	27	70
4	250	25	12	0.52	22	85	30	80
4	350	DI	12	0.52	22	85	30	80
4	250	25	18	0.52	30	105	38	100
4	350	DI	18	0.52	30	105	38	100
6	250	25	6	0.55	20	110	28	105
6	350	DI	6	0.55	20	110	28	105
6	250	25	12	0.55	26	135	34	130
6	350	DI	12	0.55	26	135	34	130
6	250	25	18	0.55	33	165	41	160
6	350	DI	18	0.55	33	165	41	160
8	250	25	6	0.60	21	150	29	155
8	350	DI	6	0.60	21	160	29	155
8	250	25	12	0.60	28	200	36	195
8	350	DI	12	0.60	28	200	36	195
8	250	25	18	0.60	35	245	43	240
8	350	DI	18	0.60	35	245	43	240
10	250	25	6	0.68	22	220	30	220
10	350	DI	6	0.68	22	220	30	220
10	250	25	12	0.68	30	250	38	280
10	350	DI	12	0.68	30	250	38	280
10	250	25	18	0.68	38	340	46	340
10	350	DI	18	0.68	38	340	46	340
12	250	25	6	0.75	26	320	34	320
12	350	DI	6	0.75	26	320	34	320
12	250	25	12	0.75	37	420	45	420
12	350	DI	12	0.75	37	420	45	420
12	250	25	18	0.75	48	520	56	520
12	350	DI	18	0.75	48	520	56	520
14	150	25	6	0.66	27	380	35	365
14	250	25	6	0.82	27	435	35	420
14	350	DI	6	0.66	27	380	35	365
14	150	25	12	0.66	38	480	46	465
14	250	25	12	0.82	38	560	46	545
14	350	DI	12	0.66	38	480	46	465
14	150	25	18	0.66	49	585	57	570
14	250	25	18	0.82	49	680	57	665
14	350	DI	18	0.66	49	585	57	570
16	150	30	6	0.70	27	460	35	440
16	250	30	6	0.89	27	535	35	515
16	350	DI	6	0.70	27	460	35	440
16	150	30	12	0.70	40	600	48	580
16	250	30	12	0.89	40	715	48	690
16	350	DI	12	0.70	40	600	48	580
16	150	30	18	0.70	50	710	58	690
16	250	30	18	0.89	50	850	58	830
16	350	DI	18	0.70	50	710	58	690

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*For dimension details of mechanical-joint bells, see Table 1; for dimension details of plain ends, see Table 2.

†Pressure rating.

‡Weight does not include accessory weights.

§Ductile iron.

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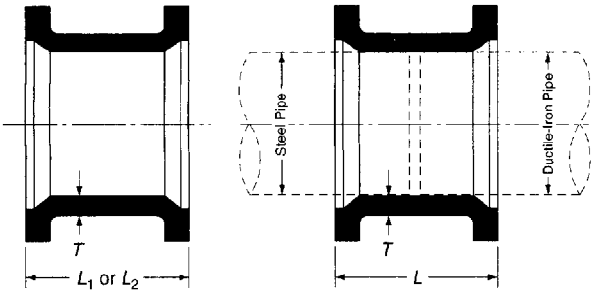
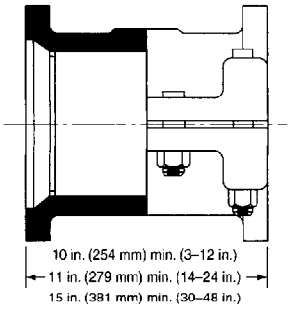


Figure 10 Mechanical-joint sleeves (see Table 10)



Split sleeves are furnished with a pressure rating of 150 psi (1.0 MPa) and can be furnished with boss and tap for service connections. Consult manufacturers for details.

Figure 10a Mechanical-joint split sleeves

Table 10 Mechanical-joint sleeves

				Solid Sleeves				Transition Sleeves*		
				L_1		L_2			L	
Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1,000s)*	T *in.*	Length *in.*	Wgt† *lb*	Length *in.*	Wgt† *lb*	Fits OD Steel Pipe	Length *in.*	Wgt† *lb*
3	250	25	0.48	7.5	25	12	30	3.50	7.5	25
3	350	DI‡	0.48	7.5	25	12	30	3.50	7.5	25
4	250	25	0.52	7.5	35	12	45	4.50	7.5	35
4	350	DI	0.52	7.5	35	12	45	4.50	7.5	35
6	250	25	0.55	7.5	45	12	65	6.62	7.5	45
6	350	DI	0.55	7.5	45	12	65	6.62	7.5	45
8	250	25	0.60	7.5	65	12	85	8.62	7.5	65
8	350	DI	0.60	7.5	65	12	85	8.62	7.5	65
10	250	25	0.68	7.5	85	12	115	10.75	7.5	85
10	350	DI	0.68	7.5	85	12	115	10.75	7.5	85
12	250	25	0.75	7.5	110	12	145	12.75	7.5	110
12	350	DI	0.75	7.5	110	12	145	12.75	7.5	110
14	150	30	0.66	9.5	150	15	195			
14	250	30	0.82	9.5	165	15	225			
14	350	DI	0.66	9.5	150	15	195			
16	150	30	0.70	9.5	180	15	235			
16	250	30	0.89	9.5	200	15	275			
16	350	DI	0.70	9.5	180	15	235			
18	150	30	0.75	9.5	215	15	285			
18	250	30	0.96	9.5	240	15	330			
18	350	DI	0.75	9.5	215	15	285			
20	150	30	0.80	9.5	240	15	325			
20	250	30	1.03	9.5	275	15	380			
20	350	DI	0.80	9.5	240	15	325			
24	150	30	0.89	9.5	320	15	425			
24	250	30	1.16	9.5	360	15	505			
24	350	DI	0.89	9.5	320	15	425			
30	150	30	1.03	15	635	24	885			
30	250	30	1.37	15	745	24	1,085			
30	250	DI	1.03	15	635	24	885			
36	150	30	1.15	15	855	24	1,190			
36	250	30	1.58	15	1,030	24	1,495			
36	250	DI	1.15	15	855	24	1,190			
42	150	30	1.28	15	1,115	24	1,550			
42	250	30	1.78	15	1,330	24	1,940			
42	250	DI	1.28	15	1,115	24	1,550			
48	150	30	1.42	15	1,385	24	1,940			
48	250	30	1.96	15	1,645	24	2,405			
48	250	DI	1.42	15	1,385	24	1,940			

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Transition sleeves are furnished with one end designed to fit standard steel pipe and the other to fit plain-end ductile-iron pipe.

†Weight does not include accessory weights.

‡Ductile iron.

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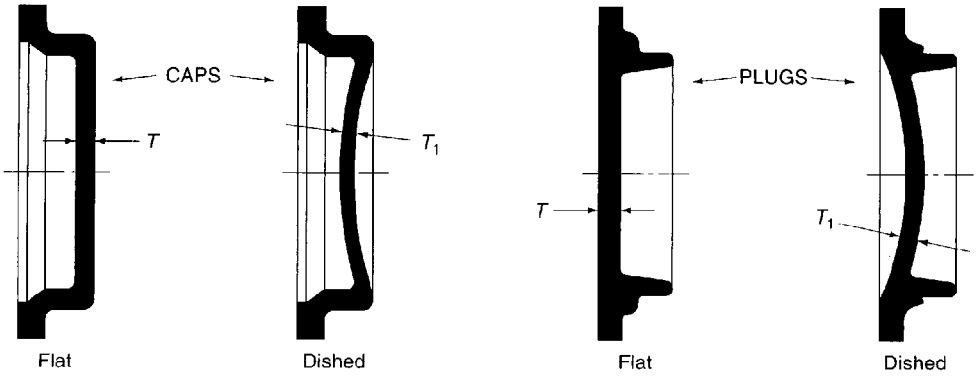

Figure 11 Mechanical-joint caps and plugs (see Table 11)

Table 11 Mechanical-joint caps and plugs

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1,000s)*	Caps				Plugs			
			Dimensions—*in.*		Weight—*lb*		Dimensions—*in.*		Weight—*lb*	
			T	T_1	Flat	Dished*	T	T_1	Flat	Dished*
3	250	25	0.50	0.48	12	12	0.50	0.48	10	10
3	350	DI†	0.50	0.48	12	12	0.50	0.48	10	10
4	250	25	0.60	0.52	15	15	0.60	0.52	15	15
4	350	DI	0.60	0.52	15	15	0.60	0.52	15	15
6	250	25	0.65	0.55	25	25	0.65	0.55	25	25
6	350	DI	0.65	0.55	25	25	0.65	0.55	25	25
8	250	25	0.70	0.60	45	45	0.70	0.60	45	45
8	350	DI	0.70	0.60	45	45	0.70	0.60	45	45
10	250	25	0.75	0.68	60	60	0.75	0.68	65	70
10	350	DI	0.75	0.68	60	60	0.75	0.68	65	70
12	250	25	0.75	0.75	80	80	0.75	0.75	85	90
12	350	DI	0.75	0.75	80	80	0.75	0.75	85	90
14	250	30	1.00	0.82	130	115	1.00	0.82	120	120
14	250	DI	0.32	0.66	120	110	0.32	0.66	115	115
16	250	30	1.11	0.89	175	155	1.11	0.89	155	150
16	250	DI	0.89	0.70	155	150	0.59	0.70	145	145
18	250	30	1.25	0.96	225	215	1.25	0.96	200	190
18	250	DI	0.96	0.75	195	185	0.96	0.75	185	180
20	250	30	1.40	1.03	285	250	1.40	1.03	255	215
20	250	DI	1.03	0.80	240	200	1.03	0.80	225	200
24	250	30	1.50	1.16	400	370	1.50	1.16	390	350
24	250	DI	1.16	0.89	345	300	1.16	0.89	335	390
30	150	30		1.37		680		1.37		660
30	250	DI		1.03		590		1.03		573
36	150	30		1.58		1,005		1.58		975
36	250	DI		1.15		850		1.15		815
42	150	30		1.78		1,535		1.78		1,355
42	250	DI		1.28		1,180		1.28		1,110
48	150	30		1.96		1,950		1.96		1,810
48	250	DI		1.42		1,595		1.42		1,455

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*All plugs and caps 30 in. and larger are "dished."

†Ductile iron.

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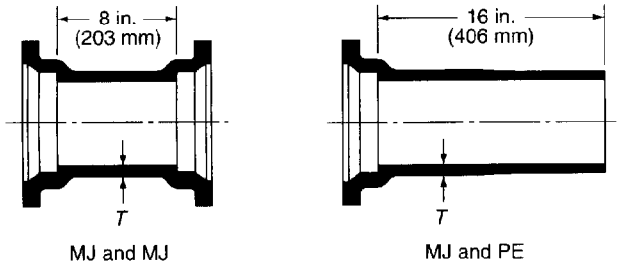

Figure 12 Mechanical-joint connecting pieces (see Table 12)

Table 12 Mechanical-joint connecting pieces*

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1,000s)*	*T*—*in.*	Weight—*lb*† MJ & MJ	Weight—*lb*† MJ & PE‡
3	250	25	0.48	35	35
3	350	DI§	0.48	35	35
4	250	25	0.52	45	45
4	350	DI	0.52	45	45
6	250	25	0.55	70	65
6	350	DI	0.55	70	65
8	250	25	0.60	95	95
8	350	DI	0.60	95	95
10	250	25	0.68	130	125
10	350	DI	0.68	130	125
12	250	25	0.75	165	165
12	350	DI	0.75	165	165
14	150	25	0.66	220	205
14	250	25	0.82	235	220
14	350	DI	0.66	220	205
16	150	30	0.70	270	250
16	250	30	0.89	290	270
16	350	DI	0.70	270	250
18	150	30	0.75	325	300
18	250	30	0.96	350	325
18	350	DI	0.75	325	300
20	150	30	0.80	390	360
20	250	30	1.03	420	385
20	350	DI	0.80	390	360
24	150	30	0.89	515	475
24	250	30	1.16	555	515
24	350	DI	0.89	515	475
30	150	30	1.03	840	730
30	250	30	1.37	905	795
30	250	DI	1.03	840	730
36	150	30	1.15	1,170	1,005
36	250	30	1.58	1,270	1,105
36	250	DI	1.15	1,170	1,005
42	150	30	1.28	1,500	1,295
42	250	30	1.78	1,635	1,430
42	250	DI	1.28	1,500	1,295
48	150	30	1.42	1,910	1,640
48	250	30	1.96	2,075	1,810
48	250	DI	1.42	1,910	1,640

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*For dimensional details of mechanical joints, see Table 1; plain ends, Table 2.

†Weight does not include accessory weights.

‡May be furnished from centrifugally cast pipe.

§Ductile iron.

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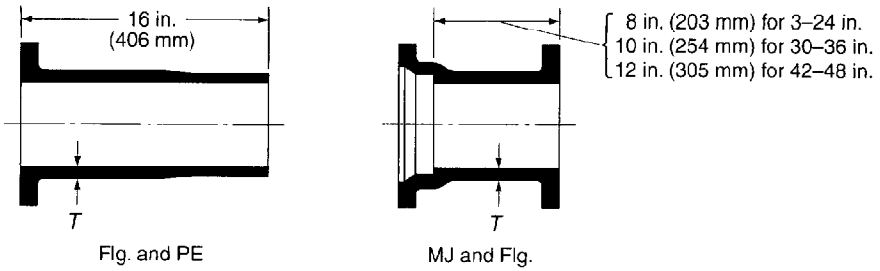

Figure 13 Connecting pieces, one-end flanged (see Table 13)

Table 13 Connecting pieces, one-end flanged*

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1,000s)*	*T*—*in.*	Weight—*lb*† MJ & Flg.‡	Weight—*lb*† Flg. & PE‡
3	250	25	0.48	30	30
3	250	DI§	0.48	30	30
4	250	25	0.52	40	40
4	250	DI	0.52	40	40
6	250	25	0.55	60	55
6	250	DI	0.55	60	55
8	250	25	0.60	85	85
8	250	DI	0.60	85	85
10	250	25	0.68	115	115
10	250	DI	0.68	115	115
12	250	25	0.75	155	155
12	250	DI	0.75	155	155
14	150	25	0.66	195	180
14	250	25	0.82	210	195
14	250	DI	0.66	195	180
16	150	30	0.70	240	220
16	250	30	0.89	260	240
16	250	DI	0.70	240	220
18	150	30	0.75	280	255
18	250	30	0.96	305	280
18	250	DI	0.75	280	255
20	150	30	0.80	340	305
20	250	30	1.03	365	335
20	250	DI	0.80	340	305
24	150	30	0.89	455	415
24	250	30	1.16	495	455
24	250	DI	0.89	455	415
30	150	30	1.03	760	600
30	250	30	1.37	840	665
30	250	DI	1.03	760	600
36	150	30	1.15	1,070	830
36	250	30	1.58	1,195	930
36	250	DI	1.15	1,070	830
42	150	30	1.28	1,505	1,115
42	250	30	1.78	1,685	1,250
42	250	DI	1.28	1,505	1,115
48	150	30	1.42	1,885	1,390
48	250	30	1.96	2,140	1,560
48	250	DI	1.42	1,885	1,390

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*For dimensional details of mechanical joints, see Table 1; plain ends, Table 2; flanges, Table 14.

†Weight does not include accessory weights.

‡May be furnished from centrifugally cast pipe.

§Ductile iron.

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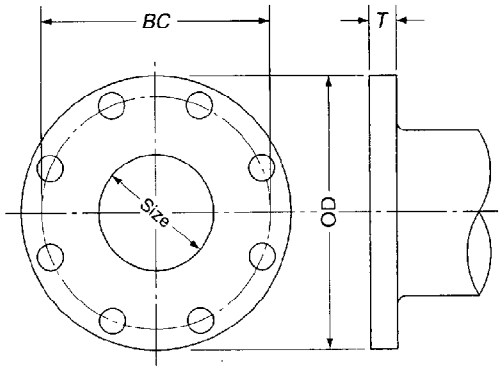

Figure 14 Flange details (see Table 14)

Table 14 Flange details

Size *in.*	Dimensions—*in.*					
	OD	*BC*	*T*	Bolt Hole Diam.	Bolt Diam. & Length—*in.*	No. of Bolts
3	7.50	6.00	0.75 ± .12	¾	⅝ × 2½	4
4	9.00	7.50	0.94 ± .12	¾	⅝ × 3	8
6	11.00	9.50	1.00 ± .12	⅞	¾ × 3½	8
8	13.50	11.75	1.12 ± .12	⅞	¾ × 3½	8
10	16.00	14.25	1.19 ± .12	1	⅞ × 4	12
12	19.00	17.00	1.25 ± .12	1	⅞ × 4	12
14	21.00	18.75	1.38 ± .19	1⅛	1 × 4¼	12
16	23.50	21.25	1.44 ± .19	1⅛	1 × 4¼	16
18	25.00	22.75	1.56 ± .19	1¼	1⅛ × 5	16
20	27.50	25.00	1.69 ± .19	1¼	1⅛ × 5	20
24	32.00	29.50	1.88 ± .19	1⅜	1¼ × 5½	20
30	38.75	36.00	2.12 ± .25	1⅜	1¼ × 6½	28
36	46.00	42.75	2.38 ± .25	1⅝	1½ × 7	32
42	53.00	49.50	2.62 ± .25	1⅝	1½ × 7½	36
48	59.50	56.00	2.75 ± .25	1⅝	1½ × 8	44

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

NOTE: For other requirements see Sec. 5.9.

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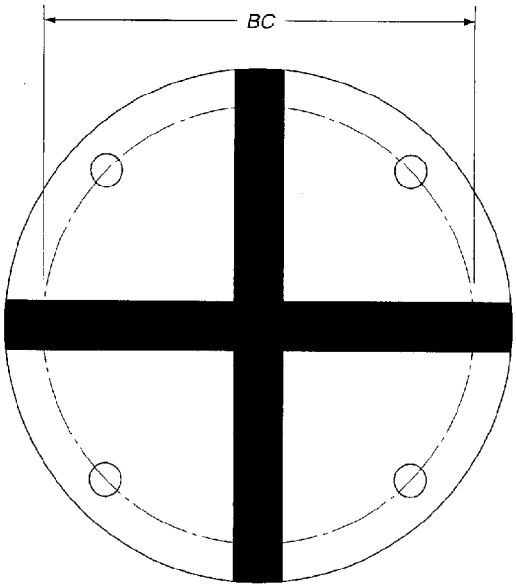

Figure 15 Base drilling details (see Table 15)

Table 15 Base drilling details*

Nom. Diam. *in.*	Dimensions—*in.*			Approx. Wgt. of Base—*lb*	
	BC	Bolt Hole Diam.	No. of Bolts	Bends	Tees
3	3.88	5/8	4	10	5
4	4.75	3/4	4	10	10
6	5.50	3/4	4	20	15
8	7.50	3/4	4	40	30
10	7.50	3/4	4	45	30
12	9.50	7/8	4	65	45
14	9.50	7/8	4	70	50
16	9.50	7/8	4	75	50
18	11.75	7/8	4	115	75
20	11.75	7/8	4	120	75
24	11.75	7/8	4	130	80
30	14.25	1	4	190	120
36	17.00	1	4	250	160
42	21.25	1 1/8	4	410	270
48	22.75	1 1/4	4	515	335

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Bases are not faced or drilled unless so specified in the purchase order.

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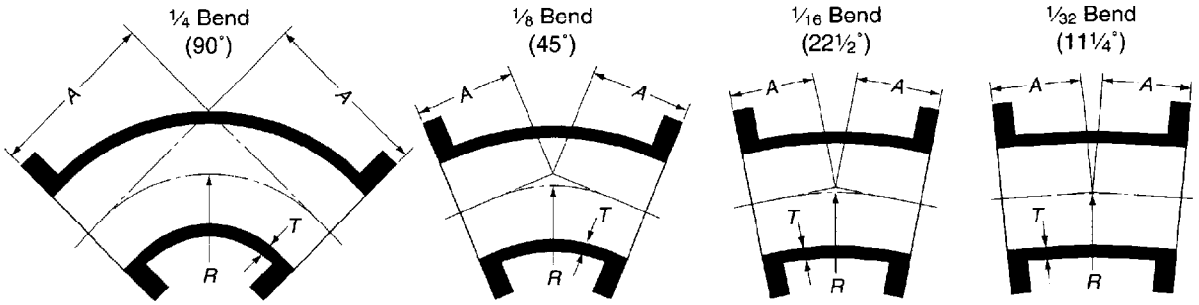

Figure 16 Flanged bends (see Table 16)

Table 16 Flanged bends

Size *in.*	PR*† *psi*	Iron Strength *psi* (*1,000s*)	*T*	Dimensions‡—*in.* ¼ Bend (90°) *A*	¼ Bend (90°) *R*	⅛ Bend (45°) *A*	⅛ Bend (45°) *R*	1/16 Bend (22½°) *A*	1/16 Bend (22½°) *R*	1/32 Bend (11¼°) *A*	1/32 Bend (11¼°) *R*	Weight—*lb* ¼ Bend (90°)	⅛ Bend (45°)	1/16 Bend (22½°)	1/32 Bend (11¼°)
3	250	25/DI§	0.48	5.5	4.0	3.0	3.62	3.0	7.56	3.0	15.25	25	20	20	20
4	250	25/DI§	0.52	6.5	4.5	4.0	4.81	4.0	10.06	4.0	20.31	45	40	40	40
6	250	25/DI§	0.55	8.0	6.0	5.0	7.25	5.0	15.06	5.0	30.50	65	55	55	55
8	250	25/DI§	0.60	9.0	7.0	5.5	8.44	5.5	17.62	5.5	35.50	105	90	90	90
10	250	25/DI§	0.68	11.0	9.0	6.5	10.88	6.5	22.62	6.5	45.69	165	130	135	135
12	250	25/DI§	0.75	12.0	10.0	7.5	13.25	7.5	27.62	7.5	55.81	235	195	205	205
14	150	25	0.66	14.0	11.5	7.5	12.06	7.5	25.12	7.5	50.75	290	220	225	225
14	250	25	0.82	14.0	11.5	7.5	12.06	7.5	25.12	7.5	50.75	330	245	250	255
14	250	DI**	0.66	14.0	11.5	7.5	12.06	7.5	25.12	7.5	50.75	290	220	225	225
16	150	30	0.70	15.0	12.5	8.0	13.25	8.0	27.62	8.0	55.81	370	280	285	285
16	250	30	0.89	15.0	12.5	8.0	13.25	8.0	27.62	8.0	55.81	430	315	325	325
16	250	DI	0.70	15.0	12.5	8.0	13.25	8.0	27.62	8.0	55.81	370	280	285	285
18	150	30	0.75	16.5	14.0	8.5	14.50	8.5	30.19	8.5	60.94	450	325	335	335
18	250	30	0.96	16.5	14.0	8.5	14.50	8.5	30.19	8.5	60.94	530	375	385	385
18	250	DI	0.75	16.5	14.0	8.5	14.50	8.5	30.19	8.5	60.94	450	325	335	335
20	150	30	0.80	18.0	15.5	9.5	16.88	9.5	35.19	9.5	71.06	580	430	435	435
20	250	30	1.03	18.0	15.5	9.5	16.88	9.5	35.19	9.5	71.06	685	485	505	505
20	250	DI	0.80	18.0	15.5	9.5	16.88	9.5	35.19	9.5	71.06	580	430	435	435
24	150	30	0.89	22.0	18.5	11.0	18.12	11.0	37.69	11.0	76.12	900	630	640	645
24	250	30	1.16	22.0	18.5	11.0	18.12	11.0	37.69	11.0	76.12	1,085	730	755	760
24	250	DI	0.89	22.0	18.5	11.0	18.12	11.0	37.69	11.0	76.12	900	630	640	645
30	150	30	1.03	25.0	21.5	15.0	27.75	15.0	57.81	15.0	116.75	1,430	1,120	1,135	1,150
30	250	30	1.37	25.0	21.5	15.0	27.75	15.0	57.81	15.0	116.75	1,755	1,335	1,385	1,395
30	250	DI	1.03	25.0	21.5	15.0	27.75	15.0	57.81	15.0	116.75	1,430	1,120	1,135	1,150
36	150	30	1.15	28.0	24.5	18.0	35.00	18.0	72.88	18.0	147.25	2,135	1,755	1,790	1,805
36	250	30	1.58	28.0	24.5	18.0	35.00	18.0	72.88	18.0	147.25	2,690	2,155	2,235	2,250
36	250	DI	1.15	28.0	24.5	18.0	35.00	18.0	72.88	18.0	147.25	2,135	1,755	1,790	1,805
42	150	30	1.28	31.0	27.5	21.0	42.25	21.0	88.00	21.0	177.69	3,055	2,600	2,665	2,680
42	250	30	1.78	31.0	27.5	21.0	42.25	21.0	88.00	21.0	177.69	3,880	3,240	3,365	3,390
42	250	DI	1.28	31.0	27.5	21.0	42.25	21.0	88.00	21.0	177.69	3,055	2,600	2,665	2,680
48	150	30	1.42	34.0	30.5	24.0	49.50	24.0	103.06	24.0	208.12	4,095	3,580	3,665	3,695
48	250	30	1.96	34.0	30.5	24.0	49.50	24.0	103.06	24.0	208.12	5,210	4,485	4,660	4,690
48	250	DI	1.42	34.0	30.5	24.0	49.50	24.0	103.06	24.0	208.12	4,095	3,580	3,665	3,695

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Pressure rating.

†Fittings made of ductile iron in the 12-in. and smaller sizes may be rated at 350 psi with the use of a special gasket.

‡Dimension details of flanges are shown in Table 14.

§3–12-in. sizes may be gray iron (class 25) or ductile iron.

**Ductile iron.

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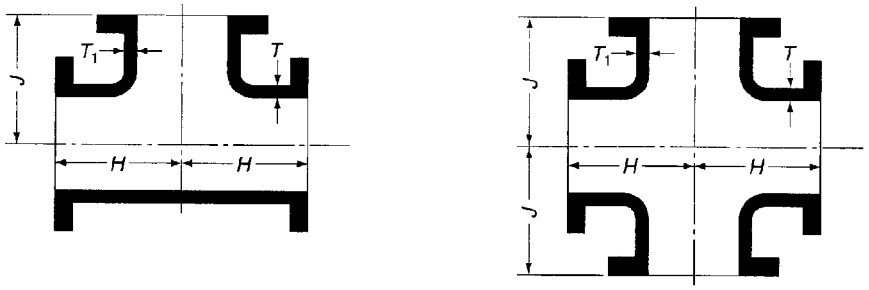

Figure 17 Flanged tees and crosses (see Table 17)

Table 17 Flanged tees and crosses

Size—*in.*		Pressure Rating*	Iron Strength	Dimensions—*in.*†				Weight—*lb*	
Run	Branch	*psi*	*psi (1,000s)*	*T*	T_1	*H*	*J*	Tee	Cross
3	3	250	25/DI‡	0.48	0.48	5.5	5.5	40	50
4	3	250	25/DI‡	0.52	0.48	6.5	6.5	60	70
4	4	250	25/DI‡	0.52	0.52	6.5	6.5	65	80
6	3	250	25/DI‡	0.55	0.48	8.0	8.0	85	95
6	4	250	25/DI‡	0.55	0.52	8.0	8.0	90	110
6	6	250	25/DI‡	0.55	0.55	8.0	8.0	95	120
8	4	250	25/DI‡	0.60	0.52	9.0	9.0	140	155
8	6	250	25/DI‡	0.60	0.55	9.0	9.0	145	165
8	8	250	25/DI‡	0.60	0.60	9.0	9.0	155	195
10	4	250	25	0.68	0.52	11.0	11.0	205	220
10	6	250	25	0.68	0.55	11.0	11.0	215	240
10	8	250	25	0.68	0.60	11.0	11.0	225	265
10	10	250	25	0.80	0.80	11.0	11.0	270	330
12	4	250	25	0.75	0.52	12.0	12.0	290	310
12	6	250	25	0.75	0.55	12.0	12.0	295	320
12	8	250	25	0.75	0.60	12.0	12.0	310	345
12	10	250	25	0.87	0.80	12.0	12.0	360	415
12	12	250	25	0.87	0.87	12.0	12.0	385	460
14	6	150	25	0.66	0.55	14.0	14.0	375	400
14	6	250	25	0.82	0.55	14.0	14.0	420	450
14	6	250	DI§	0.66	0.55	14.0	14.0	375	400
14	8	150	25	0.66	0.60	14.0	14.0	390	425
14	8	250	25	0.82	0.60	14.0	14.0	435	475
14	8	250	DI	0.66	0.60	14.0	14.0	390	425
14	10	150	25	0.66	0.68	14.0	14.0	400	460
14	10	250	25	0.82	0.68	14.0	14.0	450	505
14	10	250	DI	0.66	0.68	14.0	14.0	400	460
14	12	150	25	0.82	0.75	14.0	14.0	470	555
14	12	250	30	0.82	0.75	14.0	14.0	470	555
14	12	250	DI	0.66	0.75	14.0	14.0	425	505
14	14	150	25	0.82	0.82	14.0	14.0	500	595
14	14	250	30	0.82	0.82	14.0	14.0	500	595
14	14	250	DI	0.66	0.66	14.0	14.0	435	530
16	6	150	30	0.70	0.55	15.0	15.0	465	490
16	6	250	30	0.89	0.55	15.0	15.0	540	565
16	6	250	DI	0.70	0.55	15.0	15.0	465	490

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Fittings made of ductile iron in the 12-in. and smaller sizes may be rated at 350 psi with the use of a special gasket.

†Dimension details of flanges are in Table 14.

‡3–12-in. sizes may be gray iron (class 25) or ductile iron.

§Ductile iron.

Table continued next page.

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Table 17 Flanged tees and crosses (continued)

Size—*in.*		Pressure Rating*	Iron Strength	Dimensions—*in.*†				Weight—*lb*	
Run	Branch	*psi*	*psi (1,000s)*	T	T_1	H	J	Tee	Cross
16	8	150	30	0.70	0.60	15.0	15.0	475	520
16	8	250	30	0.89	0.60	15.0	15.0	555	590
16	8	250	DI‡	0.70	0.60	15.0	15.0	475	520
16	10	150	30	0.70	0.68	15.0	15.0	495	555
16	10	250	30	0.89	0.68	15.0	15.0	565	620
16	10	250	DI	0.70	0.68	15.0	15.0	495	555
16	12	150	30	0.70	0.75	15.0	15.0	520	605
16	12	250	30	0.89	0.75	15.0	15.0	590	665
16	12	250	DI	0.70	0.75	15.0	15.0	520	605
16	14	150	30	0.89	0.82	15.0	15.0	610	700
16	14	250	35	0.89	0.82	15.0	15.0	610	700
16	14	250	DI	0.70	0.66	15.0	15.0	530	620
16	16	150	30	0.89	0.89	15.0	15.0	635	755
16	16	250	35	0.89	0.89	15.0	15.0	635	755
16	16	250	DI	0.70	0.70	15.0	15.0	550	665
18	6	150	30	0.75	0.55	13.0	15.5	480	505
18	6	250	30	0.96	0.55	13.0	15.5	560	585
18	6	250	DI	0.75	0.55	13.0	15.5	480	505
18	8	150	30	0.75	0.60	13.0	15.5	495	535
18	8	250	30	0.96	0.60	13.0	15.5	570	605
18	8	250	DI	0.75	0.60	13.0	15.5	495	535
18	10	150	30	0.75	0.68	13.0	15.5	510	560
18	10	250	30	0.96	0.68	13.0	15.5	585	630
18	10	250	DI	0.75	0.68	13.0	15.5	510	560
18	12	150	30	0.75	0.75	13.0	15.5	535	610
18	12	250	30	0.96	0.75	13.0	15.5	605	670
18	12	250	DI	0.75	0.75	13.0	15.5	535	610
18	14	150	30	0.75	0.66	16.5	16.5	630	720
18	14	250	30	0.96	0.82	16.5	16.5	740	830
18	14	250	DI	0.75	0.66	16.5	16.5	630	720
18	16	150	30	0.96	0.89	16.5	16.5	760	880
18	16	250	35	0.96	0.89	16.5	16.5	760	880
18	16	250	DI	0.75	0.70	16.5	16.5	650	765
18	18	150	30	0.96	0.96	16.5	16.5	785	915
18	18	250	35	0.96	0.96	16.5	16.5	785	915
18	18	250	DI	0.75	0.75	16.5	16.5	665	795
20	6	150	30	0.80	0.55	14.0	17.0	610	635
20	6	250	30	1.03	0.55	14.0	17.0	710	735
20	6	250	DI	0.80	0.55	14.0	17.0	610	635
20	8	150	30	0.80	0.60	14.0	17.0	620	665
20	8	250	30	1.03	0.60	14.0	17.0	720	755
20	8	250	DI	0.80	0.60	14.0	17.0	620	665
20	10	150	30	0.80	0.68	14.0	17.0	635	685
20	10	250	30	1.03	0.68	14.0	17.0	735	780
20	10	250	DI	0.80	0.68	14.0	17.0	635	685
20	12	150	30	0.80	0.75	14.0	17.0	660	735
20	12	250	30	1.03	0.75	14.0	17.0	755	820
20	12	250	DI	0.80	0.75	14.0	17.0	660	735
20	14	150	30	0.80	0.66	14.0	17.0	665	745
20	14	250	35	1.03	0.82	14.0	17.0	770	850
20	14	250	DI	0.80	0.66	14.0	17.0	665	745
20	16	150	30	0.80	0.70	18.0	18.0	810	915
20	16	250	35	1.03	0.89	18.0	18.0	950	1,065
20	16	250	DI	0.80	0.70	18.0	18.0	810	915
20	18	150	35	1.03	0.96	18.0	18.0	965	1,100
20	18	250	DI	0.80	0.75	18.0	18.0	820	945
20	20	150	35	1.03	1.03	18.0	18.0	1,005	1,175
20	20	250	DI	0.80	0.80	18.0	18.0	855	1,015

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Fittings made of ductile iron in the 12-in. and smaller sizes may be rated at 350 psi with the use of a special gasket.

†Dimension details of flanges are in Table 14.

‡Ductile iron.

Table continued next page.

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Table 17 Flanged tees and crosses (continued)

Size—*in.*		Pressure Rating*	Iron Strength	Dimensions—*in.*†				Weight—*lb*	
Run	Branch	*psi*	*psi (1,000s)*	*T*	T_1	*H*	*J*	Tee	Cross
24	6	150	30	0.89	0.55	15.0	19.0	845	875
24	6	250	30	1.16	0.55	15.0	19.0	1,000	1,025
24	6	250	DI‡	0.89	0.55	15.0	19.0	845	875
24	8	150	30	0.89	0.60	15.0	19.0	860	895
24	8	250	30	1.16	0.60	15.0	19.0	1,010	1,045
24	8	250	DI	0.89	0.60	15.0	19.0	860	895
24	10	150	30	0.89	0.68	15.0	19.0	880	930
24	10	250	30	1.16	0.68	15.0	19.0	1,020	1,065
24	10	250	DI	0.89	0.68	15.0	19.0	880	930
24	12	150	30	0.89	0.75	15.0	19.0	890	960
24	12	250	30	1.16	0.75	15.0	19.0	1,040	1,100
24	12	250	DI	0.89	0.75	15.0	19.0	890	960
24	14	150	30	0.89	0.66	15.0	19.0	900	975
24	14	250	30	1.16	0.82	15.0	19.0	1,050	1,125
24	14	250	DI	0.89	0.66	15.0	19.0	900	975
24	16	150	30	0.89	0.70	15.0	19.0	915	1,010
24	16	250	35	1.16	0.89	15.0	19.0	1,070	1,160
24	16	250	DI	0.89	0.70	15.0	19.0	915	1,010
24	18	150	30	0.89	0.75	22.0	22.0	1,220	1,365
24	18	250	35	1.16	0.96	22.0	22.0	1,470	1,620
24	18	250	DI	0.89	0.75	22.0	22.0	1,220	1,365
24	20	150	35	1.16	1.03	22.0	22.0	1,510	1,695
24	20	250	DI	0.89	0.80	22.0	22.0	1,255	1,430
24	24	150	35	1.16	1.16	22.0	22.0	1,585	1,850
24	24	250	DI	0.89	0.89	22.0	22.0	1,330	1,570
30	12	150	30	1.03	0.75	18.0	23.0	1,490	1,565
30	12	250	30	1.37	0.75	18.0	23.0	1,780	1,840
20	12	250	DI	1.03	0.75	18.0	23.0	1,490	1,565
30	14	150	30	1.03	0.66	18.0	23.0	1,490	1,570
30	14	250	30	1.37	0.82	18.0	23.0	1,790	1,865
30	14	250	DI	1.03	0.66	18.0	23.0	1,490	1,570
30	16	150	30	1.03	0.70	18.0	23.0	1,505	1,605
30	16	250	30	1.37	0.89	18.0	23.0	1,810	1,900
30	16	250	DI	1.03	0.70	18.0	23.0	1,505	1,605
30	18	150	30	1.03	0.75	18.0	23.0	1,515	1,615
30	18	250	35	1.37	0.96	18.0	23.0	1,815	1,910
30	18	250	DI	1.03	0.75	18.0	23.0	1,515	1,615
30	20	150	30	1.03	0.80	18.0	23.0	1,540	1,670
30	20	250	35	1.37	1.03	18.0	23.0	1,840	1,960
30	20	250	DI	1.03	0.80	18.0	23.0	1,540	1,670
30	24	150	35	1.37	1.16	25.0	25.0	2,475	2,695
30	24	250	DI	1.03	0.89	25.0	25.0	2,025	2,245
30	30	150	35	1.37	1.37	25.0	25.0	2,615	2,980
30	30	250	DI	1.03	1.03	25.0	25.0	2,150	2,500
36	12	150	30	1.15	0.75	20.0	26.0	2,170	2,240
36	12	250	30	1.58	0.75	20.0	26.0	2,670	2,725
36	12	250	DI	1.15	0.75	20.0	26.0	2,170	2,240
36	14	150	30	1.15	0.66	20.0	26.0	2,175	2,240
36	14	250	30	1.58	0.82	20.0	26.0	2,680	2,740
36	14	250	DI	1.15	0.66	20.0	26.0	2,175	2,240
36	16	150	30	1.15	0.70	20.0	26.0	2,185	2,270
36	16	250	30	1.58	0.89	20.0	26.0	2,690	2,765
36	16	250	DI	1.15	0.70	20.0	26.0	2,185	2,270
36	18	150	30	1.15	0.75	20.0	26.0	2,190	2,280
36	18	250	30	1.58	0.96	20.0	26.0	2,695	2,770
36	18	250	DI	1.15	0.75	20.0	26.0	2,190	2,280

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Fittings made of ductile iron in the 12-in. and smaller sizes may be rated at 350 psi with the use of a special gasket.

†Dimension details of flanges are in Table 14.

‡Ductile iron.

Table continued next page.

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Table 17 Flanged tees and crosses (continued)

Size—*in.*		Pressure Rating*	Iron Strength	Dimensions—*in.*†				Weight—*lb*	
Run	Branch	*psi*	*psi (1,000s)*	T	T_1	H	J	Tee	Cross
36	20	150	30	1.15	0.80	20.0	26.0	2,210	2,325
36	20	250	35	1.58	1.03	20.0	26.0	2,715	2,810
36	20	250	DI‡	1.15	0.80	20.0	26.0	2,210	2,325
36	24	150	30	1.15	0.89	20.0	26.0	2,255	2,405
36	24	250	35	1.58	1.16	20.0	26.0	2,750	2,880
36	24	250	DI	1.15	0.89	20.0	26.0	2,255	2,405
36	30	150	35	1.58	1.37	28.0	28.0	3,745	4,025
36	30	250	DI	1.15	1.03	28.0	28.0	3,000	3,300
36	36	150	35	1.58	1.58	28.0	28.0	3,930	4,405
36	36	250	DI	1.15	1.15	28.0	28.0	3,160	3,620
42	12	150	30	1.28	0.75	23.0	30.0	3,165	3,240
42	12	250	30	1.78	0.75	23.0	30.0	3,950	4,005
42	12	250	DI	1.28	0.75	23.0	30.0	3,165	3,240
42	14	150	30	1.28	0.66	23.0	30.0	3,170	3,240
42	14	250	30	1.78	0.82	23.0	30.0	3,960	4,020
42	14	250	DI	1.28	0.66	23.0	30.0	3,170	3,240
42	16	150	30	1.28	0.70	23.0	30.0	3,180	3,270
42	16	250	30	1.78	0.89	23.0	30.0	3,970	4,045
42	16	250	DI	1.28	0.70	23.0	30.0	3,180	3,270
42	18	150	30	1.28	0.75	23.0	30.0	3,185	3,275
42	18	250	30	1.78	0.96	23.0	30.0	3,970	4,045
42	18	250	DI	1.28	0.75	23.0	30.0	3,185	3,275
42	20	150	30	1.28	0.80	23.0	30.0	3,205	3,320
42	20	250	30	1.78	1.03	23.0	30.0	3,990	4,080
42	20	250	DI	1.28	0.80	23.0	30.0	3,205	3,320
42	24	150	30	1.78	1.16	23.0	30.0	4,020	4,135
42	24	250	DI	1.28	0.89	23.0	30.0	3,245	3,395
42	30	150	30	1.78	1.37	31.0	31.0	5,225	5,445
42	30	250	DI	1.28	1.03	31.0	31.0	4,125	4,375
42	36	150	DI	1.28	1.15	31.0	31.0	4,265	4,655
42	36	250	DI	1.78	1.58	31.0	31.0	5,360	5,720
42	42	150	DI	1.28	1.28	31.0	31.0	4,470	5,065
42	42	250	DI	1.78	1.78	31.0	31.0	5,580	6,155
48	12	150	30	1.42	0.75	26.0	34.0	4,315	4,390
48	12	250	30	1.96	0.75	26.0	34.0	5,425	5,480
48	12	250	DI	1.42	0.75	26.0	34.0	4,315	4,390
48	14	150	30	1.42	0.66	26.0	34.0	4,315	4,385
48	14	250	30	1.96	0.82	26.0	34.0	5,435	5,495
48	14	250	DI	1.42	0.66	26.0	34.0	4,315	4,385
48	16	150	30	1.42	0.70	26.0	34.0	4,330	4,415
48	16	250	30	1.96	0.89	26.0	34.0	5,445	5,515
48	16	250	DI	1.42	0.70	26.0	34.0	4,330	4,415
48	18	150	30	1.42	0.75	26.0	34.0	4,330	4,420
48	18	250	30	1.96	0.96	26.0	34.0	5,445	5,515
48	18	250	DI	1.42	0.75	26.0	34.0	4,330	4,420
48	20	150	30	1.42	0.80	26.0	34.0	4,350	4,460
48	20	250	30	1.96	1.03	26.0	34.0	5,460	5,545
48	20	250	DI	1.42	0.80	26.0	34.0	4,350	4,460
48	24	150	30	1.42	0.89	26.0	34.0	4,385	4,535
48	24	250	30	1.96	1.16	26.0	34.0	5,485	5,595
48	24	250	DI	1.42	0.89	26.0	34.0	4,385	4,535
48	30	150	30	1.96	1.37	26.0	34.0	5,540	5,705
48	30	250	DI	1.42	1.03	26.0	34.0	4,455	4,670
48	36	150	30	1.96	1.58	34.0	34.0	7,035	7,310
48	36	250	DI	1.42	1.15	34.0	34.0	5,555	5,880
48	42	150	DI	1.42	1.28	34.0	34.0	5,720	6,215
48	42	250	DI	1.96	1.78	34.0	34.0	7,195	7,630
48	48	150	DI	1.42	1.42	34.0	34.0	5,900	6,570
48	48	250	DI	1.96	1.96	34.0	34.0	7,385	8,005

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Fittings made of ductile iron in the 12-in. and smaller sizes may be rated at 350 psi with the use of a special gasket.

†Dimension details of flanges are in Table 14.

‡Ductile iron.

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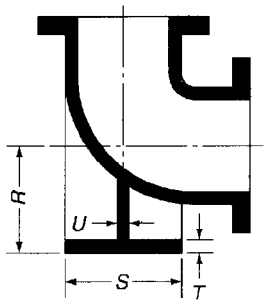

For other dimensions of base bends, see Table 16.

Figure 18 Flanged base bends (see Table 18)

Table 18 Flanged base bends

Size *in.*	Pressure Rating* *psi*	Iron Strength *psi (1,000s)*	Dimensions—*in.*				Weight—*lb*	
			$R^{\dagger}$	*S* Diam.	*T*	*U*	Base Fitting	Base Only
3	250	25/DI‡	4.88	5.00	0.56	0.50	35	10
4	250	25/DI‡	5.50	6.00	0.62	0.50	55	10
6	250	25/DI‡	7.00	7.00	0.69	0.62	85	20
8	250	25/DI‡	8.38	9.00	0.94	0.88	145	40
10	250	25/DI‡	9.75	9.00	0.94	0.88	210	45
12	250	25/DI‡	11.25	11.00	1.00	1.00	300	65
14	150	25	12.50	11.00	1.00	1.00	360	70
14	250	25	12.50	11.00	1.00	1.00	400	70
14	250	DI§	12.50	11.00	1.00	1.00	360	70
16	150	30	13.75	11.00	1.00	1.00	445	75
16	250	30	13.75	11.00	1.00	1.00	505	75
16	250	DI	13.75	11.00	1.00	1.00	445	75
18	150	30	15.00	13.50	1.12	1.12	565	115
18	250	30	15.00	13.50	1.12	1.12	645	115
18	250	DI	15.00	13.50	1.12	1.12	565	115
20	150	30	16.00	13.50	1.12	1.12	700	120
20	250	30	16.00	13.50	1.12	1.12	805	120
20	250	DI	16.00	13.50	1.12	1.12	700	120
24	150	30	18.50	13.50	1.12	1.12	1,030	130
24	250	30	18.50	13.50	1.12	1.12	1,215	130
24	250	DI	18.50	13.50	1.12	1.12	1,030	130
30	150	30	23.00	16.00	1.19	1.15	1,625	190
30	250	30	23.00	16.00	1.19	1.15	1,945	190
30	250	DI	23.00	16.00	1.19	1.15	1,625	190
36	150	30	26.00	19.00	1.25	1.15	2,385	250
36	250	30	26.00	19.00	1.25	1.15	2,940	250
36	250	DI	26.00	19.00	1.25	1.15	2,385	250
42	150	30	30.00	23.50	1.44	1.28	3,465	410
42	250	30	30.00	23.50	1.44	1.28	4,290	410
42	250	DI	30.00	23.50	1.44	1.28	3,465	410
48	150	30	34.00	25.00	1.56	1.42	4,610	515
48	250	30	34.00	25.00	1.56	1.42	5,725	515
48	250	DI	34.00	25.00	1.56	1.42	4,610	515

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Fittings made of ductile iron in the 12-in. and smaller sizes may be rated at 350 psi with the use of a special gasket.

†Dimension *R* is a finished dimension: unfinished bases will be ½ in. (3 mm) longer; details for base drilling are given in Table 15.

‡3–12-in. sizes may be gray iron (class 25) or ductile iron.

§Ductile iron.

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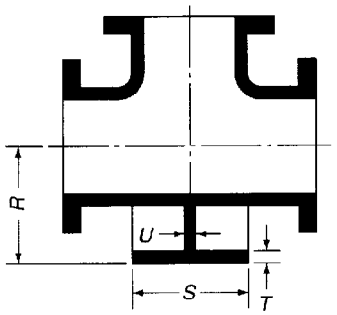

For other dimensions of base tees see Table 17.

Figure 19 Flanged base tees (see Table 19)

Table 19 Flanged base tees

Size *in.*	Pressure Rating* *psi*	Iron Strength *psi (1,000s)*	Dimensions—*in.*				Weight—*lb*	
			$R^{\dagger}$	*S* Diam.	*T*	*U*	Base Fitting	Base Only
3	250	25/DI‡	4.88	5.00	0.56	0.50	45	5
4	250	25/DI‡	5.50	6.00	0.62	0.50	75	10
6	250	25/DI‡	7.00	7.00	0.69	0.62	110	15
8	250	25/DI‡	8.38	9.00	0.94	0.88	185	30
10	250	25/DI‡	9.75	9.00	0.94	0.88	300	30
12	250	25/DI‡	11.25	11.00	1.00	1.00	430	45
14	150	25	12.50	11.00	1.00	1.00	550	50
14	250	30	12.50	11.00	1.00	1.00	550	50
14	250	DI§	12.50	11.00	1.00	1.00	485	50
16	150	30	13.75	11.00	1.00	1.00	685	50
16	250	35	13.75	11.00	1.00	1.00	685	50
16	250	DI	13.75	11.00	1.00	1.00	600	50
18	150	30	15.00	13.50	1.12	1.12	860	75
18	250	35	15.00	13.50	1.12	1.12	860	75
18	250	DI	15.00	13.50	1.12	1.12	740	75
20	150	35	16.00	13.50	1.12	1.12	1,080	75
20	250	DI	16.00	13.50	1.12	1.12	930	75
24	150	35	18.50	13.50	1.12	1.12	1,665	80
24	150	DI	18.50	13.50	1.12	1.12	1,410	80
30	150	35	23.00	16.00	1.19	1.15	2,735	120
30	250	DI	23.00	16.00	1.19	1.15	2,270	120
36	150	35	26.00	19.00	1.25	1.15	4,090	160
36	250	DI	26.00	19.00	1.25	1.15	3,320	160
42	150	DI	30.00	23.50	1.44	1.28	4,740	270
42	250	DI	30.00	23.50	1.44	1.28	5,850	270
48	150	DI	34.00	25.00	1.56	1.42	6,235	335
48	250	DI	34.00	25.00	1.56	1.42	7,720	335

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Fittings made of ductile iron in the 12-in. and smaller sizes may be rated at 350 psi with the use of a special gasket.

†Dimension *R* is a finished dimension: unfinished bases will be ½ in. (3 mm) longer; details for base drilling are given in Table 15.

‡3–12-in. sizes may be gray iron (class 25) or ductile iron.

§Ductile iron.

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Table 20 Flanged reducers

Size—*in.*				Dimensions—*in.*†			
Large	Small	Pressure Rating* *psi*	Iron Strength *psi* (*1,000s*)	*T* Large End	T_1 Small End	*L*	Wgt. *lb*
4	3	250	25/DI‡	0.52	0.48	7	30
6	3	250	25/DI‡	0.55	0.48	9	40
6	4	250	25/DI‡	0.55	0.52	9	45
8	4	250	25/DI‡	0.60	0.52	11	65
8	6	250	25/DI‡	0.60	0.55	11	75
10	4	250	25/DI‡	0.68	0.52	12	85
10	6	250	25/DI‡	0.68	0.55	12	90
10	8	250	25/DI‡	0.68	0.60	12	110
12	4	250	25/DI‡	0.75	0.52	14	120
12	6	250	25/DI‡	0.75	0.55	14	130
12	8	250	25/DI‡	0.75	0.60	14	145
12	10	250	25/DI‡	0.75	0.68	14	170
14	6	150	25	0.66	0.55	16	155
14	6	250	25	0.82	0.55	16	165
14	6	250	DI§	0.66	0.55	16	155
14	8	150	25	0.66	0.60	16	175
14	8	250	25	0.82	0.60	16	185
14	8	250	DI	0.66	0.60	16	175
14	10	150	25	0.66	0.68	16	190
14	10	250	25	0.82	0.68	16	205
14	10	250	DI	0.66	0.68	16	190
14	12	150	25	0.66	0.75	16	220
14	12	250	25	0.82	0.75	16	235
14	12	250	DI	0.66	0.75	16	220
16	6	150	30	0.70	0.55	18	190
16	6	250	30	0.89	0.55	18	210
16	6	250	DI	0.70	0.55	18	190
16	8	150	30	0.70	0.60	18	210
16	8	250	30	0.89	0.60	18	230
16	8	250	DI	0.70	0.60	18	210
16	10	150	30	0.70	0.68	18	235
16	10	250	30	0.89	0.68	18	255
16	10	250	DI	0.70	0.68	18	235
16	12	150	30	0.70	0.75	18	265
16	12	250	30	0.89	0.75	18	285
16	12	250	DI	0.70	0.75	18	265
16	14	150	30	0.70	0.66	18	280
16	14	250	30	0.89	0.82	18	315
16	14	250	DI	0.70	0.66	18	280
18	8	150	30	0.75	0.60	19	240
18	8	250	30	0.96	0.60	19	265
18	8	250	DI	0.75	0.60	29	240
18	10	150	30	0.75	0.68	19	265
18	10	250	30	0.96	0.68	19	290
18	10	250	DI	0.75	0.68	19	265
18	12	150	30	0.75	0.75	19	295
18	12	250	30	0.96	0.75	19	320
18	12	250	DI	0.75	0.75	19	295
18	14	150	30	0.75	0.66	19	310
18	14	250	30	0.96	0.82	19	350
18	14	250	DI	0.75	0.66	19	310
18	16	150	30	0.75	0.70	19	340
18	16	250	30	0.96	0.89	19	385
18	16	250	DI	0.75	0.70	19	340
20	10	150	30	0.80	0.68	20	310
20	10	250	30	1.03	0.68	20	340
20	10	250	DI	0.80	0.68	20	310
20	12	150	30	0.80	0.75	20	345
20	12	250	30	1.03	0.75	20	375
20	12	250	DI	0.80	0.75	20	345
20	14	150	30	0.80	0.66	20	355
20	14	250	30	1.03	0.82	20	405
20	14	250	DI	0.80	0.66	20	355
20	16	150	30	0.80	0.70	20	390
20	16	250	30	1.03	0.89	20	445
20	16	250	DI	0.80	0.70	20	390
20	18	150	30	0.80	0.75	20	410
20	18	250	30	1.03	0.96	20	470
20	18	250	DI	0.80	0.75	20	410
24	12	150	30	0.89	0.75	24	480
24	12	250	30	1.16	0.75	24	535
24	12	250	DI	0.89	0.75	24	480
24	14	150	30	0.89	0.66	24	490
24	14	250	30	1.16	0.82	24	565
24	14	250	DI	0.89	0.66	24	490
24	16	150	30	0.89	0.70	24	525
24	16	250	30	1.16	0.89	24	610
24	16	250	DI	0.89	0.70	24	525
24	18	150	30	0.89	0.75	24	550
24	18	250	30	1.16	0.96	24	645
24	18	250	DI	0.89	0.75	24	550
24	20	150	30	0.89	0.80	24	590
24	20	250	30	1.16	1.03	24	695
24	20	250	DI	0.89	0.80	24	590
30	18	150	30	1.03	0.75	30	810
30	18	250	30	1.37	0.96	30	970
30	18	250	DI	1.03	0.75	30	810
30	20	150	30	1.03	0.80	30	870
30	20	250	30	1.37	1.03	30	1,035
30	20	250	DI	1.03	0.80	30	870
30	24	150	30	1.03	0.89	30	970
30	24	250	30	1.37	1.16	30	1,155
30	24	250	DI	1.03	0.89	30	970
36	20	150	30	1.15	0.80	36	1,230
36	20	250	30	1.58	1.03	36	1,495
36	20	250	DI	1.15	0.80	36	1,230
36	24	150	30	1.15	0.89	36	1,345
36	24	250	30	1.58	1.16	36	1,635
36	24	250	DI	1.15	0.89	36	1,345
36	30	150	30	1.15	1.03	36	1,555
36	30	250	30	1.58	1.37	36	1,905
36	30	250	DI	1.15	1.03	36	1,555
42	24	150	30	1.28	0.89	42	1,820
42	24	250	30	1.78	1.16	42	2,235
42	24	250	DI	1.28	0.89	42	1,820
42	30	150	30	1.28	1.03	42	2,060
42	30	250	30	1.78	1.37	42	2,555
42	30	250	DI	1.28	1.03	42	2,060
42	36	150	30	1.28	1.15	42	2,345
42	36	250	30	1.78	1.58	42	2,935
42	36	250	DI	1.28	1.15	42	2,345
48	30	150	30	1.42	1.03	48	2,625
48	30	250	30	1.96	1.37	48	3,270
48	30	250	DI	1.42	1.03	48	2,625
48	36	150	30	1.42	1.15	48	2,950
48	36	250	30	1.96	1.58	48	3,710
48	36	250	DI	1.42	1.15	48	2,950
48	42	150	30	1.42	1.28	48	3,320
48	42	250	30	1.96	1.78	48	4,190
48	42	250	DI	1.42	1.28	48	3,320

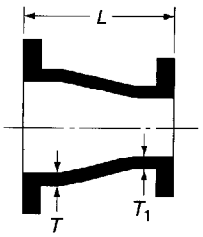

Figure 20 Flanged reducers (see Table 20)

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

*Fittings made of ductile iron in the 12-in. and smaller sizes may be rated at 350 psi with the use of a special gasket.

†Dimension details of flanges are given in Table 14. Eccentric reducers with the same dimensions and weights given for concentric reducers are available from most manufacturers if specified on the purchase order.

‡3–12-in. sizes may be gray iron (class 25) or ductile iron.

§Ductile iron.

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APPENDIX A

Flanged Fittings—Bolts, Gaskets, and Installation

This appendix is for information only and is not a part of ANSI/AWWA C110/A21.10.

The bolts and gaskets to be used with the flanged fittings are to be selected by the purchaser with due consideration for the particular pressure service and installation requirements.

SECTION A.1: BOLTS AND NUTS

Size, length, and number of bolts are shown in Table 14 of ANSI*/AWWA C110/A21.10. Bolts conform to ASME†/ANSI B18.2.1, Square and Hex Bolts and Screws Inch Series Including Hex Cap Screws and Lag Screws, and nuts conform to ASME/ANSI B18.2.2, Square and Hex Nuts. Bolts smaller than ¾ in. (19 mm) have either standard square or heavy hex heads and heavy hex nuts. Bolts ¾ in. (19 mm) and larger have either square or hex heads and either hex or heavy hex nuts. Bolts and nuts are threaded in accordance with ASME/ANSI B1.1, Unified Inch Screw Threads (UN and UNR Thread Form) class 2A external and class 2B internal. Bolts and nuts are low-carbon steel and conform to the chemical and mechanical requirements of ASTM‡ A307, Standard Specification for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength, grade B. The carbon–steel bolts should be used where gray-iron flanges are installed with flat ring gaskets that extend only to the bolts. Higher-strength bolts may properly be used where gray-iron flanges are installed with full-face gaskets. Higher-strength bolts may be used where ductile flanges are installed with either ring or full-face gaskets.

SECTION A.2: GASKETS

Gaskets are synthetic rubber, either ring or full face, and are ⅛ in. (3.2 mm) thick, unless otherwise specified by the purchaser, conforming to the dimensions shown in Table A.1, Flange gasket details. NOTE: When considering the use of gaskets thinner than ⅛ in. (3.2 mm) and/or gaskets of material other than synthetic rubber, the purchaser should contact the fitting manufacturer. Also available for most sizes are specially designed gaskets, either ring or full face, using one or more annular rings molded into the gasket to improve the gasket performance.

*American National Standards Institute, 11 W. 42nd St., New York, NY 10036.

†American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

‡American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

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SECTION A.3: INSTALLATION

The design, assembly, and installation of the flanged piping system are the responsibility of the purchaser. The following suggestions are for general guidance:

a. The underground use of flanged joints is generally not desirable because of the rigidity of the joint.

b. Flange faces should bear uniformly on the gasket and the bolts tightened in progressive crisscross order, such as by tightening the bottom bolt first; then, the top bolt; next, the bolts at either side; and, finally, the remaining bolts. This process should be repeated until all bolts are sufficiently tight to prevent leakage at the joint.

c. Users of flanged fittings should be careful to prevent bending or torsional strains from being applied to flanges, flanged fittings, or flanged appurtenances. Piping systems must be designed so that piping connected to flanges or flanged fittings is properly anchored, supported, or restrained to prevent breakage of fittings and flanges.

d. Ring gaskets are recommended for 14-in. (350-mm) and larger sizes if flat gaskets are used.

Table A.1 Flange gasket details

	Dimensions—*in.*						
	Ring		Full Face				
Nom. Size *in.*	Nom. *ID*	*OD*	Nom. *ID*	*OD*	*BC*	Bolt Hole Diam.	No. of Holes
3	3	5⅜	3	7½	6	¾	4
4	4	6⅞	4	9	7½	¾	8
6	6	8¾	6	11	9½	⅞	8
8	8	11	8	13½	11¾	⅞	8
10	10	13⅜	10	16	14¼	1	12
12	12	16⅛	12	19	17	1	12
14	14	17¾	14	21	18¾	1⅛	12
16	16	20¼	16	23½	21¼	1⅛	16
18	18	21⅝	18	25	22¾	1¼	16
20	20	23⅞	20	27½	25	1¼	20
24	24	28¼	24	32	29½	1⅜	20
30	30	34¾	30	38¾	36	1⅜	28
36	36	41¼	36	46	42¾	1⅝	32
42	42	48	42	53	49½	1⅝	36
48	48	54½	48	59½	56	1⅝	44

Metric conversions: Iron strength: psi (1,000s) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

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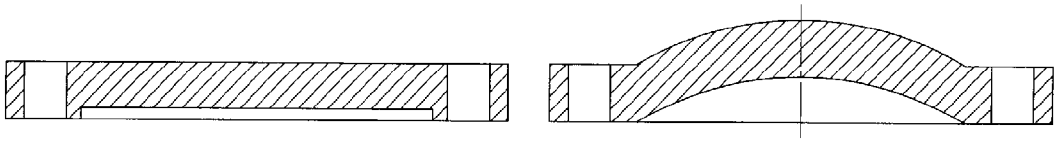
APPENDIX B

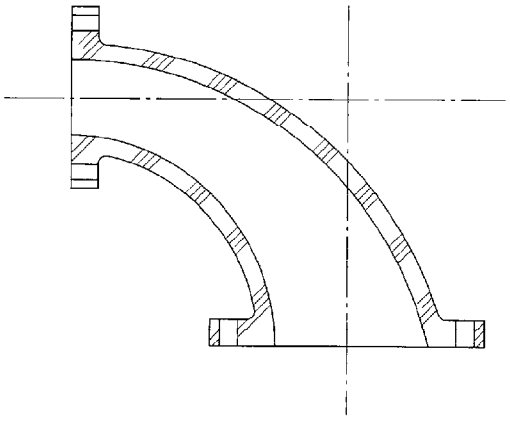
Special Fittings

This appendix is for information only and is not a part of ANSI/AWWA C110/A21.10.

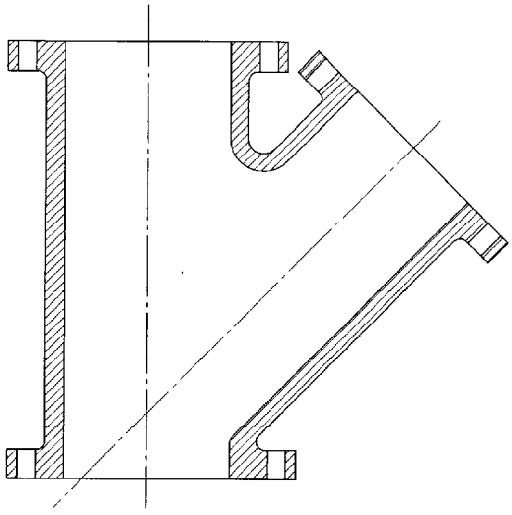
These special fittings are not a part of the standard but may be available from some manufacturers. For dimensions and pressure ratings, the manufacturer should be consulted.



Blind flanges



Flanged 90° reducing bend



Flanged wye branch

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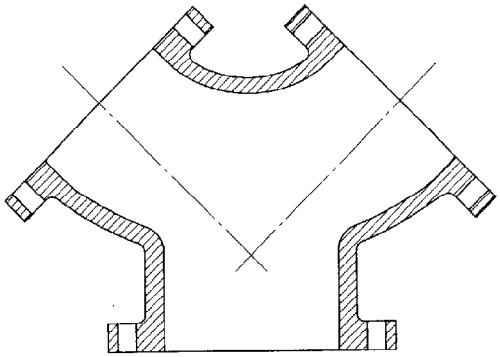
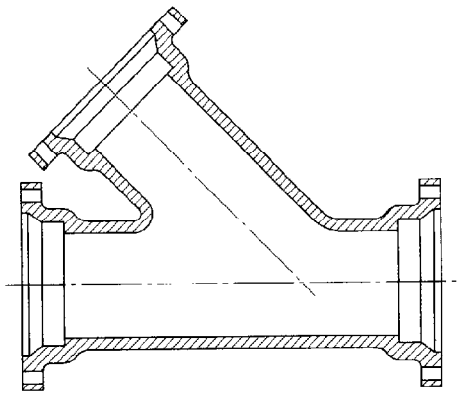
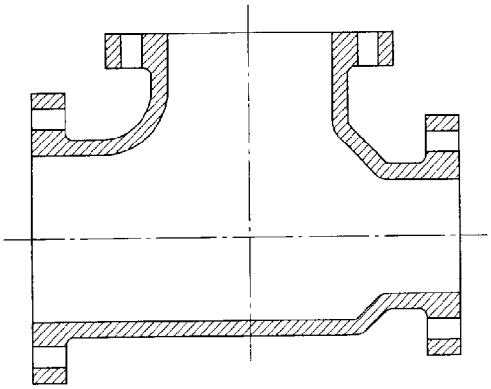


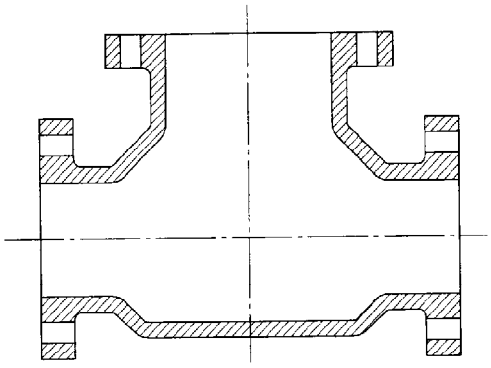
Flanged true wye



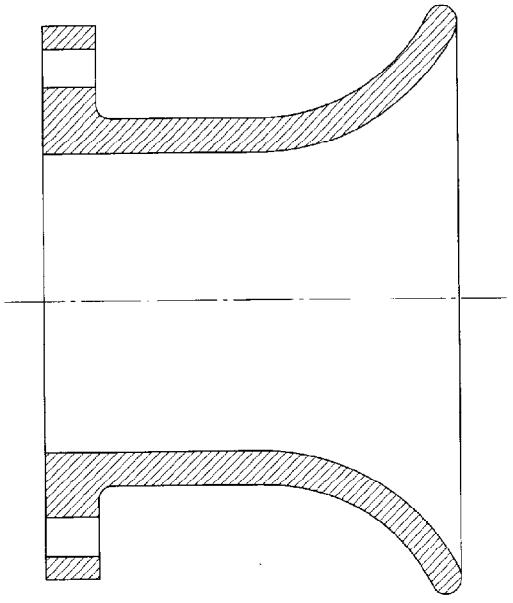
Mechanical-joint wye branch



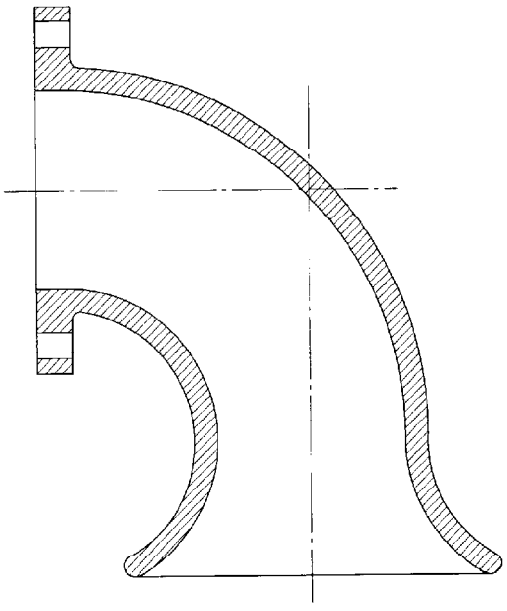
Flanged reducing tee



Flanged bullhead tee



Flange and flare



Flange and flare 90° bend

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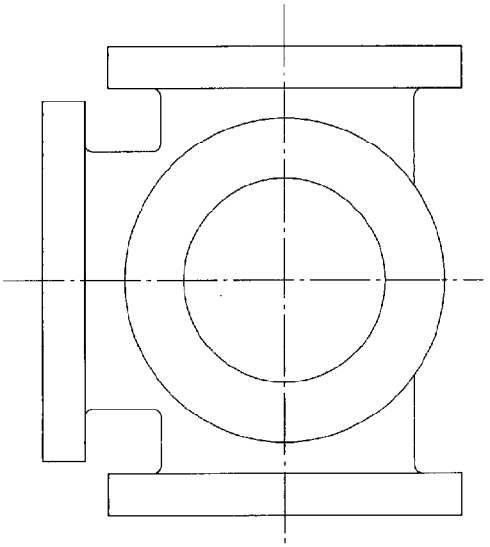
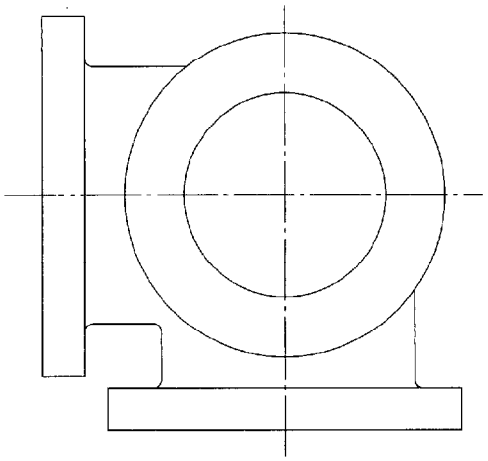
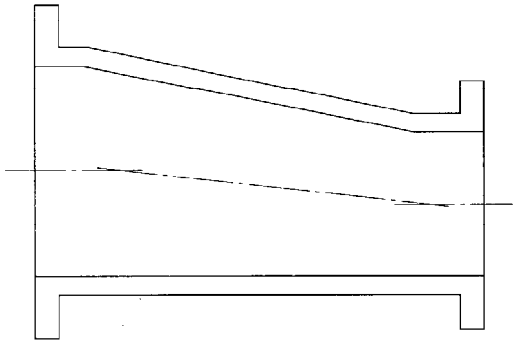


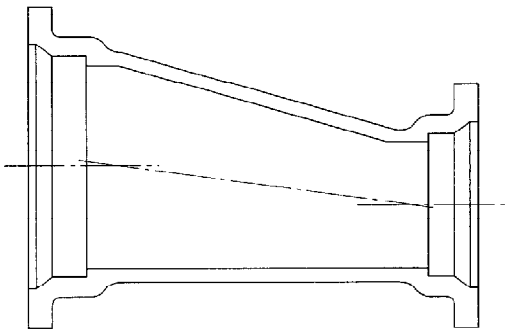
Flanged side-outlet tee



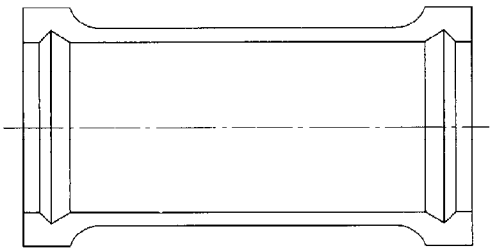
Flanged side-outlet 90° elbow



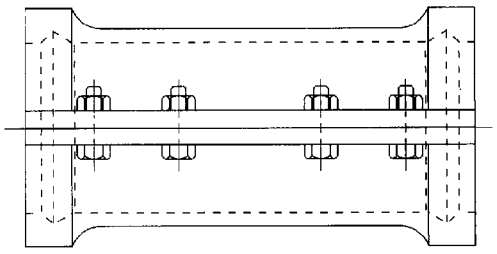
Flanged eccentric reducer



Mechanical-joint eccentric reducer



Caulked-joint sleeve



Caulked-joint split sleeve

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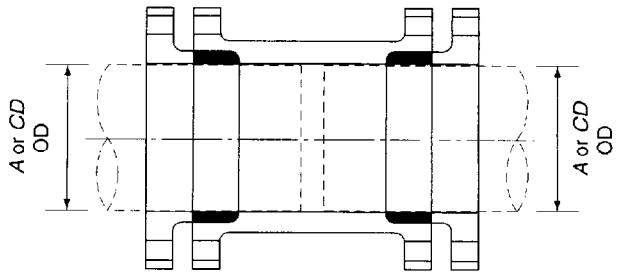
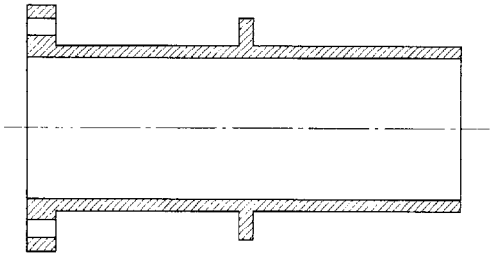


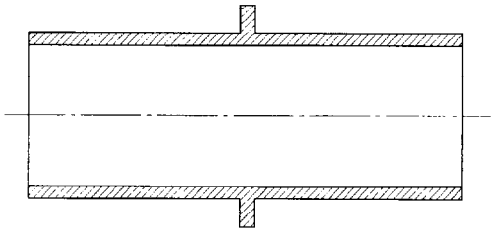
Dual (combination)-purpose modified MJ sleeve

NOTE: The joining of cast-iron pipe of the same nominal size but with different outside diameters can be accomplished with a special dual- or combination-purpose, modified mechanical-joint sleeve. This special sleeve, available from some manufacturers in 4–12-in. (102- to 305-mm) nominal size, is designed for use with pipe having either *A* or *CD* outside diameters. The sleeve employs an identical gasket at each end, which can adapt itself to either *A* or *CD* diameter pipe. These gaskets and the glands used with this sleeve are not the same as and are not interchangeable with gaskets and glands used with ANSI/AWWA C111/A21.11 standardized mechanical joints.

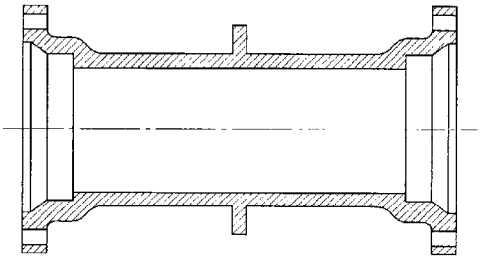
Wall Pipe



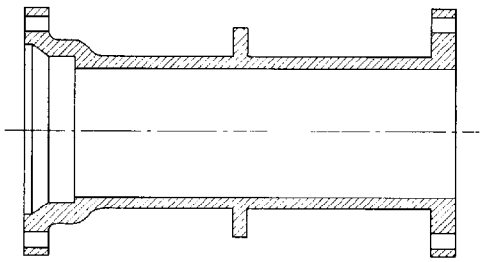
Flange and plain end



Plain end and plain end



MJ and MJ



MJ and flange

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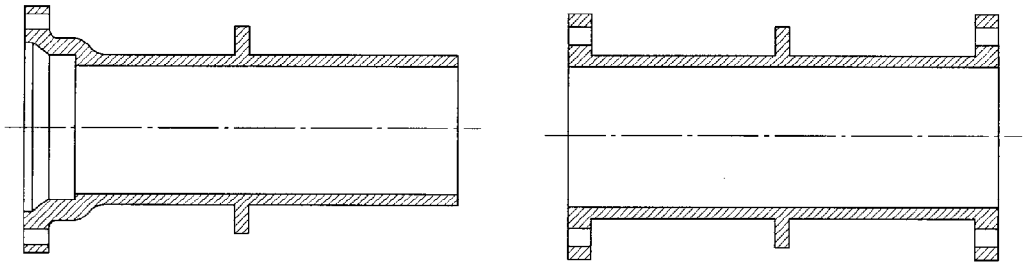
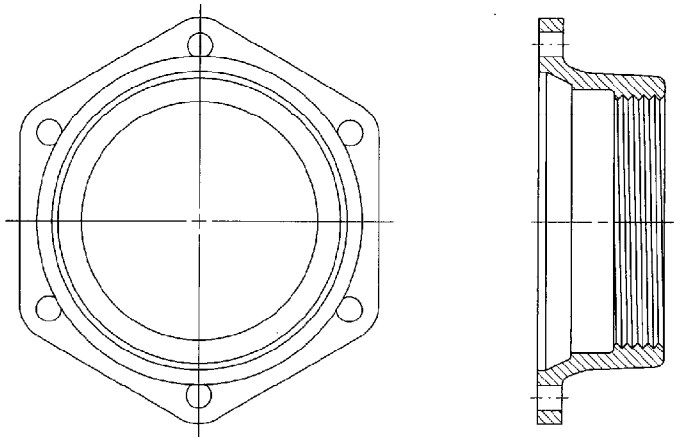


MJ and plain end

Flange and flange

NOTE: Wall pipe with collars and various combinations of ends, including plain end, flange, mechanical joint, and push-on joint, can be furnished. Flanges and mechanical-joint bells can be furnished with bolt holes tapped for studs. Sleeves with wall collars are also available on special request.



MJ threaded bell

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American Water Works Association
ANSI/AWWA C105/A21.5-99
(Revision of ANSI/AWWA C105/A21.5-93)

AMERICAN NATIONAL STANDARD

FOR

POLYETHYLENE ENCASEMENT FOR DUCTILE-IRON PIPE SYSTEMS

Administrative Secretariat

AMERICAN WATER WORKS ASSOCIATION

Cosecretariat

AMERICAN GAS ASSOCIATION

Effective date: January 1, 2000.
Approved by AWWA Board of Directors June 20, 1999.
Approved by American National Standards Institute October 26, 1999.

AMERICAN WATER WORKS ASSOCIATION

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*Alternate

†Liaison, nonvoting

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All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

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Foreword

This foreword is for information only and is not a part of AWWA C105/A21.5

I. Introduction.

I.A. *Background.* In 1926, the American Standards Association (ASA) (now American National Standards Institute [ANSI]) Committee A21, Cast-Iron Pipe and Fittings, was organized under the sponsorship of the American Gas Association (AGA), the American Society for Testing and Materials (ASTM), American Water Works Association (AWWA), and the New England Water Works Association (NEWWA). The current sponsor is AWWA, and the present scope of Committee A21 is to develop standards and manuals for ductile-iron pressure pipe for water supply service and ductile-iron and gray-iron fittings for use with this pipe. These standards and manuals include design, dimensions, materials, coatings, linings, joints, accessories, and methods of inspection and testing.

In 1958, Committee A21 was reorganized. Standards were divided into groups focusing on the topics listed above, and subcommittees were established to study each group in accordance with the review and revision policy of ASA. In 1984, the committee became AWWA Standards Committee A21 on Ductile-Iron Pipe and Fittings.

The present scope of A21 Subcommittee 4, Coatings and Linings, is to review interior and exterior corrosion of ductile-iron pipe and fittings and to draft standards for the interior and exterior protection of ductile-iron pipe and fittings. Accordingly, Subcommittee 4 is responsible for the development of

1. Standards on polyethylene encasement materials and their installation to provide corrosion protection, when required, for ductile-iron pipe and fittings.
2. Procedures for the investigation of soil to determine when polyethylene protection is indicated.

I.A.1 History of polyethylene encasement. Loose polyethylene encasement was first used experimentally in the United States in 1951 for protection of gray-iron pipe in corrosive environments. The first field installation of polyethylene wrap on gray-iron pipe in an operating water system was in 1958. The installation consisted of approximately 600 ft (180 m) of 12-in. (305-mm) pipe installed in a waste-dump fill area. Since 1958, polyethylene encasement has been used extensively in installations in severely corrosive soils throughout the United States on pipe ranging in size from 3 in. to 64 in. (76 mm to 1,600 mm) in diameter. Polyethylene encasement has been used as a soil-corrosion preventative in a number of other countries as well. An International Standard for Polyethylene Sleeving (ISO-8180)* has been adopted since the procedure was developed in the United States.

I.A.2 Research. The Cast Iron Pipe Research Association (CIPRA)† (now known as the Ductile Iron Pipe Research Association [DIPRA]) has researched several severely corrosive test sites. The tests indicate that polyethylene encasement provides a high degree of protection resulting in minimal and generally insignificant exterior surface corrosion of ductile-iron and gray-iron pipe protected in this manner.

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*International Organization for Standardization, Geneva, Switzerland.

†CIPRA became the Ductile Iron Pipe Research Association (DIPRA) in 1979.

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Investigations of many field installations in which loose polyethylene encasement has been used as protection for ductile-iron and gray-iron pipe against soil corrosion confirm DIPRA's findings. These field installations also indicate that the dielectric capability of polyethylene provides shielding for ductile-iron and gray-iron pipe from stray direct current at most levels encountered in the field.

I.B. *History.* The first edition of this standard was published in 1972 as American National Standard for Polyethylene Encasement for Gray and Ductile Cast-Iron Piping for Water and Other Liquids.

In 1976, Subcommittee 4 reviewed the 1972 edition and submitted a recommendation to Committee A21 that the standard be reaffirmed without change, except for updating the foreword.

In the 1982 revision, ANSI/AWWA C105/A21.5-82, references to gray cast-iron pipe were deleted from the title and throughout the standard because gray cast-iron pipe was no longer produced in the United States. Also, metric conversions of all dimensions were added to the standard.

The 1986 edition of the standard defined the thickness requirement for polyethylene film; provided new figures showing installation methods; and extended the length of connecting piping to be wrapped from 2 ft (0.6 m) to 3 ft (0.9 m). Additionally, a requirement for wrapping service lines of dissimilar metals for a distance of 3 ft (0.9 m) from the ductile iron pipe was also incorporated.

In the 1993 revision of the standard, Section 4.1, Materials, was expanded to include 4-mil, high-density, cross-laminated ("HDCL") polyethylene and Class B (colors) material was added to allow the purchase of colored polyethylene. Additionally, Table 1 was modified to reflect reduced tube widths comparable with push-on joint pipe and fittings, and the size range was expanded to include 60- and 64-in. (1,500- and 1,600-mm) pipe. A recommendation that circumferential wraps of tape be placed at 2-ft (0.6-m) intervals along the barrel of the pipe for installation below the water table or in areas subject to tidal actions was added to Section 4.3.1, and Section 4.3.6 was revised to indicate the preferred method of making direct service taps on polyethylene encased pipe. An illustration of this procedure was added.

II. Special Issues.

II.A. *Useful life of polyethylene.* Tests of polyethylene used to protect ductile-iron and gray-iron pipe have shown that, after 40 years of exposure to severely corrosive soils, strength loss and elongation reduction are insignificant. US Bureau of Reclamation (BUREC)* studies of polyethylene film used underground illustrate that tensile strength was nearly constant and that elongation was only slightly affected during a seven-year test period. BUREC's accelerated soil-burial testing (acceleration estimated to be 5 to 10 times that of field conditions) shows polyethylene to be highly resistant to bacteriological deterioration.

II.B. *Type of material.* The materials described in this standard are a linear low-density polyethylene film and a high-density cross-laminated film. A low-density film was used in the initial research and testing of polyethylene encasement to protect ductile-iron and gray-iron pipe from corrosion. The current materials provide the same degree of protection as the low-density film and are stronger and more damage resistant. Other types of polymeric material are also available that may provide equally suitable protection.

*Laboratory and Field Investigations of Plastic Films. US Department of the Interior, Bureau of Reclamation, Rept. No. ChE-82 (Sept. 1968).

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II.C. *Exposure to sunlight.* Prolonged exposure to sunlight will eventually deteriorate polyethylene film. Although the film is required to contain not less than 2 percent carbon black or 2 percent of a hindered-amine ultraviolet inhibitor, exposure of wrapped pipe should be kept to a minimum.

II.D. *Copper service connections.* The direct connection of copper services to ductile- and gray-iron pipelines has historically been a common practice in the waterworks industry. To minimize the possibility of bi-metallic corrosion, service lines of dissimilar metals and the attendant corporation stop should be wrapped with polyethylene or a suitable dielectric tape for a minimum clear distance of 3 ft (0.9 m) from the main (Sec. 4.4.7).

In addition, the grounding of household electrical services to the copper water service line may also result in stray current corrosion of the copper service or the ductile-iron or gray-iron main. AWWA policy opposes the grounding of electrical systems to pipe systems conveying drinking water to a customer's premises. AWWA further states that interior piping systems may be connected to an electrical service neutral and to a separate grounding electrode, provided these systems are electrically insulated from the water utility's pipe system. To minimize the possibility of stray current corrosion on the ductile-iron or gray-iron main, electrical insulating couplings should be installed at the water main.

III. Use of This Standard. AWWA has no responsibility for the suitability or compatibility of the provisions of this standard to any intended application by any user. Accordingly, each user of this standard is responsible for determining that the standard's provisions are suitable for and compatible with that user's intended application.

III.A. *Purchaser options and alternatives.* This standard includes certain options that, if desired, must be specified. These options are

1. Color of polyethylene material (Sec. 4.1.3).
2. Installation method—A, B, or C (Sec. 4.3)—if there is a preference.
3. Type of polyethylene material (Sec. 4.1.1 and 4.1.2).

III.B. *Modification to standard.* Any modification to the provisions, definitions, or terminology in this standard must be provided in the purchaser's specifications.

IV. Major Revisions. The major revisions in this edition of the standard are as follows:

1. The format has been changed to AWWA standard style.
2. Section II.D, Copper Service Connections, was added to the Foreward of the standard.
3. Definitions of parties and types of polyethylene film were added to Sec. 3.
4. Changes to Sec. 4.1., Materials, include:
   a. Deletion of low-density polyethylene film.
   b. Addition of linear low-density polyethylene film and appropriate material requirements and physical properties.
   c. Increasing the tensile strength requirement for the high-density, cross-laminated polyethylene film.
   d. Addition of impact and tear resistance requirements for both polyethylene materials.
   e. Deletion of the minus tolerance on film thickness for both materials.
   f. Addition of an ultraviolet inhibitor, any natural or colored film except black film containing carbon block.
5. Sec. 4.3, Marking, was added to facilitate traceability and to help ensure compliance with the standard.

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6. In Sec. 4.4.2.2, Method B, an alternate method of using a 3-ft sheet of polyethylene rather than a 3-ft length of polyethylene tube for joint makeup was added.

7. Sec. 5.1, Inspection and Certification by Manufacturer, was also added to help ensure compliance with this standard.

8. In appendix A, a new paragraph on stray current corrosion and a new section on uniquely severe environments were added. Additionally, the resistivity ranges in Table A.1, Soil Test Evaluation, were increased to make the procedure more conservative.

V. Comments. If you have any comments or questions about this standard, please call the AWWA Volunteer and Technical Support Group, (303) 794-7711 Ext. 6283, FAX (303) 795-7603, or write to the group at 6666 W. Quincy Ave., Denver, CO 80235.

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American Water Works Association

ANSI/AWWA C105/A21.5-99
(Revision of ANSI/AWWA C105/A21.5-93)

AMERICAN NATIONAL STANDARD FOR

POLYETHYLENE ENCASEMENT FOR DUCTILE-IRON PIPE SYSTEMS

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard covers materials and installation procedures for polyethylene encasement to be applied to underground installations of ductile-iron pipe. This standard also may be used for polyethylene encasement of fittings, valves, and other appurtenances to ductile-iron pipe systems.

Sec. 1.2 Purpose

The purpose of this standard is to provide purchasers, manufacturers, and constructors with the minimum requirements for polyethylene sheet and tubes to be used for external corrosion protection of buried ductile-iron pipe, fittings, and appurtenances.

Sec. 1.3 Application

This standard or sections of this standard can be referenced in specifications for the purchasing and installation of polyethylene sheet or tubes for corrosion protection of buried ductile iron pipe, fittings, and appurtenances.

SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, they form a part of this standard to the extent specified within the standard. In any case of conflict, the requirements of this standard shall prevail.

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ASTM D* 149—Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies.

ASTM D 882—Standard Test Method for Tensile Properties of Thin Plastic Sheeting.

ASTM D 1709—Standard Test Methods for Impact Resistance of Plastic Film by the Free-Falling Dart Method.

ASTM D 1922—Standard Test Method for Propagation Tear Resistance of Plastic Film and Thin Sheeting by Pendulum Method.

ASTM D 4976—Standard Specification for Polyethylene Plastics Molding and Extrusion Materials.

ANSI†/AWWA C600—Standard for Installation of Ductile-Iron Water Mains and Their Appurtenances.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Constructor:* The party that furnishes the work and materials for placement or installation.

2. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.

3. *Polyethylene encasement:* The encasement of piping with polyethylene film in tube or sheet form.

4. *Linear Low-Density Polyethylene Film:* Film extruded from virgin linear low-density polyethylene raw material.

5. *High-Density, Cross-Laminated Polyethylene Film:* Film extruded from virgin high-density polyethylene raw material, which is then molecularly oriented by stretching. Two single-ply layers of the film are then laminated together with their orientations at 90° to one another to form the final product.

6. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.

SECTION 4: REQUIREMENTS

Sec. 4.1 Materials

4.1.1 *Linear low-density polyethylene film.* Linear low-density polyethylene film shall be manufactured of virgin polyethylene material conforming to the following:

4.1.1.1 Raw material requirements per ASTM D4976

Group: 2 (Linear)

Density: 0.910 to 0.935 g/cm^3

Dielectric strength: Volume resistivity, 10^{15} ohm-cm, minimum

*American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

†American National Standards Institute, 11 W. 42nd St., New York, NY 10036.

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4.1.1.2 Physical properties of finished film.

Tensile strength: 3,600 psi (24.8 MPa), minimum in machine and transverse direction (ASTM D882)

Elongation: 800 percent, minimum in machine and transverse direction (ASTM D882)

Dielectric strength: 800 V/mil (31.8 V/μm) thickness, minimum (ASTM D149)

Impact resistance: 600 g, minimum (ASTM D1709 Method B)

Propagation tear resistance: 2,550 gf (grams force), minimum in machine and transverse direction (ASTM D1922)

4.1.1.3 Thickness. Linear low-density polyethylene film shall have a minimum thickness of 0.008 in. (8 mil or 200 μm).

4.1.2 *High-density, cross-laminated polyethylene film.* High-density, cross-laminated polyethylene film shall be manufactured of virgin polyethylene material conforming to the following:

4.1.2.1 Raw material requirements per ASTM D4976

Group: 2 (Linear)

High-density: 0.940 to 0.960 g/cm^3

Dielectric strength: Volume resistivity, 10^{15} ohm-cm, minimum

4.1.2.2 Physical properties of finished film.

Tensile strength: 6,300 psi (43.4 MPa), minimum in machine and transverse direction (ASTM D882)

Elongation: 100 percent, minimum in machine and transverse direction (ASTM D882)

Dielectric strength: 800 V/mil (31.8 V/μm) thickness, minimum (ASTM D149)

Impact resistance: 800 g, minimum (ASTM D1709 Method B)

Propagation tear resistance: 250 gf, minimum in machine and transverse direction (ASTM D1922)

4.1.2.3 Thickness. High-density, cross-laminated polyethylene film shall have a minimum thickness of 0.004 in. (4 mil or 100 μm).

4.1.3 *Color.* Polyethylene film may be supplied with its natural color, colors including white and black, or black (weather-resistant) containing not less than 2 percent carbon black with an average particle diameter of 50 mm or less. A minimum of 2 percent of a hindered-amine ultraviolet inhibitor is required in any natural or colored film except black film containing 2 percent or more carbon black.

Sec. 4.2 Tube Size or Sheet Width

Tube size or sheet width for each pipe diameter shall be as listed in Table 1.

Sec. 4.3 Marking

4.3.1 *Marking requirements.* The polyethylene film supplied shall be clearly marked, at a minimum of every 2-ft along its length, containing the following information:

a. Manufacturer's name or trademark.
b. Year of manufacture
c. ANSI/AWWA C105/A21.5
d. Minimum film thickness and material type (LLDPE or HDCLPE).
e. Applicable range of nominal pipe diameter size(s).
f. Warning—Corrosion Protection—Repair Any Damage

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Table 1 Polyethylene tube and sheet sizes for push-on joint pipe*

Nominal Pipe Diameter		Minimum Polyethylene Width—*in.* (*cm*)			
in.	(*mm*)	Flat Tube		Sheet	
3	(76)	14	(36)	28	(71)
4	(102)	14	(36)	28	(71)
6	(152)	16	(41)	32	(81)
8	(203)	20	(51)	40	(102)
10	(254)	24	(61)	48	(122)
12	(305)	27	(69)	54	(137)
14	(356)	30	(76)	60	(152)
16	(406)	34	(86)	68	(173)
18	(457)	37	(94)	74	(188)
20	(508)	41	(104)	82	(208)
24	(610)	54	(137)	108	(274)
30	(762)	67	(170)	134	(340)
36	(914)	81	(206)	162	(411)
42	(1,067)	81	(206)	162	(411)
48	(1,219)	95	(241)	190	(483)
54	(1,400)	108	(274)	216	(549)
60	(1,500)	108	(274)	216	(549)
64	(1,600)	121	(307)	242	(615)

* These wrap sizes should work with most push-on joint pipe and fitting bell sizes. Where bell circumferences are larger than the sheet sizes shown, the bell areas should be carefully wrapped with cut film sections, effectively lapping and securing cut edges as necessary; or, alternatively, sufficiently large tube or sheet film to effectively cover these joints should be ordered.

4.3.2 *Marking height.* Letters and numerals used for marking items *a* through *e* in Section 4.3.1. shall not be less than 1 in. in height. Item *f* in Section 4.3.1 shall be not less than 1½ in. in height.

Sec. 4.4 Installation

4.4.1 *General.* The polyethylene encasement shall prevent contact between the pipe and the surrounding backfill and bedding material, but it is not intended to be a completely airtight or watertight enclosure. All lumps of clay, mud, cinders, etc., on the pipe surface shall be removed prior to installation of the polyethylene encasement. During installation, soil or embedment material shall not be trapped between the pipe and the polyethylene.

The polyethylene film shall be fitted to the contour of the pipe creating a snug, but not tight, encasement with minimum space between the polyethylene and the pipe. Sufficient slack shall be provided in contouring to prevent stretching the polyethylene where it bridges irregular surfaces, such as bell-spigot interfaces, bolted joints, or fittings and to prevent damage to the polyethylene caused by backfilling operations. Overlaps and ends shall be secured with adhesive tape, or plastic tie straps.

For installations below the water table or in areas subject to tidal actions, tube-form polyethylene should be used with both ends thoroughly sealed with adhesive

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tape or plastic tie straps at the joint overlap. Also, circumferential wraps of tape should be placed at 2 ft (0.6 m) intervals along the barrel of the pipe to minimize the space between the polyethylene and the pipe.

4.4.2 *Pipe.* This standard includes three methods of installation of polyethylene encasement on pipe. Methods A and B are for use with polyethylene tubes, and method C is for use with polyethylene sheets.

4.4.2.1 Method A. (Refer to Figure 1.) Cut polyethylene tube to a length approximately 2 ft (0.6 m) longer than the pipe section. Slip the tube around the pipe, centering it to provide a 1-ft (0.3-m) overlap on each adjacent pipe section and bunching it accordion-fashion lengthwise until it clears the pipe ends.

Lower the pipe into the trench and make up the pipe joint with the preceding section of pipe. A shallow bell hole must be made at the joints to facilitate installation of the polyethylene tube.

After assembling the pipe joint, make the overlap of the polyethylene tube. Pull the bunched polyethylene from the preceding length of pipe, slip it over the end of the new length of pipe, and secure it in place. Then slip the end of the polyethylene from the new pipe section over the end of the first wrap until it overlaps the joint at the end of the preceding length of pipe. Secure the overlap in place. Take up the slack width at the top of the pipe as shown in Figure 2 to make a snug but not tight fit along the barrel of the pipe, securing the fold at quarter points.

Cuts, tears, punctures, or other damage to the polyethylene shall be repaired as described in Sec. 4.4.5. Proceed with the installation of the next section of pipe in the same manner.

4.4.2.2 Method B. (Refer to Figure 3.) Cut polyethylene tube to a length approximately 1 ft (0.3 m) shorter than that of the pipe section. Slip the tube around the pipe, centering it to provide 6 in. (150 mm) of bare pipe at each end. Take up the slack width at the top of the pipe as shown in Figure 2 to make a snug but not tight fit along the barrel of the pipe, securing the fold at quarter points. Secure the ends as described in Sec. 4.4.1.

Before making up a joint, slip a 3-ft (0.9-m) length of polyethylene tube over the end of the preceding pipe section, bunching it accordion-fashion lengthwise. Alternatively, place a 3-ft (0.9-m) length of polyethylene sheet in the trench under the joint to be made. After completing the joint, pull the 3-ft (0.9-m) length of

One length of polyethylene tube for each length of pipe, overlapped at joint.

Figure 1 Installation method A

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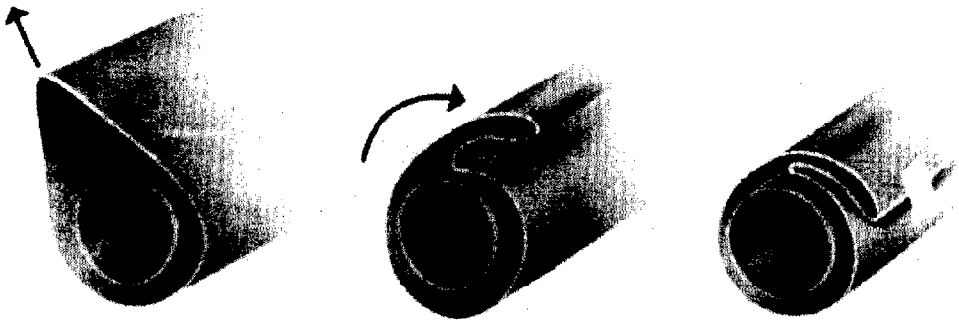
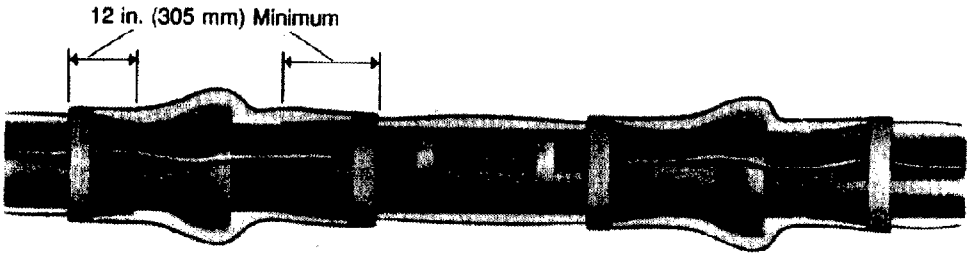


Take up the slack in the tube to make a snug but not tight fit. Fold the excess back over the top of the pipe, securing the fold at quarter points along the length of the pipe.

Figure 2 Slack-reduction procedure for installation methods A and B



Separate pieces of polyethylene tube for barrel of pipe and polyethylene tube or sheet for joints. The polyethylene over joints overlaps tube encasing barrel. (Method B is not recommended for bolted-type joints unless an additional layer of polyethylene is provided over the joint area as in methods A and C.)

Figure 3 Installation method B

polyethylene over or around the joint, overlapping the polyethylene previously installed on each adjacent section of pipe by at least 1 ft (0.3 m). Make each end snug and secure as described in Sec. 4.4.1. A shallow bell hole is necessary and shall be made at joints to facilitate the installation of the polyethylene tube or sheet.

Cuts, tears, punctures, or other damage to the polyethylene shall be repaired as described in Sec. 4.4.5. Proceed with installation of the next section of pipe in the same manner.

4.4.2.3 Method C. (Refer to Figure 4.) Cut polyethylene sheet to a length approximately 2 ft (0.6 m) longer than that of the pipe section. Center the cut length to provide a 1-ft (0.3-m) overlap on each adjacent pipe section, bunching it until it clears the pipe ends. Wrap the polyethylene around the pipe so that it circumferentially overlaps the top quadrant of the pipe. Secure the cut edge of polyethylene sheet at intervals of approximately 3 ft (0.9 m).

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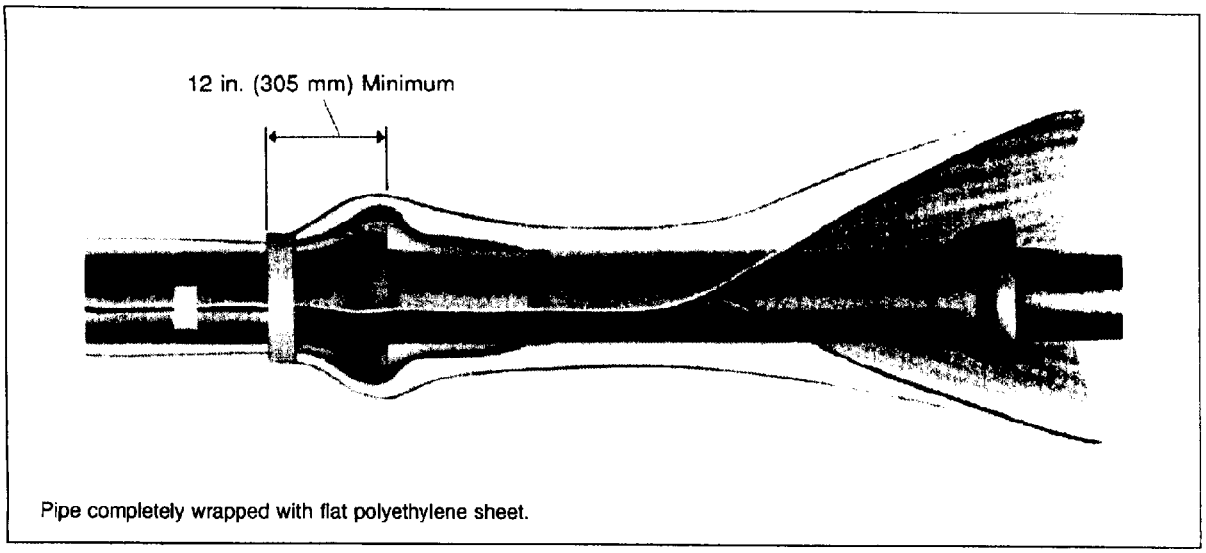

Figure 4 Installation method C

Lower the wrapped pipe into the trench and make up the pipe joint with the preceding section of pipe. A shallow bell hole is necessary and shall be made at the joints to facilitate installation of the polyethylene. After completing the joint, make the overlap and secure the ends as described in Sec. 4.4.1.

Cuts, tears, punctures, or other damage to the polyethylene shall be repaired as described in Sec. 4.4.5. Proceed with installation of the next section of pipe in the same manner.

4.4.3 *Pipe-shaped appurtenances.* Bends, reducers, offsets, and other pipe-shaped appurtenances shall be covered with polyethylene in the same manner as the pipe.

4.4.4 *Odd-shaped appurtenances.* When it is not practical to wrap valves, tees, crosses, and other odd-shaped pieces in a tube, wrap with a flat sheet or split length of polyethylene tube by passing the sheet under the appurtenance and bringing the sheet around the body. Make seams by bringing the edges of the polyethylene sheet together, folding them over twice, and taping them. Handle width and overlaps at joints as described in Sec. 4.4.2.1. Tape the polyethylene securely in place at the valve stem and other penetrations.

4.4.5 *Repairs.* Repair cuts, tears, punctures, or damage to polyethylene with adhesive tape or with a short length of polyethylene sheet, or with a tube cut open, wrapped around the pipe to cover the damaged area, and secured in place.

4.4.6 *Openings in encasement.* Provide openings for branches, service taps, blowoffs, air valves, and similar appurtenances by cutting an X in the polyethylene and temporarily folding back the film. After the appurtenance is installed, tape the slack securely to the appurtenance, and repair the cut and any other damaged areas in the polyethylene with tape. Direct service taps may also be made through the polyethylene, with any resulting damaged areas being repaired as described previously. To make direct service taps, apply two or three wraps of adhesive tape completely around the polyethylene encased pipe to cover the area where the tapping machine and chain will be mounted. This method minimizes possible damage to the polyethylene during the direct tapping procedure. After the tapping machine is mounted, the corporation stop is installed directly through the tape and polyethylene

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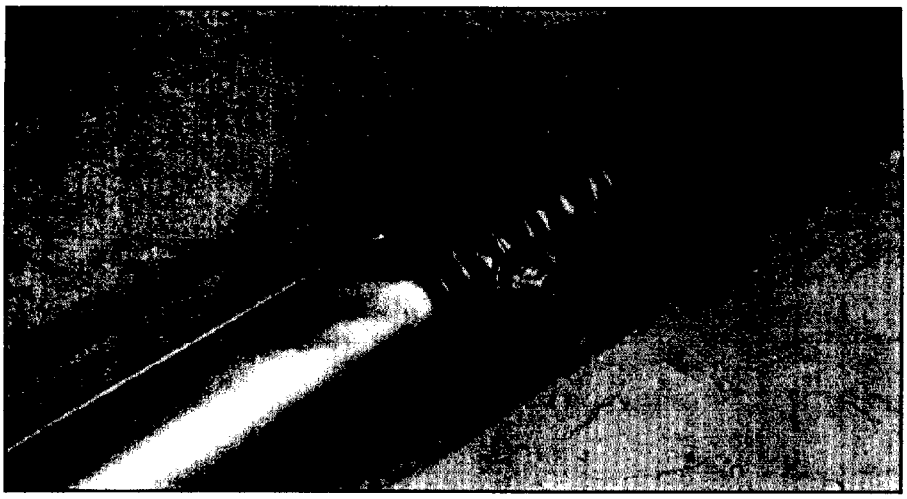

Figure 5 Preferred method for making direct service taps on PE-encased iron pipe

as shown in Figure 5. This method is very effective in eliminating damage to the polyethylene encasement caused by the tapping machine and chain during the tapping operation. After the direct tap is completed, the entire circumferential area shall be closely inspected for damage and repaired if needed.

4.4.7 *Junctions between wrapped and unwrapped pipe.* Where polyethylene-wrapped pipe joins an adjacent pipe that is not wrapped, extend the polyethylene wrap to cover the adjacent pipe for a distance of at least 3 ft (0.9 m). Secure the end with circumferential turns of adhesive tape.

Service lines of dissimilar metals shall be wrapped with polyethylene or a suitable dielectric tape for a minimum clear distance of 3 ft (0.9 m) away from the ductile-iron pipe.

4.4.8 *Backfill for polyethylene-wrapped pipe.* Use the same backfill material as that specified for pipe without polyethylene wrap, exercising care to prevent damage to the polyethylene wrapping when placing backfill. Backfill material shall be free from cinders, refuse, boulders, rocks, stones, or other material that could damage the polyethylene. In general, backfilling practice should be in accordance with the latest revision of ANSI/AWWA C600.

SECTION 5: VERIFICATION

Sec. 5.1 Inspection and Certification by Manufacturer

5.1.1 *Quality control and inspection.* The manufacturer shall establish the necessary quality control and inspection practice to ensure compliance with this standard.

5.1.2 *Manufacturer's statement.* The manufacturer shall, if required by the purchaser's specifications, provide a sworn statement that the inspection and all applicable material requirements of Section 4.1 have been met and that all results comply with the requirements of this standard.

5.1.3 *Freedom from defects.* All polyethylene film shall be clean, sound, and without defects that could impair service.

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SECTION 6: DELIVERY

This standard has no applicable information for this section.

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APPENDIX A

Notes on Procedures for Soil Survey Tests and Observations and Their Interpretation to Determine Whether Polyethylene Encasement Should Be Used

This appendix is for information only and is not a part of ANSI/AWWA C105/A21.5.

In the appraisal of soil and other conditions that affect the corrosion rate of ductile-iron pipe,* many factors must always be considered. They are outlined here. A method of evaluating and interpreting each factor and a method of weighing each factor to determine whether polyethylene encasement should be used are subsequently described.

These methods should be employed only by qualified personnel who are experienced in soil analysis and evaluation of conditions potentially corrosive to ductile-iron pipe. Factors such as moisture content, soil temperature, location of soil sample with respect to pipe, time between removal of soil sample and testing, and other factors can significantly affect the soil-test evaluation. For example, certain soil environments are considered to be potentially corrosive to ductile-iron pipe, and therefore, do not require evaluation to determine the need for corrosion protection. These environments include, but are not limited to, coal, cinders, muck, peat, mine wastes, and landfill areas high in foreign materials. Existing installations and the potential for stray direct-current corrosion should also be a part of the evaluation.

Soil Survey Tests and Observations

Factors to consider when determining the need for polyethylene encasement of pipe are outlined below. A discussion of each point follows the outline.

1. Earth resistivity.
   a. Four-pin
   b. Single-probe
   c. Saturated-sample (soil-box)
2. pH.
3. Oxidation-reduction (redox) potential.
4. Sulfides.
   a. Azide (qualitative)
5. Moisture content (relative).
   a. Prevalence
6. Soil description.
   a. Particle size
   b. Uniformity
   c. Type
   d. Color
7. Potential stray direct current.
   a. Nearby cathodic protection utilizing rectifiers
   b. Railroads (electric)
   c. Industrial equipment, including welding equipment
   d. Mine transportation equipment
8. Experience with existing installations in the area.

*NOTE: The information contained in appendix A is also applicable to gray-iron pipe. Although gray-iron pipe is no longer produced in the United States, many miles of this product remain in service.

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1. *Earth resistivity.* There are three methods for determining earth resistivity: four-pin, single-probe, and soil-box. In the field, a four-pin determination should be made with pins spaced at approximate pipe depth. This method yields an average of resistivity from the surface to a depth equal to pin spacing. However, results are sometimes difficult to interpret where dry topsoil is underlain with wetter soils and where soil types vary with depth. The Wenner configuration is used with a soil-resistance meter, which is available with varying ranges of resistance. For all-around use, a meter with a capacity of up to 10^4 ohms is suggested, because it permits both field and laboratory testing of most soils.

Because of this difficulty in interpretation, the same meter may be used with a single probe that yields resistivity at the point of the probe. A boring is made into the subsoil allowing the probe to be pushed into the soil at the desired depth.

Because the soil may not be typically wet, a sample should be removed for saturated resistivity determination. This may be accomplished with a laboratory unit that permits the introduction of water to saturation, therefore simulating saturated field conditions. The unit is used in conjunction with a soil-resistance meter.

The interpretation of the results of resistivity measurements is extremely important. A determination based on a four-pin reading with dry topsoil averaged with wetter subsoil would probably be inaccurate. Only by determining the resistivity in soil at pipe depth can an accurate interpretation be made. Also, the local situation should be determined concerning groundwater table, the presence of shallow groundwater, and the approximate percentage of time the soil is likely to be water saturated.

With ductile-iron pipe, corrosion protection provided by products of corrosion is enhanced if there are dry periods during each year. Dry periods seem to permit hardening, or toughening, of the corrosion scale or products, which then become impervious and serve as better insulators.

In making field determinations of resistivity, temperature is important. The resistivity increases as the temperature decreases. As the water in the soil approaches freezing, resistivity increases greatly and, therefore, is not reliable. Field determinations under frozen soil conditions should be avoided. Reliable results under these conditions can be obtained only by the collection of suitable subsoil samples for analysis in laboratory conditions at a proper temperature.

Interpretation of resistivity data. Because of the wide variance in results obtained using the methods described, it is difficult to interpret any single reading without knowing which method was used to obtain the reading. The interpretation should be based on the lowest reading obtained, with consideration to other conditions, such as typical moisture content of the soil. Because of the lack of exact correlation between experiences and resistivity, it is necessary to assign ranges of resistivity rather than specific numbers. Table A.1 shows the points assigned to various ranges of resistivity. These points, when considered along with points assigned to other soil characteristics (also shown in Table A.1), are significant.

2. *pH.* In the pH range of 0.0 to 4.0, soil serves well as an electrolyte. In the pH range of 6.5 to 7.5, soil conditions are optimum for sulfate reduction. In the pH range of 8.5 to 14.0, soils are generally high in dissolved salts, yielding a low soil resistivity.

In testing pH, a combination pH electrode is pushed into the soil sample, and a direct reading is made, following suitable temperature setting on the instrument. Normal procedures are followed for standardization.

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Table A.1 Soil-test evaluation

Soil Characteristics Based on Samples Taken Down to Pipe Depth	Points*
Resistivity—ohm-cm (based on water-saturated soil box)	
<1,500	10
≥1,500–1,800	8
>1,800–2,100	5
>2,100–2,500	2
>2,500–3,000	1
>3,000	0
pH:	
0–2	5
2–4	3
4–6.5	0
6.5–7.5	0†
7.5–8.5	0
>8.5	3
Redox potential:	
> +100 mV	0
+50 to +100 mV	3.5
0 to +50 mV	4
Negative	5
Sulfides:	
Positive	3.5
Trace	2
Negative	0
Moisture:	
Poor drainage, continuously wet	2
Fair drainage, generally moist	1
Good drainage, generally dry	0

*Ten points indicates that soil is corrosive to ductile-iron pipe; protection is needed.

†If sulfides are present and low or negative redox-potential results are obtained, add three points for this range.

3. *Oxidation-reduction (redox) potential.* The redox potential of a soil is significant, because the most common sulfate-reducing bacteria can live only in anaerobic conditions. A redox potential greater than +100 mV demonstrates that the soil is sufficiently aerated, preventing sulfate reducers from forming. Potentials of 0 to +100 mV may or may not indicate anaerobic conditions; however, a negative redox potential definitely indicates the anaerobic conditions in which sulfate reducers thrive. The redox test is performed using a pH/mV meter with a combination ORP electrode inserted into the soil sample. It should be noted that soil samples removed from a boring or excavation can undergo a change in redox potential when exposed to

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air. These samples should be tested immediately after the excavation. Heavy clays, muck, and organic soils are often anaerobic. For this reason, these soils should be regarded as potentially corrosive.

4. *Sulfides.* The sulfide determination is recommended because of its field expediency. A positive sulfide reaction reveals a potential problem caused by sulfate-reducing bacteria. The sodium azide–iodine qualitative test is used to identify sulfides. In this determination, a solution of 3 percent sodium azide in a 0.1N iodine solution is introduced into a test tube containing a sample of the soil. Sulfides catalyze the reaction between sodium azide and iodine resulting in nitrogen. If strong bubbling or foaming results, sulfides are present, as are sulfate-reducing bacteria. If very slight bubbling is noted, sulfides are probably present in small concentration, and the result is noted as a trace.

5. *Moisture content.* Because prevailing moisture content is extremely important to all soil corrosion, this condition must be determined. It is not necessary that the specific moisture content of a soil sample be determined, because the content probably varies throughout the year. However, local authorities should observe the soil moisture conditions many times during the year. (Although mentioned in item 1, Earth Resistivity, this variability factor is reiterated to emphasize the importance of notation.)

6. *Soil description.* In each investigation, soil types should be completely described. The description should include color and physical characteristics, such as particle size, plasticity, friability, and uniformity. Observation and testing will reveal whether the soil is high in organic content; this should be noted. In a given area, corrosivity may often be reflected in certain types and colors of soil. This information is valuable for future investigations or for determining suspect soils.

Soil uniformity is important because of the possible development of local corrosion cells caused by the difference in potential, such as different soil types contacting the pipe. The same is true for uniformity of aeration. If one segment of soil contains more oxygen than a neighboring segment, a corrosion cell can develop from the difference in potential. This cell is known as a differential aeration cell.

There are several basic types of soils that should be noted in the soil description: sand, loam, silt, clay, and muck. In addition, unusual soils, such as peat or soils high in foreign material, should be noted.

7. *Potential stray direct current.* All soil surveys should consider the possibility of stray direct current which might interfere with the ductile-iron-pipe installation. The widespread use of rectifiers and ground beds for cathodic protection of underground structures has increased the potential of stray direct current. The proximity of these cathodic protection systems should be noted. Among other potential sources of stray direct current are electric railways, industrial equipment (including welding equipment), and mine-transportation equipment.

Normally, the amount of stray current influence from cathodic protection systems on an electrically discontinuous ductile iron pipeline will be negligible. It is not detrimental to the expected life of the system, unless the pipeline comes close to an impressed-current, cathodic-protection anode bed where the current density is high. When ductile iron pipelines are exposed to high-density stray current environments, the pipeline should be rerouted or the anode bed relocated. If neither of these options is feasible, the ductile iron pipe in this area should be electrically bonded together, electrically isolated from adjacent pipe, polyethylene encased, and appropriate test leads and "current drain" installed.

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8. *Experience with existing installations.* The best information on soil corrosivity with respect to ductile-iron pipe results from experience with this material in the area under investigation. Every effort should be made to acquire these data by questioning local officials and, if possible, by observing existing installations.

Soil-Test Evaluation

When the soil-test procedures described in this standard are employed, the following tests are used in evaluating corrosivity of the soil: resistivity, pH, redox potential, sulfides, and moisture. For each of these tests, results are categorized according to their contribution to corrosivity. Point values are assigned, based on experience with ductile-iron pipe (see Table A.1). When results of these five tests/observations are available, the assigned points are totaled. If the sum is equal to 10 or more, the soil is corrosive to ductile-iron pipe, and protection against exterior corrosion should be provided. This system of evaluation is limited to soil corrosion and does not include consideration of stray direct current.

General. These notes address only ductile-iron pipe, the soil environment in which the pipe will serve, and the methods of determining a need for polyethylene encasement.

Uniquely Severe Environments

Research has shown that polyethylene encasement alone is a viable corrosion protection system for ductile- and gray-iron pipe in most environments. However, other options should be considered for environments where all the following characteristics co-exist: (1) soil resistivity ≤500 ohm-cm; (2) anaerobic conditions in which sulfate-reducing bacteria thrive [neutral pH (6.5 to 7.5), low or negative redox-potential (negative to +100 mV), and the presence of sulfides (positive or trace)]; and (3) water table intermittently or continually above the invert of the pipe.

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American Water Works Association
ANSI/AWWA C150/A21.50-96
(Revision of ANSI/AWWA C150/A21.50-91)

AMERICAN NATIONAL STANDARD

FOR

THICKNESS DESIGN OF DUCTILE-IRON PIPE

Secretariats

AMERICAN GAS ASSOCIATION
AMERICAN WATER WORKS ASSOCIATION

Effective date: Dec. 1, 1996.
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AMERICAN WATER WORKS ASSOCIATION

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All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

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Foreword

This foreword is for information only and is not a part of ANSI/AWWA C150/A21.50.

I. Introduction

I.A. *Background.* The purpose of this standard is to provide pipeline designers with a recommended design procedure and associated tabular data necessary to establish the wall thickness(es) required for buried ductile-iron pipe based on the type of pipe embedment, depths of trench cover, live load conditions, internal working pressures, and surge conditions appropriate for the specific pipeline project. Once the required wall thickness(es) has been established, the ductile-iron pipe should be specified to be manufactured in accordance with ANSI*/AWWA C151/A21.51. ANSI/AWWA C151/A21.51 contains options that must be addressed in the purchaser's specifications in response to site-specific project requirements.

Although ANSI/AWWA C150/A21.50 is commonly used for designing ductile-iron pipe for services other than water, users are also directed to ASTM† A746, Standard Specification for Ductile Iron Gravity Sewer Pipe.

I.B. *History.* American National Standards Committee A21, Cast-Iron Pipe and Fittings, was organized in 1926 under the sponsorship of the American Gas Association (A.G.A), the American Society for Testing and Materials (ASTM), the American Water Works Association (AWWA), and the New England Water Works Association (NEWWA). Between 1972 and 1984, the cosecretariats were A.G.A, AWWA, and NEWWA, with AWWA serving as administrative secretariat. In 1984, the committee became an AWWA committee with the name of American Water Works Association Standards Committee A21 on Ductile-Iron Pipe and Fittings. In 1988, NEWWA withdrew as a separate secretariat; however, it continues to maintain its representation on the AWWA Committee A21. The committee remains cosponsored by A.G.A for gas-related activities.

The present scope of AWWA Committee A21 activity is the development of standards and manuals addressing ductile-iron pressure pipe for gas, water, and other liquids, and ductile-iron and gray-iron fittings for use with such pipe. These standards and manuals include design, dimensions, materials, coatings, linings, joints, accessories, and methods of inspection and testing.

The work of AWWA Committee A21 is conducted by subcommittees. The scope of Subcommittee 1, Pipe, includes the periodic review of all current A21 standards for pipe, the preparation of revisions and new standards when needed, as well as other matters pertaining to pipe standards.

The first edition of A21.50, American National Standard for the Thickness Design of Ductile-Iron Pipe, was issued in 1965, and revisions were issued in 1971, 1976, 1981, and 1991. The standard was reaffirmed without revision in 1986. Subcommittee 1 reviewed the 1991 edition and submitted a proposed revision to AWWA Standards Committee A21 in 1995.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International

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(NSF) to develop voluntary third-party consensus standards and a certification program for all direct and indirect drinking water additives. Other members of the original consortium included the American Water Works Association Research Foundation (AWWARF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.* Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.
2. Specific policies of the state or local agency.
3. Two standards developed under the direction of NSF, ANSI†/NSF‡ 60, Drinking Water Treatment Chemicals—Health Effects, and ANSI/NSF 61, Drinking Water System Components—Health Effects.
4. Other references, including AWWA standards, *Food Chemicals Codex*, *Water Chemicals Codex*,§ and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with ANSI/NSF 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Appendix A, "Toxicology Review and Evaluation Procedures," to ANSI/NSF 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Appendix A procedures may not always be identical, depending on the certifier.

AWWA C150-96 does not address additives requirements. Thus, users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.
2. Determine the status of certifications by all parties offering to certify products for contact with, or treatment of, drinking water.
3. Determine current information on product certification.

II. Special Issues. Currently, there are no special issues related to this standard.

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*Persons in Canada, Mexico, and non-North American countries should contact the appropriate authority having jurisdiction.

†American National Standards Institute, 11 W. 42nd St., New York, NY 10036.

‡NSF International, 3475 Plymouth Rd., Ann Arbor, MI 48106.

§Both publications available from National Academy of Sciences, 2102 Constitution Ave. N.W., Washington, DC 20418.

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III. Use of This Standard. AWWA has no responsibility for the suitability or compatibility of the provisions of this standard to any intended application by any user. Accordingly, each user of this standard is responsible for determining that the standard's provisions are suitable for and compatible with that user's intended application.

III.A. *Purchaser Options and Alternatives.* As noted in Sec. I.A of the foreword, ANSI/AWWA C151/A21.51 contains options that must be addressed in the purchaser's specifications in response to site-specific requirements for ductile-iron pipe.

III.B. *Modification to Standard.* Any modification to the provisions, definitions, or terminology in this standard must be provided in the purchaser's specifications.

IV. Major Revisions. Major revisions made to the standard in this edition include the following:

1. The format has been changed to AWWA standard style.
2. The acceptance clause (Sec. I.C) has been revised to approved wording.
3. The truck load equation (Eq 5) and the surface load factor (Eq 6) have been modified to allow for a correct distribution of units.
4. Table 6, Surface load factors for single truck on unpaved road, has been changed to match the revised surface load factor equation (Eq 6).
5. The statement concerning surge allowance in the hoop stress formula (Sec. 4.1.2 and Sec. 4.2.2) has been modified to note that if anticipated surge pressures are other than 100 psi (689 kPa), the actual anticipated pressure should be used.

V. Comments. If you have any comments or questions about this standard, please call the AWWA Standards and Materials Development Department, (303) 794-7711 ext. 6283, FAX (303) 795-1440, or write to the department at 6666 W. Quincy Ave., Denver, CO 80235.

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American Water Works Association

ANSI/AWWA C150/A21.50-96
(Revision of ANSI/AWWA C150/A21.50-91)

AMERICAN NATIONAL STANDARD FOR

THICKNESS DESIGN OF DUCTILE-IRON PIPE

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard covers the thickness design of ductile-iron pipe complying with the requirements of ANSI*/AWWA C151/A21.51, Ductile-Iron Pipe, Centrifugally Cast, for Water.

Section 4.1 outlines the design procedure and Sec. 4.2 gives a design example.

Section 4.3 explains the basis of design.

As opposed to using procedures in Sec. 4.1 or Sec. 4.3, the designer may reference Tables 12 through 14 directly.

Table 12 lists thicknesses for standard laying conditions and certain depths of cover.

Table 13 lists thicknesses for 150 psi–350 psi (1,034 kPa–2,413 kPa)† water working pressure.

The greater thickness from Table 12 or Table 13 for given trench load or internal pressure should be used.

Table 14 lists working pressures and maximum depths of cover for standard laying conditions and standard pressure classes.

Table 15 lists special thickness classes of ductile-iron pipe.

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†Metric conversions given in this standard are direct conversions of US customary units and are not those specified in International Organization for Standardization (ISO) standards.

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Sec. 1.2 Purpose

The main purpose of this standard is to provide the minimum requirements for the thickness design of ductile-iron pipe, including basis of design and design procedure.

Sec. 1.3 Application

This standard can be referenced in specifications for the thickness design of ductile-iron pipe. The stipulations of this standard apply when this document has been referenced and then only to the thickness design of ductile-iron pipe.

SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, these documents form a part of this standard to the extent specified within the standard. In any case of conflict, the requirements of this standard shall prevail.

AASHTO T99—Standard Method of Test for the Moisture-Density Relations of Soils Using a 5.5 lb (2.5 kg) rammer, 12 in. (305 mm) drop.

ANSI/AWWA C151/A21.51—American National Standard for Ductile-Iron Pipe, Centrifugally Cast, for Water.

ASTM* A746—Standard Specification for Ductile Iron Gravity Sewer Pipe.

SECTION 3: DEFINITIONS

This standard has no applicable information for this section.

SECTION 4: REQUIREMENTS

Sec. 4.1 Procedure for Calculating Thickness

The thickness of ductile-iron pipe is determined by considering trench load and internal pressure separately.

4.1.1 *Step 1—Design for trench load.*

a. Determine trench load P_v. Table 1 gives trench load, including earth load P_e, plus truck load P_t, for 2.5 ft–32 ft (0.8 m–9.8 m) cover.

b. Determine the standard laying condition from the descriptions in Table 2 and select the appropriate table for diameter–thickness ratios from Tables 7 through 11. Each table lists diameter–thickness ratios calculated for both bending stress and deflection over a range of trench loads.

c. For bending-stress design, enter the column headed "Bending-Stress Design" in the appropriate table of Tables 7 through 11, and locate the tabulated trench load P_v nearest to the calculated P_v from Sec. 4.1.1.a. (If the calculated P_v is halfway between two tabulated values, use the larger P_v value.)

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Select the corresponding D/t value for this P_v.

Divide the pipe's outside diameter D (Table 5) by the D/t value to obtain net thickness t.

d. For deflection design, enter the column headed "Deflection Design" in the appropriate table of Tables 7 through 11, and locate the tabulated trench load P_v nearest to the calculated P_v from Sec. 4.1.1.a. (If the calculated P_v is less than the minimum P_v listed in the table, design for trench load is not controlled by deflection and this determination need not be completed.) If the calculated P_v is halfway between two tabulated values, use the larger P_v value.

Select the corresponding D/t_1 value for this P_v.

Divide the pipe's outside diameter D (Table 5) by the D/t_1 value to obtain minimum manufacturing thickness t_1. Deduct 0.08 in. (2.0 mm) service allowance to obtain net thickness t.

NOTE: Service allowance equals 0.08 in. (2.0 mm) for all sizes of ductile-iron pipe.

e. Compare the net thicknesses from steps c and d and select the larger of the two. This will be the net thickness required for trench load.

4.1.2 *Step 2—Design for internal pressure.* Calculate the net thickness required for internal pressure using the equation for hoop stress:

$$t = \frac{P_i D}{2S}$$

Where:

t = net thickness, in. (mm)
P_i = design internal pressure, psi (kPa) = 2 ($P_w + P_s$)
P_w = working pressure, psi (kPa)
P_s = surge allowance, 100* psi (689 kPa)
D = outside diameter of pipe, in. (mm)
S = minimum yield strength in tension = 42,000 psi (289,590 kPa)

*(If anticipated surge pressures are other than 100 psi (689 kPa), the actual anticipated pressure should be used.)

4.1.3 *Step 3—Selection of net thickness and addition of allowances.*

a. Select the net thickness t from step 1 or step 2, whichever thickness is larger.

b. Add the service allowance of 0.08 in. (2.0 mm) to the net thickness t. The resulting thickness is the minimum manufacturing thickness t_1.

c. Add the casting allowance from Table 3 to the minimum manufacturing thickness t_1. The resulting thickness is the total calculated thickness.

4.1.4 *Step 4—Selection of standard pressure class.* Use the total calculated thickness from Sec. 4.1.3.c to select a standard pressure-class thickness from Table 5. When the calculated thickness is between two nominal thicknesses, select the larger of the two.

When specifying and ordering pipe, use the pressure class listed in Table 5 for this nominal thickness.

NOTE: On specific projects, manufacturers may be willing to furnish pipe with thicknesses that fall between standard classes.

4.1.5 *Alternative procedure.* The appropriate standard pressure class may also be determined by using the Design Equations in Sec. 4.3.

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Sec. 4.2 Design Example for Calculating Thickness

Problem: Calculate the thickness for 30-in. (762-mm) ductile-iron pipe bedded in loose soil for a minimum depth of 4 in. (100 mm), backfill lightly consolidated to top of pipe, laying condition Type 3, under 10 ft (3 m) of cover for a working pressure of 150 psi (1,034 kPa).

4.2.1 *Step 1—Design for trench load.*

a. Earth load (Table 1) P_e = 8.3 psi
Truck load (Table 1) P_t = 0.7 psi
Trench load, $P_v = P_e + P_t$ = 9.0 psi

b. Select Table 9 for diameter–thickness ratios for laying condition Type 3.

c. Entering P_v of 9.0 psi in Table 9, the bending-stress design requires D/t of 163. From Table 5, diameter D of 30-in. pipe is 32.00 in.

Net thickness t for bending stress = $D/(D/t)$ = 32.00/163 = 0.20 in.

d. Also, from Table 9, the deflection design requires D/t_1 of 136.

Minimum manufacturing thickness t_1 for deflection design:

$$t_1 = \frac{D}{\frac{D}{t_1}} = \frac{32.00}{136} = 0.24 \text{ in.}$$

Deduct service allowance −0.08 in.
Net thickness t for deflection control = 0.16 in.

e. The larger net thickness is 0.20 in., obtained by the design for bending stress.

4.2.2 *Step 2—Design for internal pressure.*

$P_i = 2.0\ (P_w + P_s)$ = 2.0 (working pressure + 100 psi surge allowance)

(If anticipated surge pressures are other than 100 psi [689 kPa], then the actual anticipated pressures should be used.)

$$P_i = 2.0\ (150 + 100) = 500 \text{ psi}$$

$$t = \frac{P_i D}{2S} = \frac{500 \times 32.00}{2 \times 42{,}000} = 0.19 \text{ in.}$$

Net thickness t for internal pressure is 0.19 in.

4.2.3 *Step 3—Selection of net thickness and addition of allowances.* The larger of the thicknesses is given by the design for trench load, Step 1, and 0.20 in. is selected.

Net thickness = 0.20 in.
Service allowance = 0.08 in.
Minimum manufacturing thickness = 0.28 in.
Casting allowance = 0.07 in.
Total calculated thickness = 0.35 in.

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4.2.4 *Step 4—Selection of nominal thickness and standard pressure class.* The total calculated thickness of 0.35 in. is larger than 0.34 in., Class 150. Therefore, Class 200 is selected for specifying and ordering.

Sec. 4.3 Design Method

4.3.1 *Ductile-iron pipe thickness.* The thickness of ductile-iron pipe is determined by considering trench load and internal pressure separately.

Calculations are made for the thicknesses required to resist the bending stress and the deflection caused by trench load. The larger of the two is selected as the thickness required to resist trench load. Calculations are then made for the thickness required to resist the hoop stress of internal pressure.

The larger of these is selected as the net design thickness. To this net thickness is added a service allowance to obtain the minimum manufacturing thickness and a casting allowance to obtain the total calculated thickness.

The nominal thickness and the standard pressure class for specifying and ordering are selected from the table of nominal thicknesses for standard pressure classes (Table 5).

The reverse of the preceding procedure is used to determine the rated working pressure and maximum depth of cover for pipe of a given pressure class.

4.3.2 *Trench load P_v.* Trench load is expressed as vertical pressure in pounds per square inch (kilopascals) and is equal to the sum of earth load P_e and truck load P_t.

4.3.3 *Earth load P_e.* Earth load is computed by Eq 4 for the weight of the unit prism of soil with a height equal to the distance from the top of the pipe to the ground surface. The unit weight of backfill soil is taken to be 120 lb/ft^3 (18.85 kN/m^3). If the designer anticipates additional loads, the design load should be increased accordingly.

4.3.4 *Truck load P_t.* The truck loads shown in Table 1 were computed by Eq 5 using the surface-load factors in Table 6 and the reduction factors R from Table 4 for a single AASHTO H-20 truck on unpaved road or flexible pavement, 16,000-lb (71,170-N) wheel load, and 1.5 impact factor. The surface-load factors in Table 6 were calculated by Eq 6 for a single concentrated wheel load centered over an effective pipe length of 3 ft (0.914 m).

4.3.5 *Design for trench load.* Tables 7 through 11, the diameter–thickness ratios tables used to design for trench load, were computed with Eqs 2 and 3. Equation 2 is based on the bending stress at the bottom of the pipe. The design-bending stress f is 48,000 psi (331 × 10^3 kPa), which provides at least a 1.5 safety factor based on minimum ring yield strength and a 2.0 safety factor based on ultimate strength. Equation 3 is based on the deflection of the pipe ring section. The design deflection Δx is 3 percent of the outside diameter of the pipe, which is well below the deflection that might damage cement linings. Design values of the trench parameters E', K_b, and K_x are given in Table 2.

Tables similar to Tables 7 through 11 may be compiled for laying conditions other than those shown in this standard by calculating the trench loads P_v for a series of diameter–thickness ratios, D/t and D/t_1, using Eqs 2 and 3 with values of E', Kb, and K_x appropriate to the bedding and backfill conditions.

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Design Equations

$$t = \frac{P_i D}{2S} \qquad \text{(Eq 1)}$$

$$P_v = \frac{f}{3\left(\frac{D}{t}\right)\left(\frac{D}{t}-1\right)\left[K_b - \frac{K_x}{\frac{8E}{E'\left(\frac{D}{t}-1\right)^3}+0.732}\right]} \qquad \text{(Eq 2)}$$

$$P_v = \frac{\frac{\Delta x}{D}}{12\,K_x}\left[\frac{8E}{\left(\frac{D}{t_1}-1\right)^3}+0.732E'\right] \qquad \text{(Eq 3)}$$

$$P_e = \frac{wH}{a} \qquad \text{(Eq 4)}$$

$$P_t = RF\frac{CP}{bD} \qquad \text{(Eq 5)}$$

$$C = 1 - \frac{2}{\pi}\arcsin\left(H\sqrt{\frac{A^2+B^2+H^2}{(A^2+H^2)(B^2+H^2)}}\right) + \frac{2}{\pi}\left(\frac{A{\cdot}H{\cdot}B}{\sqrt{A^2+H^2+B^2}}\right)\left(\frac{1}{A^2+H^2}+\frac{1}{B^2+H^2}\right) \qquad \text{(Eq 6)}$$

NOTE: In Eq 6, angles are in radians.

Sec. 4.4 Explanation of Symbols Used in Design Equations

A = Outside radius of pipe. For A in feet, D in inches: $A = D/24$ (For A in metres, D in millimetres: $A = D/2{,}000$)
a = Conversion factor. For pounds per square foot to pounds per square inch: $a = 144$ (For kilonewtons per square metre to kilopascals: $a = 1$)
B = 1.5 ft (0.457 m)
b = Effective pipe length: 36 in. (0.914 m)
C = Surface load factor: see Table 6.
D = Outside diameter, in inches (millimetres): see Table 5.
E = Modulus of elasticity: 24×10^6 psi (165.5×10^6 kPa)
E' = Modulus of soil reaction, in pounds per square inch (kilopascals): see Table 2.
F = Impact factor: 1.5
f = Design bending stress: 48,000 psi (331×10^3 kPa)
H = Depth of cover, in feet (metres)
K_b = Bending moment coefficient: see Table 2.

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K_x = Deflection coefficient: see Table 2.
P = Wheel load: 16,000 lb (71,170 N)
P_e = Earth load, in pounds per square inch (kilopascals)
P_i = Design internal pressure, in pounds per square inch (kilopascals): P_i = 2 (working pressure + 100 psi [689 kPa] surge allowance)
P_t = Truck load, in pounds per square inch (kilopascals)
P_v = Trench load, in pounds per square inch (kilopascals): $P_v = P_e + P_t$
R = Reduction factor, which takes account of the fact that the part of the pipe directly below the wheels is aided in carrying the truck load by adjacent parts of the pipe that receive little or no load from the wheels: see Table 4.
S = Minimum yield strength in tension: 42,000 psi (289,590 kPa)
t = Net thickness, in inches (millimetres)
t_1 = Minimum manufacturing thickness, in inches: $t_1 = t + 0.08$ (in millimetres: $t_1 = t + 2$)
w = Soil weight: 120 lb/ft^3 (18.85 kN/m^3)
Δx = Design deflection, in inches (millimetres): $\Delta x = 0.03D$

Sec. 4.5 Special Thickness Classes

For design conditions not covered in Tables 12, 13, and 14, special (formerly standard) thickness classes shown in Table 15 continue to be available.

SECTION 5: VERIFICATION

This standard has no applicable information for this section.

SECTION 6: DELIVERY

This standard has no applicable information for this section.

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Table 1 Earth loads P_e, truck loads P_t, and trench loads P_v—psi

Depth of Cover		3-in. Pipe		4-in. Pipe		6-in. Pipe		8-in. Pipe	
ft	P_e	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v
2.5	2.1	9.9	12.0	9.9	12.0	9.9	12.0	9.8	11.9
3	2.5	7.4	9.9	7.4	9.9	7.3	9.8	7.3	9.8
4	3.3	4.4	7.7	4.5	7.8	4.4	7.7	4.4	7.7
5	4.2	3.0	7.2	3.0	7.2	3.0	7.2	3.0	7.2
6	5.0	2.1	7.1	2.1	7.1	2.1	7.1	2.1	7.1
7	5.8	1.6	7.4	1.6	7.4	1.6	7.4	1.6	7.4
8	6.7	1.2	7.9	1.2	7.9	1.2	7.9	1.2	7.9
9	7.5	1.0	8.5	1.0	8.5	1.0	8.5	1.0	8.5
10	8.3	0.8	9.1	0.8	9.1	0.8	9.1	0.8	9.1
12	10.0	0.6	10.6	0.6	10.6	0.6	10.6	0.6	10.6
14	11.7	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1
16	13.3	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6
20	16.7	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9
24	20.0	0.2	20.2	0.1	20.1	0.1	20.1	0.1	20.1
28	23.3	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4
32	26.7	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8

Depth of Cover		10-in. Pipe		12-in. Pipe		14-in. Pipe		16-in. Pipe	
ft	P_e	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v
2.5	2.1	9.7	11.8	9.6	11.7	8.7	10.8	8.2	10.3
3	2.5	7.2	9.7	7.2	9.7	6.6	9.1	6.2	8.7
4	3.3	4.4	7.7	4.4	7.7	4.4	7.7	4.1	7.4
5	4.2	2.9	7.1	2.9	7.1	2.9	7.1	2.8	7.0
6	5.0	2.1	7.1	2.1	7.1	2.1	7.1	2.0	7.0
7	5.8	1.6	7.4	1.6	7.4	1.6	7.4	1.5	7.3
8	6.7	1.2	7.9	1.2	7.9	1.2	7.9	1.2	7.9
9	7.5	1.0	8.5	1.0	8.5	1.0	8.5	1.0	8.5
10	8.3	0.8	9.1	0.8	9.1	0.8	9.1	0.8	9.1
12	10.0	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5
14	11.7	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1
16	13.3	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6
20	16.7	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9
24	20.0	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1
28	23.3	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4
32	26.7	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048; to convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

Table continued next page.

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STD.AWWA C150/A21.50-ENGL 1996 ■ 0783350 0504735 560 ■

Table 1 Earth loads P_e, truck loads P_t, and trench loads P_v—psi (continued)

Depth of Cover		18-in. Pipe		20-in. Pipe		24-in. Pipe		30-in. Pipe		36-in. Pipe	
ft	P_e	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v
2.5	2.1	7.8	9.9	7.5	9.6	7.1	9.2	6.7	8.8	6.2	8.3
3	2.5	5.9	8.4	5.7	8.2	5.4	7.9	5.2	7.7	4.9	7.4
4	3.3	3.9	7.2	3.9	7.2	3.6	6.9	3.5	6.8	3.4	6.7
5	4.2	2.6	6.8	2.6	6.8	2.4	6.6	2.4	6.6	2.3	6.5
6	5.0	1.9	6.9	1.9	6.9	1.7	6.7	1.7	6.7	1.7	6.7
7	5.8	1.4	7.2	1.4	7.2	1.3	7.1	1.3	7.1	1.3	7.1
8	6.7	1.2	7.9	1.1	7.8	1.1	7.8	1.1	7.8	1.1	7.8
9	7.5	1.0	8.5	0.9	8.4	0.9	8.4	0.9	8.4	0.8	8.3
10	8.3	0.8	9.1	0.7	9.0	0.7	9.0	0.7	9.0	0.7	9.0
12	10.0	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5
14	11.7	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1
16	13.3	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6
20	16.7	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9
24	20.0	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1
28	23.3	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4
32	26.7	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8

Depth of Cover		42-in. Pipe		48-in. Pipe		54-in. Pipe		60-in. Pipe		64-in. Pipe	
ft	P_e	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v
2.5	2.1	5.8	7.9	5.4	7.5	5.0	7.1	4.8	6.9	4.5	6.6
3	2.5	4.6	7.1	4.4	6.9	4.1	6.6	3.9	6.4	3.8	6.3
4	3.3	3.3	6.6	3.1	6.4	3.0	6.3	2.9	6.2	2.8	6.1
5	4.2	2.3	6.5	2.2	6.4	2.1	6.3	2.1	6.3	2.1	6.3
6	5.0	1.7	6.7	1.6	6.6	1.6	6.6	1.6	6.6	1.5	6.5
7	5.8	1.3	7.1	1.2	7.0	1.2	7.0	1.2	7.0	1.2	7.0
8	6.7	1.0	7.7	1.0	7.7	1.0	7.7	1.0	7.7	1.0	7.7
9	7.5	0.8	8.3	0.8	8.3	0.8	8.3	0.8	8.3	0.8	8.3
10	8.3	0.7	9.0	0.7	9.0	0.7	9.0	0.7	9.0	0.7	9.0
12	10.0	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5
14	11.7	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1
16	13.3	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6
20	16.7	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9
24	20.0	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1
28	23.3	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4
32	26.7	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048; to convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

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Table 2 Design values for standard laying conditions

Laying Condition*	Description	E' psi	Bedding Angle deg	K_b	K_x
Type 1†	Flat-bottom trench.‡ Loose backfill.	150	30	0.235	0.108
Type 2	Flat-bottom trench. Backfill lightly consolidated to centerline of pipe.	300	45	0.210	0.105
Type 3	Pipe-bedded in 4-in.-minimum loose soil.§ Backfill lightly consolidated to top of pipe.	400	60	0.189	0.103
Type 4	Pipe bedded in sand, gravel, or crushed stone to depth of ⅛ pipe diameter. 4-in. minimum. Backfill compacted to top of pipe. (Approximately 80 percent Standard Proctor, AASHTO T-99)**	500	90	0.157	0.096
Type 5	Pipe bedded to its centerline in compacted granular material, 4-in. minimum under pipe. Compacted granular or select material§ to top of pipe. (Approximately 90 percent Standard Proctor, AASHTO T-99)**	700	150	0.128	0.085

NOTES:

1) Consideration of the pipe-zone embedment conditions included in this table may be influenced by factors other than pipe strength. For additional information see ANSI/AWWA C600, Standard for Installation of Ductile-Iron Water Mains and Their Appurtenances.

2) To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*See Figure 1.

†For pipe 14 in. (356 mm) and larger, consideration should be given to the use of laying conditions other than Type 1.

‡Flat-bottom is defined as "undisturbed earth."

§Loose soil or select material is defined as "native soil excavated from the trench, free of rocks, foreign material, and frozen earth."

**AASHTO T-99, "Standard Method of Test for the Moisture–Density Relations of Soils Using a 5.5 lb (2.5 kg) Rammer and a 12 in. (305 mm) Drop." Available from the American Association of State Highway and Transportation Officials, 444 N. Capital St. N.W., Washington, DC 20001.

Table 3 Allowances for casting tolerance

Size in.	Casting Allowance in.
3–8	0.05
10–12	0.06
14–42	0.07
48	0.08
54–64	0.09

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4.

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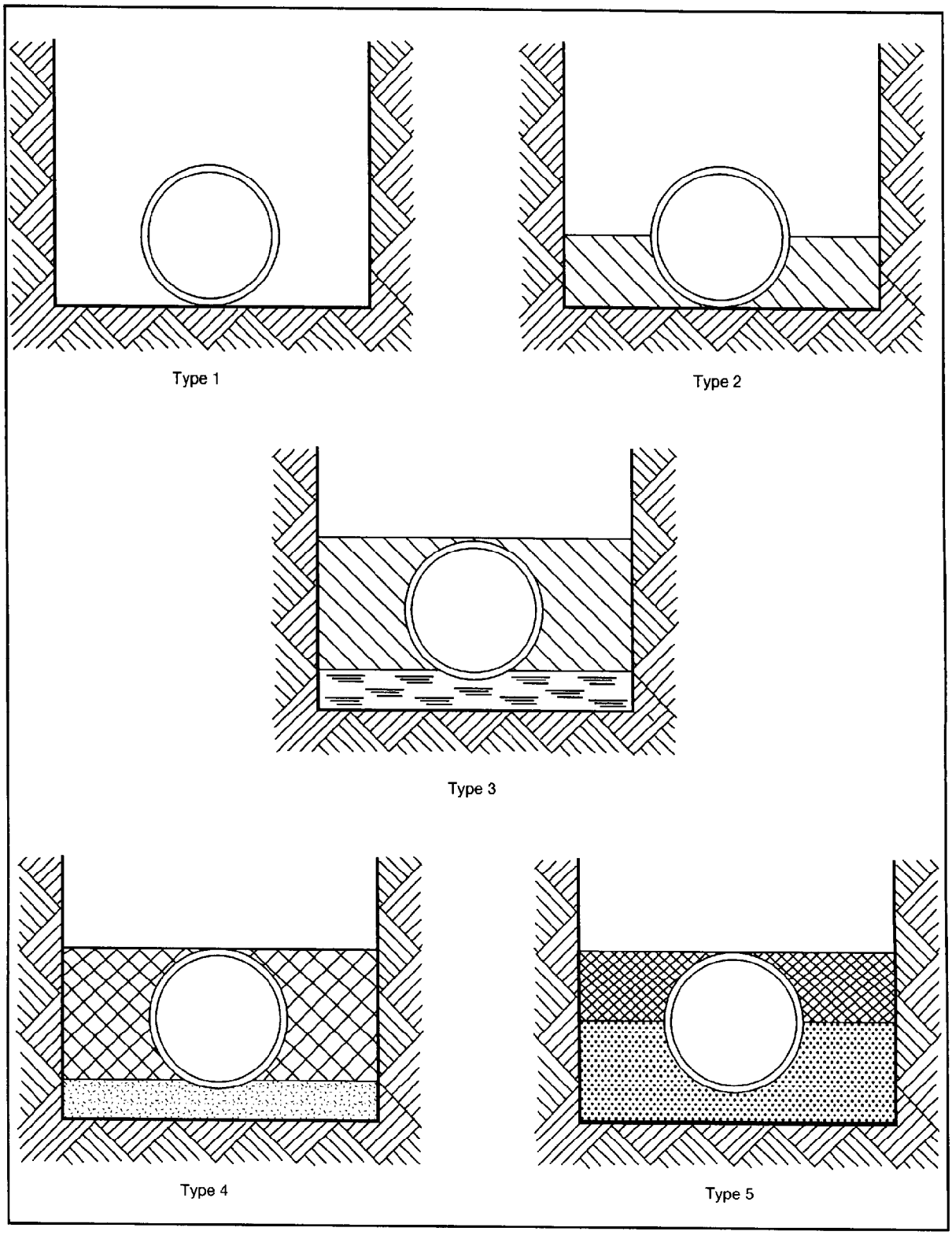

Figure 1 Standard pipe laying conditions (see Table 2)

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Table 4 Reduction factors R for truck load calculations

Size *in.*	Depth of Cover—*ft*			
	<4	4–7	>7–10	>10
	Reduction Factor			
3–12	1.00	1.00	1.00	1.00
14	0.92	1.00	1.00	1.00
16	0.88	0.95	1.00	1.00
18	0.85	0.90	1.00	1.00
20	0.83	0.90	0.95	1.00
24–30	0.81	0.85	0.95	1.00
36–64	0.80	0.85	0.90	1.00

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048.

Table 5 Nominal thicknesses for standard pressure classes of ductile-iron pipe

Size *in.*	Outside Diameter *in.*	Pressure Class				
		150	200	250	300	350
		Nominal Thickness—*in.*				
3	3.96	—	—	—	—	0.25*
4	4.80	—	—	—	—	0.25*
6	6.90	—	—	—	—	0.25*
8	9.05	—	—	—	—	0.25*
10	11.10	—	—	—	—	0.26
12	13.20	—	—	—	—	0.28
14	15.30	—	—	0.28	0.30	0.31
16	17.40	—	—	0.30	0.32	0.34
18	19.50	—	—	0.31	0.34	0.36
20	21.60	—	—	0.33	0.36	0.38
24	25.80	—	0.33	0.37	0.40	0.43
30	32.00	0.34	0.38	0.42	0.45	0.49
36	38.30	0.38	0.42	0.47	0.51	0.56
42	44.50	0.41	0.47	0.52	0.57	0.63
48	50.80	0.46	0.52	0.58	0.64	0.70
54	57.56	0.51	0.58	0.65	0.72	0.79
60	61.61	0.54	0.61	0.68	0.76	0.83
64	65.67	0.56	0.64	0.72	0.80	0.87

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4.

*Calculated thicknesses for these sizes and pressure ratings are less than those shown above. (See Table 13 for actual calculated thicknesses.) Presently these are the lowest nominal thicknesses available in these sizes.

Pressure classes are defined as the rated water working pressure of the pipe in pounds per square inch (psi). The thicknesses shown are adequate for the rated water working pressure plus a surge allowance of 100 psi (689 kPa). Calculations are based on a minimum yield strength in tension of 42,000 psi (289,590 kPa) and 2.0 safety factor times the sum of working pressure and 100 psi (689 kPa) surge allowance.

Thickness can be calculated for rated water working pressure and surges other than the above by use of the formula shown in Sec. 4.1.2.

Ductile-iron pipe is available for water working pressures greater than 350 psi (2,413 kPa).

Pipe is available with thicknesses greater than Pressure Class 350. See Table 15.

Lowest nominal thicknesses shown in Table 15.1 of ANSI/AWWA C115/A21.15 for threaded flanged pipe are still required.

Lowest nominal thicknesses shown in ANSI/AWWA C606 for pipe with grooved and shouldered joints are still required.

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Table 6 Surface load factors for single truck on unpaved road

Depth of Cover *ft*	Pipe Size—*in.* 3	4	6	8	10	12	14	16	18
	Surface Load Factor—*C*								
2.5	0.0589	0.0713	0.1020	0.1328	0.1615	0.1901	0.2178	0.2443	0.2698
3	0.0437	0.0530	0.0759	0.0990	0.1207	0.1424	0.1637	0.1843	0.2044
4	0.0265	0.0321	0.0460	0.0602	0.0736	0.0871	0.1005	0.1136	0.1265
5	0.0176	0.0213	0.0306	0.0401	0.0490	0.0581	0.0672	0.0761	0.0849
6	0.0125	0.0151	0.0217	0.0284	0.0348	0.0413	0.0478	0.0542	0.0606
7	0.0093	0.0113	0.0162	0.0212	0.0260	0.0308	0.0357	0.0405	0.0453
8	0.0072	0.0087	0.0125	0.0164	0.0201	0.0238	0.0276	0.0313	0.0350
9	0.0057	0.0069	0.0099	0.0130	0.0160	0.0190	0.0219	0.0249	0.0279
10	0.0046	0.0056	0.0081	0.0106	0.0130	0.0154	0.0179	0.0203	0.0227
12	0.0032	0.0039	0.0056	0.0074	0.0091	0.0108	0.0125	0.0142	0.0159
14	0.0024	0.0029	0.0042	0.0055	0.0067	0.0080	0.0092	0.0105	0.0117
16	0.0018	0.0022	0.0032	0.0042	0.0051	0.0061	0.0071	0.0080	0.0090
20	0.0012	0.0014	0.0020	0.0027	0.0033	0.0039	0.0045	0.0052	0.0058
24	0.0008	0.0010	0.0014	0.0019	0.0023	0.0027	0.0032	0.0036	0.0040
28	0.0006	0.0007	0.0010	0.0014	0.0017	0.0020	0.0023	0.0026	0.0030
32	0.0005	0.0006	0.0008	0.0011	0.0013	0.0015	0.0018	0.0020	0.0023

Depth of Cover *ft*	Pipe Size—*in.* 20	24	30	36	42	48	54	60	64
	Surface Load Factor—*C*								
2.5	0.2941	0.3390	0.3962	0.4437	0.4813	0.5115	0.5366	0.5488	0.5592
3	0.2237	0.2602	0.3085	0.3507	0.3857	0.4153	0.4412	0.4543	0.4657
4	0.1391	0.1635	0.1972	0.2284	0.2559	0.2808	0.3040	0.3164	0.3277
5	0.0936	0.1106	0.1347	0.1576	0.1786	0.1982	0.2173	0.2278	0.2377
6	0.0669	0.0793	0.0970	0.1143	0.1304	0.1458	0.1612	0.1698	0.1781
7	0.0500	0.0594	0.0730	0.0863	0.0988	0.1111	0.1235	0.1306	0.1374
8	0.0387	0.0461	0.0567	0.0672	0.0773	0.0871	0.0973	0.1031	0.1088
9	0.0309	0.0367	0.0453	0.0538	0.0620	0.0700	0.0784	0.0833	0.0880
10	0.0251	0.0299	0.0370	0.0440	0.0507	0.0574	0.0644	0.0685	0.0725
12	0.0176	0.0210	0.0259	0.0309	0.0357	0.0405	0.0456	0.0486	0.0515
14	0.0130	0.0155	0.0192	0.0229	0.0265	0.0301	0.0339	0.0362	0.0384
16	0.0100	0.0119	0.0147	0.0176	0.0204	0.0232	0.0262	0.0279	0.0297
20	0.0064	0.0076	0.0095	0.0113	0.0131	0.0149	0.0169	0.0181	0.0192
24	0.0045	0.0053	0.0066	0.0079	0.0091	0.0104	0.0118	0.0126	0.0134
28	0.0033	0.0039	0.0049	0.0058	0.0067	0.0077	0.0087	0.0093	0.0099
32	0.0025	0.0030	0.0037	0.0044	0.0052	0.0059	0.0067	0.0071	0.0076

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048.

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Table 7 Diameter-thickness ratios for laying condition Type 1*

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
4.40	3.46	170	5.40	4.03	145
4.43	3.48	169	5.45	4.06	144
4.46	3.50	168	5.49	4.09	143
4.50	3.51	167	5.54	4.13	142
4.54	3.53	166	5.59	4.16	141
4.57	3.55	165	5.65	4.20	140
4.61	3.57	164	5.70	4.23	139
4.64	3.59	163	5.75	4.27	138
4.68	3.61	162	5.80	4.31	137
4.72	3.63	161	5.86	4.35	136
4.76	3.65	160	5.91	4.39	135
4.80	3.67	159	5.97	4.43	134
4.84	3.69	158	6.03	4.47	133
4.88	3.71	157	6.09	4.52	132
4.92	3.74	156	6.15	4.56	131
4.96	3.76	155	6.21	4.61	130
5.00	3.78	154	6.27	4.66	129
5.04	3.81	153	6.33	4.71	128
5.08	3.83	152	6.40	4.76	127
5.13	3.86	151	6.46	4.82	126
5.17	3.89	150	6.53	4.87	125
5.21	3.91	149	6.60	4.93	124
5.26	3.94	148	6.67	4.99	123
5.30	3.97	147	6.74	5.05	122
5.35	4.00	146	6.82	5.11	121

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*$E' = 150$ psi; $K_b = 0.235$; $K_x = 0.108$.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 7 Diameter-thickness ratios for laying condition Type 1* (continued)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
6.89	5.18	120	9.56	7.89	95
6.97	5.25	119	9.71	8.07	94
7.05	5.32	118	9.87	8.25	93
7.13	5.39	117	10.03	8.44	92
7.21	5.46	116	10.20	8.64	91
7.29	5.54	115	10.37	8.85	90
7.38	5.62	114	10.55	9.06	89
7.47	5.71	113	10.74	9.29	88
7.56	5.79	112	10.93	9.53	87
7.65	5.88	111	11.13	9.78	86
7.75	5.97	110	11.34	10.04	85
7.85	6.07	109	11.55	10.31	84
7.95	6.17	108	11.78	10.60	83
8.05	6.27	107	12.01	10.90	82
8.16	6.38	106	12.25	11.22	81
8.27	6.49	105	12.50	11.56	80
8.38	6.61	104	12.76	11.91	79
8.49	6.73	103	13.03	12.28	78
8.61	6.86	102	13.31	12.67	77
8.74	6.99	101	13.60	13.08	76
8.86	7.12	100	13.91	13.51	75
8.99	7.26	99	14.23	13.97	74
9.13	7.41	98	14.56	14.45	73
9.27	7.57	97	14.91	14.96	72
9.41	7.73	96	15.27	15.50	71

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*E' = 150 psi; K_b = 0.235; K_x = 0.108.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

Table continued next page.

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Table 7 Diameter-thickness ratios for laying condition Type 1* (continued)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
15.65	16.07	70	28.94	40.32	50
16.05	16.68	69	30.07	42.73	49
16.46	17.32	68	31.28	45.35	48
16.89	18.00	67	32.57	48.20	47
17.35	18.73	66	33.95	51.31	46
17.83	19.50	65	35.42	54.72	45
18.33	20.32	64	37.00	58.44	44
18.85	21.19	63	38.69	62.53	43
19.40	22.12	62	40.50	67.03	42
19.98	23.12	61	42.46	71.99	41
20.59	24.18	60	44.56	77.47	40
21.23	25.32	59	46.84	83.54	39
21.91	26.54	58	49.30	90.28	38
22.63	27.85	57	51.96	97.80	37
23.38	29.26	56	54.86	106.20	36
24.18	30.77	55	58.02	115.62	35
25.02	32.39	54	61.46	126.21	34
25.92	34.15	53	65.23	138.18	33
26.86	36.05	52	69.36	151.73	32
27.87	38.10	51	73.92	167.15	31

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*E' = 150 psi; K_b = 0.235; K_x = 0.108.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 8 Diameter-thickness ratios for laying condition Type 2*

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
6.29	6.18	170	7.74	6.76	145
6.34	6.19	169	7.80	6.79	144
6.39	6.21	168	7.87	6.83	143
6.44	6.23	167	7.94	6.86	142
6.50	6.25	166	8.01	6.89	141
6.55	6.26	165	8.08	6.93	140
6.60	6.28	164	8.15	6.97	139
6.66	6.30	163	8.22	7.01	138
6.71	6.32	162	8.29	7.05	137
6.77	6.34	161	8.37	7.09	136
6.82	6.37	160	8.44	7.13	135
6.88	6.39	159	8.52	7.17	134
6.94	6.41	158	8.59	7.22	133
6.99	6.43	157	8.67	7.26	132
7.05	6.46	156	8.75	7.31	131
7.11	6.48	155	8.83	7.36	130
7.17	6.50	154	8.91	7.41	129
7.23	6.53	153	8.99	7.46	128
7.29	6.56	152	9.07	7.51	127
7.35	6.58	151	9.16	7.57	126
7.42	6.61	150	9.25	7.63	125
7.48	6.64	149	9.33	7.69	124
7.54	6.67	148	9.42	7.75	123
7.61	6.70	147	9.51	7.81	122
7.67	6.73	146	9.60	7.87	121

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*$E' = 300$ psi; $K_b = 0.210$; $K_x = 0.105$.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 8 Diameter-thickness ratios for laying condition Type 2* (continued)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
9.70	7.94	120	12.79	10.73	95
9.79	8.01	119	12.96	10.91	94
9.89	8.08	118	13.13	11.10	93
9.99	8.16	117	13.31	11.29	92
10.09	8.23	116	13.49	11.50	91
10.19	8.31	115	13.68	11.71	90
10.29	8.40	114	13.88	11.94	89
10.40	8.48	113	14.08	12.17	88
10.51	8.57	112	14.30	12.42	87
10.62	8.66	111	14.51	12.67	86
10.73	8.76	110	14.74	12.94	85
10.84	8.86	109	14.97	13.22	84
10.96	8.96	108	15.21	13.52	83
11.08	9.07	107	15.46	13.83	82
11.21	9.18	106	15.72	14.16	81
11.33	9.29	105	15.99	14.50	80
11.46	9.41	104	16.28	14.86	79
11.59	9.54	103	16.57	15.24	78
11.73	9.67	102	16.87	15.64	77
11.87	9.80	101	17.19	16.06	76
12.01	9.94	100	17.52	16.51	75
12.16	10.09	99	17.86	16.98	74
12.31	10.24	98	18.22	17.48	73
12.46	10.40	97	18.59	18.00	72
12.62	10.56	96	18.98	18.56	71

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*E' = 300 psi; K_b = 0.210; K_x = 0.105.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 8 Diameter-thickness ratios for laying condition Type 2* (continued)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
19.39	19.14	70	33.84	44.09	50
19.82	19.77	69	35.08	46.56	49
20.27	20.43	68	36.41	49.26	48
20.73	21.13	67	37.83	52.19	47
21.23	21.87	66	39.34	55.40	46
21.74	22.67	65	40.96	58.89	45
22.28	23.51	64	42.70	62.73	44
22.85	24.41	63	44.57	66.93	43
23.45	25.37	62	46.57	71.56	42
24.07	26.39	61	48.73	76.66	41
24.74	27.49	60	51.06	82.29	40
25.43	28.66	59	53.57	88.54	39
26.17	29.91	58	56.30	95.48	38
26.95	31.26	57	59.25	103.21	37
27.77	32.71	56	62.46	111.85	36
28.64	34.26	55	65.96	121.54	35
29.56	35.93	54	69.79	132.44	34
30.53	37.74	53	73.98	144.74	33
31.57	39.69	52	78.57	158.68	32
32.67	41.80	51	83.64	174.54	31

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*E' = 300 psi; K_b = 0.210; K_x = 0.105.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 9 Diameter-thickness ratios for laying condition Type 3*

Trench Load (P_v)—psi			Trench Load (P_v)—psi		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
3.25	7.26	310	4.45	7.38	260
3.29	7.27	308	4.51	7.38	258
3.33	7.27	306	4.57	7.39	256
3.37	7.27	304	4.63	7.39	254
3.41	7.28	302	4.69	7.40	252
3.45	7.28	300	4.76	7.41	250
3.49	7.28	298	4.82	7.42	248
3.54	7.29	296	4.89	7.42	246
3.58	7.29	294	4.96	7.43	244
3.63	7.30	292	5.03	7.44	242
3.67	7.30	290	5.10	7.45	240
3.72	7.30	288	5.17	7.46	238
3.76	7.31	286	5.24	7.47	236
3.81	7.31	284	5.31	7.48	234
3.86	7.32	282	5.39	7.48	232
3.91	7.32	280	5.47	7.49	230
3.96	7.33	278	5.54	7.51	228
4.01	7.33	276	5.62	7.52	226
4.06	7.34	274	5.70	7.53	224
4.11	7.34	272	5.79	7.54	222
4.17	7.35	270	5.87	7.55	220
4.22	7.35	268	5.96	7.56	218
4.28	7.36	266	6.04	7.58	216
4.33	7.36	264	6.13	7.59	214
4.39	7.37	262	6.22	7.60	212

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*E' = 400 psi; K_b = 0.189; K_x = 0.103.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 9 Diameter-thickness ratios for laying condition Type 3* (continued)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
6.32	7.62	210	8.89	8.16	165
6.41	7.63	208	8.96	8.18	164
6.51	7.65	206	9.03	8.20	163
6.60	7.66	204	9.10	8.22	162
6.70	7.68	202	9.17	8.24	161
6.80	7.70	200	9.25	8.27	160
6.91	7.72	198	9.32	8.29	159
7.01	7.74	196	9.39	8.31	158
7.12	7.76	194	9.47	8.33	157
7.22	7.78	192	9.54	8.36	156
7.33	7.80	190	9.62	8.38	155
7.45	7.82	188	9.69	8.41	154
7.56	7.84	186	9.77	8.43	153
7.68	7.87	184	9.85	8.46	152
7.80	7.89	182	9.92	8.49	151
7.92	7.92	180	10.00	8.52	150
8.04	7.95	178	10.08	8.54	149
8.16	7.98	176	10.16	8.57	148
8.29	8.01	174	10.24	8.60	147
8.42	8.04	172	10.33	8.64	146
8.55	8.07	170	10.41	8.67	145
8.62	8.09	169	10.49	8.70	144
8.69	8.11	168	10.58	8.73	143
8.75	8.13	167	10.66	8.77	142
8.82	8.14	166	10.75	8.81	141

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*$E' = 400$ psi; $K_b = 0.189$; $K_x = 0.103$.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 9 Diameter-thickness ratios for laying condition Type 3* (continued)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
10.83	8.84	140	13.34	10.25	115
10.92	8.88	139	13.46	10.34	114
11.01	8.92	138	13.58	10.42	113
11.10	8.96	137	13.71	10.51	112
11.19	9.00	136	13.83	10.61	111
11.28	9.04	135	13.96	10.71	110
11.37	9.09	134	14.09	10.81	109
11.46	9.13	133	14.22	10.91	108
11.56	9.18	132	14.36	11.02	107
11.65	9.23	131	14.50	11.13	106
11.75	9.28	130	14.64	11.25	105
11.84	9.33	129	14.78	11.37	104
11.94	9.38	128	14.93	11.50	103
12.04	9.44	127	15.08	11.63	102
12.14	9.49	126	15.23	11.77	101
12.25	9.55	125	15.39	11.91	100
12.35	9.61	124	15.55	12.06	99
12.45	9.67	123	15.71	12.21	98
12.56	9.74	122	15.88	12.37	97
12.67	9.80	121	16.06	12.54	96
12.78	9.87	120	16.23	12.72	95
12.89	9.94	119	16.42	12.90	94
13.00	10.02	118	16.61	13.09	93
13.11	10.09	117	16.80	13.29	92
13.23	10.17	116	17.00	13.50	91

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*E' = 400 psi; K_b = 0.189; K_x = 0.103.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 9 Diameter-thickness ratios for laying condition Type 3* (continued)

Trench Load (P_v)—psi			Trench Load (P_v)—psi		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
17.21	13.72	90	25.85	24.88	65
17.42	13.95	89	26.43	25.74	64
17.64	14.18	88	27.04	26.66	63
17.86	14.43	87	27.68	27.64	62
18.10	14.70	86	28.36	28.68	61
18.34	14.97	85	29.08	29.80	60
18.59	15.26	84	29.83	30.99	59
18.85	15.56	83	30.63	32.27	58
19.12	15.88	82	31.47	33.64	57
19.40	16.21	81	32.36	35.12	56
19.68	16.56	80	33.31	36.70	55
19.99	16.93	79	34.30	38.41	54
20.30	17.31	78	35.37	40.25	53
20.62	17.72	77	36.49	42.24	52
20.96	18.15	76	37.69	44.39	51
21.31	18.61	75	38.97	46.72	50
21.68	19.09	74	40.33	49.25	49
22.07	19.59	73	41.78	51.99	48
22.47	20.13	72	43.33	54.98	47
22.88	20.69	71	44.98	58.25	46
23.32	21.29	70	46.76	61.81	45
23.78	21.93	69	48.66	65.72	44
24.26	22.60	68	50.71	70.01	43
24.76	23.32	67	52.91	74.72	42
25.29	24.08	66	55.28	79.92	41

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*E' = 400 psi; K_b = 0.189; K_x = 0.103.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 9 Diameter-thickness ratios for laying condition Type 3* (continued)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
57.84	85.67	40	74.27	125.67	35
60.61	92.04	39	78.49	136.78	34
63.61	99.11	38	83.11	149.32	33
66.86	106.99	37	88.19	163.54	32
70.40	115.80	36	93.79	179.71	31

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*E' = 400 psi; K_b = 0.189; K_x = 0.103.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 10 Diameter-thickness ratios for laying condition Type 4*

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
5.93	9.70	310	8.00	9.82	260
6.00	9.70	308	8.10	9.83	258
6.07	9.71	306	8.20	9.83	256
6.14	9.71	304	8.31	9.84	254
6.21	9.71	302	8.41	9.85	252
6.29	9.72	300	8.52	9.86	250
6.36	9.72	298	8.63	9.86	248
6.43	9.73	296	8.74	9.87	246
6.51	9.73	294	8.85	9.88	244
6.59	9.73	292	8.97	9.89	242
6.67	9.74	290	9.08	9.90	240
6.74	9.74	288	9.20	9.91	238
6.83	9.75	286	9.32	9.92	236
6.91	9.75	284	9.44	9.93	234
6.99	9.76	282	9.57	9.94	232
7.08	9.76	280	9.69	9.95	230
7.16	9.77	278	9.82	9.96	228
7.25	9.77	276	9.95	9.97	226
7.34	9.78	274	10.08	9.98	224
7.43	9.78	272	10.21	9.99	222
7.52	9.79	270	10.35	10.01	220
7.61	9.79	268	10.49	10.02	218
7.71	9.80	266	10.62	10.03	216
7.80	9.81	264	10.77	10.05	214
7.90	9.81	262	10.91	10.06	212

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*E' = 500 psi; K_b = 0.157; K_x = 0.096.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 10 Diameter-thickness ratios for laying condition Type 4* (continued)

Trench Load (P_v)—psi			Trench Load (P_v)—psi		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
11.05	10.08	210	14.86	10.66	165
11.20	10.09	208	14.96	10.69	164
11.35	10.11	206	15.05	10.71	163
11.50	10.13	204	15.15	10.73	162
11.66	10.15	202	15.25	10.75	161
11.81	10.17	200	15.34	10.78	160
11.97	10.19	198	15.44	10.80	159
12.13	10.21	196	15.54	10.82	158
12.29	10.23	194	15.64	10.85	157
12.45	10.25	192	15.74	10.87	156
12.62	10.27	190	15.84	10.90	155
12.79	10.30	188	15.94	10.93	154
12.96	10.32	186	16.04	10.96	153
13.13	10.35	184	16.14	10.98	152
13.30	10.37	182	16.24	11.01	151
13.48	10.40	180	16.34	11.04	150
13.66	10.43	178	16.45	11.07	149
13.84	10.46	176	16.55	11.11	148
14.02	10.50	174	16.65	11.14	147
14.20	10.53	172	16.76	11.17	146
14.39	10.57	170	16.86	11.21	145
14.48	10.59	169	16.96	11.24	144
14.57	10.60	168	17.07	11.28	143
14.67	10.62	167	17.18	11.31	142
14.76	10.64	166	17.28	11.35	141

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*$E' = 500$ psi; $K_b = 0.157$; $K_x = 0.096$.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 10 Diameter-thickness ratios for laying condition Type 4* (continued)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
17.39	11.39	140	20.29	12.91	115
17.50	11.43	139	20.42	13.00	114
17.60	11.48	138	20.55	13.09	113
17.71	11.52	137	20.69	13.19	112
17.82	11.56	136	20.82	13.29	111
17.93	11.61	135	20.96	13.39	110
18.04	11.66	134	21.10	13.50	109
18.15	11.71	133	21.24	13.61	108
18.26	11.76	132	21.39	13.73	107
18.37	11.81	131	21.54	13.85	106
18.49	11.86	130	21.69	13.98	105
18.60	11.92	129	21.84	14.11	104
18.72	11.97	128	22.00	14.24	103
18.83	12.03	127	22.16	14.38	102
18.95	12.09	126	22.32	14.53	101
19.06	12.15	125	22.49	14.68	100
19.18	12.22	124	22.66	14.84	99
19.30	12.28	123	22.83	15.01	98
19.42	12.35	122	23.01	15.18	97
19.54	12.42	121	23.20	15.36	96
19.66	12.50	120	23.38	15.55	95
19.78	12.57	119	23.58	15.75	94
19.91	12.65	118	23.78	15.95	93
20.04	12.73	117	23.99	16.17	92
20.16	12.82	116	24.20	16.39	91

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*E' = 500 psi; K_b = 0.157; K_x = 0.096.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 10 Diameter-thickness ratios for laying condition Type 4* (continued)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
24.42	16.62	90	33.95	28.60	65
24.64	16.87	89	34.61	29.53	64
24.88	17.12	88	35.30	30.51	63
25.12	17.39	87	36.04	31.56	62
25.37	17.67	86	36.81	32.68	61
25.63	17.97	85	37.63	33.88	60
25.90	18.28	84	38.50	35.16	59
26.18	18.60	83	39.42	36.53	58
26.47	18.94	82	40.39	38.00	57
26.77	19.30	81	41.42	39.58	56
27.09	19.67	80	42.51	41.28	55
27.42	20.07	79	43.67	43.12	54
27.76	20.48	78	44.91	45.09	53
28.11	20.92	77	46.22	47.22	52
28.49	21.38	76	47.62	49.53	51
28.87	21.87	75	49.11	52.03	50
29.28	22.38	74	50.70	54.74	49
29.70	22.93	73	52.41	57.69	48
30.15	23.50	72	54.23	60.90	47
30.62	24.11	71	56.18	64.40	46
31.11	24.75	70	58.27	68.23	45
31.62	25.43	69	60.52	72.42	44
32.16	26.16	68	62.93	77.02	43
32.72	26.92	67	65.54	82.08	42
33.32	27.74	66	68.35	87.66	41

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*E' = 500 psi; K_b = 0.157; K_x = 0.096.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 10 Diameter-thickness ratios for laying condition Type 4* (continued)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
71.39	93.82	40	90.93	136.74	35
74.67	100.65	39	95.97	148.66	34
78.24	108.24	38	101.49	162.12	33
82.11	116.70	37	107.56	177.37	32
86.33	126.15	36	114.25	194.72	31

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*$E' = 500$ psi; $K_b = 0.157$; $K_x = 0.096$.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 11 Diameter-thickness ratios for laying condition Type 5*

Trench Load (P_v)—psi			Trench Load (P_v)—psi		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
3.06	15.09	660	4.60	15.11	535
3.10	15.09	655	4.69	15.11	530
3.15	15.09	650	4.77	15.11	525
3.20	15.09	645	4.86	15.11	520
3.25	15.09	640	4.95	15.11	515
3.30	15.09	635	5.05	15.11	510
3.35	15.09	630	5.14	15.11	505
3.40	15.09	625	5.24	15.12	500
3.46	15.09	620	5.35	15.12	495
3.51	15.09	615	5.45	15.12	490
3.57	15.10	610	5.56	15.12	485
3.63	15.10	605	5.67	15.12	480
3.68	15.10	600	5.78	15.12	475
3.75	15.10	595	5.90	15.13	470
3.81	15.10	590	6.02	15.13	465
3.87	15.10	585	6.15	15.13	460
3.94	15.10	580	6.28	15.13	455
4.00	15.10	575	6.41	15.13	450
4.07	15.10	570	6.54	15.14	445
4.14	15.10	565	6.68	15.14	440
4.21	15.10	560	6.83	15.14	435
4.29	15.10	555	6.98	15.14	430
4.36	15.10	550	7.13	15.14	425
4.44	15.11	545	7.29	15.15	420
4.52	15.11	540	7.46	15.15	415

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*E' = 700 psi; K_b = 0.128; K_x = 0.085.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 11 Diameter-thickness ratios for laying condition Type 5* (continued)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
7.63	15.15	410	13.23	15.28	300
7.80	15.16	405	13.37	15.29	298
7.98	15.16	400	13.52	15.29	296
8.17	15.16	395	13.67	15.30	294
8.36	15.17	390	13.83	15.30	292
8.56	15.17	385	13.98	15.30	290
8.77	15.17	380	14.14	15.31	288
8.98	15.18	375	14.30	15.31	286
9.20	15.18	370	14.46	15.32	284
9.43	15.19	365	14.62	15.33	282
9.66	15.19	360	14.79	15.33	280
9.91	15.20	355	14.96	15.34	278
10.16	15.20	350	15.13	15.34	276
10.42	15.21	345	15.30	15.35	274
10.69	15.22	340	15.48	15.35	272
10.97	15.22	335	15.65	15.36	270
11.26	15.23	330	15.83	15.37	268
11.56	15.24	325	16.02	15.37	266
11.87	15.24	320	16.20	15.38	264
12.19	15.25	315	16.39	15.39	262
12.52	15.26	310	16.58	15.40	260
12.66	15.27	308	16.77	15.40	258
12.80	15.27	306	16.97	15.41	256
12.94	15.27	304	17.16	15.42	254
13.08	15.28	302	17.36	15.43	252

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*$E' = 700$ psi; $K_b = 0.128$; $K_x = 0.085$.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 11 Diameter-thickness ratios for laying condition Type 5* (continued)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
17.57	15.44	250	23.44	15.79	200
17.77	15.45	248	23.70	15.81	198
17.98	15.45	246	23.97	15.83	196
18.19	15.46	244	24.24	15.86	194
18.40	15.47	242	24.50	15.88	192
18.62	15.48	240	24.77	15.91	190
18.84	15.49	238	25.04	15.93	188
19.06	15.51	236	25.31	15.96	186
19.28	15.52	234	25.59	15.99	184
19.51	15.53	232	25.86	16.02	182
19.73	15.54	230	26.13	16.06	180
19.97	15.55	228	26.41	16.09	178
20.20	15.57	226	26.68	16.12	176
20.43	15.58	224	26.96	16.16	174
20.67	15.59	222	27.23	16.20	172
20.91	15.61	220	27.51	16.24	170
21.16	15.62	218	27.65	16.26	169
21.40	15.64	216	27.78	16.28	168
21.65	15.65	214	27.92	16.31	167
21.90	15.67	212	28.06	16.33	166
22.15	15.69	210	28.19	16.35	165
22.40	15.71	208	28.33	16.37	164
22.66	15.73	206	28.47	16.40	163
22.92	15.75	204	28.60	16.42	162
23.18	15.77	202	28.74	16.45	161

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*E' = 700 psi; K_b = 0.128; K_x = 0.085.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 11 Diameter-thickness ratios for laying condition Type 5* (continued)

Trench Load (P_v)—psi			Trench Load (P_v)—psi		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
28.87	16.48	160	32.13	17.42	135
29.01	16.50	159	32.25	17.47	134
29.15	16.53	158	32.38	17.53	133
29.28	16.56	157	32.50	17.58	132
29.41	16.59	156	32.62	17.64	131
29.55	16.62	155	32.75	17.70	130
29.68	16.65	154	32.87	17.76	129
29.82	16.68	153	32.99	17.83	128
29.95	16.71	152	33.11	17.89	127
30.08	16.74	151	33.23	17.96	126
30.21	16.78	150	33.35	18.03	125
30.34	16.81	149	33.47	18.11	124
30.48	16.85	148	33.59	18.18	123
30.61	16.89	147	33.71	18.26	122
30.74	16.92	146	33.83	18.34	121
30.87	16.96	145	33.95	18.42	120
30.99	17.00	144	34.07	18.51	119
31.12	17.04	143	34.19	18.60	118
31.25	17.09	142	34.31	18.69	117
31.38	17.13	141	34.43	18.78	116
31.50	17.17	140	34.55	18.88	115
31.63	17.22	139	34.68	18.98	114
31.76	17.27	138	34.80	19.09	113
31.88	17.32	137	34.92	19.20	112
32.01	17.37	136	35.05	19.31	111

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*$E' = 700$ psi; $K_b = 0.128$; $K_x = 0.085$.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 11 Diameter-thickness ratios for laying condition Type 5* (continued)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
35.17	19.43	110	39.41	24.60	85
35.30	19.55	109	39.67	24.95	84
35.43	19.68	108	39.94	25.31	83
35.56	19.81	107	40.22	25.70	82
35.69	19.95	106	40.51	26.10	81
35.83	20.09	105	40.82	26.52	80
35.96	20.24	104	41.14	26.97	79
36.10	20.39	103	41.48	27.44	78
36.25	20.55	102	41.84	27.93	77
36.39	20.72	101	42.21	28.46	76
36.54	20.89	100	42.60	29.01	75
36.69	21.07	99	43.02	29.59	74
36.85	21.26	98	43.45	30.20	73
37.01	21.45	97	43.92	30.85	72
37.17	21.66	96	44.40	31.53	71
37.34	21.87	95	44.91	32.26	70
37.52	22.09	94	45.46	33.03	69
37.70	22.32	93	46.03	33.85	68
37.89	22.56	92	46.64	34.71	67
38.08	22.82	91	47.28	35.63	66
38.28	23.08	90	47.96	36.61	65
38.49	23.36	89	48.68	37.65	64
38.71	23.65	88	49.44	38.77	63
38.93	23.95	87	50.25	39.95	62
39.17	24.27	86	51.11	41.21	61

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*$E' = 700$ psi; $K_b = 0.128$; $K_x = 0.085$.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 11 Diameter-thickness ratios for laying condition Type 5* (continued)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †	Bending-Stress Design	Deflection Design	$\frac{D}{t}$ or $\frac{D}{t_1}$ †
52.02	42.57	60	75.88	81.36	45
52.99	44.01	59	78.54	86.10	44
54.02	45.56	58	81.40	91.29	43
55.12	47.23	57	84.50	97.01	42
56.28	49.01	56	87.85	103.31	41
57.53	50.93	55	91.47	110.27	40
58.86	53.00	54	95.40	117.98	39
60.28	55.23	53	99.67	126.56	38
61.79	57.64	52	104.32	136.11	37
63.41	60.25	51	109.40	146.78	36
65.14	63.07	50	114.94	158.75	35
67.00	66.13	49	121.02	172.21	34
68.99	69.46	48	127.69	187.41	33
71.12	73.09	47	135.03	204.63	32
73.41	77.04	46	143.14	224.22	31

NOTE: To convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*$E' = 700$ psi; $K_b = 0.128$; $K_x = 0.085$.

†The $\frac{D}{t}$ or $\frac{D}{t_1}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ or $\frac{D}{t_1}$ should be used.

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Table 12 Thickness for earth load plus truck load

		Laying Condition									
		Type 1		Type 2		Type 3		Type 4		Type 5	
Size *in.*	Depth of Cover* *ft*	Total Calculated Thickness† *in.*	Use Pressure Class	Total Calculated Thickness† *in.*	Use Pressure Class	Total Calculated Thickness† *in.*	Use Pressure Class	Total Calculated Thickness† *in.*	Use Pressure Class	Total Calculated Thickness† *in.*	Use Pressure Class
3	2.5	0.18	350	0.17	350	0.17	350	0.16	350	0.15	350
	3	0.18	350	0.17	350	0.16	350	0.15	350	0.15	350
	4	0.17	350	0.16	350	0.16	350	0.15	350	0.14	350
	5	0.17	350	0.16	350	0.16	350	0.15	350	0.14	350
	6	0.17	350	0.16	350	0.16	350	0.15	350	0.14	350
	7	0.17	350	0.16	350	0.16	350	0.15	350	0.14	350
	8	0.17	350	0.16	350	0.16	350	0.15	350	0.14	350
	9	0.17	350	0.16	350	0.16	350	0.15	350	0.15	350
	10	0.18	350	0.17	350	0.16	350	0.15	350	0.15	350
	12	0.18	350	0.17	350	0.16	350	0.15	350	0.15	350
	14	0.18	350	0.17	350	0.17	350	0.16	350	0.15	350
	16	0.19	350	0.18	350	0.17	350	0.16	350	0.15	350
	20	0.19	350	0.19	350	0.18	350	0.16	350	0.15	350
	24	0.20	350	0.19	350	0.19	350	0.17	350	0.15	350
	28	0.21	350	0.20	350	0.19	350	0.18	350	0.15	350
	32	0.21	350	0.20	350	0.20	350	0.18	350	0.16	350
4	2.5	0.19	350	0.18	350	0.17	350	0.16	350	0.15	350
	3	0.19	350	0.18	350	0.17	350	0.16	350	0.15	350
	4	0.18	350	0.17	350	0.16	350	0.15	350	0.15	350
	5	0.18	350	0.17	350	0.16	350	0.15	350	0.15	350
	6	0.18	350	0.17	350	0.16	350	0.15	350	0.15	350
	7	0.18	350	0.17	350	0.16	350	0.15	350	0.15	350
	8	0.18	350	0.17	350	0.16	350	0.15	350	0.15	350
	9	0.18	350	0.17	350	0.16	350	0.15	350	0.15	350
	10	0.18	350	0.17	350	0.16	350	0.16	350	0.15	350
	12	0.19	350	0.18	350	0.17	350	0.16	350	0.15	350
	14	0.19	350	0.18	350	0.17	350	0.16	350	0.15	350
	16	0.20	350	0.19	350	0.18	350	0.16	350	0.15	350
	20	0.21	350	0.20	350	0.19	350	0.17	350	0.15	350
	24	0.21	350	0.21	350	0.20	350	0.18	350	0.16	350
	28	0.22	350	0.21	350	0.20	350	0.19	350	0.16	350
	32	0.23	350	0.22	350	0.21	350	0.19	350	0.16	350

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048.

*Pipe may be available for depths of cover greater than those shown in the table.

†Total calculated thickness includes service allowance and casting tolerance added to net thickness.

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Table 12 Thickness for earth load plus truck load (continued)

Size *in.*	Depth of Cover* *ft*	Laying Condition: Type 1 Total Calculated Thickness† *in.*	Type 1 Use Pressure Class	Type 2 Total Calculated Thickness† *in.*	Type 2 Use Pressure Class	Type 3 Total Calculated Thickness† *in.*	Type 3 Use Pressure Class	Type 4 Total Calculated Thickness† *in.*	Type 4 Use Pressure Class	Type 5 Total Calculated Thickness† *in.*	Type 5 Use Pressure Class
6	2.5	0.22	350	0.20	350	0.19	350	0.17	350	0.16	350
	3	0.21	350	0.19	350	0.18	350	0.17	350	0.15	350
	4	0.20	350	0.18	350	0.17	350	0.16	350	0.15	350
	5	0.19	350	0.18	350	0.17	350	0.16	350	0.15	350
	6	0.19	350	0.18	350	0.17	350	0.16	350	0.15	350
	7	0.20	350	0.18	350	0.17	350	0.16	350	0.15	350
	8	0.20	350	0.18	350	0.17	350	0.16	350	0.15	350
	9	0.20	350	0.19	350	0.18	350	0.16	350	0.15	350
	10	0.21	350	0.19	350	0.18	350	0.16	350	0.15	350
	12	0.21	350	0.20	350	0.18	350	0.17	350	0.16	350
	14	0.22	350	0.20	350	0.19	350	0.17	350	0.16	350
	16	0.23	350	0.21	350	0.20	350	0.17	350	0.16	350
	20	0.24	350	0.22	350	0.21	350	0.18	350	0.16	350
	24	0.25	350	0.24	350	0.22	350	0.19	350	0.17	350
	28	—	—	0.25	350	0.23	350	0.21	350	0.17	350
	32	—	—	—	—	0.24	350	0.22	350	0.17	350
8	2.5	0.24	350	0.22	350	0.21	350	0.18	350	0.16	350
	3	0.23	350	0.21	350	0.19	350	0.17	350	0.16	350
	4	0.22	350	0.20	350	0.18	350	0.17	350	0.16	350
	5	0.21	350	0.19	350	0.18	350	0.17	350	0.16	350
	6	0.21	350	0.19	350	0.18	350	0.17	350	0.16	350
	7	0.21	350	0.20	350	0.18	350	0.17	350	0.16	350
	8	0.22	350	0.20	350	0.19	350	0.17	350	0.16	350
	9	0.22	350	0.20	350	0.19	350	0.17	350	0.16	350
	10	0.23	350	0.21	350	0.19	350	0.17	350	0.16	350
	12	0.24	350	0.22	350	0.20	350	0.18	350	0.16	350
	14	0.25	350	0.23	350	0.21	350	0.18	350	0.16	350
	16	0.25	350	0.24	350	0.22	350	0.19	350	0.17	350
	20	—	—	0.25	350	0.23	350	0.20	350	0.17	350
	24	—	—	—	—	0.25	350	0.21	350	0.17	350
	28	—	—	—	—	—	—	0.23	350	0.18	350
	32	—	—	—	—	—	—	0.25	350	0.19	350

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048.

*Pipe may be available for depths of cover greater than those shown in the table.

†Total calculated thickness includes service allowance and casting tolerance added to net thickness.

Table continued next page.

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Table 12 Thickness for earth load plus truck load (continued)

Size *in.*	Depth of Cover* *ft*	Laying Condition: Type 1 Total Calculated Thickness† *in.*	Type 1 Use Pressure Class	Type 2 Total Calculated Thickness† *in.*	Type 2 Use Pressure Class	Type 3 Total Calculated Thickness† *in.*	Type 3 Use Pressure Class	Type 4 Total Calculated Thickness† *in.*	Type 4 Use Pressure Class	Type 5 Total Calculated Thickness† *in.*	Type 5 Use Pressure Class
10	2.5	—	—	0.25	350	0.23	350	0.20	350	0.18	350
	3	0.26	350	0.24	350	0.22	350	0.19	350	0.18	350
	4	0.25	350	0.22	350	0.21	350	0.19	350	0.17	350
	5	0.24	350	0.22	350	0.20	350	0.18	350	0.17	350
	6	0.24	350	0.22	350	0.20	350	0.18	350	0.17	350
	7	0.24	350	0.22	350	0.20	350	0.19	350	0.17	350
	8	0.25	350	0.22	350	0.21	350	0.19	350	0.17	350
	9	0.25	350	0.23	350	0.21	350	0.19	350	0.17	350
	10	0.26	350	0.23	350	0.21	350	0.19	350	0.17	350
	12	—	—	0.24	350	0.22	350	0.20	350	0.18	350
	14	—	—	0.26	350	0.23	350	0.20	350	0.18	350
	16	—	—	—	—	0.24	350	0.21	350	0.18	350
	20	—	—	—	—	—	—	0.22	350	0.19	350
	24	—	—	—	—	—	—	0.24	350	0.19	350
	28	—	—	—	—	—	—	0.26	350	0.20	350
	32	—	—	—	—	—	—	—	—	0.21	350
12	2.5	—	—	0.27	350	0.25	350	0.21	350	0.19	350
	3	0.28	350	0.25	350	0.23	350	0.20	350	0.18	350
	4	0.26	350	0.24	350	0.22	350	0.19	350	0.18	350
	5	0.26	350	0.23	350	0.21	350	0.19	350	0.18	350
	6	0.26	350	0.23	350	0.21	350	0.19	350	0.18	350
	7	0.26	350	0.23	350	0.21	350	0.19	350	0.18	350
	8	0.27	350	0.24	350	0.22	350	0.20	350	0.18	350
	9	0.27	350	0.24	350	0.22	350	0.20	350	0.18	350
	10	0.28	350	0.25	350	0.23	350	0.20	350	0.18	350
	12	—	—	0.26	350	0.24	350	0.21	350	0.18	350
	14	—	—	0.28	350	0.25	350	0.21	350	0.19	350
	16	—	—	—	—	0.26	350	0.22	350	0.19	350
	20	—	—	—	—	—	—	0.24	350	0.20	350
	24	—	—	—	—	—	—	0.26	350	0.20	350
	28	—	—	—	—	—	—	0.28	350	0.21	350
	32	—	—	—	—	—	—	—	—	0.23	350

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048.

*Pipe may be available for depths of cover greater than those shown in the table.

†Total calculated thickness includes service allowance and casting tolerance added to net thickness.

Table continued next page.

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Table 12 Thickness for earth load plus truck load (continued)

Size *in.*	Depth of Cover* *ft*	Laying Condition: Type 1 Total Calculated Thickness† *in.*	Type 1 Use Pressure Class	Type 2 Total Calculated Thickness† *in.*	Type 2 Use Pressure Class	Type 3 Total Calculated Thickness† *in.*	Type 3 Use Pressure Class	Type 4 Total Calculated Thickness† *in.*	Type 4 Use Pressure Class	Type 5 Total Calculated Thickness† *in.*	Type 5 Use Pressure Class
14	2.5	‡	‡	0.29	300	0.26	250	0.23	250	0.20	250
	3			0.28	250	0.25	250	0.22	250	0.20	250
	4			0.26	250	0.24	250	0.21	250	0.19	250
	5			0.25	250	0.23	250	0.21	250	0.19	250
	6			0.25	250	0.23	250	0.21	250	0.19	250
	7			0.26	250	0.24	250	0.21	250	0.19	250
	8			0.26	250	0.24	250	0.21	250	0.19	250
	9			0.27	250	0.24	250	0.22	250	0.19	250
	10			0.28	250	0.25	250	0.22	250	0.20	250
	12			0.29	300	0.26	250	0.23	250	0.20	250
	14			0.31	350	0.28	250	0.23	250	0.20	250
	16			—	—	0.29	300	0.24	250	0.21	250
	20			—	—	—	—	0.26	250	0.21	250
	24			—	—	—	—	0.29	300	0.22	250
	28			—	—	—	—	—	—	0.25	250
	32			—	—	—	—	—	—	0.27	250
16	2.5	‡	‡	0.31	300	0.27	250	0.23	250	0.21	250
	3			0.29	250	0.26	250	0.23	250	0.20	250
	4			0.27	250	0.25	250	0.22	250	0.20	250
	5			0.27	250	0.24	250	0.22	250	0.20	250
	6			0.27	250	0.24	250	0.22	250	0.20	250
	7			0.27	250	0.25	250	0.22	250	0.20	250
	8			0.28	250	0.25	250	0.22	250	0.20	250
	9			0.28	250	0.26	250	0.22	250	0.20	250
	10			0.29	250	0.26	250	0.23	250	0.20	250
	12			0.31	300	0.28	250	0.24	250	0.21	250
	14			0.33	350	0.29	250	0.24	250	0.21	250
	16			—	—	0.31	300	0.25	250	0.21	250
	20			—	—	0.34	350	0.28	250	0.22	250
	24			—	—	—	—	0.30	250	0.24	250
	28			—	—	—	—	0.34	350	0.27	250
	32			—	—	—	—	—	—	0.29	250

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048.

*Pipe may be available for depths of cover greater than those shown in the table.

†Total calculated thickness includes service allowance and casting tolerance added to net thickness.

‡For pipe 14 in. (356 mm) and larger, consideration should be given to laying conditions other than Type 1.

Table continued next page.

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Table 12 Thickness for earth load plus truck load (continued)

Size *in.*	Depth of Cover* *ft*	Laying Condition: Type 1 Total Calculated Thickness† *in.*	Type 1 Use Pressure Class	Type 2 Total Calculated Thickness† *in.*	Type 2 Use Pressure Class	Type 3 Total Calculated Thickness† *in.*	Type 3 Use Pressure Class	Type 4 Total Calculated Thickness† *in.*	Type 4 Use Pressure Class	Type 5 Total Calculated Thickness† *in.*	Type 5 Use Pressure Class
18	2.5	‡	‡	0.32	300	0.28	250	0.24	250	0.21	250
	3			0.30	250	0.27	250	0.23	250	0.21	250
	4			0.28	250	0.26	250	0.23	250	0.20	250
	5			0.28	250	0.25	250	0.22	250	0.20	250
	6			0.28	250	0.25	250	0.22	250	0.20	250
	7			0.28	250	0.26	250	0.23	250	0.20	250
	8			0.29	250	0.26	250	0.23	250	0.20	250
	9			0.30	250	0.27	250	0.23	250	0.21	250
	10			0.31	250	0.28	250	0.24	250	0.21	250
	12			0.33	300	0.29	250	0.24	250	0.21	250
	14			0.35	350	0.31	250	0.25	250	0.22	250
	16			—	—	0.33	300	0.26	250	0.22	250
	20			—	—	—	—	0.29	250	0.23	250
	24			—	—	—	—	0.32	300	0.26	250
	28			—	—	—	—	0.36	350	0.29	250
	32			—	—	—	—	—	—	0.32	300
20	2.5	‡	‡	0.33	250	0.29	250	0.25	250	0.21	250
	3			0.31	250	0.28	250	0.24	250	0.21	250
	4			0.30	250	0.27	250	0.23	250	0.21	250
	5			0.29	250	0.26	250	0.23	250	0.20	250
	6			0.29	250	0.26	250	0.23	250	0.20	250
	7			0.30	250	0.27	250	0.23	250	0.21	250
	8			0.30	250	0.27	250	0.24	250	0.21	250
	9			0.31	250	0.28	250	0.24	250	0.21	250
	10			0.32	250	0.29	250	0.24	250	0.21	250
	12			0.35	300	0.31	250	0.25	250	0.22	250
	14			0.37	350	0.33	250	0.26	250	0.22	250
	16			—	—	0.35	300	0.28	250	0.23	250
	20			—	—	—	—	0.32	250	0.24	250
	24			—	—	—	—	0.35	300	0.28	250
	28			—	—	—	—	0.38	350	0.32	250
	32			—	—	—	—	—	—	0.35	300

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048.

*Pipe may be available for depths of cover greater than those shown in the table.

†Total calculated thickness includes service allowance and casting tolerance added to net thickness.

‡For pipe 14 in. (356 mm) and larger, consideration should be given to laying conditions other than Type 1.

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Table 12 Thickness for earth load plus truck load (continued)

Size *in.*	Depth of Cover* *ft*	Laying Condition: Type 1 Total Calculated Thickness† *in.*	Type 1 Use Pressure Class	Type 2 Total Calculated Thickness† *in.*	Type 2 Use Pressure Class	Type 3 Total Calculated Thickness† *in.*	Type 3 Use Pressure Class	Type 4 Total Calculated Thickness† *in.*	Type 4 Use Pressure Class	Type 5 Total Calculated Thickness† *in.*	Type 5 Use Pressure Class
24	2.5	‡	‡	0.36	250	0.32	200	0.26	200	0.22	200
	3			0.33	200	0.30	200	0.25	200	0.22	200
	4			0.32	200	0.29	200	0.25	200	0.21	200
	5			0.31	200	0.28	200	0.24	200	0.21	200
	6			0.31	200	0.28	200	0.24	200	0.21	200
	7			0.32	200	0.29	200	0.25	200	0.22	200
	8			0.33	200	0.30	200	0.25	200	0.22	200
	9			0.35	250	0.30	200	0.26	200	0.22	200
	10			0.36	250	0.31	200	0.26	200	0.22	200
	12			0.39	300	0.33	200	0.27	200	0.23	200
	14			0.41	350	0.36	250	0.29	200	0.24	200
	16			—	—	0.38	300	0.31	200	0.24	200
	20			—	—	—	—	0.36	250	0.26	200
	24			—	—	—	—	0.40	300	0.32	200
	28			—	—	—	—	0.43	350	0.37	250
	32			—	—	—	—	—	—	0.40	300
30	2.5	‡	‡	0.40	250	0.34	150	0.29	150	0.24	150
	3			0.37	200	0.33	150	0.28	150	0.23	150
	4			0.36	200	0.32	150	0.27	150	0.23	150
	5			0.35	200	0.31	150	0.26	150	0.23	150
	6			0.35	200	0.31	150	0.27	150	0.23	150
	7			0.36	200	0.32	150	0.27	150	0.23	150
	8			0.37	200	0.33	150	0.27	150	0.23	150
	9			0.39	250	0.34	150	0.28	150	0.24	150
	10			0.41	250	0.35	200	0.29	150	0.24	150
	12			0.44	300	0.38	200	0.30	150	0.25	150
	14			0.48	350	0.41	250	0.33	150	0.26	150
	16			—	—	0.44	300	0.37	200	0.26	150
	20			—	—	—	—	0.43	300	0.29	150
	24			—	—	—	—	0.48	350	0.38	200
	28			—	—	—	—	—	—	0.44	300
	32			—	—	—	—	—	—	0.48	350

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048.

*Pipe may be available for depths of cover greater than those shown in the table.

†Total calculated thickness includes service allowance and casting tolerance added to net thickness.

‡For pipe 14 in. (356 mm) and larger, consideration should be given to laying conditions other than Type 1.

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Table 12 Thickness for earth load plus truck load (continued)

Size *in.*	Depth of Cover* *ft*	Laying Condition: Type 1 Total Calculated Thickness† *in.*	Type 1 Use Pressure Class	Type 2 Total Calculated Thickness† *in.*	Type 2 Use Pressure Class	Type 3 Total Calculated Thickness† *in.*	Type 3 Use Pressure Class	Type 4 Total Calculated Thickness† *in.*	Type 4 Use Pressure Class	Type 5 Total Calculated Thickness† *in.*	Type 5 Use Pressure Class
36	2.5	‡	‡	0.43	250	0.37	150	0.31	150	0.25	150
	3			0.41	200	0.36	150	0.30	150	0.25	150
	4			0.39	200	0.34	150	0.29	150	0.24	150
	5			0.39	200	0.34	150	0.29	150	0.24	150
	6			0.39	200	0.34	150	0.29	150	0.24	150
	7			0.40	200	0.35	150	0.29	150	0.24	150
	8			0.42	200	0.36	150	0.30	150	0.25	150
	9			0.44	250	0.38	150	0.31	150	0.25	150
	10			0.46	250	0.39	200	0.31	150	0.26	150
	12			0.50	300	0.42	200	0.33	150	0.27	150
	14			0.54	350	0.46	250	0.38	150	0.28	150
	16			—	—	0.50	300	0.43	250	0.29	150
	20			—	—	—	—	0.51	300	0.33	150
	24			—	—	—	—	0.56	350	0.44	250
	28			—	—	—	—	—	—	0.51	300
	32			—	—	—	—	—	—	0.56	350
42	2.5	‡	‡	0.47	200	0.40	150	0.32	150	0.27	150
	3			0.44	200	0.38	150	0.31	150	0.26	150
	4			0.42	200	0.37	150	0.30	150	0.25	150
	5			0.43	200	0.37	150	0.31	150	0.26	150
	6			0.43	200	0.37	150	0.31	150	0.26	150
	7			0.44	200	0.38	150	0.31	150	0.26	150
	8			0.46	200	0.40	150	0.32	150	0.26	150
	9			0.48	250	0.41	150	0.33	150	0.27	150
	10			0.50	250	0.43	200	0.34	150	0.27	150
	12			0.55	300	0.47	200	0.36	150	0.28	150
	14			0.60	350	0.52	250	0.43	200	0.30	150
	16			—	—	0.57	300	0.49	250	0.31	150
	20			—	—	—	—	0.57	300	0.38	150
	24			—	—	—	—	—	—	0.50	250
	28			—	—	—	—	—	—	0.58	350
	32			—	—	—	—	—	—	0.63	350

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048.

*Pipe may be available for depths of cover greater than those shown in the table.

†Total calculated thickness includes service allowance and casting tolerance added to net thickness.

‡For pipe 14 in. (356 mm) and larger, consideration should be given to laying conditions other than Type 1.

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Table 12 Thickness for earth load plus truck load (continued)

Size *in.*	Depth of Cover* *ft*	Laying Condition: Type 1 Total Calculated Thickness† *in.*	Type 1 Use Pressure Class	Type 2 Total Calculated Thickness† *in.*	Type 2 Use Pressure Class	Type 3 Total Calculated Thickness† *in.*	Type 3 Use Pressure Class	Type 4 Total Calculated Thickness† *in.*	Type 4 Use Pressure Class	Type 5 Total Calculated Thickness† *in.*	Type 5 Use Pressure Class
48	2.5	‡	‡	0.50	200	0.44	150	0.35	150	0.29	150
	3			0.48	200	0.42	150	0.34	150	0.28	150
	4			0.46	150	0.41	150	0.33	150	0.28	150
	5			0.47	200	0.41	150	0.34	150	0.28	150
	6			0.48	200	0.41	150	0.34	150	0.28	150
	7			0.49	200	0.43	150	0.35	150	0.28	150
	8			0.51	200	0.44	150	0.35	150	0.29	150
	9			0.54	250	0.46	150	0.37	150	0.29	150
	10			0.56	250	0.48	200	0.38	150	0.30	150
	12			0.62	300	0.54	250	0.40	150	0.31	150
	14			0.67	350	0.60	300	0.49	200	0.33	150
	16			—	—	0.65	350	0.56	250	0.34	150
	20			—	—	—	—	0.66	350	0.43	150
	24			—	—	—	—	—	—	0.57	250
	28			—	—	—	—	—	—	0.66	350
54	2.5	‡	‡	0.54	200	0.47	150	0.38	150	0.31	150
	3			0.53	200	0.46	150	0.37	150	0.30	150
	4			0.51	150	0.44	150	0.36	150	0.30	150
	5			0.52	200	0.45	150	0.37	150	0.30	150
	6			0.53	200	0.46	150	0.37	150	0.30	150
	7			0.54	200	0.47	150	0.38	150	0.31	150
	8			0.57	200	0.49	150	0.39	150	0.32	150
	9			0.60	250	0.51	150	0.40	150	0.32	150
	10			0.63	250	0.53	200	0.41	150	0.33	150
	12			0.69	300	0.61	250	0.44	150	0.34	150
	14			0.75	350	0.68	300	0.55	200	0.36	150
	16			—	—	0.73	350	0.63	250	0.37	150
	20			—	—	—	—	0.74	350	0.48	150
	24			—	—	—	—	—	—	0.64	250
	28			—	—	—	—	—	—	0.74	350

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048.

*Pipe may be available for depths of cover greater than those shown in the table.

†Total calculated thickness includes service allowance and casting tolerance added to net thickness.

‡For pipe 14 in. (356 mm) and larger, consideration should be given to laying conditions other than Type 1.

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Table 12 Thickness for earth load plus truck load (continued)

		Laying Condition									
		Type 1		Type 2		Type 3		Type 4		Type 5	
Size *in.*	Depth of Cover* *ft*	Total Calculated Thickness† *in.*	Use Pressure Class	Total Calculated Thickness† *in.*	Use Pressure Class	Total Calculated Thickness† *in.*	Use Pressure Class	Total Calculated Thickness† *in.*	Use Pressure Class	Total Calculated Thickness† *in.*	Use Pressure Class
60	2.5	‡	‡	0.56	200	0.48	150	0.39	150	0.32	150
	3			0.54	150	0.47	150	0.38	150	0.31	150
	4			0.53	150	0.46	150	0.38	150	0.31	150
	5			0.54	150	0.47	150	0.38	150	0.31	150
	6			0.55	200	0.48	150	0.39	150	0.31	150
	7			0.57	200	0.49	150	0.39	150	0.32	150
	8			0.59	200	0.51	150	0.40	150	0.33	150
	9			0.63	250	0.53	150	0.42	150	0.33	150
	10			0.67	250	0.55	200	0.43	150	0.34	150
	12			0.74	300	0.65	250	0.46	150	0.35	150
	14			0.79	350	0.72	300	0.58	200	0.37	150
	16			—	—	0.78	350	0.67	250	0.38	150
	20			—	—	—	—	0.79	350	0.51	150
	24			—	—	—	—	—	—	0.68	250
	28			—	—	—	—	—	—	0.79	350
64	2.5	‡	‡	0.58	200	0.50	150	0.40	150	0.32	150
	3			0.56	150	0.49	150	0.39	150	0.32	150
	4			0.55	150	0.48	150	0.39	150	0.32	150
	5			0.56	150	0.48	150	0.39	150	0.32	150
	6			0.57	200	0.49	150	0.40	150	0.32	150
	7			0.59	200	0.51	150	0.41	150	0.33	150
	8			0.62	200	0.53	150	0.42	150	0.33	150
	9			0.67	250	0.55	150	0.43	150	0.34	150
	10			0.70	250	0.58	200	0.45	150	0.35	150
	12			0.78	300	0.68	250	0.48	150	0.37	150
	14			0.84	350	0.76	300	0.61	200	0.38	150
	16			—	—	0.82	350	0.70	250	0.40	150
	20			—	—	—	—	0.83	350	0.54	150
	24			—	—	—	—	—	—	0.72	250
	28			—	—	—	—	—	—	0.83	350

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048.

*Pipe may be available for depths of cover greater than those shown in the table.

†Total calculated thickness includes service allowance and casting tolerance added to net thickness.

‡For pipe 14 in. (356 mm) and larger, consideration should be given to laying conditions other than Type 1.

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Table 13 Thickness for internal pressure

Pipe Size *in.*	Rated Water Working Pressure—*psi* 150 Total Calculated Thickness* *in.*	150 Use Pressure Class	200 Total Calculated Thickness* *in.*	200 Use Pressure Class	250 Total Calculated Thickness* *in.*	250 Use Pressure Class	300 Total Calculated Thickness* *in.*	300 Use Pressure Class	350 Total Calculated Thickness* *in.*	350 Use Pressure Class
3	0.15	350	0.16	350	0.16	350	0.17	350	0.17	350
4	0.16	350	0.16	350	0.17	350	0.18	350	0.18	350
6	0.17	350	0.18	350	0.19	350	0.20	350	0.20	350
8	0.18	350	0.19	350	0.21	350	0.22	350	0.23	350
10	0.21	350	0.22	350	0.23	350	0.25	350	0.26	350
12	0.22	350	0.23	350	0.25	350	0.27	350	0.28	350
14	0.24	250	0.26	250	0.28	250	0.30	300	0.31	350
16	0.25	250	0.27	250	0.30	250	0.32	300	0.34	350
18	0.27	250	0.29	250	0.31	250	0.34	300	0.36	350
20	0.28	250	0.30	250	0.33	250	0.36	300	0.38	350
24	0.30	200	0.33	200	0.37	250	0.40	300	0.43	350
30	0.34	150	0.38	200	0.42	250	0.45	300	0.49	350
36	0.38	150	0.42	200	0.47	250	0.51	300	0.56	350
42	0.41	150	0.47	200	0.52	250	0.57	300	0.63	350
48	0.46	150	0.52	200	0.58	250	0.64	300	0.70	350
54	0.51	150	0.58	200	0.65	250	0.72	300	0.79	350
60	0.54	150	0.61	200	0.68	250	0.76	300	0.83	350
64	0.56	150	0.64	200	0.72	250	0.80	300	0.87	350

NOTES:

1. To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.
2. The thicknesses shown are adequate for the rated working pressure plus a surge allowance of 100 psi (689 kPa). Calculations are based on a minimum yield strength in tension of 42,000 psi (289,590 kPa) and a 2.0 safety factor times the sum of working pressure and 100 psi (689 kPa) surge allowance.

*Total calculated thickness includes service allowance and casting tolerance added to net thickness.

Table 14 Rated working pressure and maximum depth of cover

Size *in.*	Pressure Class* *psi*	Nominal Thickness *in.*	Laying Condition: Type 1 Trench	Type 2 Trench	Type 3 Trench	Type 4 Trench	Type 5 Trench
			Maximum Depth of Cover—*ft*†				
3	350	0.25	78	88	99	100‡	100‡
4	350	0.25	53	61	69	85	100‡
6	350	0.25	26	31	37	47	65
8	350	0.25	16	20	25	34	50
10	350	0.26	11§	15	19	28	45
12	350	0.28	10§	15	19	28	44
14	250	0.28	**	11§	15	23	36
	300	0.30	**	13	17	26	42
	350	0.31	**	14	19	27	44
16	250	0.30	**	11§	15	24	34
	300	0.32	**	13	17	26	39
	350	0.34	**	15	20	28	44
18	250	0.31	**	10§	14	22	31
	300	0.34	**	13	17	26	36
	350	0.36	**	15	19	28	41
20	250	0.33	**	10	14	22	30
	300	0.36	**	13	17	26	35
	350	0.38	**	15	19	28	38
24	200	0.33	**	8§	12	17	25
	250	0.37	**	11	15	20	29
	300	0.40	**	13	17	24	32
	350	0.43	**	15	19	28	37
30	150	0.34	**	—	9	14	22
	200	0.38	**	8§	12	16	24
	250	0.42	**	11	15	19	27
	300	0.45	**	12	16	21	29
	350	0.49	**	15	19	25	33

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048; and to convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*Ductile-iron pipe is adequate for the rated working pressure indicated for each nominal size plus a surge allowance of 100 psi (689 kPa). Calculations are based on a 2.0 safety factor times the sum of working pressure and 100 psi (689 kPa) surge allowance. Ductile-iron pipe for working pressures higher than 350 psi (2,413 kPa) is available.

†An allowance for a single H-20 truck with 1.5 impact factor is included for all depths of cover.

‡Calculated maximum depth of cover exceeds 100 ft (30.5 m).

§Minimum allowable depth of cover is 3 ft (0.9 m).

**For pipe 14 in. (356 mm) and larger, consideration should be given to the use of laying conditions other than Type 1.

Table continued next page.

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Table 14 Rated working pressure and maximum depth of cover (continued)

Size *in.*	Pressure Class* *psi*	Nominal Thickness *in.*	Laying Condition: Type 1 Trench	Type 2 Trench	Type 3 Trench	Type 4 Trench	Type 5 Trench
			Maximum Depth of Cover—*ft*†				
36	150	0.38	**	—	9	14	21
	200	0.42	**	8§	12	15	23
	250	0.47	**	10	14	18	25
	300	0.51	**	12	16	20	28
	350	0.56	**	15	19	24	32
42	150	0.41	**	—	9	13	20
	200	0.47	**	8	12	15	22
	250	0.52	**	10	14	17	25
	300	0.57	**	12	16	20	27
	350	0.63	**	15	19	23	32
48	150	0.46	**	—	9	13	20
	200	0.52	**	8	11	15	22
	250	0.58	**	10	13	17	24
	300	0.64	**	12	15	19	27
	350	0.70	**	15	18	22	30
54	150	0.51	**	—	9	13	20
	200	0.58	**	8	11	14	22
	250	0.65	**	10	13	16	24
	300	0.72	**	13	15	19	27
	350	0.79	**	15	18	22	30
60	150	0.54	**	5§	9	13	20
	200	0.61	**	8	11	14	22
	250	0.68	**	10	13	16	24
	300	0.76	**	13	15	19	26
	350	0.83	**	15	18	22	30
64	150	0.56	**	5§	9	13	20
	200	0.64	**	8	11	14	21
	250	0.72	**	10	13	16	24
	300	0.80	**	12	15	19	26
	350	0.87	**	15	17	21	29

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4; to convert feet (ft) to metres (m), multiply by 0.3048; and to convert pounds per square inch (psi) to kilopascals (kPa), multiply by 6.895.

*Ductile-iron pipe is adequate for the rated working pressure indicated for each nominal size plus a surge allowance of 100 psi (689 kPa). Calculations are based on a 2.0 safety factor times the sum of working pressure and 100 psi (689 kPa) surge allowance. Ductile-iron pipe for working pressures higher than 350 psi (2,413 kPa) is available.

†An allowance for a single H-20 truck with 1.5 impact factor is included for all depths of cover.

‡Calculated maximum depth of cover exceeds 100 ft (30.5 m).

§Minimum allowable depth of cover is 3 ft (0.9 m).

**For pipe 14 in. (356 mm) and larger, consideration should be given to the use of laying conditions other than Type 1.

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Table 15 Special thickness classes of ductile-iron pipe*

Size *in.*	Outside Diameter *in.*	Thickness Class 50	51	52	53	54	55	56
		Thickness—*in.*						
3	3.96	—	0.25	0.28	0.31	0.34	0.37	0.40
4	4.80	—	0.26	0.29	0.32	0.35	0.38	0.41
6	6.90	0.25	0.28	0.31	0.34	0.37	0.40	0.43
8	9.05	0.27	0.30	0.33	0.36	0.39	0.42	0.45
10	11.10	0.29	0.32	0.35	0.38	0.41	0.44	0.47
12	13.20	0.31	0.34	0.37	0.40	0.43	0.46	0.49
14	15.30	0.33	0.36	0.39	0.42	0.45	0.48	0.51
16	17.40	0.34	0.37	0.40	0.43	0.46	0.49	0.52
18	19.50	0.35	0.38	0.41	0.44	0.47	0.50	0.53
20	21.60	0.36	0.39	0.42	0.45	0.48	0.51	0.54
24	25.80	0.38	0.41	0.44	0.47	0.50	0.53	0.56
30	32.00	0.39	0.43	0.47	0.51	0.55	0.59	0.63
36	38.30	0.43	0.48	0.53	0.58	0.63	0.68	0.73
42	44.50	0.47	0.53	0.59	0.65	0.71	0.77	0.83
48	50.80	0.51	0.58	0.65	0.72	0.79	0.86	0.93
54	57.56	0.57	0.65	0.73	0.81	0.89	0.97	1.05

NOTE: To convert inches (in.) to millimetres (mm), multiply by 25.4.

*These special thickness classes were designated standard thickness classes in the 1986 edition of this standard.

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American Water Works Association
ANSI/AWWA C900-97
(Revision of ANSI/AWWA C900-89)

AWWA STANDARD

FOR

POLYVINYL CHLORIDE (PVC) PRESSURE PIPE AND FABRICATED FITTINGS, 4 IN. THROUGH 12 IN. (100 mm THROUGH 300 mm), FOR WATER DISTRIBUTION

Effective date: Feb. 1, 1998.
First edition approved by AWWA Board of Directors June 8, 1975.
This edition approved June 15, 1997.
Approved by American National Standards Institute Dec. 1, 1997.

AMERICAN WATER WORKS ASSOCIATION

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This document is an American Water Works Association (AWWA) standard. It is not a specification. AWWA standards describe minimum requirements and do not contain all of the engineering and administrative information normally contained in specifications. The AWWA standards usually contain options that must be evaluated by the user of the standard. Until each optional feature is specified by the user, the product or service is not fully defined. AWWA publication of a standard does not constitute endorsement of any product or product type, nor does AWWA test, certify, or approve any product. The use of AWWA standards is entirely voluntary. AWWA standards are intended to represent a consensus of the water supply industry that the product described will provide satisfactory service. When AWWA revises or withdraws this standard, an official notice of action will be placed on the first page of the classified advertising section of *Journal AWWA*. The action becomes effective on the first day of the month following the month of *Journal AWWA* publication of the official notice.

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All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

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Foreword

This foreword is for information only and is not a part of AWWA C900.

I. Introduction.

I.A. *Background.* This standard pertains to 4-in. through 12-in. (100-mm through 300-mm) polyvinyl chloride (PVC) pressure pipe and fabricated fittings with cast-iron-pipe-equivalent (CI) outside diameter (OD) dimensions and with wall-thickness dimension ratios (DRs) of 14, 18, and 25. Design considerations are provided in AWWA M23, *PVC Pipe—Design and Installation* (1980), which provides detailed information on PVC pipe covered by ANSI/AWWA C900. The manual includes chapters on general properties of PVC pipe; manufacturing, testing, and inspection; pressure capacity; design factors for external forces; hydraulics; receiving, storage, and handling; testing and maintenance; and service connections (tapping). Recommended installation guidance is provided in ANSI/AWWA C605, Standard for Underground Installation of PVC Pressure Pipe and Fittings for Water.

In addition, ANSI/AWWA C907, Standard for Polyvinyl Chloride (PVC) Pressure Fittings for Water, 4 in. Through 8 in. (100 mm Through 200 mm), provides information on injection-molded fittings for use with the PVC pipes covered by ANSI/AWWA C900.

For PVC pipe and fittings diameters greater than 12 in. (300 mm), refer to ANSI/AWWA C905, Standard for PVC Pressure Pipe and Fabricated Fittings, 14 in. Through 36 in., for Water Transmission.

I.B. *History.* This is the fourth edition of AWWA C900. In 1966, AWWA appointed Committee 8350-D to study and report on the adaptability of plastic pipe for use within the water industry. The committee presented its report on June 6, 1967, at AWWA's annual conference. The report included a recommendation that a task group be appointed to prepare standards for the use of plastic materials. The AWWA Standards Committee on Thermoplastic Pressure Pipe was established in 1968. The first, second, and third editions of this standard were approved by the AWWA Board of Directors on June 8, 1975; Jan. 25, 1981; and Jan. 29, 1989, respectively.

In June 1988, the Thermoplastic Pressure Pipe Committee was divided into two separate committees: the Polyvinyl Chloride Pressure Pipe and Fittings Standards Committee and the Polyolefin Pressure Pipe and Fittings Standards Committee. This edition of ANSI/AWWA C900 was approved by the AWWA Board of Directors on June 15, 1997.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF) to develop voluntary third-party consensus standards and a certification program for all direct and indirect drinking water additives. Other members of the original consortium included the American Water Works Association Research Foundation (AWWARF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA), and the Association of State Drinking Water Administrators (ASDWA) joined later.

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In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.* Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.
2. Specific policies of the state or local agency.
3. Two standards developed under the direction of NSF, ANSI†/NSF‡ 60, Drinking Water Treatment Chemicals—Health Effects, and ANSI/NSF 61, Drinking Water System Components—Health Effects.
4. Other references, including AWWA standards, *Food Chemicals Codex*, *Water Chemicals Codex*,§ and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with ANSI/NSF 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Appendix A, "Toxicology Review and Evaluation Procedures," to ANSI/NSF 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Appendix A procedures may not always be identical, depending on the certifier.

AWWA C900-97 does not address additives requirements. Thus, users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements including applicable standards.
2. Determine the status of certifications by all parties offering to certify products for contact with, or treatment of, drinking water.
3. Determine current information on product certification.

II. Special Issues. This standard has no applicable information for this section.

III. Use of This Standard. AWWA has no responsibility for the suitability or compatibility of the provisions of this standard to any intended application by any user. Accordingly, each user of this standard is responsible for determining that the standard's provisions are suitable for and compatible with that user's intended application.

III.A. *Purchaser Options and Alternatives.* The following items should be covered in the purchaser's specifications:

---

*Persons in Canada, Mexico, and non-North American countries should contact the appropriate authority having jurisdiction.

†American National Standards Institute, 11 W. 42nd St., New York, NY 10036.

‡NSF International, 3475 Plymouth Rd., Ann Arbor, MI 48106.

§Both publications available from National Academy of Sciences, 2102 Constitution Ave. N.W., Washington, DC 20418.

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1. Standard used—that is, ANSI/AWWA C900, Standard for Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 4 In. Through 12 In. (100 mm Through 300 mm), for Water Distribution, of latest revision.

2. Pipe and fabricated fittings.

a. Nominal size (for example, 4 in.).

b. Pressure class or DR (see Table 1).

c. Linear feet of each pressure class or DR for each nominal pipe size to be furnished.

d. Number, nominal size, pressure class, or DR and configuration for all fittings and couplings (for example, 20, nominal 10-in. DR 18, tees).*

3. Specifications. When desired, requirements such as the following should be specified in the purchase contract:

a. Affidavit of compliance (Sec. 6.3).

b. Standard lengths (Sec. 4.3.2.3).

c. Shipping and delivery (Sec. 6.2).

d. Standard configurations (Sec. 4.5.2.2).

4. Plant inspection. If plant inspections are desired, provisions must be specified in the purchase contract (Sec. 5.3):

a. Production notice. The manufacturer should be required to give adequate advance notice of when and where production of ordered materials will start.

b. Inspection aids. The manufacturer should be required to make available to the purchaser, without charge, such tools and assistance as are necessary for the inspection and handling of materials.

c. Inspection limitations. To exclude inspection of proprietary manufacturing processes, the manufacturer should be required to give advance notice to the purchaser.

III.B. *Modification to Standard.* Any modification to the provisions, definitions, or terminology in this standard must be provided in the purchaser's specifications.

IV. Major Revisions. Major changes made to the standard in this edition include the following:

1. The format has been changed to AWWA standard style.

2. The acceptance clause (Sec. I.C) and the definitions of parties (Sec. 3) have been revised to approved wording.

3. Fabricated PVC fittings have been added.

4. Appendix A, Design Requirements and Criteria for Polyvinyl Chloride (PVC) Pipe for Water Distribution, has been removed (see AWWA M23).

V. Comments. If you have any comments or questions about this standard, please call the AWWA Standards and Materials Development Department, (303) 794-7711 ext. 6283, FAX (303) 795-1440, or write to the department at 6666 W. Quincy Ave., Denver, CO 80235.

*NOTE: Purchaser's specifications may allow or require the use of fittings other than those described in ANSI/AWWA C900. Some examples of compatible fittings include those covered in AWWA Standards C907, C153, and C110.

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ANSI/AWWA C900-97
(Revision of ANSI/AWWA C900-89)

AWWA STANDARD FOR

POLYVINYL CHLORIDE (PVC) PRESSURE PIPE AND FABRICATED FITTINGS, 4 IN. THROUGH 12 IN. (100 mm THROUGH 300 mm), FOR WATER DISTRIBUTION

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard covers 4-in. through 12-in. (100-mm through 300-mm) polyvinyl chloride (PVC) pressure pipe and fabricated fittings with cast-iron-pipe-equivalent (CI) outside diameter (OD) dimensions and with wall-thickness-dimension ratios (DRs) 14, 18, and 25.

Sec. 1.2 Purpose

The purpose of this standard is to provide direction and guidance for manufacturing, testing, selecting, and purchasing PVC pressure pipe and fabricated fittings for underground water distribution systems.

Sec. 1.3 Application

This standard can be referenced in specifications for purchasing and receiving PVC pressure pipe and fabricated fittings, 4 in. through 12 in. (100 mm through 300 mm), for water distribution. This standard can be used as a guide for manufacturing and testing this type of pressure pipe. The stipulations of this standard apply when this document has been referenced and then only to PVC pressure pipe and fabricated fittings, 4 in. through 12 in. (100 mm through 300 mm).

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SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, they form a part of this standard to the extent specified within the standard. In any case of conflict, the requirements of this standard shall prevail.

ANSI*/ASTM† D1784—Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds.

ASTM D1598—Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure.

ASTM D1599—Standard Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings.

ASTM D2122—Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings.

ASTM D2152—Standard Test Method for Adequacy of Fusion of Extruded Poly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion.

ASTM D2241—Standard Specification for Poly(Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series).

ASTM D2412—Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.

ASTM D2564—Standard Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems.

ASTM D2837—Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials.

ASTM D2855—Standard Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings.

ASTM D3139—Standard Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals.

ASTM F477—Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe.

NSF‡ 61—Drinking Water System Components—Health Effects.

PPI§ TR-3—Policies and Procedures for Developing Recommended Hydrostatic Design Stresses for Thermoplastic Pipe Materials.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Dimension ratio (DR):* For pipe covered by this standard, the DR is determined by dividing the average OD of the pipe by its minimum wall thickness and rounding off the dimensionless quotient, when necessary, to the nearest whole number.

*American National Standards Institute, 11 W. 42nd St., New York, NY 10036.

†American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

‡NSF International, 3475 Plymouth Rd., Ann Arbor, MI 48106.

§Plastics Pipe Institute, 1275 K St. N.W., Ste. 400, Washington, DC 20005.

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2. *Fabricated PVC fitting:* Fabricated fittings comprise single or multiple segments of PVC pipe cut in wedge shapes, or otherwise prepared to accept leg insertions, and joined under factory-controlled conditions to form an essentially homogeneous structure. Reinforcement may be applied and permanently bonded to the outside surfaces of the fitting.

3. *Hydrostatic design basis (HDB):* The long-term, hydrostatic-strength (hoop stress) rating of a specific plastic pipe material as determined by hydrostatic tests, evaluation, and categorization procedures in accordance with ASTM D2837. This standard requires the use of PVC compounds that qualify for an HDB rating of 4,000 psi (27.58 MPa).

4. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.

5. *Pressure class (PC):* A pipe's designated design capacity, in pounds per square inch (psi), that corresponds with its recommended safe sustained operating pressure. Pressure class designations include an allowance for pressure surges above the maximum sustained operating pressure caused by instantaneous velocity changes of 2 ft/s (0.61 m/s). Pressure class designations are based on long-term, pressure testing at 73.4°F (23°C).

6. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.

7. *Sample/specimen:* The word "sample" is only used to describe a piece or quantity of bulk material that has been selected by some sampling process. Pieces or quantities taken from production for testing are called "specimens." To describe the piece on which a test is made, "specimen" or "test specimen" is used.

8. *Supplier:* The party that supplies material or services. A supplier may or may not be the manufacturer.

SECTION 4: REQUIREMENTS

Sec. 4.1 Permeation

The selection of materials is critical for water service and distribution pipe in locations where there is likelihood the pipe will be exposed to significant concentrations of pollutants comprised of low molecular weight petroleum products or organic solvents or their vapors. Research has documented that pipe materials such as polyethylene, polybutylene, polyvinyl chloride, and asbestos cement, and elastomers, such as used in jointing gaskets and packing glands, may be subject to permeation by lower molecular weight organic solvents or petroleum products. If a water pipe must pass through such a contaminated area or an area subject to contamination, consult with the manufacturer regarding permeation of pipe walls, jointing materials, and so forth, *before* selecting materials for use in that area.

Sec. 4.2 Materials

4.2.1 *Pipes, couplings, and fabricated fittings.* PVC pipe, couplings, and fabricated fittings shall be made from virgin PVC resin that has been compounded to provide physical and chemical properties that equal or exceed cell class 12454-B as defined in ASTM D1784, and shall qualify for a hydrostatic design basis (HDB) of 4,000 psi (27.58 MPa) at 73.4°F (23°C) per the requirements of PPI TR-3.

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4.2.2 *Rework materials.* Clean rework materials generated from the manufacturer's own pipe or fitting production may be used by the same manufacturer for the same purposes provided that the following criteria are present:

a. They comply with all applicable requirements of ASTM D1784 for cell class 12454-B and this standard.

b. The finished products are equal in quality to products made from virgin PVC compounds.

4.2.3 *Certification for potable-water service.* PVC compounds and products shall be tested for chemical extractants and certified as suitable for potable-water distribution service by an accredited testing agency acceptable to the purchaser, in accordance with requirements that are no less restrictive than the applicable requirements specified in NSF 61.

4.2.4 *Gaskets and lubricants.* Gaskets and lubricants intended for use with PVC pipe, couplings, and fabricated fittings shall be made from materials that are compatible with the pipe and with each other when used together. Gaskets and lubricants shall not adversely affect the potable quality of the water that is to be transported (see foreword, Sec. I.C).

4.2.4.1 Elastomeric gaskets. One gasket shall be furnished with each bell end of every pipe, fitting, and coupling. Elastomeric gaskets shall meet the requirements of ASTM F477 for high-head (50 ft of head or higher) applications.

4.2.5 *Fabricated fitting overwrapped reinforcement.* Optional reinforcement, either PVC or non-PVC, may be applied by the manufacturer to meet the requirements of this standard.

4.2.5.1 Resin. All resins used shall be a commercial grade of unsaturated polyester resin or epoxy resin.

4.2.5.2 Glass. All glass reinforcing materials shall be commercial "E" type glass in the form of mat, continuous roving or roving fabric, or a combination of these, having a coupling agent that bonds the glass reinforcement and the resin.

Sec. 4.3 Pipe Requirements

4.3.1 *Workmanship.* When manufactured, pipe shall be homogeneous throughout; free from voids, cracks, inclusions, and other defects; and as uniform as commercially practical in color, density, and other physical properties. Pipe surfaces shall be free from nicks and significant scratches.* The joining surfaces of pipe spigots and integral-bell and sleeve-reinforced bell sockets shall be free of imperfections that might cause leakage at joints.

4.3.2 *Dimensions.*

4.3.2.1 Pipe barrel. The dimensions and tolerances of the pipe barrel shall conform with the applicable requirements listed in Table 1 when measured as specified in ASTM D2122.

4.3.2.2 Elastomeric-gasket bell ends. The dimensions of the integral bell ends shall meet one of the following requirements when measured according to ASTM D2122.

a. The bell wall thickness at any point shall conform to the dimension ratio of the pipe except in the annular gasket ring groove and bell entry lip portions where the wall shall be at least the minimum thickness of the pipe barrel (Table 1).

*Scratches that extend 10 percent or more into the pipe wall shall be considered significant.

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Table 1 Dimensions, pressure classes, and dimension ratios (DRs) for PVC* pipe with cast-iron-pipe-equivalent ODs

Nominal Size	Pressure Class at 73.4°F (23°C)			OD—*in. (mm)*				Wall Thickness—*in. (mm)*			
				Average		Tolerance		Minimum		Tolerance	
in.	*psi*	*(kPa)*	DR								
4	100	(690)	25	4.800	(121.9)	±0.009	(0.23)	0.192	(4.88)	+0.023	(0.58)
4	150	(950)	18	4.800	(121.9)	±0.009	(0.23)	0.267	(6.78)	+0.032	(0.81)
4	200	(1,380)	14	4.800	(121.9)	±0.009	(0.23)	0.343	(8.71)	+0.041	(1.04)
6	100	(690)	25	6.900	(175.3)	±0.011	(0.28)	0.276	(7.01)	+0.033	(0.84)
6	150	(950)	18	6.900	(175.3)	±0.011	(0.28)	0.383	(9.73)	+0.046	(0.17)
6	200	(1,380)	14	6.900	(175.3)	±0.011	(0.28)	0.493	(12.52)	+0.059	(1.50)
8	100	(690)	25	9.050	(229.9)	±0.015	(0.38)	0.362	(9.19)	+0.043	(1.09)
8	150	(950)	18	9.050	(229.9)	±0.015	(0.38)	0.503	(12.78)	+0.060	(1.52)
8	200	(1,380)	14	9.050	(229.9)	±0.015	(0.38)	0.646	(16.41)	+0.078	(1.98)
10	100	(690)	25	11.100	(281.9)	±0.015	(0.38)	0.444	(11.28)	+0.053	(1.35)
10	150	(950)	18	11.100	(281.9)	±0.015	(0.38)	0.617	(15.67)	+0.074	(1.88)
10	200	(1,380)	14	11.100	(281.9)	±0.015	(0.38)	0.793	(20.14)	+0.095	(2.41)
12	100	(690)	25	13.200	(335.3)	±0.015	(0.38)	0.528	(13.41)	+0.063	(1.60)
12	150	(950)	18	13.200	(335.3)	±0.015	(0.38)	0.733	(18.62)	+0.088	(2.24)
12	200	(1,380)	14	13.200	(335.3)	±0.015	(0.38)	0.943	(23.95)	+0.113	(2.87)

*Hydrostatic design stress (HDS) = 1,600 psi.

b. Designs not meeting the requirements of 4.3.2.2(a) shall be tested to verify that the joint assemblies qualify for a hydrostatic design basis (HDB) category of 4,000 psi (27.58 MPa) when tested in accordance with ASTM D2837 as modified in ASTM D3139.

4.3.2.3 Standard lengths. Pipe shall be furnished in standard laying lengths of 20 ft ± 1 in. (6.1 m ± 25 mm), unless otherwise agreed on at time of purchase.

4.3.3 *Physical properties.*

4.3.3.1 Sustained pressure. The pipe or fabricated fitting shall not fail, balloon, burst, or weep, as defined in ASTM D1598, at the applicable sustained pressure listed in Table 2 when six specimens are tested for 1,000 h as specified in ASTM D2241. Either free-end or restrained-end closures that are free of leaks at maximum pressure shall be used.

4.3.3.2 Burst pressure. The quick-burst strength of pipe, including any integral bell end, shall meet the applicable minimum pressure requirement listed in Table 3 when tested in accordance with the specimen and sample sizes, conditioning, and procedural requirements listed in ASTM D1599. At least three of the five test specimens shall have a portion of the required markings located at least one pipe diameter away from an end closure. For bell-end pipe, the bell shall be included as a part of at least two test specimens. The ability to attain hydrostatic pressure equal to or greater than the values in Table 3 within 60–70 seconds shall indicate passing this test requirement.

4.3.3.3 Hydrostatic integrity. The pipe, including any integral bell end or affixed coupling, shall not fail, balloon, burst, or weep when subjected to an internal

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Table 2 Sustained-pressure requirements

	Pressure Class		Pressure Required for Test With Water at 73.4°F (23°C)	
DR	*psi*	*(kPa)*	*psi*	*(kPa)*
14	200	1,380	650	(4,480)
18	150	950	500	(3,450)
25	100	690	350	(2,410)

NOTE: Test pressures were derived using a pipe fiber stress of 4,200 psi (29,000 kPa).

Table 3 Burst-pressure requirements

	Pressure Class		Pressure Required for Test With Water at 73.4°F (23°C)	
DR	*psi*	*(kPa)*	*psi*	*(kPa)*
14	200	1,380	985	(6,790)
18	150	950	755	(5,210)
25	100	690	535	(3,690)

NOTE: Test pressures were derived using a pipe fiber stress of 6,400 psi (44,175 kPa).

pressure equal to four times its designated pressure class, as listed in Table 1, for a minimum dwell of 5 seconds. The pipe shall attain ambient temperature before testing. When the ambient temperature is higher than 77°F (25°C), the test pressure shall be reduced by applying the appropriate temperature coefficient from Table 4.

4.3.3.4 Flattening. Three specimens of pipe, a minimum of 2 in. (50 mm) long, shall be flattened between parallel plates in a suitable press until the distance between the plates is 40 percent of the OD of the pipe. The three specimens shall be oriented in accordance with the section entitled "Procedure" of ASTM D2412; except, if no minimum wall thickness has been identified, a spider line shall be used as the base line. The rate of flattening shall be uniform and such that the compression is completed within 2 to 5 min. The applied load shall then be removed and the specimen examined. There shall be no evidence of splitting, cracking, or breaking.

4.3.3.5 Extrusion quality. The pipe shall not fail when tested by the acetone-immersion method as specified in ASTM D2152.

Sec. 4.4 Machined Coupling Requirements

4.4.1 *Workmanship.* The body and joining surfaces of couplings machined from extruded pipe shall conform with the same requirements as specified for pipe in Sec. 4.3.

4.4.2 *Dimensions.* The computed dimension ratio of gasketed PVC couplings machined from extruded pipe shall not be greater than the DR of the pipe, except in the annular gasket space and coupling entry where the wall thickness shall be at least the minimum wall thickness of the pipe (Table 1).

4.4.3 *Burst pressure.* The quick-burst strength of couplings shall not be less than the minimum burst pressure specified for the pipe with which the couplings are designed to be used when tested as specified in Sec. 4.3.3.2.

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Table 4 Temperature coefficients

Pipe Temperature		Pressure Rating Reduction Coefficient
°F	(°C)	
80	(27)	0.88
90	(32)	0.75
100	(38)	0.62
110	(43)	0.50
120	(49)	0.40
130	(54)	0.30
140	(60)	0.22

4.4.4 *Hydrostatic integrity.* Couplings shall not fail, balloon, burst, or weep when subjected to an internal pressure equal to four times the designated pressure class of the pipe with which it is designed to be used. The coupling shall attain ambient temperature before testing. When the ambient temperature is higher than 77°F (25°C), the test pressure shall be reduced using Table 4.

4.4.5 *Standard quantities.* If elastomeric-gasketed couplings are to be used as the primary pipe-joining method, one such coupling of a corresponding size and pressure class shall be furnished with each length of plain-end pipe.

Sec. 4.5 Fabricated Fitting Requirements

4.5.1 *Workmanship.* Fittings shall be fabricated from PVC pipe meeting the requirements of this standard. The component pipe segments and the bonds between them shall be free from voids, cracks, inclusions, and other defects. The joining surfaces of spigots and bells shall be free from imperfections that could cause leaks. When component segments are joined using solvent cement, the procedure shall conform with the standard practice for making pressure joints in ASTM D2855.

4.5.2 *Dimensions.*

4.5.2.1 Fitting barrel. All edge-joined segments of a fabricated fitting shall have the same dimension ratio.

4.5.2.2 Standard configurations. Standard configurations shall include customary angles for branch connections or bends. Non-standard angles of branch connections or bends may be specified. Leg lengths shall be the minimum practical for the method of fabrication, unless otherwise specified.

4.5.2.3 Reinforcement of solvent cement joints. Fitting segments that are joined by solvent cementing shall be designed on the basis of a maximum lap shear strength of the solvent cement joint of 900 psi (6.2 MPa). Overwrapped reinforcement shall not be considered in design of the solvent cement joint.

4.5.3 *Segment joint quality.*

4.5.3.1 Edge-joined fabricated fitting segments. There shall be no evidence of arcing or sparks from the probe tip when butt-fused or thermally welded joints are subjected to the following test.

A grounding medium compatible with PVC pipe shall be applied to the inside or outside of each butt-fused or thermally welded segment joint before any reinforcement is applied. The grounding medium in the prepared resin (polyester or epoxy) is graphite, which is added to the resin in the proportion of 20 percent by volume. The

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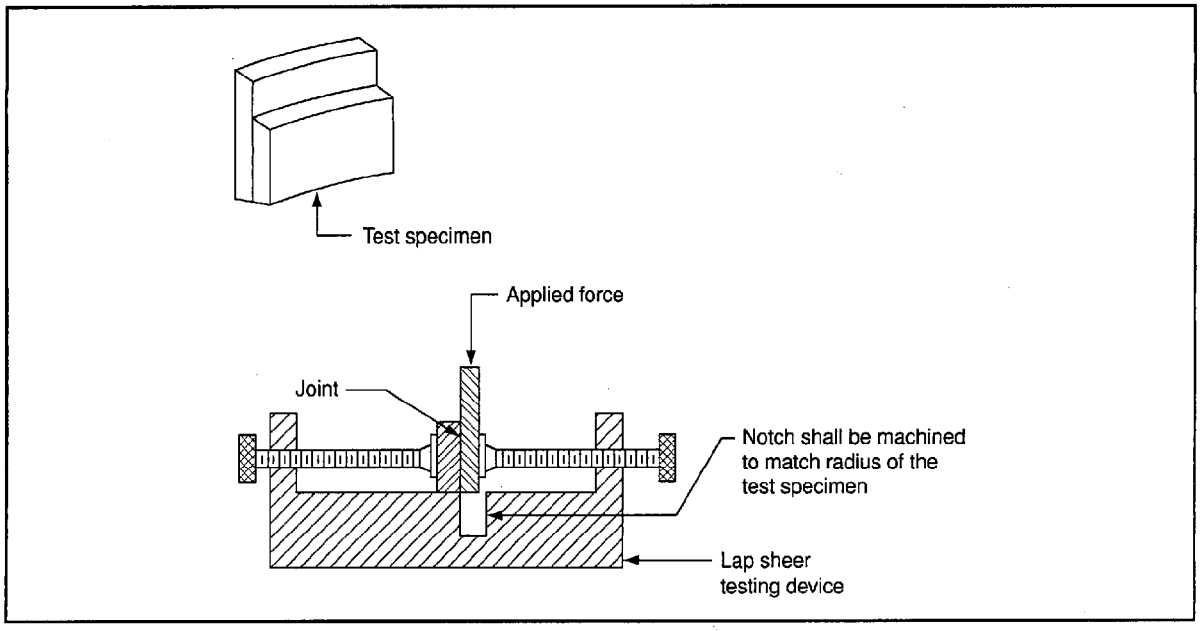

Figure 1 Lap shear test

grounding medium shall cover the joint with a strip not less than 1 in. (25 mm) wide. A suitable probe, energized with 25,000 V, shall be swept along the joint line approximately 0.1 in. (3 mm) away from the PVC surface of the joined segments on the side opposite to the grounding medium. Any discontinuity in the segment joint is indicated by the jump of an arc (sparking) from the probe tip and shall be cause for rejection of the fitting.

4.5.3.2 Solvent cemented bond quality. Specimens for lap shear testing shall be prepared in accordance with the requirements of ASTM D2564, except as modified in this standard. The test specimens shall be obtained from a sample solvent cemented joint produced by solvent cementing component pipe segments identical to those to be used to fabricate fittings. After at least a 72-h solvent cement curing time at 73.4 ± 3.6°F (23 ± 2°C), three specimens shall be tested per segment joint. Each specimen shall be a section of the segment joint measuring approximately 1 in. × 2 in. (25 mm × 50 mm) and shall not include any overwrapping reinforcement. A portion of each test specimen shall be machined off as needed to obtain a specimen similar to that shown in Figure 1. After placing the specimen in a testing device similar to that shown in Figure 1, apply the force at a shear speed of 0.05 in. (1.25 mm)/min. The minimum average lap shear strength of the three specimens shall be 900 psi (6.2 MPa).

NOTE: Where mechanical joint restraint devices are used to control thrust movements of fabricated fittings, consult with the fittings manufacturer to determine the tensile thrust limitations for the specific sizes, configurations, and pressure classes specified.

4.5.4 *Pressure test.* The fabricated fitting shall not fail, balloon, burst, or weep when subjected to an internal pressure equal to four times its designated pressure class for a minimum of 1 h.

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Sec. 4.6 Joint Requirements

Bell-end pipe, couplings, and fittings designed for making PVC joints using elastomeric gaskets to effect the pressure seal shall be tested as assembled joints and shall meet the laboratory performance requirements specified in ASTM D3139. (These are qualifying test requirements to determine proper design and performance of specimen joints.)

Sec. 4.7 Pressure-Class Designations

4.7.1 *Pipe and couplings.* Pressure-classes (PCs) shall be as listed in Table 1 for the three different DRs covered by this standard. The pressure classes apply to maximum sustained working pressure and provide for a pressure rise above maximum working pressure caused by surge (water hammer) from an instantaneous water velocity change of 2 ft/s (0.61 m/s). Pipe pressure-classes shall be based on a safety factor of 2.5 when calculated using the following equation:

$$PC = \left[\frac{2}{DR-1} \times \frac{HDB}{F}\right] - P_s \qquad \text{(Eq 1)}$$

Where:

PC = Pressure class, in pounds per square inch (for sustained pipe temperature above 73.4°F [23°C], see Table 4)
DR = Dimension ratio (Sec. 3)
HDB = Hydrostatic design basis, which for this standard shall be 4,000 psi (27.58 MPa)
F = Safety factor, which for this standard shall be 2.5
P_s = Surge pressure allowance, in pounds per square inch, based on an instantaneous velocity change of 2 ft/s (0.61 m/s). The pressure rise for a 2 ft/s (0.61 m/s) abrupt velocity change is 40, 35, and 30 psi (280, 240, and 200 kPa) for DRs 14, 18, and 25, respectively.

4.7.2 *Fabricated fittings.* Fabricated PVC fittings meeting the requirements of this standard shall have the pressure class designations listed in Table 1 that are equivalent to the dimension ratio of the pipe used in their fabrication. The determination of pressure classes and safety factors for fabricated fittings shall follow the method given in Sec. 4.7.1 for pipe meeting the requirements of this standard, ignoring the effect of any overwrapped reinforcement.

SECTION 5: VERIFICATION

Sec. 5.1 Quality-Control and Qualification Test Requirements

The manufacturer shall take adequate measures in the production of extruded PVC pipe, couplings, and fabricated fittings to assure product compliance with the requirements of this standard. The pipe, couplings, and fabricated fittings shall be tested at 73.4 ± 3.6°F (23 ± 2°C), unless otherwise specified, in accordance with the requirements of Sec. 4.3, 4.4, 4.5, and 4.6 at intervals as required in this standard.

5.1.1 *Pipe dimensions.* The dimensions of pipe produced from each extrusion outlet, and the bell or sleeve-reinforced bell of pipe with such ends, shall be measured

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in accordance with Sec. 4.3.2 at the beginning of production of each specific material and each size. Thereafter, one specimen from each extrusion outlet shall be measured each hour.

5.1.2 *Coupling dimensions.* The dimensions of machined couplings shall be measured in accordance with Sec. 4.4.2 at the beginning of production of each specific material and each size. Thereafter, one specimen shall be measured each hour.

5.1.3 *Sustained pressure.* At the beginning of production and semiannually thereafter, specimens of 4-in. (100-mm) or 6-in. (150-mm) pipe and of 8-in. (200-mm) or larger pipe that are made from each PVC pressure pipe commercial compound (i.e., material) shall be tested in accordance with Sec. 4.3.3.1. (These tests are for qualification of the compound and the extrusion process—not for quality control of the product.)

5.1.4 *Pipe burst strength.* The quick-burst strength of pipe produced from each extrusion outlet shall be tested in accordance with Sec. 4.3.3.2 at the beginning of production of each specific material and each size. Thereafter, one specimen from each extrusion outlet shall be tested every 24 h.

5.1.5 *Coupling burst strength.* The quick-burst strength of machined couplings shall be tested in accordance with Sec. 4.4.3 at the beginning of production of each specific material and each size. Thereafter, one specimen shall be tested every 8 h.

5.1.6 *Flattening capability.* The flattening capability of pipe shall be tested in accordance with Sec. 4.3.3.4 at the beginning of production from each extrusion outlet for each specific material and each size. Thereafter, one specimen from each extrusion outlet shall be tested every 8 h.

5.1.7 *Extrusion quality.* The pipe produced from each extrusion outlet shall be tested in accordance with Sec. 4.3.3.5 at the beginning of production of each specific material and each size. Thereafter, one specimen from each extrusion outlet shall be tested every 8 h.

5.1.8 *Fitting segment fusion.* Each fitting manufactured using the butt-fusion or thermal welding method of segment joining shall be tested in accordance with Sec. 4.5.3.1.

5.1.9 *Fitting segment solvent cemented bond quality.* Where solvent cementing is used to join fitting segments, the quality of the bond shall be tested in accordance with Sec. 4.5.3.2 at the startup of a production run. Thereafter, the quality of the bond shall be tested at least once every 15 calendar days of production or 200 fittings, whichever is more frequent.

5.1.10 *Fabricated fitting pressure tests.*

5.1.10.1 Qualification pressure test. For a specific production process and whenever the production process is changed, a representative fabricated fitting specimen shall be subjected to a sustained pressure test in accordance with Sec. 4.3.3.1. A representative specimen shall be the most critically stressed fitting configuration. (NOTE: Critical stresses generally occur where fitting segments are joined together.)

5.1.10.2 Quality control pressure test. At the beginning of production and at least once every 15 calendar days of production or 200 fittings, whichever is more frequent, a fabricated fitting specimen shall be tested in accordance with Sec. 4.5.4.

5.1.11 *Provision for test failure.* When any PVC product fails to meet a requirement specified in this standard or in a referenced standard, additional tests shall be performed to determine which products are acceptable of those produced

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since the last favorable test. Products that fail to meet any requirement shall be rejected.

5.1.12 *Hydrostatic proof test for pipe.* Each standard and random length of pipe shall be proof tested in accordance with Sec. 4.3.3.3.

5.1.13 *Hydrostatic proof test for machined couplings.* Each separate machined coupling shall be proof tested in accordance with Sec. 4.4.4.

5.1.14 *Additional test requirements.* The purchaser or supplier may allow the manufacturer to conduct hydrostatic proof tests for pipes or couplings at test frequencies other than required in Sec. 5.1.12 and 5.1.13.

Sec. 5.2 Quality-Control Records

The manufacturer shall maintain, for a period of not less than two years, a record of all quality-control tests and shall, if requested, submit the pertinent record to the purchaser.

Sec. 5.3 Plant Inspection

5.3.1 *Plant access.* The purchaser shall have free access to those parts of a manufacturer's plant that are necessary to assure that products comply with all requirements.

5.3.2 *Responsibility for compliance.* Plant inspection by the purchaser or the omission of such inspections shall not relieve the manufacturer of the responsibility to furnish materials complying with the applicable requirements of this standard.

SECTION 6: DELIVERY

Sec. 6.1 Marking

6.1.1 *General.* Pipe, couplings, and fittings shall bear identification markings that will remain legible during normal handling, storage, and installation. The markings shall be applied in a manner that will not reduce the strength of any product covered by this standard.

6.1.2 *Pipe.* Marking on pipe shall include the following and shall be applied at intervals of not more than 5 ft (1.5 m):

a. Nominal size (for example, 4 in.).
b. PVC.
c. Dimension ratio (for example, DR 25).
d. AWWA pressure class (for example, PC 100).
e. AWWA designation number for this standard (ANSI/AWWA C900-97).
f. Manufacturer's name or trademark and production-record code.
g. Seal (mark) of the testing agency verifying the suitability of the pipe material for potable-water service (Sec. 4.2.3).

6.1.3 *Couplings and fabricated fittings.* Marking on couplings and fabricated fittings shall include the following:

a. Nominal size and deflection angle if applicable (for example, 8 in. × 4 in. or 8-in. 45°).
b. PVC.
c. AWWA pressure class (for example, PC 150).
d. AWWA designation number for this standard (ANSI/AWWA C900-97).
e. Manufacturer's name or trademark.

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f. Seal (mark) of the testing agency verifying the suitability of the coupling or fitting for potable-water service (Sec. 4.2.3).

Sec. 6.2 Shipping and Delivery

6.2.1 *Shipping.* All pipe, couplings, and fabricated fittings shall, unless otherwise specified by the purchaser, be prepared for standard commercial shipment.

6.2.2 *Delivery.* Pipe, couplings, and fabricated fittings that do not comply with the applicable requirements of this standard or that are damaged when received shall be replaced by the manufacturer or supplier at the agreed point of delivery.

Sec. 6.3 Affidavit of Compliance

The manufacturer shall, if so specified by the purchaser, furnish an affidavit that all delivered materials comply with the requirements of this standard and of the purchaser.

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APPENDIX A

Bibliography

This appendix is for information only and is not a part of AWWA C900.

1. ANSI/AWWA C605—Standard for Underground Installation of Polyvinyl Chloride (PVC) Pressure Pipe and Fittings for Water.

2. ANSI/AWWA C905—Standard for Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, Nominal Diameters 14 in. Through 48 in. (350 mm Through 1,200 mm) for Water Transmission and Distribution.

3. ANSI/AWWA C907—Standard for Polyvinyl Chloride (PVC) Pressure Fittings for Water—4 In. Through 8 in. (100 mm Through 200 mm).

4. AWWA Manual M23, *PVC Pipe, Design, and Installation.* AWWA, Denver, Colo. (1980).

5. *Uni-Bell Handbook of PVC Pipe Design and Construction,* third edition. Dallas, Texas: Uni-Bell PVC Pipe Association (1991).

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American Water Works Association
ANSI/AWWA C950-95
(Revision of ANSI/AWWA C950-88)

AWWA STANDARD

FOR

FIBERGLASS PRESSURE PIPE

AMERICAN NATIONAL STANDARD

Effective date: Oct. 1, 1996.
First edition approved by AWWA Board of Directors Jan. 25, 1981.
This edition approved Jan. 22, 1995.
Approved by American National Standards Institute July 10, 1995.

AMERICAN WATER WORKS ASSOCIATION

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AWWA Standard

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American National Standard

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All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

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Foreword

This foreword is for information only and is not part of ANSI/AWWA C950.

I. Introduction

I.A. *Background.* This standard provides direction and guidance in selecting and purchasing fiberglass pipe for use as pressure pipe in water distribution (including services) and transmission systems for both aboveground and belowground installations.

This standard covers 1-in. through 144-in. (25-mm through 3,600-mm) diameter pressure pipes. The primary materials used are thermosetting polyester or epoxy resins, glass-fiber reinforcement, and, if used, aggregate. There are five pressure classes, which range from 50 psi through 250 psi (345 kPa through 1,724 kPa), in 50-psi (345-kPa) increments. Stiffness classes covered are 9, 18, 36, and 72 psi (62, 124, 248, and 496 kPa). This standard may be used to the extent applicable for other sizes, pressure classes, and stiffness classes.

I.B. *History.* In June 1971, the AWWA Engineering and Construction Technical and Professional Committee organized the Reinforced Plastics Committee to evaluate both the use of reinforced plastics in the water-supply industry and the need for appropriate AWWA standards. The Reinforced Plastics Committee found sufficient use and interest to support a recommendation that a standard be developed for fiberglass pipe. The Standards Council authorized the formation of the Standards Committee on Thermosetting Fiberglass Reinforced Plastic Pipe in October 1972, and committee organization was completed in December 1974. The first edition of the standard was approved by the AWWA Board of Directors on Jan. 25, 1981. The second edition was approved on June 23, 1988.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF) to develop voluntary third-party consensus standards and a certification program for all direct and indirect drinking water additives. Other members of the original consortium included the American Water Works Association Research Foundation (AWWARF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.* Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.
2. Specific policies of the state or local agency.

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3. Two standards developed under the direction of NSF, ANSI*/NSF† 60, Drinking Water Treatment Chemicals—Health Effects, and ANSI/NSF 61, Drinking Water System Components—Health Effects.

4. Other references, including AWWA standards, *Food Chemicals Codex*, *Water Chemicals Codex*,‡ and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with ANSI/NSF 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Appendix A, "Toxicology Review and Evaluation Procedures," to ANSI/NSF 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Appendix A procedures may not always be identical, depending on the certifier.

ANSI/AWWA C950-95 does not address additives requirements. Thus, users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.
2. Determine the status of certifications by all parties offering to certify products for contact with, or treatment of, drinking water.
3. Determine current information on product certification.

II. Special Issues

II.A. *Nominal Metric Pipe Sizes, Dimensions, and Tolerances.* Nominal metric pipe sizes, dimensions, and tolerances were obtained from International Organization for Standardization (ISO) specification 7370, Glass Fibre Reinforced Thermosetting Plastics (GRP) Pipes and Fittings—Nominal Diameters, Specified Diameters and Standard Lengths, and proposed addenda to that document.

III. Use of This Standard. AWWA has no responsibility for the suitability or compatibility of the provisions of this standard to any intended application by any user. Accordingly, each user of this standard is responsible for determining that the standard's provisions are suitable for and compatible with that user's intended application.

III.A. *Purchaser Options and Alternatives.* The following items should be covered in the purchaser's specifications:

1. Standard used—that is, ANSI/AWWA C950, Standard for Fiberglass Pressure Pipe, of latest revision.
2. Pipe diameter size and series (Sec. 4.5.1).
3. Pressure classes (Sec. 4.6).
4. Stiffness classes (Sec. 4.7).
5. Specific service and installation considerations.
6. Lineal feet of each pressure and stiffness class and size.

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*American National Standards Institute, 11 W. 42nd St., New York, NY 10036.

†NSF International, 3475 Plymouth Rd., Ann Arbor, MI 48106.

‡ Both publications available from National Academy of Sciences, 2102 Constitution Ave. N.W., Washington, DC 20418.

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7. Whether plant inspection is required (Sec. 5.1.1).

The purchaser may also specify the following:

1. Cell classification (Sec. 4.3).
2. Standard laying lengths (Sec. 4.5.2).
3. Joint configuration (Sec. 4.9).
4. Line layout showing pressure zones, including applicable design and transient pressures within zones and points of change between zones.

III.B. *Manufacturer Options and Alternatives.* The following items should be provided in the manufacturer's specifications:

1. Cell classification (Sec. 4.3).
2. Stiffness class (Sec. 4.7).
3. Joint details (Sec. 4.9).
4. Nominal wall thickness.
5. Weight.
6. Total quantity of jointing materials and field allowances.

When requested by the purchaser, it is understood that the manufacturer also will supply the following:

1. Special design calculations.
2. Special lengths (Sec. 4.5.2).
3. Special preparations needed for shipment (Sec. 6.2).
4. Affidavit of compliance (Sec. 6.3).

III.C. *Modification to Standard.* Any modifications to the provisions, definitions, or terminology in this standard must be provided in the purchaser's or manufacturer's specifications.

IV. Major Revisions. Major changes made to the standard in this revision include the following:

1. Tables 1, 3, 4, 7, and 8 through 13 were metricized.
2. The format has been changed to AWWA standard style.
3. The acceptance clause (Sec. I.C.) and the definitions of parties (Sec. 3) have been revised to approved wording.
4. Section 4.9, Joint Types and Requirements, was revised.
5. The information in Appendixes A through D on design, testing, installation, shipping, handling, and storage has been removed from the standard and included in AWWA Manual M45, Fiberglass Pipe Design.

V. Comments. If you have any comments or questions about this standard, please call the AWWA Standards and Materials Development Department, (303) 794-7711 ext. 6283, FAX (303) 795-1440, or write to the department at 6666 W. Quincy Ave., Denver, CO 80235.

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American Water Works Association

ANSI/AWWA C950-95
(Revision of ANSI/AWWA C950-88)

AWWA STANDARD FOR

FIBERGLASS PRESSURE PIPE

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard covers the fabrication and the testing of nominal 1-in. through 144-in. (25-mm through 3,600-mm) fiberglass pipe and joining systems for use in both aboveground and belowground water systems. Service and distribution piping systems and transmission piping systems are included.

Both glass-fiber-reinforced thermosetting-resin pipe (RTRP) and glass-fiber-reinforced plastic-mortar pipe (RPMP) are fiberglass pipes. Epoxy-resin and polyester-resin systems are covered, and commercial-grade E-type glass is specified as the glass-fiber reinforcement material in the pipe wall. Liner materials incorporated include thermosetting or thermoplastic resin, reinforced or unreinforced, with or without fillers. Pressure classes covered are 50, 100, 150, 200, and 250 psig (345, 689, 1,034, 1,379, and 1,724 kPa). Stiffness classes covered are 9, 18, 36, and 72 psi (62, 124, 248, and 496 kPa). This standard may be used to the extent applicable for other diameters, pressure classes, and stiffness classes. For information on design, hydraulics, and installation, refer to AWWA Manual M45, *Fiberglass Pipe Design.*

Sec. 1.2 Purpose

The main purpose of this standard is to provide the minimum requirements for fiberglass pressure pipe, including design, fabrication, and testing requirements.

Sec. 1.3 Application

This standard can be referenced in specifications for purchasing and receiving fiberglass pressure pipe. This standard can be used as a guide for manufacturing this type of fiberglass pressure pipe. The stipulations of this standard apply when this document has been referenced and then only to fiberglass pressure pipe.

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SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, these documents form a part of this standard to the extent specified within the standard. In case of conflict, the requirements of this standard shall prevail.

ASTM* C33—Standard Specification for Concrete Aggregates.

ASTM D638—Standard Test Method for Tensile Properties of Plastics.

ASTM D695—Standard Test Method for Compressive Properties of Rigid Plastics.

ASTM D1599—Standard Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings.

ASTM D2105—Standard Test Method for Longitudinal Tensile Properties of 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube.

ASTM D2290—Standard Test Method for Apparent Tensile Strength of Ring or Tubular Plastics and Reinforced Plastics by Split Disk Method.

ASTM D2412—Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.

ASTM D2992—Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings.

ASTM D3517—Standard Specification for 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe.

ASTM D3567—Standard Practice for Determining Dimensions of 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings.

ASTM D3681—Standard Test Method for Chemical Resistance of 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe in a Deflected Condition.

ASTM D4161—Standard Specification for 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

ASTM D5365—Standard Test Method for Long-Term Ring-Bending Strain of 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe.

ASTM F477—Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Aggregate:* Siliceous sand conforming to ASTM C33, except that the requirements for gradation need not apply.

2. *Centrifugal casting:* A process used to manufacture tubular goods by applying resin and reinforcement to the inside of a mold that is rotated and heated, subsequently polymerizing the resin system. The outside diameter (OD) of the finished pipe is determined by the inside diameter (ID) of the mold tube. The ID of the finished pipe is determined by the amount of material introduced into the mold.

*American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

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Other materials that will not adversely affect the laminate performance may be introduced in the process during manufacture of the pipe.

3. *Constructor:* The party that furnishes the work and materials for placement or installation.

4. *Epoxy resin (thermosetting):* A polymer containing two or more three-membered rings, each consisting of one oxygen and two carbon atoms. The polymer is cured by cross-linking with an amine or anhydride hardener, with or without heat, catalyst, or both.

5. *Fiberglass pipe:* A tubular product containing glass-fiber reinforcements embedded in or surrounded by cured thermosetting resin. The composite structure may contain aggregate, granular or platelet fillers, thixotropic agents, and pigments or dyes. Thermoplastic or thermosetting liners or coatings may be included.

6. *Filament winding:* A process used to manufacture tubular goods by winding continuous glass-fiber roving or roving tape onto the outside of a mandrel or core pipe liner in a predetermined pattern under controlled tension. The roving may be saturated with liquid resin or preimpregnated with partially cured resin. Subsequent polymerization of the resin system may require application of heat. The ID of the finished pipe is fixed by the mandrel diameter or the inner diameter of the core pipe liner. The OD of the finished pipe is determined by the amount of material that is wound on the mandrel or core pipe liner. Other materials may be introduced in the process during the manufacture of the pipe, which will not adversely affect the laminate performance.

7. *Fixed end*: End of a pipe test specimen with an end closure configuration such that internal pressure produces only hoop and radial stresses in a straight pipe test specimen. Longitudinal thrust is absorbed by separate means such as tie-rods, etc.

8. *Free end*: End of a pipe test specimen with an end closure configuration such that internal pressure produces longitudinal stresses in addition to hoop and radial stresses in the pipe test specimen.

9. *Glass fabric:* A bidirectional fabric reinforcing material made by the weaving of glass-fiber yarn.

10. *Glass fibers:* A commercial grade of glass E-type filaments with binder and sizing that are compatible with the impregnating resin.

11. *Joint restraint*: A separate external device or structure that is assembled or constructed around a joint to provide restraint to longitudinal tensile forces.

12. *Liner:* A filled or unfilled thermoplastic or thermosetting resin layer, nonreinforced or reinforced, that forms the interior surface of the pipe.

13. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.

14. *Mat:* A fibrous material consisting of random-oriented, chopped, or swirled filaments loosely held together with a binder.

15. *Polyester resin (thermosetting):* An ethylenic unsaturated polymer with two or more ester groups, dissolved in a reactive diluent with vinyl unsaturation. The polymer is cured by cross-linking by means of a free-radical-initiated curing mechanism, such as peroxide catalyst and heat.

16. *Purchaser:* The person, company, or organization that purchases materials or work to be performed.

17. *Purchaser's agent:* The authorized representative of the purchaser who is entrusted with the inspection of materials and production records and the observance

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of production operations and quality-control tests to ensure that the products comply with the requirements of this standard and of the purchaser.

18. *Reinforced plastic–mortar pipe (RPMP):* A fiberglass pipe with aggregate.

19. *Reinforced thermosetting-resin pipe (RTRP):* A fiberglass pipe without aggregate.

20. *Resin:* Any of a class of solid or pseudosolid organic materials, often of high molecular weight, with no definite melting point. In the broad sense, the term is used to designate any polymer that is a basic material for plastics.

21. *Restrained joint*: Pipe joint capable of withstanding internal pressure and longitudinal tensile loads.

22. *Rigid joint*: A restrained joint that is not capable of axial displacement or angular rotation.

23. *Roving:* A collection of parallel glass strands or filaments, coated with a finish or coupling agent to improve compatibility with resins, gathered without mechanical twist. Roving may be processed in a continuous or chopped form.

24. *Supplier:* The party that supplies materials or services. A supplier may or may not be the manufacturer.

25. *Stiffness class:* The nominal stiffness of a specified pipe. (The stiffness class is determined as specified in Sec. 4.7)

26. *Surface layer:* A filled or unfilled resin layer, nonreinforced or reinforced, that is applied to the exterior surface of the pipe structural wall.

27. *Surfacing mat:* A thin mat of fine fibers used primarily to produce a smooth surface on a reinforced plastic.

28. *Tape:* A unidirectional glass-fiber reinforcement consisting of rovings knitted or woven into ribbon form.

29. *Thermoplastic resin:* A plastic that can be repeatedly softened by heating and hardened by cooling and that in the softened state can be fused or shaped by flow.

30. *Thermosetting resin:* A plastic that, after having been cured by heat or other means, is substantially infusible and insoluble.

31. *Unrestrained joint*: Pipe joint capable of withstanding internal pressure, but not longitudinal tensile loads.

32. *Woven roving:* A glass-fiber fabric reinforcing material made by the weaving of glass-fiber roving.

SECTION 4: REQUIREMENTS

Sec. 4.1 Permeation

The selection of materials is critical for water service and distribution piping in locations where there is likelihood the pipe will be exposed to significant concentrations of pollutants comprised of low molecular weight petroleum products or organic solvents or their vapors. Research has documented that pipe materials, such as polyethylene, polybutylene, polyvinyl chloride, and asbestos cement, and elastomers, such as used in jointing gaskets and packing glands, may be subject to permeation by lower molecular weight organic solvents or petroleum products. If a water pipe must pass through such a contaminated area or an area subject to contamination, consult with the manufacturer regarding permeation of pipe walls, jointing materials, and so forth, **before** selecting materials for use in that area.

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Sec. 4.2 Workmanship

The pipe shall be free from defects, including indentations, delaminations, bubbles, pinholes, cracks, pits, blisters, foreign inclusions, and resin-starved areas that, due to their nature, degree, or extent, detrimentally affect the strength and serviceability of the pipe. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

Sec. 4.3 Cell Classification System

This standard covers products defined by a cell classification system and identifies the method of manufacture (type), construction and materials (grade), and liner construction (liner). The types, grades, and liners are identified in the following paragraphs. It should be noted that all possible combinations of types, grades, and liners may not be commercially available.

4.3.1 *Types.* The product type is determined by the method of manufacture, as follows:

Type I: Filament wound.

Type II: Centrifugally cast.

4.3.2 *Grades.* The product grade is determined by construction (glass-fiber-reinforced or glass-fiber-reinforced mortar) and materials (epoxy or polyester), as follows:

Grade 1: Glass-fiber-reinforced epoxy (RTRP epoxy).

Grade 2: Glass-fiber-reinforced polyester (RTRP polyester).

Grade 3: Glass-fiber-reinforced epoxy mortar (RPMP epoxy).

Grade 4: Glass-fiber-reinforced polyester mortar (RPMP polyester).

4.3.3 *Liners.* The product-liner classification is determined by whether or not a liner is used and, if used, whether it is a thermoplastic, reinforced, or nonreinforced thermoset. Classification of liners is as follows:

Liner A: No liner.

Liner B: Thermoplastic liner.

Liner C: Reinforced thermoset liner.

Liner D: Nonreinforced thermoset liner.

Sec. 4.4 Materials

The resins, reinforcement, colorants, fillers, and other materials, when combined as a composite structure, shall produce pipe products that meet the performance requirements of this standard as specified in Sec. 5.1.2.

4.4.1 *Qualification for potable water service.* The materials used to make pipe products shall contain no ingredient in an amount that has been demonstrated to migrate into water in quantities that are considered to be toxic.

4.4.2 *Certification.* Fiberglass pipe intended for use in the transport of potable water shall be evaluated and certified for such use as required by the local authority.* The seal or mark of the laboratory that evaluates the pipe should be included on the fiberglass pipe.

4.4.3 *Gaskets and lubricants.* Gaskets and lubricants shall be made from materials that (1) are compatible with the plastic materials and with each other when

*See Sec. I.C. Acceptance in the foreword for additional guidance.

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used together, (2) will not support the growth of bacteria, and (3) will not adversely affect the potable qualities of water.

Sec. 4.5 Pipe Dimensions

4.5.1 *Diameters.* Pipe diameters and tolerances shall be as shown in Tables 1, 2, 3, 4, 5, and 6 when measured in accordance with ASTM D3567. These tables include dimensions for pipe based on both inside and outside diameters. In the latter case, tables are provided for steel-pipe-equivalent ODs, cast-iron-pipe-equivalent ODs, and metric ODs commonly used in international practice. As a group, the tables cover nominal pipe sizes 1 in. through 144 in. (25 mm through 3,600 mm); individual tables cover only a portion of the total range.

4.5.2 *Length.* Pipe shall be furnished in standard laying lengths as agreed on by the purchaser and manufacturer. A maximum of 15 percent of the footage of each pipe size may be furnished in random lengths. Each random length furnished shall not vary by more than 25 percent from the standard laying length specified, except for special orders.

NOTE: Common practice in the industry provides for laying lengths of 10, 20, 30, 40, or 60 ft (3, 6, 9, 12, and 18 m).

4.5.3 *Wall thickness.* The average wall thickness of the pipe shall not be less than the nominal wall thickness published in the manufacturer's literature current at the time of purchase, and the minimum wall thickness at any point shall not be less than 87.5 percent of that nominal wall thickness when measured in accordance with ASTM D3567.

Sec. 4.6 Pressure Classes

The standard pressure classes for pipe shall be 50, 100, 150, 200, and 250 psig (345, 689, 1,034, 1,379, and 1,724 kPa). The pressure classes refer to the maximum sustained working pressure. They are determined in accordance with Sec. 4.6.2 using a design factor of 1.8. The pressure classes may have to be changed for pipes conveying water at elevated temperatures (in accordance with the manufacturer's recommendations) and whenever there is a need to provide more allowance for surge pressure.

For pipe subjected to circumferential bending, the effect of such bending on the hydrostatic design pressure class of the pipe must be considered.

4.6.1 *Thermoplastic lined pipe.* The pressure classes for thermoplastic lined pipe are based on a water temperature of 73.4°F (23°C). The classes shall be reduced for use at temperatures greater than 73.4°F (23°C). The temperature-derating service factors shall be supplied by the pipe manufacturer.

4.6.2 *Long-term hydrostatic design pressure.* The pressure classes shall be based on long-term hydrostatic-design-pressure data extrapolated to 50 years, using procedure B of ASTM D2992 or, alternately, with the procedure specified in Annex A.1 of ASTM D3517. Procedure A data from ASTM D2992 may be used in place of procedure B data at the option of the manufacturer. End fixtures used during testing shall be representative of the product use as follows:

Service	Test End Fixture
Restrained joints	Free ends
Unrestrained joints	Fixed ends

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Table 1 Dimensions for inside diameter series pipe

Nominal Pipe Size		Inside Diameter		Tolerance	
in.	*(mm)*[*]	*in.*	*(mm)*	*in.*	*(mm)*
1	(25)	1.00	(25.4)	±0.06	(±1.5)
1½	(40)	1.50	(38.1)	±0.06	(±1.5)
2	(50)	2.00	(50.8)	±0.06	(±1.5)
2½	(65)	2.50	(63.5)	±0.06	(±1.5)
3	(80)	3.00	(76.2)	±0.12	(±3.0)
4	(100)	4.00	(101.6)	±0.12	(±3.0)
6	(150)	6.00	(152.4)	±0.25	(±6.3)
8	(200)	8.00	(203.2)	±0.25	(±6.3)
10	(250)	10.00	(254.0)	±0.25	(±6.3)
12	(300)	12.00	(304.8)	±0.25	(±6.3)
14	(350)	14.00	(355.6)	±0.25	(±6.3)
15	(375)	15.00	(381.0)	±0.25	(±6.3)
16	(400)	16.00	(406.4)	±0.25	(±6.3)
18	(450)	18.00	(457.2)	±0.25	(±6.3)
20	(500)	20.00	(508.0)	±0.25	(±6.3)
21	(550)	21.00	(533.4)	±0.25	(±6.3)
24	(600)	24.00	(609.6)	±0.25	(±6.3)
27	(700)	27.00	(685.8)	±0.27	(±6.9)
30	(800)	30.00	(762.0)	±0.30	(±7.6)
33	(850)	33.00	(838.2)	±0.33	(±8.4)
36	(900)	36.00	(914.4)	±0.36	(±9.1)
39	(1,000)	39.00	(990.6)	±0.39	(±9.9)
42	(1,100)	42.00	(1,066.8)	±0.42	(±10.7)
45	(1,150)	45.00	(1,143.0)	±0.45	(±11.4)
48	(1,200)	48.00	(1,219.2)	±0.48	(±12.2)
51	(1,300)	51.00	(1,295.4)	±0.51	(±13.0)
54	(1,400)	54.00	(1,371.6)	±0.54	(±13.7)
60	(1,500)	60.00	(1,524.0)	±0.60	(±15.2)
66	(1,700)	66.00	(1,676.4)	±0.66	(±16.8)
72	(1,800)	72.00	(1,828.8)	±0.72	(±18.3)
78	(2,000)	78.00	(1,981.2)	±0.78	(±19.8)
84	(2,200)	84.00	(2,133.6)	±0.84	(±21.3)
90	(2,300)	90.00	(2,286.0)	±0.90	(±22.9)
96	(2,400)	96.00	(2,438.4)	±0.96	(±24.4)
102	(2,600)	102.00	(2,590.8)	±1.00	(±25.4)
108	(2,800)	108.00	(2,743.2)	±1.00	(±25.4)
114	(2,900)	114.00	(2,895.6)	±1.00	(±25.4)
120	(3,000)	120.00	(3,048.0)	±1.00	(±25.4)
132	(3,400)	132.00	(3,352.8)	±1.00	(±25.4)
144	(3,600)	144.00	(3,657.6)	±1.00	(±25.4)

[*]Closest customary metric equivalent.

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Table 2 Metric dimensions for inside diameter (ID) series pipe

Nominal Pipe Size		Inside Diameter					
Metric Dimension*	Closest US Customary Unit Equivalent	Range *mm*		US Customary Unit Equivalent† *in.*		Tolerance	
mm	*in.*	*Minimum*	*Maximum*	*Minimum*	*Maximum*	*mm*	*(in.)*
25	1	23.5	26.5	0.93	1.04	±1.5	(±0.06)
40	1½	38	42	1.50	1.65	±1.5	(±0.06)
50	2	48	52	1.89	2.05	±1.5	(±0.06)
80	3	78	82	3.07	3.23	±1.5	(±0.06)
100	4	97	103	3.82	4.06	±1.5	(±0.06)
150	6	147	153	5.79	6.02	±1.5	(±0.06)
200	8	196	204	7.72	8.03	±1.5	(±0.06)
250	10	246	255	9.69	10.04	±1.5	(±0.06)
300	12	296	306	11.65	12.05	±1.8	(±0.07)
350	14	346	357	13.62	14.06	±2.1	(±0.08)
400	16	396	408	15.59	16.06	±2.4	(±0.09)
450	18	446	459	17.56	18.07	±2.7	(±0.11)
500	20	496	510	19.53	20.08	±3.0	(±0.12)
600	24	595	612	23.43	24.09	±3.6	(±0.14)
700	27	695	714	27.36	28.11	±4.2	(±0.17)
800	30	795	816	31.30	32.13	±4.2	(±0.17)
900	36	895	918	35.24	36.14	±4.2	(±0.17)
1,000	39	995	1,020	39.17	40.16	±4.2	(±0.17)
1,200	48	1,195	1,220	47.05	48.03	±5.0	(±0.20)
1,400	54	1,395	1,420	54.92	55.91	±5.0	(±0.20)
1,600	63	1,595	1,620	62.80	63.78	±5.0	(±0.20)
1,800	72	1,795	1,820	70.67	71.65	±5.0	(±0.20)
2,000	78	1,995	2,020	78.54	79.53	±5.0	(±0.20)
(2,200)	84	2,195	2,220	86.42	87.40	±5.0	(±0.20)
2,400	96	2,395	2,420	94.29	95.28	±6.0	(±0.24)
(2,600)	102	2,595	2,620	102.17	103.15	±6.0	(±0.24)
2,800	108	2,795	2,820	110.04	111.02	±6.0	(±0.24)
(3,000)	120	2,995	3,020	117.91	118.90	±6.0	(±0.24)
3,200	126	3,195	3,220	125.79	126.77	±6.0	(±0.24)
(3,400)	132	3,395	3,420	133.66	134.65	±7.0	(±0.28)
3,600	144	3,595	3,620	141.54	142.52	±7.0	(±0.28)

*Values taken from international practice; values in parentheses indicate nonpreferred diameters.

Sec. 4.7 Stiffness Classes

The standard stiffness classes shall be 9, 18, 36, and 72 psi (62, 124, 248, and 496 kPa) and shall be determined in accordance with Sec. 5.1.2.2.

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Sec. 4.8 Long-Term Ring-Bending Strain

4.8.1 *Long-term ring-bending strain* S_b. Long-term ring-bending strain can be determined with creep-failure tests instrumented to detect an abrupt, significant reduction in mechanical properties. The test data should be statistically extrapolated to establish strength at 50 years. The value for S_b may be determined by testing per ASTM D5365, using a water test solution with any pH between 5 and 9. If these test results are not available, the value for S_b may be taken as the results of either of the following testing methods:

1. In accordance with ASTM D3681, using 1*N* H_2SO_4.
2. Using results of ASTM D2992, method B, extrapolated to 50 years.

Sec. 4.9 Joint Types and Requirements

The pipe shall have a joining system that shall provide for fluid tightness for the intended service condition.

4.9.1 *Unrestrained.* Pipe joints capable of withstanding internal pressure but not longitudinal forces.

4.9.1.1 Coupling or bell-and-spigot gasket joints. Joints with a groove on either the spigot or in the bell to retain an elastomeric gasket that shall be the sole element of the joint to provide watertightness.

4.9.1.2 Mechanical couplings with elastomeric seals.

4.9.2 *Restrained.* Pipe joints capable of withstanding internal pressure and longitudinal forces.

4.9.2.1 Joints similar to the joints in Sec. 4.9.1.1 with supplemental restraining elements.

4.9.2.2 Butt joint with laminated overlay.

4.9.2.3 Bell-and-spigot with laminated overlay.

4.9.2.4 Bell-and-spigot adhesive bonded. Three types of adhesive-bonded joints are permitted by this standard. Each shall meet or exceed the hoop tensile and axial tensile strength requirements of the pipes as prescribed in Sec. 5.1.2.3 and Sec. 5.1.2.4. The permissible adhesive-bonded joints are as follows:

1. Tapered bell and spigot: An adhesive joint that is manufactured with a tapered socket for use in conjunction with a tapered spigot section and a suitable adhesive.
2. Straight bell and spigot: An adhesive joint that is manufactured with an untapered socket for use with a pipe with an untapered spigot and a suitable adhesive.
3. Tapered bell and straight spigot: An adhesive joint that is manufactured with a tapered socket to be used with a pipe with an untapered spigot and a suitable adhesive.

4.9.2.5 Flanged. Both integral and loose ring.

4.9.2.6 Mechanical. Elastomeric sealed with supplemental restraining elements.

4.9.3 *Performance requirements.*

4.9.3.1 Joint tightness. All joints shall meet the Laboratory Performance Requirements of Sec. 7 of ASTM D4161. Rigid joints (see Sec. 4.9.2.2, Sec. 4.9.2.3, Sec. 4.9.2.4, and Sec. 4.9.2.5) shall be exempt from angular deflection requirements.

4.9.3.2 Gaskets. Elastomeric gaskets shall conform to the requirements of ASTM F477.

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NOTE: The inclusion of longitudinal joint restraints may increase service loads on the pipe to be greater than those experienced with unrestrained joints. The purchaser is cautioned to take into consideration all conditions that may be encountered in the anticipated service and to consult with the manufacturer regarding the suitability of a particular type and class of pipe for service with restrained joints.

SECTION 5: VERIFICATION

Sec. 5.1 Inspection and Testing

5.1.1 *Plant inspection by purchaser.* Plant inspection by the purchaser or the omission of such inspection shall not relieve the manufacturer of the responsibility to furnish products that comply with the applicable requirements of this standard and of the purchaser.

5.1.1.1 Production notice. When plant inspection is specified by the purchaser, the manufacturer shall provide the purchaser with adequate advance notice of when and where the production of ordered products will commence.

Table 3 Dimensions for outside diameter (OD) series pipe with steel-pipe-equivalent (IPS) ODs

Nominal Pipe Size		Outside Diameter		Tolerance	
in.	*(mm)**	*in.*	*(mm)*	*in.*	*(mm)*
1	(25)	1.315	(33.40)	+0.060	(+1.52)
				–0.016	(–0.41)
1½	(40)	1.900	(48.26)	+0.060	(+1.52)
				–0.018	(–0.46)
2	(50)	2.375	(60.33)	+0.060	(+1.52)
				–0.018	(–0.46)
2½	(65)	2.875	(73.03)	+0.060	(+1.52)
				–0.018	(–0.46)
3	(80)	3.500	(88.90)	+0.060	(+1.52)
				–0.018	(–0.46)
4	(100)	4.500	(144.30)	+0.060	(+1.52)
				–0.018	(–0.46)
6	(150)	6.625	(168.28)	+0.066	(+1.68)
				–0.028	(–0.71)
8	(200)	8.625	(219.08)	+0.086	(+2.18)
				–0.040	(–1.02)
10	(250)	10.750	(273.05)	+0.108	(+2.74)
				–0.048	(–1.22)
12	(300)	12.750	(323.85)	+0.128	(+3.25)
				–0.056	(–1.42)
14	(350)	14.000	(355.60)	+0.140	(+3.56)
				–0.062	(–1.57)
16	(400)	16.000	(406.40)	+0.160	(+4.06)
				–0.070	(–1.78)

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5.1.1.2 Inspection limitations. If a manufacturer desires to exclude inspection of proprietary manufacturing processes, the manufacturer shall so advise the purchaser.

5.1.1.3 Plant access. The purchaser's agent shall have free access to those parts of a manufacturer's plant that are necessary to assure that products comply

Table 4 Dimensions for outside diameter (OD) series pipe with cast-iron-pipe-equivalent ODs

Nominal Pipe Size		Outside Diameter		Tolerance	
in.	*(mm)**	*in.*	*(mm)*	*in.*	*(mm)*
2	(50)	2.50	(63.5)	+0.05	(+1.3)
				−0.05	(−1.3)
3	(80)	3.96	(100.6)	+0.06	(+1.5)
				−0.06	(−1.5)
4	(100)	4.80	(121.9)	+0.06	(+1.5)
				−0.06	(−1.5)
6	(150)	6.90	(175.3)	+0.06	(+1.5)
				−0.06	(−1.5)
8	(200)	9.05	(229.9)	+0.06	(+1.5)
				−0.06	(−1.5)
10	(250)	11.10	(281.9)	+0.06	(+1.5)
				−0.06	(−1.5)
12	(300)	13.20	(335.3)	+0.06	(+1.5)
				−0.06	(−1.5)
14	(350)	15.30	(388.6)	+0.05	(+1.3)
				−0.08	(−2.0)
16	(400)	17.40	(442.0)	+0.05	(+1.3)
				−0.08	(−2.0)
18	(450)	19.50	(495.3)	+0.05	(+1.3)
				−0.08	(−2.0)
20	(500)	21.60	(548.6)	+0.05	(+1.3)
				−0.08	(−2.0)
24	(600)	25.80	(655.3)	+0.05	(+1.3)
				−0.08	(−2.0)
30	(800)	32.00	(812.8)	+0.08	(+2.0)
				−0.06	(−1.5)
36	(900)	38.30	(972.8)	+0.08	(+2.0)
				−0.06	(−1.5)
42	(1,100)	44.50	(1,130.3)	+0.08	(+2.0)
				−0.06	(−1.5)
48	(1,200)	50.80	(1,290.3)	+0.08	(+2.0)
				−0.06	(−1.5)
54	(1,800)	57.56	(1,462.0)	+0.08	(+2.0)
				−0.06	(−1.5)
60	(1,500)	61.61	(1,564.9)	+0.08	(+2.0)
				−0.06	(−1.5)

*Closest customary metric equivalent.

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Table 5 Metric dimensions for outside diameter (OD) series pipe

Nominal Pipe Size		Outside Diameter			
Metric Dimension*	Closest US Customary Unit Equivalent	Metric Dimension	US Customary Unit Equivalent†	Tolerance	
mm	*in.*	*mm*	*in.*	*mm*	*(in.)*
25	1	30	1.18	+1.5	(+0.06)
				−2.0	(−0.08)
40	1½	45	1.77	+1.6	(+0.06)
				−2.0	(−0.08)
50	2	55	2.17	+1.6	(+0.06)
				−2.0	(−0.08)
80	3	86	3.39	+1.7	(+0.07)
				−2.0	(−0.08)
100	4	106	4.17	+1.8	(+0.07)
				−2.0	(−0.08)
150	6	157	6.18	+1.9	(+0.07)
				−2.0	(−0.08)
200	8	208	8.19	+2.0	(+0.08)
				−2.0	(−0.08)
250	10	259	10.20	+2.1	(+0.08)
				−2.0	(−0.08)
300	12	310	12.20	+2.3	(+0.09)
				−2.0	(−0.08)
400	16	412	16.22	+2.5	(+0.10)
				−2.0	(−0.08)
500	20	514	20.24	+2.8	(+0.11)
				−2.0	(0.08)
600	24	616	24.25	+3.0	(+0.12)
				−2.0	(−0.08)
700	27	718	28.27	+3.3	(+0.13)
				−2.0	(−0.08)
800	30	820	32.28	+3.5	(+0.14)
				−2.0	(−0.08)
900	36	922	36.30	+3.8	(+0.15)
				−2.0	(−0.08)
1,000	39	1,024	40.31	+4.0	(+0.16)
				−2.0	(−0.08)
1,200	48	1,228	48.35	+4.5	(+0.18)
				−2.0	(−0.08)
1,400	54	1,432	56.38	+5.0	(+0.20)
				−2.0	(−0.08)
1,600	63	1,636	64.41	+5.5	(+0.22)
				−2.0	(−0.08)
1,800	72	1,840	72.44	+6.0	(+0.24)
				−2.0	(−0.08)

*Values taken from international practice; values in parentheses indicate nonpreferred diameters.

†US customary unit equivalent ID obtained by dividing millimetres by 25.4.

Table continued next page.

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Table 5 Metric dimensions for outside diameter (OD) series pipe—continued

Nominal Pipe Size		Outside Diameter			
Metric Dimension*	Closest US Customary Unit Equivalent	Metric Dimension	US Customary Unit Equivalent†	Tolerance	
mm	*in.*	*mm*	*in.*	*mm*	*(in.)*
2,000	78	2,044	80.47	+6.5	(+0.26)
				−2.0	(−0.08)
(2,200)	84	2,248	88.50	+7.0	(+0.28)
				−2.0	(−0.08)
2,400	96	2,452	96.54	+7.5	(+0.30)
				−2.0	(−0.08)
(2,600)	102	2,656	104.57	+8.0	(+0.31)
				−2.0	(−0.08)
2,800	108	2,860	112.60	+8.5	(+0.33)
				−2.0	(−0.08)
(3,000)	120	3,064	120.63	+9.0	(+0.35)
				−2.0	(−0.08)
3,200	126	3,268	128.66	+9.5	(+0.37)
				−2.0	(−0.08)
(3,400)	132	3,472	136.69	+10.0	(+0.39)
				−2.0	(−0.08)
3,600	144	3,676	144.72	+10.5	(+0.41)
				−2.0	(−0.08)

*Values taken from international practice; values in parentheses indicate nonpreferred diameters.
†US customary unit equivalent ID obtained by dividing millimetres by 25.4.

with all requirements of this standard and of the purchaser. Access may be limited to areas of the manufacturer's plant not specifically excluded by the terms of Sec. 5.1.1.2.

5.1.1.4 Inspection aids. The manufacturer shall make available to the purchaser's agent, without charge, such tools and assistance as are necessary for inspection and handling of materials.

5.1.2 *Quality control tests and records.* The manufacturer shall take adequate measures in the production of products to assure compliance with the requirements of this standard. To ensure compliance, the following tests shall be performed at the indicated intervals, unless otherwise specified by the purchaser. The manufacturer shall maintain a record of all quality control tests for a period of not less than two years and, if requested, shall submit the data to the purchaser.

5.1.2.1 Hydrostatic leak tests. Unless otherwise agreed on by the purchaser and supplier, the manufacturer shall perform hydrostatic leak tests to all pipe sizes 1 in. through 54 in. (25 mm through 1,400 mm). For sizes greater than 54 in. (1,400 mm), the frequency of hydrostatic leak tests shall be as agreed on by the manufacturer and purchaser. The pipe shall not fail, leak, or weep when tested at ambient temperatures according to Sec. 5.1.2.1.1.

5.1.2.1.1 A length of pipe, when tested, shall be placed in a hydrostatic-pressure test machine that seals the ends of the pipe. The pipe shall be filled with water,

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Table 6 Metric dimensions for outside diameter (OD) series pipe with ductile-iron-pipe-equivalent ODs*

Nominal Pipe Size		Outside Diameter			
Metric Dimension	Closest US Customary Unit Equivalent	Metric Dimension	US Customary Unit Equivalent†	Tolerance	
mm	*in.*	*mm*	*in.*	*mm*	*(in.)*
80	3	98	3.86	+1.0	(+0.04)
				–2.7	(–0.11)
100	4	118	4.65	+1.0	(+0.04)
				–2.8	(–0.11)
150	6	170	6.69	+1.0	(+0.04)
				–2.9	(–0.11)
200	8	222	8.74	+1.0	(+0.04)
				–3.0	(–0.12)
250	10	274	10.79	+1.0	(+0.04)
				–3.1	(–0.12)
300	12	326	12.83	+1.0	(+0.04)
				–3.3	(–0.13)
350	14	378	14.88	+1.0	(+0.04)
				–3.4	(–0.13)
400	16	429	16.89	+1.0	(+0.04)
				–3.5	(–0.14)
500	20	532	20.94	+1.0	(+0.04)
				–3.8	(–0.15)
600	24	635	25.00	+1.0	(+0.04)
				–4.0	(–0.16)
700	27	738	29.06	+1.0	(+0.04)
				–4.3	(–0.17)
800	30	842	33.15	+1.0	(+0.04)
				–4.5	(–0.18)
900	36	945	37.20	+1.0	(+0.04)
				–4.8	(–0.19)
1,000	39	1,048	41.26	+1.0	(+0.04)
				–5.0	(–0.20)
1,200	48	1,255	49.41	+1.0	(+0.04)
				–5.5	(–0.22)
1,400	54	1,462	57.56	+1.0	(+0.04)
				–6.0	(–0.24)
1,600	63	1,668	65.67	+1.0	(+0.04)
				–7.4	(–0.29)
1,800	72	1,875	73.82	+1.0	(+0.04)
				–8.2	(–0.32)
2,000	78	2,082	81.97	+1.0	(+0.04)
				–9.0	(–0.35)

*Values taken from ISO 2531.

†US customary unit equivalent OD obtained by dividing millimetres by 25.4.

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expelling all air, and an internal water pressure shall be applied at a uniform rate until a pressure of two times the pressure class is reached (see Table 7). This test pressure shall be maintained for at least 30 s. The pipe shall show no visual signs of weeping or leakage. Integral bells, including reinforcement sleeves, if any, or affixed couplings, shall be tested with the pipe.

5.1.2.2 Stiffness tests. The manufacturer shall perform stiffness tests at a frequency of one test for each 100 lengths of pipe produced or from each manufacturing run, whichever provides the most frequent sampling of each class and size. The minimum pipe stiffness ($F/\Delta y$) shall be determined at 5 percent deflection using the apparatus and procedure of ASTM D2412, with three exceptions. The exceptions are (1) the wall thickness shall be measured to the nearest 0.01 in. (0.25 mm); (2) the specimen taken from the pipe barrel shall be loaded to 5 percent deflection, the load shall be recorded, and the specimen shall be examined for evidence of crazing or cracking; and (3) test frequency shall be as specified in this paragraph.

5.1.2.2.1 The pipe shall exhibit, without structural damage, the minimum stiffness specified in Table 8 when tested in accordance with Sec. 5.1.2.2.

5.1.2.2.2 At deflection level A (Table 9), there shall be no visual evidence, when inspected without magnification, of cracking or crazing in a sample of the pipe barrel. At deflection level B (Table 9), there shall be no visual indication, when inspected without magnification, of structural damage to the pipe wall evidenced by interlaminar separation, tensile failure of the glass-fiber reinforcement, fracture, or buckling of the pipe wall. Both level A and level B criteria must be met. The pipe stiffness test specimen may be used for these tests.

NOTE: The deflection criteria presented in Table 9 are based on a maximum installed long-term field deflection of 5 percent. If the pipe sample fails to meet either or both requirements (that is, for levels A and B), the long-term allowable deflection must be reduced proportionally for the pipes represented by the sample.

Table 7 Hydrostatic leak test pressure requirements

Pressure Class		Hydrostatic Test Pressure	
psi	*kPa*	*psi*	*kPa*
50	345	100	689
100	689	200	1,379
150	1,034	300	2,068
200	1,379	400	2,758
250	1,724	500	3,447

Table 8 Minimum pipe stiffness requirements for 5 percent deflection

Nominal Pipe Size		Stiffness Class—*psi (kPa)*			
		9 (62)	18 (124)	36 (248)	72 (496)
in.	*(mm)*	Minimum Pipe Stiffness Required—*psi (kPa)*			
1–8	(25–200)	NR*	NR	36.0 (248)	72.0 (496)
10	(250)	NR	18.0 (124)	36.0 (248)	72.0 (496)
12–144	(300–3,600)	9.0 (62)	18.0 (124)	36.0 (248)	72.0 (496)

*Not recommended.

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Table 9 Initial ring deflections

	Stiffness Class—*psi (kPa)*			
	9 (62)	18 (124)	36 (248)	72 (496)
Deflection Level	Initial Ring Deflection—% of diameter			
A	18	15	12	9
B	30	25	20	15

5.1.2.3 Hoop tensile strength tests. The manufacturer shall perform hoop tensile strength tests at a frequency of one test for each 100 lengths of pipe produced or from each manufacturing run, whichever provides the most frequent sampling of each class and size. The minimum hoop tensile strength properties shall be determined from the average of the test results of three specimens cut from the sample when using the apparatus and procedure of one of the following test methods:

1. ASTM D2290, procedure A. Specimen width shall be appropriate to the diameter and wall thickness of the pipe. Reduced-section specimens are acceptable. A test apparatus with a varying rate of motion may be used, provided the speed of testing does not exceed 0.10 in./min (2.5 mm/min) in accordance with procedure A. Except in cases of disagreement, routine quality control tests may be performed at ambient conditions of temperature and humidity, and calculations need not include the standard deviation.

2. ASTM D638. The widths of specimens may be increased for pipe wall thicknesses greater than 0.55 in. (14 mm). Means may be provided to minimize the bending moment imposed during the test. Except in cases of disagreement, calculations from routine quality control test results need not include the standard deviation.

3. ASTM D1599.

5.1.2.3.1 The pipe shall meet or exceed the minimum short-term hoop tensile strength calculated by Eq 1 or Eq 2, whichever is greater. The minimum short-term hoop tensile strengths calculated per Eq 2 are given in Table 10.

$$F = \frac{S_i}{S_r}(Pr) \qquad \text{(Eq 1)}$$

$$F = 4.0\,(Pr) \qquad \text{(Eq 2)}$$

Where:

F = required minimum hoop tensile strength, lbf per inch of width (kN/m)
S_i = initial design hoop tensile strength, psi (kPa)
S_r = hoop tensile stress at pressure class, psi (kPa)
P = specified pressure class from Table 7, psi (kPa)
r = nominal pipe radius, in. [(OD—single wall thickness)/2] (m)

5.1.2.3.2 The values of S_i and S_r should be established from the manufacturer's long-term hydrostatic tests performed in accordance with Sec. 4.6.2. S_i shall be taken as the 95 percent lower-confidence level, back extrapolated to 0.1 h. This

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takes into consideration variations in glass-fiber strength and manufacturing methods. S_r is the calculated hoop tensile stress at the pressure class.

5.1.2.4 Axial tensile strength tests. The manufacturer shall perform axial tensile strength tests at a frequency of one test for each 100 lengths of pipe produced or from each manufacturing run, whichever provides the most frequent sampling of each class and size. The minimum axial tensile strength shall be determined from the average of the test results of three specimens cut from the sample when using the apparatus and procedure of ASTM D638 or ASTM D2105, depending on the size of the pipe specimens to be tested.

5.1.2.4.1 The pipe shall meet or exceed the minimum axial tensile strength requirements listed in Table 11 when tested in accordance with ASTM D638 or ASTM D2105. The values in Table 11 are the minimum criteria and are based on buried pipe fully restrained in the axial direction due to soil friction. The values may not be indicative of the axial strength of some products or of the axial strength required under certain installation conditions and joint configurations.

5.1.2.5 Beam-strength tests. The beam-strength test is a design-qualification test required only when there is a significant change in the design or construction of the pipe. A significant change is considered to occur when the average axial tensile strength as determined in Sec. 5.1.2.4 decreases more than 15 percent. Two methods can be used.

Method 1: Method 1 can be used for pipe sizes up to and including 27 in. (700 mm). In method 1, the pipe shall withstand, without failure, the beam loads listed in Table 12 when tested in accordance with the beam-strength test method of ASTM D3517.

Method 2: Method 2 can be used for all pipe sizes. In method 2, the pipe shall meet or exceed (1) the minimum axial tensile strength listed in Table 11 when tested in accordance with Sec. 5.1.2.4; and (2) the minimum axial compressive strength listed in Table 13 when tested in accordance with ASTM D695.

5.1.2.6 Dimensions. The manufacturer shall inspect one length per 100 lengths of pipe before shipment for dimensions and tolerances outlined in Sec. 4.5.

Sec. 5.2 Rejection and Retesting

If the results of any test do not conform to the requirements of this standard, then that test may be repeated on two additional samples from the same lot of pipe. Each of the two samples shall conform to the requirements specified. If either of the two additional samples fail, the lot may be rejected, at the option of the purchaser. Rejection should be reported to the manufacturer or supplier promptly and in writing.

SECTION 6: DELIVERY

Sec. 6.1 Marking

Each standard length and random length shall be clearly marked. Marking shall be applied without indentation so as to remain legible during normal handling and installation practices. At a minimum, these markings shall consist of the following: (1) the phrase *AWWA C950*; (2) nominal pipe size, cell classification, and diameter series; (3) AWWA pressure class; (4) stiffness class; and (5) manufacturer's mark and identity code.

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Table 10 Minimum hoop tensile strength requirements (from Eq 2)

Nominal Pipe Size		Pressure Class—*psi (kPa)*									
		50	(345)	100	(689)	150	(1,034)	200	(1,379)	250	(1,724)
		Minimum Hoop Tensile Strength *lbf/in. of width (kN/m of width)*									
in.	*(mm)*[*]										
1	(25)	100	(18)	200	(35)	300	(53)	400	(70)	500	(88)
1½	(40)	150	(26)	300	(53)	450	(79)	600	(105)	750	(131)
2	(50)	200	(35)	400	(70)	600	(105)	800	(140)	1,000	(175)
2½	(65)	250	(44)	500	(88)	750	(131)	1,000	(175)	1,250	(219)
3	(80)	300	(53)	600	(105)	900	(158)	1,200	(210)	1,500	(263)
4	(100)	400	(70)	800	(140)	1,200	(210)	1,600	(280)	2,000	(350)
6	(150)	600	(105)	1,200	(210)	1,800	(315)	2,400	(420)	3,000	(525)
8	(200)	800	(140)	1,600	(280)	2,400	(420)	3,200	(560)	4,000	(700)
10	(250)	1,000	(175)	2,000	(350)	3,000	(525)	4,000	(700)	5,000	(875)
12	(300)	1,200	(210)	2,400	(420)	3,600	(630)	4,800	(840)	6,000	(1,050)
14	(350)	1,400	(245)	2,800	(490)	4,200	(735)	5,600	(980)	7,000	(1,225)
15	(375)	1,500	(263)	3,000	(525)	4,500	(788)	6,000	(1,050)	7,500	(1,313)
16	(400)	1,600	(280)	3,200	(560)	4,800	(840)	6,400	(1,120)	8,000	(1,400)
18	(450)	1,800	(315)	3,600	(630)	5,400	(945)	7,200	(1,260)	9,000	(1,575)
20	(500)	2,000	(350)	4,000	(700)	6,000	(1,050)	8,000	(1,400)	10,000	(1,750)
21	(550)	2,100	(368)	4,200	(735)	6,300	(1,103)	8,400	(1,470)	10,500	(1,838)
24	(600)	2,400	(420)	4,800	(840)	7,200	(1,260)	9,600	(1,680)	12,000	(2,100)
27	(700)	2,700	(473)	5,400	(945)	8,100	(1,418)	10,800	(1,890)	13,500	(2,363)
30	(800)	3,000	(525)	6,000	(1,050)	9,000	(1,575)	12,000	(2,100)	15,000	(2,625)
33	(850)	3,300	(578)	6,600	(1,155)	9,900	(1,733)	13,200	(2,310)	16,500	(2,888)
36	(900)	3,600	(630)	7,200	(1,260)	10,800	(1,890)	14,400	(2,520)	18,000	(3,150)
39	(1,000)	3,900	(683)	7,800	(1,365)	11,700	(2,048)	15,600	(2,730)	19,500	(3,413)
42	(1,100)	4,200	(735)	8,400	(1,470)	12,600	(2,205)	16,800	(2,940)	21,000	(3,675)
45	(1,150)	4,500	(788)	9,000	(1,575)	13,500	(2,363)	18,000	(3,150)	22,500	(3,938)
48	(1,200)	4,800	(840)	9,600	(1,680)	14,400	(2,520)	19,200	(3,360)	24,000	(4,200)
51	(1,300)	5,100	(893)	10,200	(1,785)	15,300	(2,678)	20,400	(3,570)	25,500	(4,463)
54	(1,400)	5,400	(945)	10,800	(1,890)	16,200	(2,835)	21,600	(3,780)	27,000	(4,725)
60	(1,500)	6,000	(1,050)	12,000	(2,100)	18,000	(3,150)	24,000	(4,200)	30,000	(5,250)
66	(1,700)	6,600	(1,155)	13,200	(2,310)	19,800	(3,465)	26,400	(4,620)	33,000	(5,775)
72	(1,800)	7,200	(1,260)	14,400	(2,520)	21,600	(3,780)	28,800	(5,040)	36,000	(6,300)
78	(2,000)	7,800	(1,365)	15,600	(2,730)	23,400	(4,095)	31,200	(5,460)	39,000	(6,825)
84	(2,200)	8,400	(1,470)	16,800	(2,940)	25,200	(4,410)	33,600	(5,880)	42,000	(7,350)
90	(2,300)	9,000	(1,575)	18,000	(3,150)	27,000	(4,725)	36,000	(6,300)	45,000	(7,875)
96	(2,400)	9,600	(1,680)	19,200	(3,360)	28,800	(5,040)	38,400	(6,720)	48,000	(8,400)
102	(2,600)	10,200	(1,785)	20,400	(3,570)	30,600	(5,355)	40,800	(7,140)	51,000	(8,925)
108	(2,800)	10,800	(1,890)	21,600	(3,780)	32,400	(5,,670)	43,200	(7,560)	54,000	(9,450)
114	(2,900)	11,400	(1,995)	22,800	(3,990)	34,200	(5985)	45,600	(7,980)	57,000	(9,975)
120	(3,000)	12,000	(2,100)	24,000	(4,200)	36,000	(6,300)	48,000	(8,400)	60,000	(10,500)
132	(3,400)	13,200	(2,310)	26,400	(4,620)	39,600	(6,930)	52,800	(9,240)	66,000	(11,550)
144	(3,600)	14,400	(2,520)	28,800	(5,040)	43,200	(7,560)	57,600	(10,080)	72,000	(12,600)

[*]Closest customary metric equivalent.

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Table 11 Minimum axial tensile strength requirements

Nominal Pipe Size		Pressure Class—*psi (kPa)*									
		50	(345)	100	(689)	150	(1,034)	200	(1,379)	250	(1,724)
		Minimum Axial Tensile Strength									
in.	*(mm)**	*lbf/in. of circumference (kN/m of circumference)*									
1	(25)	360	(63)	360	(63)	360	(63)	360	(63)	360	(63)
1½	(40)	360	(63)	360	(63)	360	(63)	360	(63)	360	(63)
2	(50)	360	(63)	360	(63)	360	(63)	360	(63)	360	(63)
2½	(65)	360	(63)	360	(63)	360	(63)	360	(63)	360	(63)
3	(80)	360	(63)	360	(63)	360	(63)	360	(63)	360	(63)
4	(100)	360	(63)	360	(63)	360	(63)	360	(63)	360	(63)
6	(150)	360	(63)	360	(63)	360	(63)	360	(63)	387	(68)
8	(200)	580	(102)	580	(102)	580	(102)	580	(102)	580	(102)
10	(250)	580	(102)	580	(102)	580	(102)	580	(102)	726	(127)
12	(300)	580	(102)	580	(102)	644	(113)	697	(122)	871	(153)
14	(350)	580	(102)	580	(102)	751	(132)	813	(142)	1,016	(178)
15	(375)	580	(102)	580	(102)	805	(141)	870	(152)	1,089	(191)
16	(400)	580	(102)	580	(102)	859	(150)	929	(163)	1,161	(203)
18	(450)	580	(102)	608	(108)	911	(160)	972	(170)	1,215	(213)
20	(500)	580	(102)	675	(118)	1,013	(177)	1080	(189)	1,350	(236)
21	(550)	580	(102)	709	(124)	1,063	(186)	1134	(199)	1,418	(248)
24	(600)	580	(102)	810	(142)	1,215	(213)	1296	(227)	1,620	(284)
27	(700)	580	(102)	911	(156)	1,367	(239)	1458	(255)	1,823	(319)
30	(800)	580	(102)	952	(167)	1,428	(250)	1499	(263)	1,873	(328)
33	(850)	640	(111)	1,047	(183)	1,570	(275)	1648	(289)	2,060	(361)
36	(900)	700	(122)	1,142	(200)	1,713	(300)	1798	(315)	2,248	(394)
39	(1,000)	780	(137)	1,237	(217)	1,856	(325)	1948	(341)	2,435	(426)
42	(1,100)	800	(140)	1,332	(233)	1,998	(350)	2098	(367)	2,622	(459)
45	(1,150)	860	(150)	1,332	(233)	1,998	(350)	2126	(372)	2,658	(465)
48	(1,200)	920	(161)	1,393	(244)	2,090	(366)	2268	(397)	2,835	(496)
51	(1,300)	980	(171)	1,480	(259)	2,200	(389)	2410	(422)	3,012	(527)
54	(1,400)	1,040	(182)	1,567	(274)	2,351	(412)	2552	(447)	3,189	(558)
60	(1,500)	1,140	(200)	1,742	(305)	2,612	(457)	2835	(496)	3,544	(621)
66	(1,700)	1,260	(220)	1,916	(336)	2,873	(503)	3119	(546)	3,898	(683)
72	(1,800)	1,360	(238)	2,090	(366)	3,135	(549)	3402	(596)	4,253	(745)
78	(2,000)	1,480	(260)	2,106	(369)	3,159	(553)	3475	(609)	4,344	(761)
84	(2,200)	1,600	(280)	2,268	(397)	3,402	(596)	3742	(655)	4,678	(819)
90	(2,300)	1,720	(301)	2,430	(426)	3,645	(638)	4010	(702)	5,012	(878)
96	(2,400)	1,840	(322)	2,592	(454)	3,888	(681)	4277	(749)	5,346	(936)
102	(2,600)	1,940	(340)	2,754	(482)	4,131	(723)	4544	(796)	5,680	(995)
108	(2,800)	2,060	(360)	2,916	(511)	4,374	(766)	4811	(843)	6,014	(1,053)
114	(2,900)	2,160	(382)	3,078	(539)	4,617	(809)	5078	(889)	6,348	(1,112)
120	(3,000)	2,280	(400)	3,240	(567)	4,860	(851)	5346	(936)	6,683	(1,170)
132	(3,400)	2,520	(440)	3,564	(624)	5,340	(935)	5881	(1,030)	7,351	(1,287)
144	(3,600)	2,740	(480)	3,888	(681)	5,832	(1,021)	6415	(1,123)	8,019	(1,404)

*Closest customary metric equivalent.

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Table 12 Beam strength requirements

Nominal Pipe Size		Beam Load P	
in.	*(mm)**	*lbf*	*kN*
1	(25)	10	(.04)
1½	(40)	25	(.11)
2	(50)	45	(.20)
2½	(65)	75	(.33)
3	(80)	100	(.44)
4	(100)	185	(.82)
6	(150)	425	(1.9)
8	(200)	800	(3.6)
10	(250)	1,200	(5.3)
12	(300)	1,600	(7.1)
14	(350)	2,200	(9.8)
15	(375)	2,600	(11.6)
16	(400)	3,000	(13.3)
18	(450)	4,000	(17.8)
20	(500)	4,400	(19.6)
21	(550)	5,000	(22.2)
24	(600)	6,400	(28.5)
27	(700)	8,000	(35.6)

*Closest customary metric equivalent.

Sec. 6.2 Shipping

All pipe and couplings shall, unless otherwise specified by the purchaser, be prepared for standard commercial shipment.

Sec. 6.3 Affidavit of Compliance

The manufacturer shall, if so specified by the purchaser, furnish an affidavit that all delivered materials comply with the requirements of this standard and of the purchaser.

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Table 13 Minimum axial compressive strength requirements

Nominal Pipe Size		Minimum Axial Compressive Strength	
in.	*(mm)*[*]	*lbf/in. of circumference*	*(kN/m of circumference)*
1–6	(25–150)	360	(63)
8–30	(200–800)	580	(102)
33	(850)	640	(111)
36	(900)	700	(122)
39	(1,000)	780	(137)
42	(1,100)	800	(140)
45	(1,150)	860	(150)
48	(1,200)	920	(161)
51	(1,300)	980	(171)
54	(1,400)	1,040	(182)
60	(1,500)	1,140	(200)
66	(1,700)	1,260	(220)
72	(1,800)	1,360	(238)
78	(2,000)	1,480	(260)
84	(2,200)	1,600	(280)
90	(2,300)	1,720	(301)
96	(2,400)	1,840	(322)
102	(2,600)	1,940	(340)
108	(2,800)	2,060	(360)
114	(2,900)	2,180	(382)
120	(3,000)	2,280	(400)
132	(3,400)	2,520	(440)
144	(3,600)	2,740	(480)

*Closest customary metric equivalent.

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AWWA STANDARD

FOR

FACTORY-COATED BOLTED STEEL TANKS FOR WATER STORAGE

AMERICAN NATIONAL STANDARD

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AWWA Standard

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All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

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Foreword

This foreword is for information only and is not a part of AWWA D103.

I. Introduction.

I.A. *Background.* This standard covers factory-coated bolted steel tanks for water storage and is based on the accumulated knowledge and experience of manufacturers of bolted steel tanks.*

I.B. *History.* The first version of this standard was prepared in cooperation with the Bolted Tank Manufacturer's Association and was issued in 1980. It was prepared in response to the increasing use of bolted tanks for water storage. AWWA D103-80 was later updated and approved as AWWA D103-87 on June 14, 1987. The third and current edition of ANSI/AWWA D103-97 was approved by the AWWA Board of Directors on June 15, 1997.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF) to develop voluntary third-party consensus standards and a certification program for all direct and indirect drinking water additives. Other members of the original consortium included the American Water Works Association Research Foundation (AWWARF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.† Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.
2. Specific policies of the state or local agency.
3. Two standards developed under the direction of NSF, ANSI‡/NSF§ 60, Drinking Water Treatment Chemicals—Health Effects, and ANSI/NSF 61, Drinking Water System Components—Health Effects.
4. Other references, including AWWA standards, *Food Chemicals Codex*, *Water Chemicals Codex*,** and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with ANSI/NSF 61. Individual states or local agencies have authority to

*The word *tanks* is used hereinafter broadly in place of the lengthy phrase *standpipes or reservoirs for water storage.*

†Persons in Canada, Mexico, and non-North American countries should contact the appropriate authority having jurisdiction.

‡American National Standards Institute, 11 W. 42nd St., New York, NY 10036.

§NSF International, 3475 Plymouth Rd., Ann Arbor, MI 48106.

**Both publications available from National Academy of Sciences, 2102 Constitution Ave. N.W., Washington, DC 20418.

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accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Appendix A, "Toxicology Review and Evaluation Procedures," to ANSI/NSF 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Appendix A procedures may not always be identical, depending on the certifier.

AWWA D103-97 does not address additives requirements. Thus, users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements including applicable standards.
2. Determine the status of certifications by all parties offering to certify products for contact with, or treatment of, drinking water.
3. Determine current information on product certification.

II. Special Issues.

II.A. *Purchase.* When tanks are purchased using this standard, the purchaser must specify certain basic requirements. The purchaser may desire to modify, delete, or amplify sections of this standard to suit special conditions. It is strongly recommended that such modifications, deletions, or amplifications be made by supplementing this standard rather than by rewriting or incorporating sections from this standard into a separate specification.

II.B. *Design and Construction.* The details of design and construction covered by this standard are minimum requirements. A tank cannot be represented as adhering to the provisions of AWWA D103 if it does not meet the minimum requirements of this standard.

II.C. *Coatings.* Tanks covered by this standard shall be supplied with factory-applied coatings. Field coating is limited to repair of damaged coatings.

Tanks with factory-applied coatings and bolted construction have a long life expectancy. Regular inspection and repair of damaged or deteriorated areas may be the determining factors in the length of tank life.

II.D. *Foundations.* Tank foundations are one of the more important aspects of tank design. Detailed requirements for tank foundations are covered in Sec. 11 of this standard. This standard does not require the manufacturer or constructor to be responsible for the design of the tank foundation unless otherwise specified by the purchaser. Unless otherwise specified by the purchaser, the purchaser must obtain an adequate soil investigation at the tank site, including recommendations of the type of foundation to be used, the depth of foundation required, and the design soil-bearing pressure. This information, as well as specifications for an adequate soil investigation, should be established by a qualified geotechnical engineer. The top of the foundation should be 6 in. minimum above the finished grade, unless otherwise specified by the purchaser.

A drainage inlet structure or suitable erosion protection should be provided to receive the discharge from the tank overflow. The overflow shall not be connected directly to a sewer or a storm drain without an air break.

II.E. *Annual Inspection and Maintenance.* Inspection and maintenance is important if maximum tank life is to be attained. Inspections should occur at least every 3 to 5 years. In particular, accumulations of dirt and weeds from around the outside base of the tank, which may trap moisture and accelerate corrosion, as well as accumulated silt inside on the floor, should be removed.

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II.F. *Disinfection Procedures and Cathodic Protection.* This standard does not cover disinfecting procedures* (see Sec. 9.4) or cathodic protection.

1. If the disinfecting is to be done by the tank constructor, the purchaser must specify how such disinfecting is to be done.
2. The purchaser is responsible for determining the need for, the design of, and the specifications for cathodic protection (see ANSI/AWWA D104).

II.G. *Recommended Items to Be Furnished by the Purchaser and Manufacturer.* The following recommendations on items to be furnished by both the purchaser and the manufacturer are considered good practice, but are not requirements of ANSI/AWWA D103.

When a bolted steel tank is to be purchased under the provisions of this standard, the purchaser should provide the following:

1. The site on which the tank is to be built, including sufficient space to permit the structure to be erected by customary methods.
2. Foundation design and construction unless otherwise specified.
3. Water at the proper pressure for testing, as required, and facilities for disposal of wastewater after testing.
4. A suitable right-of-way from the nearest public road to the erection site.
5. Any materials furnished by the purchaser to be used by the constructor for construction of the tank.

The manufacturer should furnish the following:

1. Foundation loads and reactions imposed on the foundations by the tank.
2. Anchor bolts, if required, for wind, earthquake, or other lateral loads, or if specified to be furnished.
3. All labor and materials, except materials furnished by the purchaser, that are necessary to manufacture the structure components, including the accessories required by this standard.

Variations in the responsibilities of both the purchaser and the manufacturer as previously outlined may be made by the contractual agreement. The purchaser and the bidder should each furnish information identified in the sections that follow.

III. Use of This Standard. AWWA has no responsibility for the suitability or compatibility of the provisions of this standard to any application by any user. Accordingly, each user of this standard is responsible for determining that the standard's provisions are suitable for and compatible with that user's intended application.

III.A. *Purchaser Options and Alternatives.* The following information should be furnished by the purchaser when taking bids for a standpipe or reservoir:

1. For standpipes, the capacity and top capacity level.
2. For reservoirs, the capacity and diameter.
3. Desired time for completion.
4. Site location.
5. Type of road available for access to the site, and whether the road is public or private.
6. Name of and distance to the nearest town.
7. Name of and distance to the nearest railroad siding.

*Various disinfection procedures are presented in AWWA C652, Standard for Disinfection of Water-Storage Facilities.

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8. Availability of electric power; who furnishes it and at what fee, if any; what voltage is available; whether direct or alternating current; and, if alternating current, what cycle and phase.

9. Availability of compressed air and what pressure, volume, and fee are available, if any.

10. The bottom capacity level of the tank when empty if different from the level when the tank would be emptied through the specified discharge piping (Sec. 1.2.9).

11. The type of pipe and fittings for fluid conductors and the type of pipe joint if different from that permitted in Sec. 2.9.

12. If snow loading is to be omitted when the tank is located in an area where actual snow loading is insignificant (Sec. 3.2.3).

13. Specific wind-load requirements, including whether a sliding check for unanchored tanks is required (Sec. 3.2.4).

14. Unless the purchaser specifies that seismic design be omitted, all seismic designs will be based on pseudo-dynamic criteria (Sec. 12). When seismic design is required, purchaser shall identify which zone—1, 2A, 2B, 3 or 4—is to be used.

15. Locations of manholes, ladders, and any additional accessories required (Sec. 5).

NOTE: Only one shell manhole will be provided unless the purchaser otherwise specifies (Sec. 5.1).

16. The number and location of pipe connections, and type and size of pipe to be accommodated.

NOTE: Connections to the piping furnished by the constructor are to be made by the purchaser (Sec. 5.2).

17. If a removable silt stop is required (Sec. 5.2.1).

18. Overflow type, whether stub or to ground; size of pipe; pumping and discharge rates (Sec. 5.3).

19. If the roof ladder for providing access to roof hatches and vents is to be omitted (Sec. 5.4.3).

20. If safety cages, rest platforms, ladder locks, roof-ladder handrails, or other safety devices are required, and on which ladders (Sec. 5.5).

NOTE: The purchaser should specify the beginning location of the outside tank ladder if it is other than 8 ft above the level of the tank bottom.

21. If a special vent is required for screening the tank vent (Sec. 5.7).

22. If shop inspection is required, and whether typical mill-test reports are required (Sec. 9.1).

23. Unless otherwise specified, soil investigation, including foundation-design criteria (Sec. 11.2), type of foundation (Sec. 11.4.1), depth of foundation below existing grade, and design soil-bearing pressure, including factor of safety.

NOTE: The top of the foundation is to be 6 in. minimum above the finish grade unless otherwise specified by the purchaser (Sec. 11.5.1).

24. If a steel tank bottom or a steel base setting ring is to be used (Sec. 11.4.1, type 6).

25. When a pile-supported foundation is required, the purchaser should specify pile type and depth below existing grade (Sec. 11.5.4).

26. If all requirements of ACI 301, Specifications for Structural Concrete for Buildings, are applicable to the concrete work (Sec. 11.6).

27. Vertical distance from finished ground level to the crown of inlet and outlet pipes (that is, pipe cover) at tank foundation (Sec. 11.7.2).

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28. Completion of the Tabulation Form for Seismic Data when seismic design is required (Sec. 12.1.2).

29. If vertical acceleration is to be considered and how it is to be applied in seismic design (Sec. 12.3.7.1).

30. Amount of freeboard for sloshing wave (Sec. 12.3.7.2).

31. If seismic design of roof framing and columns is required (Sec. 12.3.7.3), and the amount of live loads and vertical acceleration to be used.

32. If local seismic data are available and if they are to be used in place of acceleration and spectral velocity values (Sec. 12.4) and the reduction factor to be used if scaled-down response spectra are used (Sec. 12.4.1).

33. If an aluminum dome roof is to be provided as discussed in Sec. 13.

34. If the aluminum dome roof is to be provided, whether the exterior of the dome is to have a factory-applied baked-on finish.

III.B. *Information to Be Furnished by the Manufacturer or Constructor.* The following information shall be furnished by the manufacturer or constructor for a standpipe or reservoir:

1. Dimensions of the standpipe or reservoir, including the diameter, shell height type of bottom, type of roof, type of coating, details of bolted joints, and type and size of plates, members, and anchorages shall be identified. The gross moment and shear imparted to the foundation under seismic and wind loading should also be identified at the time of the bid.

2. The number, names, and sizes of all accessories. This includes the type of roof ladder if an alternative method from that required in Sec. 5.4.3 is proposed.

3. If the purchaser specifies that the tank is to be cathodically protected, the constructor shall certify in the bid that the tank will be erected so as to provide electrical continuity of all tank components in contact with water.

III.C. *Items for Consideration by the Purchaser.* The design, construction, and final placement of a storage tank into service requires cooperation between the purchaser, manufacturer, and constructor of the tank. Various practices are used to ensure successful tank placement. The following items are suggested for inclusion in the purchaser's specifications, unless local practice dictates otherwise. Please note that this material is not stipulated in the text of ANSI/AWWA D103.

1. The purchaser may want to provide for field inspection to be performed either by the purchaser or by a commercial inspection agency, the cost of which shall be paid by the purchaser. As an option, the purchaser may require the manufacturer or constructor to perform the inspection work and, at the conclusion of the work, to submit a written report. The report should include a statement indicating that the tank has been erected according to the manufacturer's instructions, that the required testing has been performed, and that any leaks have been repaired.

2. The roof opening in the tank should be located near the overflow to provide for visual inspection of the overflow.

3. This standard assumes that the purchaser (owner) provides sufficient water replacement and circulation to prevent freezing in the tank and riser pipe. Where low usage may result in the possibility of freezing, the purchaser shall waste water or provide heat to prevent freezing. The purchaser is referred to National Fire Protection Association (NFPA)* document NFPA 22, Water Tanks for Private Fire Protection, for heater sizing. Purchasers are cautioned against allowing ice to build

*National Fire Protection Association, One Batterymarch Park, Quincy, MA 02269.

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up for use as insulation because the ice may break loose and damage the tank. Where reference to ice damage is discussed in the standard, it is in anticipation of improper operation rather than approval of an icing condition.

4. On completion of the tank erection, it is recommended that the constructor dispose of all rubbish and other unsightly material caused by the operations and leave the premises in as good a condition as found at the start of the tank erection. It is recommended that the purchaser provide appropriate containers for placement and removal of disposed materials. Section 8.5 of ANSI/AWWA D103 does not list requirements for cleanup.

5. ANSI/AWWA D103 does not require the manufacturer or constructor to blind and fill the tank to top capacity level, according to the manufacturer's recommendations (see Sec. 9.2). It is common practice for the purchaser to provide this effort. Should the purchaser require that the manufacturer or constructor provide this service and a supply of water, this must be provided for in the purchaser's specifications.

6. ANSI/AWWA D103 does not require the manufacturer or constructor to furnish foundation plans (see Sec. 11.1.1). Should the purchaser specify submission of foundation plans, the purchaser must furnish adequate information relative to the type of foundation, foundation depth, and allowable soil-bearing pressure. (See Sec. II.D of the foreword and Sec. 11 for further information.)

7. ANSI/AWWA D103 does not require the manufacturer or constructor to construct and install a foundation. Should the purchaser require that a foundation be provided by the manufacturer or constructor, any information other than that contained in Sec. 11 of this standard must also be provided by the purchaser.

8. It is recommended that the purchaser retain a qualified geotechnical consultant to conduct a proper soil investigation. Unless otherwise specified by the purchaser, ANSI/AWWA D103 does not require that the manufacturer or constructor provide this service (see Sec. 11.3).

9. ANSI/AWWA D103 does not require the manufacturer or constructor to provide specifications for the preparation of sub-base materials (Sec. 11.4.1.6). Should the purchaser require that the manufacturer or constructor provide such specifications, this must be provided in the purchaser's specifications.

III.D. *Modification to Standard.* Any modification to the provisions, definitions, or terminology in this standard must be provided in the purchaser's specifications.

IV. Major Revisions. Major changes made to the standard in this revision include the following:

1. The format of the foreword has been changed to AWWA standard style.

2. The acceptance clause (Sec. I.C) and the definitions of parties (Sec. 3) have been revised to approved wording.

3. Changes have been made to Sec. 12, Seismic Design of Flat-Bottomed Water Storage Tanks, to reflect the changes made to ANSI/AWWA D100, Standard for Welded Steel Tanks for Water Storage.

4. A new Sec. 13 was created for structurally supported aluminum dome roofs, which replaces appendix A.

V. Comments. If you have any comments or questions about this standard, please call the AWWA Standards and Materials Development Department, (303) 794-7711 ext. 6283, FAX (303) 795-1440, or write to the department at 6666 W. Quincy Ave., Denver, CO 80235.

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ANSI/AWWA D103-97
(Revision of ANSI/AWWA D103-87)

AWWA STANDARD FOR

FACTORY-COATED BOLTED STEEL TANKS FOR WATER STORAGE

SECTION 1: GENERAL

Sec. 1.1 Scope

The purpose of this standard is to facilitate the manufacture, installation, and procurement of cylindrical bolted steel tanks for the storage of water.

1.1.1 *Tank roofs.* All tanks storing potable water shall have roofs. Tanks storing nonpotable water may be constructed without roofs.

1.1.2 *Work outlined.* The work to be performed by the parties in completing the activities described in this standard is outlined as follows:

1. Foundation constructor:

Section 2, Materials. See Sec. 2.3 for foundation-reinforcing steel.

Section 11, Foundation Design and Construction. The constructor or purchaser is responsible for construction of the foundation. The purchaser is responsible for the design of the foundation.

2. Manufacturer:

Section 2, Materials (except as indicated in item 1 above.)
Section 3, General Design.
Section 4, Sizing of Standpipes and Reservoirs.
Section 5, Accessories for Standpipes and Reservoirs.
Section 6, Welding.
Section 7, Shop Fabrication.
Section 9, Inspection and Testing. See Sec. 9.1 regarding shop inspection.
Section 10, Coatings (except as indicated in item 3).
Section 12, Seismic Design of Flat-Bottom Water-Storage Tanks.

3. Constructor of tank:

Section 6, Welding. (To be used in the field only after prior acceptance by the manufacturer and purchaser.)
Section 8, Erection.
Section 9, Inspection and Testing (except as indicated in item 2).

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Section 10, Coatings. See Sec. 10.2 regarding coating repair to be done in the field.

1.1.3 *Items not covered.* This standard does not cover all details of design and construction because of the large variety of sizes and shapes of tanks. Where details for any specific design are not given, the manufacturer, subject to the approval of the purchaser, shall provide details that are designed and constructed to be as adequate and as safe as those that would otherwise be provided under this standard.

1.1.4 *Local requirements.* This standard is not intended to cover storage tanks erected in areas subject to regulations more stringent than the requirements contained within this standard. In such cases, this standard should be followed on purchases made under the provisions of this standard, insofar as it does not conflict with local requirements. Where more stringent local, municipal, county, or state government requirements exist, such requirements may govern, and this standard shall be interpreted to supplement them.

Sec. 1.2 Definitions

The following definitions shall apply in this standard:

1.2.1 *Capacity:* The net volume that may be removed from a tank filled just to the top capacity level and emptied to the bottom capacity level. The bottom capacity level, if not otherwise specified by the purchaser, shall be the water level in the tank shell when the tank is emptied through the specified discharge piping.

1.2.2 *Constructor:* The party that furnishes the work and materials for placement or installation.

1.2.3 *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.

1.2.4 *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.

1.2.5 *Reservoir:* A flat-bottom cylindrical tank having a shell height equal to or smaller than its diameter.

1.2.6 *Standpipe:* A flat-bottom cylindrical tank having a shell height greater than its diameter.

1.2.7 *Tank:* A standpipe or a reservoir used for water storage.

Sec. 1.3 Responsibilities of Parties

1.3.1 *Manufacturer's responsibility.* The manufacturer shall furnish a structure free of defective materials, including coatings. This responsibility shall be in effect for a period of one year from the date of completion but not more than 14 months from the date of delivery. Any materials proven to be defective within this time shall be replaced or repaired by the manufacturer.

1.3.2 *Constructor's responsibility.* The constructor shall erect the structure free of defects in workmanship. This responsibility shall be in effect for a period of 12 months from the date of acceptance but not more than 12 months from the date of completion of installation by the constructor. Any faulty workmanship found within those periods shall be repaired by the constructor.

1.3.3 *Inspection and repair of tank.* The purchaser must provide the constructor and the manufacturer with the opportunity to inspect and repair the tank, if required, within the responsibility periods enumerated in Sec. 1.3.1 and 1.3.2. Failure of the purchaser to provide an opportunity to inspect within these periods will relieve the constructor and manufacturer of responsibility unless otherwise agreed.

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Sec. 1.4 Drawings to Be Furnished

After award of the contract the manufacturer shall prepare the anchor-bolt layout, when applicable, and assembly drawings, which are to be submitted to the purchaser for approval unless waived, before proceeding with any fabrication. If required by the purchaser, details of all bolted and welded joints shall be referenced on the drawings.

Sec. 1.5 References

This standard references the following documents. In their latest editions, they form a part of this standard to the extent specified within the standard. In any case of conflict, the requirements of this standard shall prevail.

AA* SPC—Standards for Aluminum Sand and Permanent Mold Castings.

AA SAS—Specifications for Aluminum Structures (Sec. 1).

AAMA† 605—Voluntary Specification for High Performance Organic Coatings on Architectural Extrusions and Panels.

ACI‡ 301—Standard Specification for Structural Concrete.

ACI 318—Building Code Requirements for Structural Concrete.

AISC§ ASD—Specification for Structural Steel Buildings—Allowable Stress Design.

AISI** 1010—Carbon Steel: Plates; Structural Shapes; Rolled Floor Plates; Steel Sheet Piling.

AISI SG-673—Specification for the Design of Cold-Formed Steel Structural Members.

ANSI††/ASTM‡‡ A6—Standard Specification for General Requirements for Rolled Steel Bars, Plates, Shapes, and Sheet Piling.

ANSI/ASTM A36—Standard Specification for Carbon Structural Steel.

ANSI/ASTM A53—Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.

ANSI/ASTM A181—Standard Specification for Carbon Steel for Forgings, for General-Purpose Piping.

ANSI/ASTM A194—Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service.

ANSI/ASTM A216—Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service.

ANSI/ASTM A572—Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel.

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*Aluminum Association, 818 Connecticut Ave., Washington, DC 20006.

†Architectural Aluminum Manufacturers Association, 35 E. Wacker Dr., Chicago, IL 60601.

‡American Concrete Institute, Box 19150, Redford Station, Detroit, MI 48219.

§American Institute of Steel Construction, One E. Wacker Dr., Ste. 3100, Chicago, IL 60601-2001.

**American Iron and Steel Institute, 1101 17th St. N.W., Washington, DC 20036.

††American National Standards Institute, 11 W. 42nd St., New York, NY 10036.

‡‡American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

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ANSI/ASTM A607—Standard Specification for Steel, Sheet and Strip, High Strength, Low-Alloy, Columbium or Vanadium, or Both, Hot-Rolled and Cold-Rolled.

ANSI/ASTM A668—Standard Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use.

ANSI/ASTM A715—Standard Specification for Steel Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled, with Improved Formability.

ANSI/AWS* A5.1—Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.

ANSI/AWWA C652—Standard for Disinfection of Water-Storage Facilities.

ANSI/AWWA D104—Standard for Automatically Controlled, Impressed-Current Cathodic Protection for the Interior of Steel Water Tanks.

API† 6A—Specification for Wellhead Equipment.

API 12B—Specification for Bolted Tanks for Storage of Production Liquids.

ASTM A48—Standard Specification for Gray Iron Castings.

ASTM A123—Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.

ASTM A153—Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.

ASTM A240—Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels.

ASTM A283—Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates.

ASTM A307—Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength.

ASTM A325—Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength.

ASTM A490—Standard Specification for Heat-Treated Steel Structural Bolts, 150 ksi Minimum Tensile Strength.

ASTM A563—Standard Specification for Carbon and Alloy Steel Nuts.

ASTM A568—Standard Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for.

ASTM A570—Standard Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled, Structural Quality.

ASTM B695—Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel.

ASTM D395—Standard Test Methods for Rubber Property—Compression Set.

ASTM D412—Standard Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension.

ASTM D471—Standard Test Method for Rubber Property—Effect of Liquids.

ASTM D573—Standard Test Method for Rubber—Deterioration in an Air Oven.

ASTM D1171—Standard Test Method for Rubber Deterioration—Surface Ozone Cracking Outdoors or Chamber (Triangular Specimens).

ASTM D1229—Standard Test Method for Rubber Property—Compression Set at Low Temperatures.

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*American Welding Society, P.O. Box 351040, Miami, FL 33125.

†American Petroleum Institute, 1220 L St. N.W., Washington, DC 20005.

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ASTM D1751—Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types).

ASTM D2240—Standard Test Method for Rubber Property—Durometer Hardness.

ASTM D2244—Standard Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates.

NFPA* 22—Standard for Water Tanks for Private Fire Protection.

SSPC† SP8—Pickling.

SSPC SP10—Joint Surface Preparation Standard Near-White Blast Cleaning.

Fed. Spec.‡ TT-S-230—Sealing Compound: Elastomeric Type, Single Component.

Fed Spec. ZZ-R-765—Rubber Silicone: Low- and High-Temperature and Tear Resistant.

SECTION 2: MATERIALS

Sec. 2.1 General

All materials to be incorporated in any structure to meet the provisions of this standard shall be new, previously unused, and in first-class condition, and shall comply with all of the requirements of this standard.

Sec. 2.2 Bolts and Anchor Bolts

2.2.1 *Bolts.* Bolts for joining tank panels shall conform to the requirements of ASTM A307, ASTM A325, ASTM A490, or API 12B. Nuts for these bolts shall conform to ANSI/ASTM A194 or ASTM A563.

2.2.2 *Anchor bolts.* Anchor bolts shall conform to the requirements of ANSI/ASTM A36, ASTM A307, or ANSI/ASTM A572, grade 50.

Sec. 2.3 Foundation-Reinforcing Steel

Reinforcing steel in foundations shall comply with the requirements of ACI 318.

Sec. 2.4 Plates and Sheets

Plate and sheet materials shall be open-hearth, electric-furnace, or basic-oxygen-process steel conforming to any of the following ASTM specifications: A36; A283, grade C or D; A570, grade 30, 33, 36, 40, 45, or 50; A572, grade 42, 50, or 60; A607, grade 50, 55, or 60; or A715, grade 50. Plates and sheets may be furnished on the weight basis, with permissible underrun according to the tolerance table for plates ordered to weight published in ANSI/ASTM A6 and for sheets ordered to weight published in ASTM A568. Steel grades designating a yield strength of 50,000 psi or more should not be used on 15-ft or smaller diameter tanks that have form-flanged connections.

*National Fire Protection Association, One Batterymarch Park, Quincy, MA 02269.

†Steel Structures Painting Council, 40 24th St., Ste. 600, Pittsburgh, PA 15222-4643.

‡Federal Specifications, Superintendent of Documents, US Government Printing Office, Washington, DC 20402.

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Sec. 2.5 Structural Shapes

Hot-rolled structural shapes for use under the provisions of this standard shall conform to AISC S335. Material shall conform to ANSI/ASTM A36 or AISI 1010. Aluminum shapes of a suitable alloy for load and service requirements may be used for portions of the tank not in contact with water. The design of all aluminum members shall be in accordance with AA SAS and to the loads specified in Sec. 3 of this standard.

Sec. 2.6 Castings

Iron castings shall conform to ASTM A48, class 30. Steel castings shall conform to ANSI/ASTM A216, grade WCB. Aluminum castings shall conform to AA SPC.

Sec. 2.7 Forgings

2.7.1 *Forgings from plate and sheet materials.* Forgings from plate and sheet materials shall conform to the plate and sheet materials permitted under Sec. 2.4.

2.7.2 *Forgings from other than plate or sheet materials.* Forgings from other than plate or sheet materials shall conform to ANSI/ASTM A668, class E.

2.7.3 *Forged and rolled pipe flanges.* Forged and rolled pipe flanges shall conform to ASTM A181, class 60.

Sec. 2.8 Electrodes

Manual, shielded-metal, arc-welding electrodes shall conform to the requirements of AWS A5.1. Welding electrodes shall be of any E60XX or E70XX classification suitable for the electric current characteristics, the position of welding, and other conditions of intended use. Welding electrodes for other welding processes shall conform to applicable AWS specifications for filler metal.

Sec. 2.9 Pipe for Fluid Conductors

Inlet, outlet, overflow, and other pipes, and all fittings for fluid use shall be as specified by the purchaser. If steel pipe is not otherwise specified, it shall conform to or exceed ANSI/ASTM A53 carbon steel or ASTM A240 300 series stainless steel. Unless otherwise specified, joints may be either screwed or flanged at the option of the manufacturer. Pipe and fittings from warehouse stock may be used if certified by the warehouse to be in accordance with this standard or the purchaser's specifications.

Sec. 2.10 Gaskets and Sealants

The manufacturer shall use gaskets or sealants or a combination of both in accordance with the following requirements.

2.10.1 *Gaskets.* Gasket material shall be of adequate tensile strength and resilience to obtain a leak-proof seal at all seams and joints. Gasket material shall be resistant to weather and ozone exposure as designated by ASTM D1171. Physical requirements are described in Table 1.

2.10.2 *Sealants.* Sealants shall comply with the following:

1. Resistance to temperature. The sealant shall remain flexible when in continuous operation over a temperature range of –40°F to +170°F (–40°C to +76.7°C).

2. Weatherability. The sealant shall be resistant to hardening and cracking. The sealant shall be essentially solid and contain no plasticizers or extenders that could cause shrinkage due to weathering. The sealant shall be resistant to ozone and ultraviolet light.

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Table 1 Physical requirements for gasket material*

Description	Strip and Extruded Gasket Material
Tensile strength, initial, psi minimum, ASTM D412	1,200 psi 8,274 kPa
Tensile strength after oven aging as percent of initial, minimum, ASTM D573	70%
Tensile strength after immersion in distilled water as percent of initial, minimum, ASTM D471	60%
Ultimate elongation, initial, percent of minimum, ASTM D412	175%
Ultimate elongation after oven aging as percent of initial, minimum, ASTM D573	70%
Hardness, Shore A, ASTM D2240	75 ± 5
Hardness change Shore A, after oven aging, ASTM D573	7
Compression set as maximum percent of original, after oven aging, ASTM D395	40%
Low-temperature compression set as maximum percent of original, ASTM D1229	60%
Tear strength, pounds per inch	160 lb/in. 28 kn/m

*Dimensions and tolerances shall be as specified by the manufacturers for the specific standpipe or reservoir requirements.

3. Chemical resistance. The sealant shall be chemically resistant without extraction to water and shall not swell or degrade under normal water-storage conditions.

4. Material specification. The sealant shall be acceptable for use on food-contact surfaces.

5. Primers for sealant. Some sealant materials require the use of a primer on metal or glass for maximum adhesion. Most of these primers contain a volatile solvent. After evaporation of the solvent, the primer shall comply with the requirements of Sec. 2.10.2, item 4.

SECTION 3: GENERAL DESIGN

Sec. 3.1 Types of Joints

3.1.1 *Bolted joints.* All vertical, horizontal, shell-to-roof, and shell-to-bottom plates or sheets shall be field bolted. Bolt holes shall be shop punched or drilled for field assembly. The bolted joints between roof, shell, and bottom sheets and plates that are required to contain water or to be weathertight shall be sealed with suitable gasket material, sealant, or gasket material and sealant as required to make a watertight joint (see Sec. 2.10).

3.1.1.1 It is standard practice for field-assembled tanks to require fit-up alignments. This is acceptable, and the manufacturer's erection procedures shall be followed.

3.1.2 *Welded joints.* Welding may be used to join shop-fabricated subassemblies that are subsequently bolted into place in the field.

Sec. 3.2 Design Loads

The following loads shall be considered in the design of tank structures and foundations.

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3.2.1 *Dead load.* Dead load shall be the estimated weight of all permanent construction and fittings. The unit weights used shall be 490 lb/ft^3 (7,849.1 kg/m^3) for steel and 144 lb/ft^3 (2,306.7 kg/m^3) for concrete.

3.2.2 *Water load.* Water load shall be the weight of all of the liquid when the tank is filled to top capacity level. Unit weight used for water shall be 62.4 lb/ft^3 (1,000 kg/m^3).

3.2.3 *Roof design loads.*

3.2.3.1 Snow load. Snow load shall be a minimum of 25 lb/ft^2 (1,200 Pa) on the horizontal projection of the tank for surfaces having a slope of 30° or less with the horizontal. For surfaces with greater slope, the snow loads shall be neglected. The snow load may be reduced when the tank is located where the lowest one-day mean low temperature is +5°F (–15°C) or warmer, and local experience indicates that a lesser load may be used.

3.2.3.2 The minimum roof-design live load shall be 15 lb/ft^2 (720 Pa). The roof plates or sheets may deflect between structural supports in order to support load.

3.2.4 *Wind load.* Wind pressure shall be assumed to be 30 lb/ft^2 (1,400 Pa) on vertical plane surfaces, 18 lb/ft^2 (860 Pa) on projected areas of cylindrical surfaces, and 15 lb/ft^2 (720 Pa) on projected areas of conical and double-curved plate surfaces. These quantities are based on a wind velocity of 100 mph (44.7 m/second). For structures designed for wind velocities of more than 100 mph (44.7 m/second), all aforementioned unit pressures shall be adjusted in proportion to the square of the velocity. When a sliding check for an unanchored tank is specified, a coefficient of friction equal to the tangent of 30 degrees is assumed. The total wind shear force $\leq W$ (tan 30°).

Where:

W = total weight of tank shell, floor, and roof

3.2.5 *Earthquake load.* Structures located in zones 1, 2A, 2B, 3, or 4 shall be designed for seismic loads as defined in Sec. 12 of this standard (for exception, see Sec. 3.2.5.2).

3.2.5.1 Structures located in zone 0 do not require design for earthquake resistance.

3.2.5.2 The purchaser may specify that earthquake design is not required on structures located in zone 1.

3.2.6 *Platform and ladder load.* A vertical load (and only one such load in each case) shall be applied as follows: 1,000 lb (453.6 kg) to each platform; 500 lb (226.8 kg) to any 10 ft^2 (0.93 m^2) area on the tank roof; 500 lb (226.8 kg) on each vertical section of the ladder. All structural parts and connections shall be properly proportioned to withstand such loads. The aforementioned load need not be combined with the snow load specified in Sec. 3.2.3, but shall be combined with the dead load. The platform and roof plating may deflect between structural supports in order to support the loading.

Sec. 3.3 Design Criteria

With the exception of other criteria specifically provided for elsewhere in this standard, the structural design of all standpipes and reservoirs shall be in compliance with the following:

1. AISI SG-671.
2. AISC S335.

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Sec. 3.4 Tank Shell

In the design of the tank shell, the hydrostatic water pressure at the lower edge of each ring of sheets or plates in the tank shell shall be assumed to act undiminished on the entire area of the ring.

3.4.1 *Shell thickness.* When the net tensile stress governs, the thickness of cylindrical shell plates stressed by pressure of the tank contents shall be calculated by the formula*

$$t = \frac{2.6HDSG}{f_t(S-d)} \qquad \text{(Eq 1)}$$

Where:

t = shell plate thickness, in inches
H = height of liquid from the top capacity line just to overflow to the bottom of the shell course being designed, in feet
D = tank diameter, in feet
S = bolt spacing in line perpendicular to line of stress, in inches
G = specific gravity of liquid (1.0 for water)
f_t = allowable tensile stress, in pounds per square inch (Sec. 3.5.3)
d = bolt-hole diameter, in inches

3.4.2 *Compressive stress.* The allowable compressive stress in each ring of sheets or plates under wind or earthquake loading combined with dead load shall be determined by the formula

$$f_s = 15,000\left(\frac{2}{3}\right)\left(100\frac{t}{R}\right)\times\left[2-\left(\frac{2}{3}\right)\left(100\frac{t}{R}\right)\right] \le 15,000 \qquad \text{(Eq 2)}$$

Where:

f_s = allowable compressive stress, in pounds per square inch
t = shell thickness, in inches
R = shell radius, in inches

3.4.3 *Allowable stresses increased by one third.* The allowable stresses may be increased by one third when produced by wind or seismic loading acting alone or in combination with the design dead and water loads, provided the required section computed on this basis is not less than that required for the design dead and water load computed without the one-third stress increase.

*The equations shown throughout this standard are currently for use with the inch-pound system of units only. Metric equivalents are being developed by the Steel Elevated Tanks, Standpipes, and Reservoirs Committee and will be published in the next update of this standard.

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Sec. 3.5 Bolted Joints

In the design of bolted joints, the effect of the gasket and sealant shall be neglected, provided the compressed thickness of the gasket or sealant does not exceed 1/16 in. (1.6 mm).

3.5.1 *Minimum spacing.* The center-to-center distance between bolts shall not be less than $2d$, where d is the diameter of the bolt, in inches (millimetres). The distance from the center of any bolt to an edge or seam shall not be less than $1.5d$. In no case shall the center-to-center or edge-to-center distance be less than

$$\frac{P}{0.6F_y t} \qquad \text{(Eq 3)}$$

Where:

P = force transmitted by the bolt, in pounds
F_y = published yield strength of the sheet or plate, in pounds per square inch
t = thickness of the thinner sheet, in inches

3.5.2 *Multiple bolt lines.* When multiple bolt lines are used, the effective net section area shall not be taken as greater than 85 percent of the gross area.

3.5.3 *Tension on the net section.* The tensile stress on the net section of a bolted connection shall not exceed the lesser of the values determined by the following formulas:

$$f_t = 0.6F_y(1.0 - 0.9r + 3rd/s) \leq 0.6F_y \qquad \text{(Eq 4)}$$

or

$$f_t = 0.40F_u \qquad \text{(Eq 5)}$$

Where:

f_t = allowable tensile stress, in pounds per square inch
F_y = published yield strength of the sheet material, in pounds per square inch
r = force transmitted by the bolt or bolts at the section considered, divided by the tensile force in the member at that section. If r is less than 0.2, it may be taken to equal zero
d = diameter of bolt, in inches
s = spacing of bolts perpendicular to line of stress, in inches
F_u = published ultimate strength of the sheet material, in pounds per square inch

3.5.4 *Hole bearing stress.* The hole bearing stress on the area $d \times t$ shall not exceed $1.35F_y$. The symbols d and F_y are as defined in Sec. 3.5.3; t is the thickness of the plate under consideration.

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3.5.5 *Bolt shear.* Shear on bolts in live and dead loads shall not exceed the value as determined from the formula

$$f_v = \frac{F_u \times 0.6 \times 0.9}{2.2} = 0.25F_u \qquad \text{(Eq 6)}$$

Where:

f_v = allowable shear stress to the affected area, whether tensile stress area or gross area, in pounds per square inch
F_u = ultimate tensile stress of bolt, in pounds per square inch, as determined by the formula

$$F_u = \frac{F}{A_{ts}} \qquad \text{(Eq 6a)}$$

Where:

F = breaking load of the bolt as determined from tensile tests, in pounds
A_{ts} = tensile stress area as determined from the formula

$$A_{ts} = 0.7854\left(d - \frac{0.9743}{n}\right)^2 \qquad \text{(Eq 6b)}$$

Where:

d = nominal diameter of the bolt, in inches
n = number of threads per inch

3.5.6 *Bolt tension.* The tensile stress on bolts, other than anchor bolts, shall not exceed the lesser of the following:

$$f_t = 0.6F_y \qquad \text{(Eq 7)}$$

or

$$f_t = \frac{F_u}{2.2} \qquad \text{(Eq 8)}$$

The symbols in these expressions are as previously defined in this section, following Eq 5.

When tensile straps are required in a butt-flanged connection, they shall be designed in accordance with Figure 1.

Sec. 3.6 Weld Design Values

3.6.1 *Structural joints.* Welded structural joints shall be proportioned so that the stresses on a section through the throat of the weld, exclusive of weld

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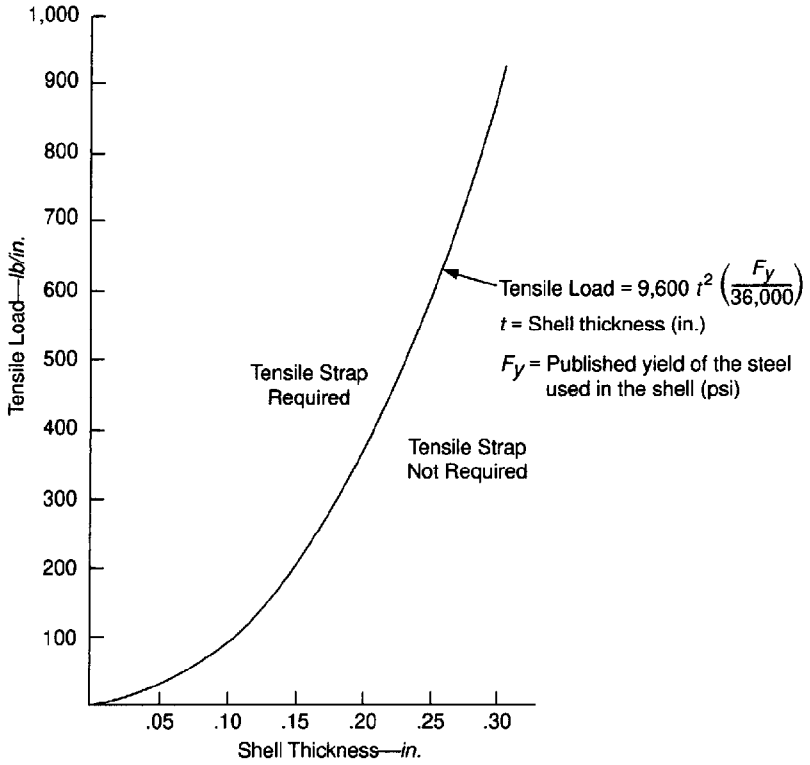

NOTE: This chart is applicable only to tanks with formed flange connections having $^1/_2$-in. (12.7-mm) diameter bolts on 2-in. (50.8-mm) centers at a bolt circle 2 in. (50.8 mm) larger than the shell OD. No increase in allowable loads is permitted when using this chart.

Figure 1 Tensile straps aid in transferring vertical loads across horizontal joints

reinforcement, do not exceed the following percentages of the allowable working tensile stress of the structural material joined.

3.6.1.1 Groove welds. Tension, 85 percent; compression, 100 percent; shear, 75 percent.

3.6.1.2 Fillet welds. Transverse shear, 65 percent; longitudinal shear, 50 percent.

NOTE: Stress in a fillet weld shall be considered as shear on the throat, for any direction of the applied load. The throat of a fillet weld shall be assumed as 0.707 times the length of the shorter leg of the fillet weld having a flat or slightly convex profile.

Sec. 3.7 Top and Intermediate Shell Girders

3.7.1 *Top girder.* A tank without a roof shall have a top girder or angle having a minimum section modulus as determined by the formula

$$S = \frac{HD^2}{10,000}\left(\frac{V}{100}\right)^2 \qquad \text{(Eq 9)}$$

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Where:

S = minimum required section modulus, in cubic inches, of the top angle or girder, including a portion of the tank shell for the allowable distance below as specified in the introductory paragraph of Sec. 3.3, and, if applicable above, the ring attachment to the shell
H = height of the cylindrical portion of the tank shell, in feet
D = tank diameter, in feet
V = wind velocity, greater than 100 mph

3.7.1.1 The total vertical leg of the top girder or angle may be used in the computations, provided that the vertical leg width does not exceed the width-to-thickness ratios set forth in Sec. 3.3.

3.7.2 *Intermediate girders.* The following formula shall be used to determine whether intermediate girders are required between the roof or top girder and the bottom:

$$h = \frac{10.625(10)^6 t}{P(D/t)^{1.5}} \qquad \text{(Eq 10)}$$

Where:

h = vertical distance between the intermediate wind girder and the top angle of the shell or the top wind girder of an open-top tank, in feet
P = wind pressure, in pounds per square foot. This shall be assumed to be 18 unless the wind velocity is specified to be greater than 100 mph, in which case

$$P = 18\left(\frac{\text{wind velocity, in mph}}{100}\right)^2 \qquad \text{(Eq 10a)}$$

D = tank diameter, in feet
t = average shell thickness for the vertical distance h, in inches

3.7.2.1 In determining the maximum height of unstiffened shell, an initial calculation shall be made using the thickness of the top shell course. Additional calculations shall be based on the average thickness obtained by including part or all of the next lower course or courses, until the calculated h is equal to or smaller than the height of shell used in determining the average thickness. If h continues to calculate greater than the height of the shell used in determining the average thickness, then no intermediate girder is required.

3.7.2.2 After establishing the location of the first intermediate girder, if required, repeat the procedure for additional intermediate girders, using the preceding intermediate girder as the top of the tank. Locating the intermediate wind girder at the maximum spacing calculated by the preceding rules will usually result in a shell below the intermediate wind girder having a greater stability against wind loading than the shell above the intermediate girder. The girder may be located at a spacing less than the maximum spacing, but the lower shell must be checked for adequacy against the maximum wind pressure, as previously described or in the following alternative subparagraphs.

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1. Change the width W of each shell course into a transposed width W_{tr} of shell course, having a uniform thickness, by the following relationship:

$$W_{tr} = W\left(\frac{t_{uniform}}{t_{actual}}\right)^{2.5} \quad \text{(Eq 11)}$$

Where:

$t_{uniform}$ = uniform thickness into which the entire shell will be transformed
t_{actual} = actual thickness of the plate course being transformed

2. The sum of the transposed width of each course will give the height of an equivalent transformed shell. For equal stability above or below the intermediate wind girder, the girder should be located at the mid-height of the transformed shell. The location of the girder on the transformed shell shall be transposed to the actual shell by the foregoing thickness relationship, using the actual thickness of the shell course on which the girder will finally be located and all actual thicknesses above this course.

3.7.2.3 When intermediate girders are required, they shall be proportioned in accordance with the formula

$$S = \frac{hD^2}{10{,}000} \times \left(\frac{V}{100}\right)^2 \quad \text{(Eq 12)}$$

Refer to Sec. 3.7.1 and 3.7.2 for an explanation of these symbols.

Sec. 3.8 Roof Supports

Roof supports or stiffeners, if used, shall be designed in accordance with the current specifications of AISC (ASD), with the following stipulations or exceptions:

1. The roof sheet will provide the necessary lateral support of roof rafters from the friction between the roof plates and rafter compression flange, with the following exceptions:
   a. Trusses and open-web joists used as rafters.
   b. Rafters having a nominal depth greater than 15 in. (381 mm)
   c. Rafters having a slope greater than 2 in 12.
2. The roof rafter and purlin depth may be less than fb/600,000 times the span length, provided the roof slope is ¾ in 12 or greater. The symbol fb is the bending unit stress (actual), equal to the bending moment divided by the section modulus of the member.
3. The maximum slenderness ratio L/r for the column supporting rafters shall be 175. L is the laterally unsupported length of the column, in inches, and r is the least radius of gyration, in inches. Columns supporting roofs shall be designed as secondary members.
4. Roof trusses shall be placed above the maximum water level in climates where ice may form.
5. Roof rafters shall be placed above the top capacity level. No part shall project below the top capacity level.

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6. The maximum spacing between roof supports shall be determined by the formula

$$L = \sqrt{\frac{288F_y t^2}{W}} \leq 60 \qquad \text{(Eq 13)}$$

Where:

L = maximum spacing, in inches
F_y = published yield strength of the roof sheet material, in pounds per square inch
t = roof sheet thickness, in inches
W = roof dead load plus live load acting on roof surface, in pounds per square foot

Sec. 3.9 Steel Thickness

Steel thicknesses shall comply with the following:

1. Sheets on roofs having a slope of 1 in 2.75 or greater, for which the tank diameter does not exceed 35 ft (10.7 m), shall have a minimum thickness of 0.070 in. (1.8 mm).

2. Sheets on roofs having a slope less than 1 in 2.75, regardless of tank diameter, shall have a minimum thickness of 0.094 in. (2.4 mm).

3. The minimum thickness of the bottom sheets shall be 0.094 in. (2.4 mm).

4. The maximum thickness of shell plates shall be ⅜ in. (9.5 mm); the minimum thickness shall be 0.094 in. (2.39 mm).

5. The sheet thicknesses in ANSI/AWWA D103 designs are based on the criteria of hydraulic, wind, and seismic loadings with applicable bolted-joint efficiencies.

Sec. 3.10 Foundation Bolts

Foundation anchor bolts may be either upset or not upset and shall comply with the material requirements stated in Sec. 2.2.2. Anchor bolts shall be designed to resist the maximum uplift force. Allowable stresses may be increased as permitted in Sec. 3.4.3. The minimum anchor bolt diameter shall be ¾ in. (19.1 mm) and all anchor bolts shall be galvanized. The allowable tensile stress (F_t) shall be as follows based upon the gross (nominal) area of the bolt. They shall be proportioned for the maximum possible uplift, using the tensile stress area (Sec. 3.5.5) of the thread or the un-upset rod diameter, whichever is smaller, and 70 percent of the allowable tensile stress from Sec. 3.5.6. In no event should anchor bolts be less than ¾ in. in diameter. Foundation bolts may extend to within 3 in. of the bottom of the pier, but not necessarily more than far enough to develop the maximum uplift. Foundation bolts shall terminate in a right-angle hook, bend, head, or washer plate. The bond for plain-rod foundation bolts shall be calculated using the following formula:

$$F_t = 0.33F_u$$

Where:

F_u = minimum tensile strength of the bolt, in pounds per square inch

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The tensile capacity of the threaded portion of an upset rod shall be larger than the body area times $0.6 F_y$, where F_y equals minimum yield strength of the bolt, in pounds per square inch. Anchor bolts may extend to within 3 in. (76.2 mm) of the bottom of a pier or footing, but not necessarily more than required to develop the maximum tension. Anchor bolts shall terminate in a right-angle hook, bend, head, or washer plate. The bond for plain-rod anchor bolts, in addition to the pullout resistance of the hook, bend, head, or washer plate, shall be calculated by the formula

$$U = \frac{4.8\sqrt{f'_c}}{d \times 2} \leq 160 \qquad \text{(Eq 14)}$$

Where:

U = unit bond stress, in pounds per square inch
f'_c = concrete compressive strength, in pounds per square inch
d = diameter of the anchor bolts, in inches

3.10.1 *Bolt projection.* The threaded ends of foundation anchor bolts shall project 2 in. (50.8 mm) above the nominal level of the tops of the foundation anchor bolt nuts to provide for variations in the foundation elevations. Lock nuts shall be provided or the threaded ends of anchor bolts shall be peened to prevent loosening of anchor nuts.

Sec. 3.11 Reinforcement Around Openings

All welded or bolted connections greater than 4 in. (101.6 mm) in diameter in the tank shell and other locations that are subject to hydrostatic pressure, where the thicknesses are established in accordance with the design criteria given in Sec. 3.3, shall be reinforced. The reinforcement may be the flange of a fitting, an additional ring of metal, a thicker plate, or any combination of these.

3.11.1 *Tank shell.* The amount of reinforcement for an opening in the tank shell shall be computed as follows:

The minimum cross-sectional area of the reinforcement shall not be less than the product of the maximum dimension of the hole cut in the tank shell and any bolt holes in the line perpendicular to the direction of the maximum stress and the required shell thickness. The cross-sectional area of the reinforcement shall be measured perpendicular to the direction of maximum stress coincident with the maximum dimension of the opening (100 percent reinforcement). All effective reinforcement shall be made within a distance equal to the maximum dimension of the hole in the shell. The direction of reinforcement shall be perpendicular to the maximum stress. The reinforcement shall be in either direction from the centerline of the shell opening.

3.11.2 *Fittings.* In the computation of the net reinforcing area of a fitting having a neck (such as a boilermaker's flange or a manhole saddle), the following portions of the neck may be considered as part of the area of reinforcement.

1. That portion extending outward from the outside surface of the shell for a distance equal to four times the neck wall thickness or, if the neck wall thickness is not uniform within that distance, to the point of transition.
2. That portion lying within the shell thickness.
3. If the neck extends inwardly, that portion extending inward from the inside surface of the shell for a distance as specified in item 1 above.

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3.11.2.1 The aggregate strength of the weld attaching a fitting to the shell or any intervening reinforcing plate, or both, shall at least equal the proportion of the forces passing through the entire reinforcement that is computed to pass through the fitting.

3.11.2.2 The aggregate strength of the weld attaching any intervening reinforcing plate to the shell shall at least equal the proportion of the forces passing through the entire reinforcement that is computed to pass through the reinforcing plate.

3.11.2.3 The attachment weld joining the flanged fitting or reinforcing plate to the shell shall be considered effective along the outer periphery only for the parts lying outside of the area bounded by parallel lines drawn tangent to the shell opening perpendicular to the direction of maximum stress. The outer peripheral welding, however, shall be applied completely around the reinforcement. All of the inner peripheral weld shall be considered effective. The outer peripheral weld shall be of a size equal to the thickness of the shell or reinforcing plate, whichever is less.

3.11.2.4 Manhole necks, nozzle necks, reinforcing plates, and shell openings that have sheared or oxygen-cut surfaces shall have uniform and smooth surfaces, with the corners rounded, except where these surfaces are fully covered by attachment welds.

3.11.2.5 Flange unions.

3.11.2.5.1 Piping flanges shall conform to the requirements given within this standard, except that, if specified by the purchaser, alternative types having equivalent strength, tightness, and utility may be furnished.

3.11.2.5.2 Except as otherwise provided in Sec. 3.11.2.5.1, bolted piping flanges shall be attached by bolts or bolt studs, and shall conform to the following:

1. Flanges shall be furnished in the sizes given in Table 2, as specified by the purchaser, and shall conform to the provisions of Table 2 and Figure 2.
2. The inner flange shall be provided with bolt-head or bolt-stud nut retainers.
3. The length of thread shall conform to the requirements of Table 2. In all other respects, the threads shall conform to the requirements of API 6A.

3.11.2.5.3 When bolted piping flanges conforming to Table 2 and Figure 2 are furnished, the tank members shall be drilled for flange attachment in accordance with the following stipulations:

1. The bolt-circle diameter and the number of bolt holes shall be as shown in Table 2 and Figure 2.
2. Bolt-hole sizes shall be optional with the manufacturer, but shall conform with the bolt-fit tolerance as shown in Table 2.
3. Flange bolt holes shall straddle the radial centerlines on roofs and bottoms, and vertical centerlines on staves, except that for the 4-in. (101.6-mm) diameter, five-hole flange the odd hole shall be located on the centerline toward the center for the roof or the top of the sheet.

SECTION 4: SIZING OF STANDPIPES AND RESERVOIRS

Sec. 4.1 Standard Capacities

The standard capacities for standpipes and reservoirs shall be as published by the manufacturer and shall be calculated to the nearest 1,000 gal (m^3).

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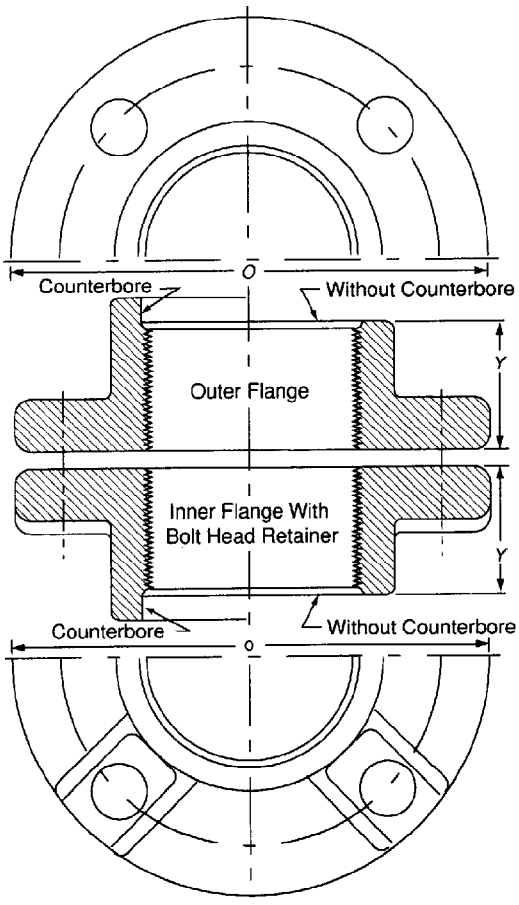
Table 2 Bolted piping flanges

Size—*in.*	2	3	4	6	8
Diameter of bolt circle, in. (mm)	4 (101.6)	5 3/8 (136.5)	6 3/8 (161.9)	9 (228.6)	11 1/4 (285.8)
Number of bolts	4 (101.6)	4 (101.6)	5 (127.0)	6 (152.4)	8 (203.2)
Diameter of bolts, in. (mm)	1/2 (12.7)	5/8 (15.9)	5/8 (15.9)	5/8 (15.9)	5/8 (15.9)
Diameter of bolt holes, in. (mm)	5/8 (15.9)	3/4 (19.1)	3/4 (19.1)	3/4 (19.1)	3/4 (19.1)
Minimum thread length, Y, in. (mm)	7/8 (22.2)	1 3/16 (30.2)	1 5/16 (33.3)	1 9/16 (39.7)	1 3/4 (44.5)
Depth of counterbore	Optional with manufacturer				
Outside diameter of flange, O, in. (mm)	5 1/8 (130.2)	6 5/8 (168.3)	7 3/4 (196.9)	10 1/2 (266.7)	12 3/4 (323.94)



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NOTE: Sections through flanges are shown at bolt holes.

Figure 2 Bolted piping flanges

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Sec. 4.2 Shell Heights for Standpipes

The purchaser shall specify the required shell height for standpipes in accordance with the manufacturer's modular sizes.

Sec. 4.3 Diameters for Reservoirs

The purchaser shall specify the required reservoir diameter, with an allowable variation to conform with the manufacturer's standard modular sizes and capacity.

SECTION 5: ACCESSORIES FOR STANDPIPES AND RESERVOIRS

Sec. 5.1 Shell Manholes

One manhole, unless otherwise specified, shall be provided in the first ring of the tank shell at a location to be designated by the purchaser. In tanks with one manhole, a sheet opposite the manhole may be removed for additional ventilation if required for inspections or recoating. If any manhole cover weighs more than 50 lb (22.7 kg), a hinge or davit shall be provided.

5.1.1 *Size and shape.* Manholes may be either circular, 24 in. (610 mm) in diameter; square, 24 in. (610 mm) × 24 in. (610 mm); or elliptical, 18 in. (457 mm) × 22 in. (558.8), minimum size. Flush rectangular manholes with a minimum length of 24 in. (610 mm) in the shortest direction and a maximum length of 48 in. (1,219 mm) in the longest direction are also acceptable. Cutouts for rectangular manholes must have a minimum 6 in. (152 mm) radius at the corners.

5.1.2 *Reinforcing.* The shell plate where the manhole is located shall be reinforced to comply with Sec. 3.11, and all portions of the manhole, including the bolting, the cover, and reinforcement of the neck, shall be designed to withstand the weight and pressure of the tank contents.

Sec. 5.2 Pipe Connections

The pipe connections shall be of the size specified by the purchaser. They are usually attached to the tank bottom. Point of attachment shall be designated by the purchaser (see foreword, Sec. III.C, item 5).

5.2.1 *Silt stop.* If a removable silt stop is required, it shall be at least 4 in. in height, and the fitting or piping connection shall be flush with the tank floor when the stop is removed. If a removable silt stop is not required, the fitting or connecting pipe, or both, shall extend above the floor by at least 4 in.

5.2.2 *Shell connections.* Shell connections are permitted, provided the purchaser makes adequate provisions to protect the pipe from freezing and provides adequate pipe flexibility to account for shell rotation and deflections of the shell when filled.

5.2.3 *Flexibility.* Sufficient piping flexibility to accommodate seismic movements and settlement in the piping system shall be provided to protect the connections.

Sec. 5.3 Overflow

The tank shall be equipped with an overflow of the type and size specified by the purchaser. If a stub overflow is specified, it shall project at least 12 in. beyond the

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tank shell. If an overflow to ground is required, it shall be brought down the outside of the tank shell and supported at proper intervals with suitable brackets. The overflow to the ground shall discharge over a drainage inlet structure or a splash block. It shall terminate at the top in a weir box or other appropriate intake. A top stiffener shall not be cut or partially removed. The overflow pipe and intake shall have a capacity at least equal to the pumping rate as specified by the purchaser, with a water level not more than 6 in. (152.4 mm) above the weir. The overflow pipe shall terminate at the bottom with an elbow. If carbon steel is specified by the purchaser, the overflow pipe shall have screwed or welded connections if it is smaller than 4 in. (101.6 mm) in diameter, or flanged or welded connections if it is 4 in. (101.6 mm) in diameter or larger. The purchaser shall specify the maximum flow rate, in gallons per minute, for which the overflow shall be designed. Internal overflows are not recommended but may be provided if specified by the purchaser. The internal overflow pipe shall have a minimum thickness of ¼ in. (6.4 mm).

Sec. 5.4 Ladders

5.4.1 *Outside tank ladder.* The constructor shall furnish a tank ladder on the outside of the shell beginning 8 ft (2.4 m), or as specified, above the level of the tank bottom, and located to provide access to the roof manway. The minimum clear width of step surface for rungs shall be 16 in. (406.4 mm), and rungs shall be equally spaced not less than 11 in. (279.4 mm), nor more than 15 in. (381 mm), on center. The perpendicular distance from the centerline of the rungs to the tank wall shall not be less than 7 in. (177.8 mm). Rung size shall not be less than ¾ in. (19 mm) in diameter, or equivalent section. The maximum spacing of supports attaching the ladder to the tank shall not exceed 10 ft (3 m). The minimum design live load shall be 2 loads of 250 lb (113.4 kg), each concentrated between any two consecutive attachments to the tank. Each rung in the ladder shall be designed for a single concentrated load of 250 lb (113.4 kg), minimum. The design loads shall be concentrated at such a point or points as will cause the maximum stress in the structural ladder member being considered. Side rails may be of any shape having section properties adequate to support the design loads and providing a means of securely fastening each rung to the side rail so as to lock each rung to the side rails.

5.4.2 *Inside tank ladder.* Inside tank ladders are not recommended. If an inside ladder is required, it shall comply with the requirements of Sec. 5.4.1.

5.4.3 *Roof ladder.* Unless otherwise specified, the constructor shall furnish access to roof hatches and vents. Such access shall be reached from the outside tank ladder according to the following:

1. For slopes 5 in 12 or greater, a ladder or stairway shall be provided.
2. Slopes less than 5 in 12 and greater than 2 in 12 shall be provided with a single handrail and nonskid walkway.
3. Slopes 2 in 12 or less do not require a handrail or nonskid surface.

5.4.4 *Minimum requirements.* Minimum requirements for ladders, hatches, and so forth can be found in OSHA 29 CFR Part 1910, "Occupational Safety and Health Standards," General Industry Standards. NOTE: Regardless of the access protection provided to tank roof hatches and vents, weather conditions on tank roofs are extremely variable and workers and their supervisors are expected to exercise good judgment in matters of safety. Among other things, this may include the use of safety lines when windy, icing, or other hazardous conditions exist.

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Sec. 5.5 Safety Devices

If a safety cage, rest platforms, roof-ladder handrails, ladder lock, anti-climb device, or other safety devices are required by federal or local laws or regulations, the purchaser shall so specify. None of these are recommended for use inside the tank.

Sec. 5.6 Roof Openings

5.6.1 *Ladder.* The manufacturer shall furnish a roof opening, which shall be placed near the outside tank ladder and which shall be provided with a hinged cover and a hasp for locking. The opening shall have a clear dimension of at least 24 in. (610 mm) in one direction and 15 in. (381 mm) in the other direction. The opening shall have either (1) a curb at least 4 in. (101.6 mm) in height, and the cover shall have a downward overlap of at least 2 in. (50.8 mm), or (2) a gasketed weathertight cover, in lieu of the 4-in. (101.6-mm) curb and 2-in. (50.8-mm) overlap. When a combined screened vent-manhole cover equipped with locking hasp is provided at the roof center opening, the ladder opening may be omitted.

5.6.2 *Roof center.* An additional opening, with a removable cover having an opening dimension or diameter of at least 20 in. (508 mm) and 4-in. (101.6-mm) minimum height neck, shall be provided at, or near, the center of the tank. In lieu of the 4-in. (101.6-mm) neck, a gasketed, weathertight cover is also acceptable.

Sec. 5.7 Vent

If the tank roof is of tight construction, a suitable vent shall be furnished above the maximum water level. The vent shall have a capacity to pass air so that at the maximum possible rate of the water, either entering or leaving the tank, excessive pressure will not be developed. The overflow pipe shall not be considered a tank vent.

WARNING: An improperly vented tank may cause external pressures to act on the tank, which will cause buckling even at a low pressure differential.

5.7.1 *Location.* Even if more than one vent is required, one tank vent shall always be located near the center of the roof. The vent shall be designed and constructed to prevent the ingress of birds or animals.

5.7.2 *Screening.* When governing health authorities require screening against insects, a pressure-vacuum screened vent or a separate pressure-vacuum relief mechanism shall be provided which will operate in the event that the screens frost over or become clogged with foreign material. The screens or relief mechanism shall not be damaged by the occurrence and shall return automatically to the operating position after the clogging is cleared.

NOTE: The purchaser should clean the screens and check the pallets or relief mechanism for operation at least once a year, but preferably each spring and fall.

Sec. 5.8 Additional Accessories and Exceptions

Any additional accessories required to be furnished shall be specified by the purchaser. Exceptions to the provisions of this section may be specified by the purchaser to suit special situations.

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SECTION 6: WELDING

Sec. 6.1 General

The field assembly of all vertical, horizontal, shell-to-roof, and shell-to-bottom plates or sheets shall be by bolting. Welding shall be limited to the shop installation of nozzles, vents, manways, connections, and subassemblies. Field welding is to be kept to a minimum and used only after acceptance by the manufacturer and purchaser.

Sec. 6.2 Welds

All welds in the tank and structural members shall be made according to the minimum requirements of AWS. Manufacturers shall maintain a welder training program and shall be able to certify if requested that these welds were made by AWS qualified welders and inspected according to AWS standards. These welds are to be made to ensure complete fusion with the base metal, within the limits specified for each joint, in strict accordance with the following procedure.

6.2.1 *Weather conditions.* Welding shall not be performed when the surfaces of the parts to be welded are wet from rain, snow, or ice; when rain or snow is falling on such surfaces; or during periods of high winds, unless the welder or welding operator and work are properly protected. Welding shall not be done when the base metal temperature is less than 0°F (–17.8°C). When the base metal temperature is within the range 0°F–32°F (–17.8°C–0°C), the base metal within 3 in. (76.2 mm) of the place where welding is to be started shall be heated until it is warm to the touch.

6.2.2 *Peening.* Peening of weld layers may be used to prevent undue distortion. Surface layers shall not be peened.

6.2.2.1 Peening shall be performed with light blows from a power hammer using a blunt-nosed tool.

6.2.3 *Contour.* All welds that are to be grit blasted before coating should be rough ground to remove any high points prior to grit blasting. Welds that will not be grit blasted shall be ground to a smooth contour.

6.2.3.1 Undercutting of base metal in the plate adjoining the weld shall be repaired.

6.2.3.2 All craters shall be filled to the full cross section of the weld.

6.2.4 *Reinforcement.* The reinforcement of butt welds shall be as small as practicable, preferably not more than 1/16 in. (1.6 mm). In no case shall the face of the weld lie below the surface of the plates being joined.

6.2.5 *Gouging.* Gouging at the root of welds and gouging of welds to remove defects may be performed with a round-nosed tool or by arc or oxygen gouging.

6.2.6 *Cleaning between beads.* Each bead of multiple-pass weld shall be cleaned of slag and other loose deposits before the next bead is applied.

Sec. 6.3 Preparation of Surfaces to Be Welded

Surfaces to be welded shall be free from loose scale, slag, heavy rust, grease, paint, and any other foreign material except tightly adherent mill scale. A light film of weldable rust-preventive coating or compound may be disregarded. Such surfaces shall also be smooth, uniform, and free from fins, tears, and other defects that adversely affect proper welding. A fine film of rust adhering to cut or sheared edges after wire brushing need not be removed.

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Sec. 6.4 Low-Hydrogen Electrodes

The use of low-hydrogen electrodes will be helpful when welding is performed at low temperatures. When the designated low-hydrogen covered electrodes are used, preheating of the steel is not required unless the metal temperature is 32°F (0°C) or lower. After filler metal has been removed from its original package, it shall be protected or stored so that its characteristics or welding properties are not affected. In the case of low-hydrogen electrodes, this means keeping the electrodes warm and dry up to the time they are removed from the rod-storage oven. Low-hydrogen electrodes shall be stored, and rebaked if necessary, in accordance with electrode conditioning recommendations contained in AWS A5.1.

Sec. 6.5 Undercuts and Penetration of Welds

Welds shall be examined visually for compliance with the following:

6.5.1 *Butt and lap joints subject to primary stress.* For butt and lap joints subject to primary stress due to weight or pressure of tank contents, there shall be complete joint penetration and no undercutting.

6.5.2 *Butt joint subject to secondary stress.* For butt joints subject to secondary stress, there shall be complete joint penetration and no undercutting.

6.5.3 *Lap joints subject to secondary stress.* For lap joints subject to secondary stress, the maximum undercut permitted shall be 12 ½ percent of the thinnest sheet measured at each edge of the weld.

Sec. 6.6 Cleaning of Welds

The manufacturer shall remove weld scale or slag, spatter, burrs, and other sharp or rough projections in a manner that will leave the surface suitable for the subsequent cleaning and coating operation. Weld seams need not be chipped or ground, provided they may be satisfactorily cleaned and coated.

SECTION 7: SHOP FABRICATION

Sec. 7.1 Straightening

Any required straightening of material shall be done by methods that will not damage the steel. Minor cold straightening is permitted. Cold straightening may be done by hammering, or preferably, by rolling or pressing. Heat may be used in straightening more severe deformations.

Sec. 7.2 Finish of Plate Edges—Welded Work

The plate edges to be bolted or welded may be universal mill edges or they may be prepared by shearing, machining, chipping, or by mechanically guided oxygen or plasma arc cutting. Edges of irregular contour may be prepared by oxygen or plasma arc cutting.

7.2.1 *Oxygen or plasma arc cutting.* When edges of plates are oxygen or plasma arc cut, the surface obtained shall be uniform and smooth and shall be cleaned of slag accumulations before welding. All cutting shall follow closely the lines prescribed.

7.2.2 *Shearing.* Shearing may be used for material ⅜ in. (9.5 mm) or less in thickness.

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Sec. 7.3 Rolling

Plates and sheets shall be cold rolled or pressed to suit the curvature of the tank and the erection procedure.

Sec. 7.4 Double-Curved Plates

Plates and sheets that are curved in two directions may be pressed or rolled either cold or hot.

Sec. 7.5 Manufacturing Tolerances

7.5.1 *Tanks with horizontally flanged shell joints.* Parts fabricated and punched for tanks with horizontally flanged shell joints shall comply with the dimensions and tolerances of API 12B.

7.5.2 *Tanks with horizontally lapped shell joints.* The tolerance on bolt-hole spacing for tanks with horizontally lapped shell joints shall be ±1/32 in. (0.8 mm) between any two holes, measured in the flat before forming.

Sec. 7.6 Coatings

Bolted tanks are supplied with factory-applied coatings (refer to Sec. 10 for coatings).

Sec. 7.7 Shipping

All material shall be loaded, transported to the site, unloaded, and stored in such a manner as to prevent damage.

SECTION 8: ERECTION

Sec. 8.1 General

The manufacturer shall provide instructions for the erection of the tank, and the tank shall be erected in accordance with these instructions.

Sec. 8.2 Bolting

All bolts shall be located and installed in accordance with the instructions on erecting the tank provided by the manufacturer.

Sec. 8.3 Gasketing and Sealants

Gasketing and sealants or both shall be supplied by the manufacturer and installed between all joints in compliance with the erection instructions. The constructor shall exercise care in properly locating and installing any special gaskets (chime lap gaskets, tapered inserts, and so forth) supplied by the manufacturer.

Sec. 8.4 Coating Repair

The coating shall be visually inspected by the constructor and any damage to the factory-applied coatings shall be repaired in strict compliance with the manufacturer's recommendations (see Sec. 10.2).

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Sec. 8.5 Cleanup

On completion of the erection, the constructor shall, if required by the purchaser's specifications, dispose of all rubbish and other unsightly material caused by the operations and shall leave the premises in as good a condition as found at the start of the tank erection.

SECTION 9: INSPECTION AND TESTING

Sec. 9.1 Shop Inspection

9.1.1 *Shop inspection.* The purchaser may, if specified, require shop inspection by a commercial inspection agency, the cost of which shall be paid by the purchaser. Shop inspection shall at a minimum consist of a visual inspection of the fabricating practices and operations to determine compliance with this standard.

9.1.2 *Mill-test reports.* When specified by the purchaser, copies of certified mill-test reports shall be furnished by the manufacturer. The manufacturer shall obtain copies of all mill-test reports.

9.1.3 *Coating thickness test data.* When specified, the manufacturer shall supply certified test data on the coating thickness.

Sec. 9.2 Testing

9.2.1 *Repair of leaks.* Any leaks found shall be repaired by the constructor. It is preferred that repair of joints be made while the water level is above the point being repaired. See the foreword, Sec. III.C, item 7, for recommendations on blinding and filling the tank, which is not covered by this standard.

9.2.2 *Holiday testing.* When specified, independent field holiday detection testing shall be performed on the interior coated surfaces below maximum water level in accordance with the manufacturer's recommendations.

Sec. 9.3 Disposal of Test Water

The purchaser shall provide a means of disposing of test water with a connection to the inlet pipe or drain pipe.

Sec. 9.4 Disinfecting

Regardless of the sequence used for testing the tank, it shall be disinfected after the final test and the tank may then be filled with potable water and placed into service. Disinfection shall not be the responsibility of the constructor or manufacturer unless otherwise specified by the purchaser (see ANSI/AWWA C652).

SECTION 10: COATINGS

Sec. 10.1 General

Bolted tanks are manufactured by several tank manufacturers and coated in their own facilities and shipped worldwide. The following generic systems are representative of those in general use. Equivalent generic systems, for which documentation consisting of test data, service history, and toxicological information

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have been provided by the tank manufacturer, shall be considered for use in storage tanks under the provisions of this standard.

Sec. 10.2 Coating Repair

It shall be the responsibility of each tank manufacturer to provide a procedure for field repair and touch-up of damaged coatings.

Sec. 10.3 Galvanized Coatings

When hot-dip galvanized coatings are to be supplied, zinc metal suitable for immersion in drinking water shall be applied to the tank parts after fabrication in accordance with the recommended practice of the American Hot Dip Galvanizers Association* in compliance with ASTM A123 and ASTM A153.

Sec. 10.4 Glass Coatings

When glass fused-to-steel coatings are provided, the coatings shall be applied according to the tank manufacturer's recommendations. Glass coatings are to comply with the following.

10.4.1 *Surface preparation.* The steel shall be cleaned of all oils and lubricants. Mill scale and rust must be removed from the steel surface by grit blasting in accordance with SSPC SP10 or by pickling in compliance with SSPC SP8.

10.4.2 *Coatings.*

10.4.2.1 The steel is to be primed with applications of catalytic nickel oxide when tanks are fabricated from hot-rolled steel. Hot-rolled steel is susceptible to fish scaling, which is a hydrogen defect that can be controlled by applications of catalytic nickel oxide. Such a primer is necessary if both sides of hot-rolled steel are glass coated.

10.4.2.2 Glass coatings can be applied by wet spraying, flow coating, dipping, or electrophoretic deposition. The coating thickness shall be between 6 mils (0.15 mm) and 19 mils (0.48 mm).

10.4.2.3 The glass coating must be cured or fused to the steel by firing. This is most conveniently done in a furnace, but can be carried out by means of induction or resistance heating. The temperature should be above 1,200°F and preferably in the range of 1,450°F to 1,600°F.

10.4.3 *Inspection.* The coating shall be inspected for any visible defects or holidays. If severe conditions are encountered, a wet-pad resistance test should be used to determine the extent of microscopic defects on the tank interior surfaces only (Sec. 10.9).

Sec. 10.5 Thermoset Liquid Suspension Coatings

When thermoset liquid suspension epoxies are used, the coatings shall be applied according to the tank manufacturer's recommendations. Coatings are to comply with the following.

10.5.1 *Surface preparation.* Surface preparation shall comply with the following.

10.5.1.1 The steel shall be thoroughly cleaned by a wash-rinse followed immediately by hot air drying.

10.5.1.2 The steel shall then be grit blasted on both sides in accordance with SSPC SP10. The surface anchor pattern shall be a minimum of 1 mil (0.03 mm).

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10.5.2 *Coatings.* The coatings are to be applied in compliance with the following.

10.5.2.1 Within 30 min of blast cleaning (Sec. 10.5.1.2), the interior surfaces of the tank shall receive one coat of amine-cured thermoset epoxy in strict accordance with the manufacturer's recommendations.

10.5.2.2 The exterior surfaces of the tank shall receive one coat of epoxy primer or equal as determined by the tank manufacturer.

10.5.2.3 The interior and exterior coatings (Sec. 10.5.2.1 and 10.5.2.2) shall be oven heated until the coats have a tacky finish, with partial thermal cross-linking.

10.5.2.4 The interior surfaces of the tank shall receive a second coat of amine-cured epoxy to provide a total of 5-mil (0.13-mm) minimum dry film thickness.

10.5.2.5 The exterior surfaces of the tank shall receive a finish coat of acrylic baking enamel and be thermally cured. Minimum dry film thickness shall be a total of 3 mils (0.08 mm).

10.5.2.6 The interior and exterior finish coats shall be oven-heated at 425°F–525°F (218.3°C–273.8°C) for a minimum of 10 min to completely thermal cross-link both thermoset coatings.

10.5.2.7 Exterior coatings may be modified by agreement between the purchaser and the tank manufacturer.

10.5.3 *Inspection.*

10.5.3.1 Inspection of interior. A representative sampling of interior coated surfaces shall be inspected and accepted by the tank manufacturer prior to shipment. The inspection shall include a nondestructive mil-thickness test (Mikrotest or equal), a holiday detection test (Tinker Razor or equal), and methyl ethyl ketone (MEK) solvent test consisting of 20 wipes or equal.

10.5.3.2 Inspection of exterior. A representative sampling of exterior coated surfaces shall be inspected and accepted by the tank manufacturer prior to shipment. The inspection shall include a nondestructive mil-thickness test (Mikrotest or equal).

Sec. 10.6 Thermoset Powder Coatings

When thermoset powder coatings are used, the coatings shall be applied according to the tank manufacturer's recommendations. Thermoset powder coatings are to comply with the following.

10.6.1 *Surface preparation.* The steel shall be steel-grit blasted on all sides in accordance with SSPC SP10.

10.6.2 *Application.* The coating is to be applied in compliance with the following.

10.6.2.1 After blast cleaning, the interior and exterior surfaces shall be dry-powder coated by electrostatic application with a powder coating.

10.6.2.2 The dry powder shall be deposited at a rate to yield 3 mil-minimum dry film thickness.

10.6.2.3 The surfaces shall be oven cured in accordance with the dry-powder coating manufacturer's standard practice and specifications.

10.6.3 *Inspection.*

10.6.3.1 Inspection interior. A representative sampling of interior coated surfaces shall be inspected and accepted by the tank manufacturer prior to shipment. The inspection shall include a nondestructive mil-thickness test (Mikrotest or equal), a holiday detection test (Tinker Razor or equal), and methyl ethyl ketone (MEK) solvent test consisting of 20 wipes or equal.

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10.6.3.2 Inspection exterior. A representative sampling of exterior coated surfaces shall be inspected and accepted by the tank manufacturer prior to shipment. The inspection shall include a nondestructive mil-thickness test (Mikrotest or equal).

Sec. 10.7 Marking

All of the tank components shall be given a piece mark number for ease of assembly. In lieu of this, the tank manufacturer's standard practice may be used.

Sec. 10.8 Protection

All coated parts shall be protected from damage during shipment.

Sec. 10.9 Holiday Testing

All holiday tests shall be nondestructive and shall use an electric DC meter and a wet sponge device. The maximum voltage of the meter shall be 67.5 volts. The sponge shall be dipped in tap water as required to keep it uniformly damp, not soaked or dry. No "conductive" or "wetting" additives shall be used in the tap water. Refer to the tank manufacturer's recommendations for setting, testing, and operation of the meter by a trained technician.

SECTION 11: FOUNDATION DESIGN AND CONSTRUCTION

Sec. 11.1 General Requirements

The foundations are important because unequal settlement changes the distribution of stresses in the structure and may cause leakage or buckling of the plates.

11.1.1 *Foundation plans.* The manufacturer (or constructor) is not required to furnish foundation plans unless specified by the purchaser. Should the purchaser require foundation plans by the manufacturer or constructor, see Sec. II.D and III.C of the foreword for additional information. Anchor bolts, when required, shall be designed and furnished by the manufacturer.

11.1.2 *Foundation installation.* Foundations may be installed by either the purchaser or the constructor (see the foreword, Sec. II.D and III.C). The earth around the foundation shall be regraded sufficiently to permit efficient work during tank erection and to prevent ponding of water in the foundation area. The tops of the foundations shall be accurately located at the proper elevation.

11.1.3 *Water load.* Water load as defined in Sec. 3.2.2, shall be considered as live load as defined by ACI 318 (see Sec. 11.6). The appropriate factors for all live loads shall be used in foundation design.

Sec. 11.2 Soil-Bearing Value

The purchaser shall specify the allowable soil-bearing pressure using an appropriate factor of safety (Sec. 11.3). However, in no case shall the specified bearing pressure exceed that which would cause intolerable settlements and impair the structural integrity of the tank.

11.2.1 *Soil investigation.* A soil investigation shall be provided by the purchaser to determine the following:

1. The presence or absence of rock, old excavation, or fill.
2. Whether the site is a suitable place on which to build the structure.

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3. The classification of soil strata, after appropriate sampling.
4. The type of foundation that will be required at the site.
5. The elevation of groundwater, and whether dewatering is required.
6. The bearing capacity of the soil, and the depth at which footings must be founded.
7. Whether piling will be required for support of foundations, and the length of such piling.
8. The elevations of the existing grade and other topographical features that may affect the foundation design or construction.
9. The homogeneity and compressibility of the soils across the tank site, so that the possibility of total and differential settlement of the structure may be evaluated.

Sec. 11.3 Factor of Safety

The following minimum factors of safety shall be used in determining the allowable soil-bearing pressure. The ultimate bearing capacity should be based on sound principles of geotechnical engineering. See the foreword, Sec. III.C, item 10, for additional information.

11.3.1 *Standpipes and reservoirs.* A factor of safety of 3 shall be provided, based on calculated ultimate bearing capacity when all direct loads and wind are considered.

11.3.1.1 A factor of safety of 2.25 shall be provided, based on calculated ultimate bearing capacity when all direct loads and earthquake loads are considered.

Sec. 11.4 Foundations

All tanks shall be supported on a concrete ringwall, concrete slab, or structurally compacted granular berm as specified by the purchaser. The top of the foundation shall be a minimum of 6 in. (152.4 mm) above the finished grade, unless otherwise specified by the purchaser. Tanks that require anchor bolts shall be supported on a ringwall or a concrete slab.

11.4.1 *Types of foundations.* The tank foundation shall be one of the following types.

11.4.1.1 Type 1. Tanks supported on ringwalls. A sand or fine stone cushion at least 3 in. (76.2 mm) thick shall be provided above the earthen interior under the tank bottom. A 1-in. minimum space between the tank bottom and the top of the ringwall shall be filled with a nonshrink grout or a 1:1.5 cement-sand grout. The grout shall fill the entire space beneath the tank from the outside edge of the tank bottom to the cushion. In no case shall the width of grout placed under the tank bottom be less than 6 in. The top of the foundation shall be thoroughly saturated with water before grout is placed. The materials and labor for grouting shall be furnished by the constructor. In lieu of grout under the shell, the shell may be supported on a minimum ½-in. (12.7-mm)-thick cane-fiber joint filler meeting the requirements of ASTM D1751 if the foundation under the shell meets the tolerances of Sec. 11.6.1.

11.4.1.2 Type 2. Tanks supported on concrete slabs. A sand or fine stone cushion not less than 1 in. (25.4 mm) thick shall be provided between the flat bottom and the concrete slab foundation. In lieu of a cushion, the bottom may be supported on a minimum ½-in. (12.7-mm)-thick cane-fiber joint filler meeting the requirements of ASTM D1751. The tank shell shall be supported with grout or, alternatively, fiber joint filler if the foundation under the shell meets the tolerances of Sec. 11.6.1. When grouted, a 1-in. (25.4-mm) minimum space between the tank bottom and the top of

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the concrete shall be filled with a nonshrink grout or a 1:1.5 cement-sand grout. The grout shall fill the entire space beneath the tank from the outside edge of the tank bottom to the cushion. In no case shall the width of grout placed under the tank bottom be less than 6 in. (152.4 mm). The top of the foundation shall be thoroughly saturated with water before grout is placed. The materials and labor for grouting shall be furnished by the constructor.

NOTE: When a steel base-setting ring is used in conjunction with a concrete slab, no grout or fiber joint filler is required (see Sec. 11.4.1.6 for Type 6 foundations).

11.4.1.3 Type 3. Tanks within ringwalls. Tanks may be placed on a cushion within a concrete ringwall. The cushion shall consist of a minimum of 6 in. (152.4 mm) of sand or fine stone. The inside of the ringwall is to be a minimum of ¾ in. (19 mm) outside the bottom plates of the tank. Adequate provisions for drainage inside the ringwall must be made.

11.4.1.4 Type 4. Tanks supported on granular berms. The berm shall be well-graded stone or gravel. The berm shall extend a minimum of 3 ft (0.9 m) beyond the tank shell and from there have a maximum slope of 1:1.5. The berm under the shell shall be level within ±⅛ in. (3.2 mm) in any 10 ft (3 m) of circumference and within ±½ in. (12.7 mm) in the total circumference. Adequate protection shall be provided to ensure against foundation washout.

11.4.1.5 Type 5. Tanks supported on granular berms with steel retainer rings. The berm shall be well-graded stone or gravel. The berm shall extend to the retainer ring. The size and coating of the steel retainer ring shall be specified by the purchaser and shall be a minimum of 12 in. (304.8 mm) from the shell or a sufficient distance to ensure berm stability under the shell in the event that the steel retainer ring is removed. The berm under the shell shall be level within ±⅛ in. (3.2 mm) in any 10 ft (3 m) of circumference and within ±½ in. (12.7 mm) in the total circumference.

11.4.1.6 Type 6. Tanks with base setting ring embedded in concrete slab. The base setting ring shall be supported on a ringwall foundation prior to placement of slab concrete. A minimum clear distance of 3 in. (76.2 mm) between the top of the slab and the bottom of the base setting ring shall be provided. The outside curb shall have a minimum width of 8 in. (203.2 mm), and its top shall be level within ±1 in. of the top of the slab. A minimum of one elastomer water stop shall be bonded to the inside base setting ring surface at a minimum distance of 2 in. below the top of the concrete slab. Shrinkage-reinforcing steel shall be used in the concrete slab adjacent to both the inside and the outside of the base setting ring in accordance with ACI 318. For concrete slabs supported on grade, the manufacturer shall provide specifications for the preparation of sub-base material, if required by the purchasers specifications (see foreword, Sec. III.C, item 11).

Sec. 11.5 Detail Design of Foundations

11.5.1 *Height above ground.* The tops of the concrete foundations shall be a minimum of 6 in. (152.4 mm) above the adjacent grade, unless otherwise specified by the purchaser.

11.5.2 *Minimum depth of foundations.* The minimum depth of foundations shall be determined from Figure 3. The extreme frost penetration depths in Figure 3 shall be the minimum depth of foundation below the ground line. Foundation depth shall be increased in localities where soil or other factors are favorable to deep frost penetration and may be reduced for piers resting on rock. Consult local records for

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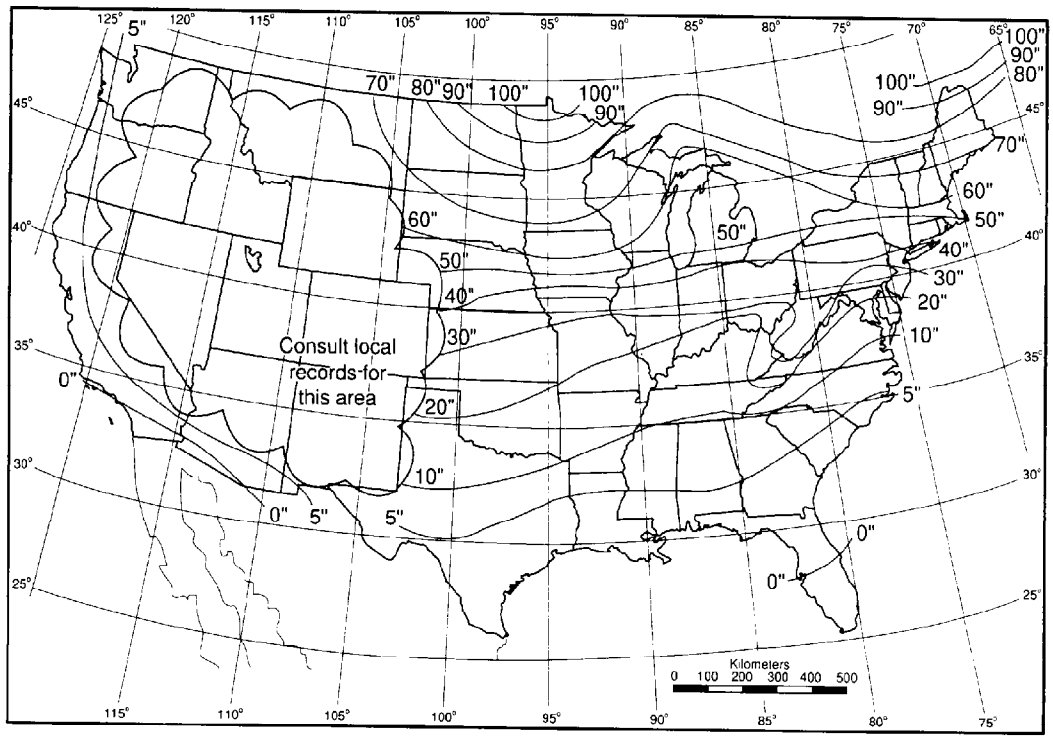

Figure 3 Extreme frost penetration—inches (based on state averages)

the extreme frost penetration in the circled area of Figure 3. Uplift or soil-bearing requirements may dictate greater depths. Minimum depth shall be 12 in. (304.8 mm).

11.5.3 *Size of top.* The tops of foundations shall project at least 3 in. beyond the tank shell. In base setting ring applications, the top of the foundation should project a minimum of 8 in. (203 mm) beyond the tank shell. The top corners shall be either neatly rounded or finished with a suitable bevel. When anchor bolts are required, the foundations shall extend at least 9 in. (228.6 mm) beyond the tank shell.

11.5.4 *Pile foundations.* If a pile-supported foundation is required, the purchaser shall specify the pile type and depth below existing grade to be used for bidding and design capacities for live and dead loads, including the weight of all soil above the footing, and for live and dead loads combined with wind or seismic loads or both.

Sec. 11.6 Concrete Design, Materials, and Construction

The design of the concrete foundations, the specifications for the cement and aggregate, and the mixing and placing of the aggregate shall be in accordance with ACI 318, except as may be modified in this section and the following subsections. Concrete work shall conform to all requirements of ACI 301, except as modified by agreement between the purchaser and constructor.

11.6.1 *Tolerances on concrete foundations.* Ringwalls and slabs, after grouting or before placing the cane-fiber joint filler, shall be level within ±⅛ in. (±3.08 mm) in any 30-ft (9.1-m) circumference under the shell. The levelness on the circumference shall not vary by more than ±¼ in. (6.4 mm) from an established plane. The tolerance on poured concrete before grouting shall be ±1 in. (25.4 mm).

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11.6.2 *Finish.* The top portions of foundations, to a level 6 in. (152.4 mm) below the proposed ground level, shall be finished to a smooth form finish in compliance with ACI 301. Any small holes may be troweled over with mortar as soon as possible after the forms are removed.

11.6.3 *Anchor bolts.* It is the responsibility of the constructor to locate the anchor bolts within ¼ in. (6.35 mm) of the manufacturer's anchor bolt layout design.

11.6.4 *Base-setting ring.* If a base-setting ring is required, it is the responsibility of the constructor to level the setting ring within 1/16 in. (1.54 mm) of level and concentric within ¼ in. (6.35 mm). The constructor shall locate the manufacturer-supplied base-setting ring in conformance with the manufacturer's design.

Sec. 11.7 Backfill

For tanks with ringwall foundation, all topsoil, organic material, and undesirable material within the ringwall shall be removed and replaced with a controlled, load-bearing backfill specified by the designer of the foundation. The natural soils and load-bearing backfill within the ringwall shall be capable of supporting the tank bottom without general settlement or localized settlement causing breakdown of the tank bottom adjacent to the ringwall.

11.7.1 *Material and compaction.* Load-bearing backfill shall be suitable non-frozen material placed and compacted in uniform horizontal lifts to the degree of compaction required by the foundation design. The water load and ringwall height shall be considered in determining the required degree of compaction.

11.7.2 *Pipe cover.* Pipe cover shall be provided in compliance with Figure 4 unless local conditions dictate that more or less cover should be used.

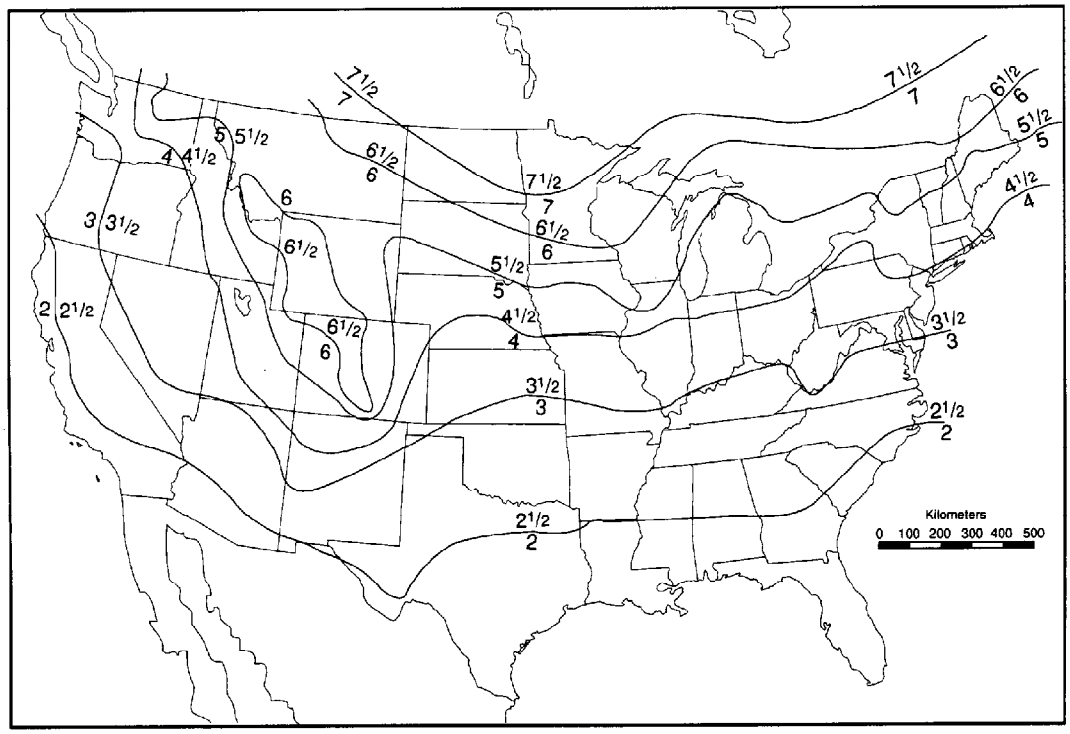

Figure 4 Recommended depth of pipe cover—feet above top of pipe

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SECTION 12: SEISMIC DESIGN OF FLAT-BOTTOM WATER-STORAGE TANKS

Sec. 12.1 General

12.1.1 *Applicability.* This section shall be used as prescribed by Sec. 3.2.5.

12.1.2 *Tabulation form for seismic data.* A sample tabulation form for seismic data, for use by the purchaser, is included in Sec. 12.7. It is followed by an example to demonstrate the use of the form. The tabulation form for seismic loads shall be completed by the purchaser.

Sec. 12.2 Seismic Design Considerations

12.2.1 *Effective-mass method.* The design of ground-supported, flat-bottom tanks recognizes the reduction in seismic load due to the sloshing of the contained liquid. This design procedure is referred to as the effective-mass method. See the references in Sec. 12.8 for details of this design method.

12.2.2 *Anchored and unanchored tanks.* Flat-bottom tanks may be anchored or unanchored to resist earthquakes.*

12.2.2.1 Anchored tanks could be susceptible to tearing of the shell if anchorage is not properly designed. Care must be taken to ensure that anchor-bolt attachments are stronger than the anchor bolt. Experience shows that properly designed anchored tanks retain greater reserve strength to seismic overload than unanchored tanks. Anchorage shall be designed such that anchor bolts yield before the shell attachment fails.

12.2.2.2 Seismic resistance of an unanchored tank is related to the height-to-diameter ratio of the structure.

Sec. 12.3 Seismic Design Loads

The following design loads are based on a consistent probability of seismic disturbance in the United States. A use factor has been included based upon use and importance of the storage tank. Allowable stresses in this section apply only to loading conditions, which include seismic loads defined in this standard. Static load and wind conditions are covered by Sec. 3. Allowable stresses for anchor bolts shall conform to AISC (ASD) allowable stresses.

12.3.1 *Effective-mass procedure.* The effective-mass procedure considers two response modes of the tank and its contents: (1) the high-frequency amplified response to lateral ground motion of the tank shell and roof together with a portion of the liquid contents that moves in unison with the shell, and (2) the low-frequency amplified response of a portion of the liquid contents in the fundamental sloshing mode. The design requires the determination of the hydrodynamic mass associated with each mode and the lateral force and overturning moment applied to the shell resulting from the response of the masses to lateral ground motion.

*If an unanchored tank design is used, the maximum thickened bottom annulus width (radial direction) used to resist overturning shall be limited to 7 percent of the tank radius. For the maximum thickness of the bottom annulus, refer to Sec. 12.3.3.2. The tank must be anchored if these criteria cannot be met.

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The base shear and overturning moment due to seismic forces applied to the bottom of the shell shall be determined in accordance with the following formulas:

Base shear:

$$V_{ACT} = \frac{18ZI}{R_w}[0.14(W_s + W_r + W_1) + SC_1W_2] \quad \text{(Eq 15)}$$

Overturning moment:

$$M = \frac{18ZI}{R_w}[0.14(W_sX_s + W_rH_t + W_1X_1) + SW_2X_2C_1] \quad \text{(Eq 16)}$$

Where:

V_{ACT} = actual lateral shear, in pounds
M = overturning moment applied to the bottom of tank shell, in foot-pounds or other consistent units
Z = zone coefficient from Figure 5 and Table 3
I = use factor from Table 6
R_w = force reduction coefficient from Table 4
W_s = total weight of tank shell bottom, and significant appurtenances in pounds. The bottom shall not be included in the calculation for overturning moment in Eq 16
X_s = height from the bottom of the tank shell to the center of gravity of the shell, in feet
W_r = total weight of the tank roof (including framing and knuckle) plus permanent loads, if any, as specified by the purchaser, in pounds. Only that portion of the roof that bears on the shell shall be considered for the overturning moment in Eq 16
H_t = total height of the tank shell, in feet
W_1 = weight of effective mass of tank contents that moves in unison with the tank shell, in pounds (Sec. 12.3.2)
X_1 = height from the bottom of the tank shell to the centroid of lateral seismic force applied to W_1, in feet (Sec. 12.3.2)
S = site amplification factor from Table 5. Assumed to be 1.5 unless otherwise specified by purchaser
W_2 = weight of effective mass of the first mode sloshing contents of the tank, in pounds (Sec. 12.3.2)
X_2 = height from the bottom of the tank shell to the centroid of lateral seismic force applied to W_2, in feet (Sec. 12.3.3)

C_1 is determined as follows:

For the condition where $T_w < 4.5$ seconds:

$$C_1 = \frac{1}{6T_w} \quad \text{(Eq 16a)}$$

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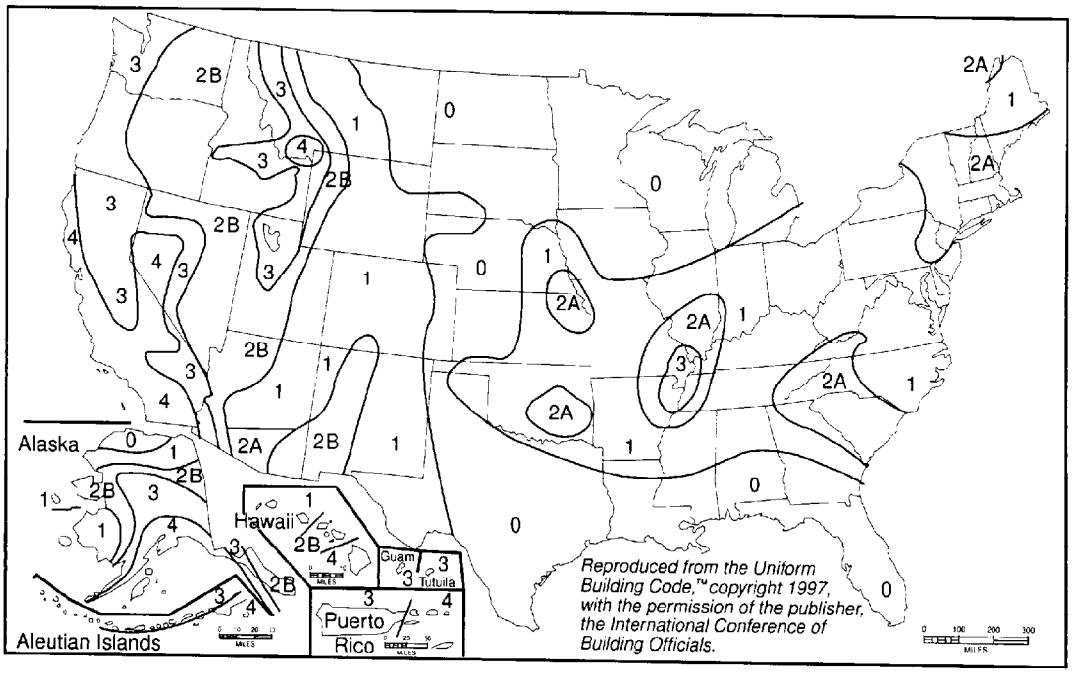
Table 3 Zone coefficient (Z)

Zone*	Zone Coefficient Z
1	0.075
2A	0.15
2B	0.20
3	0.30
4	0.40

*For determination of zone, see Figure 5.

Table 4 Force reduction coefficient

Structure	Force Reduction Coefficient R_w
Anchored flat-bottom tank	4.5
Unanchored flat-bottom tank	3.5



Zone "0" indicates no seismic design required.

Figure 5 Seismic zone map for determining zone coefficient from Table 3

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Table 5 Site amplification factor S

	Soil Profile Type			
	A	B	C	D
Site Amplification Factor*	1.0	1.2	1.5	2.0

*The following is an explanation for the determination of the site amplification factor, which shall be supplied by the purchaser. Site effects on tank response shall be established based on the following four soil profile factors:

1. *Soil Profile Type A* is a profile with:

a. Rock of any characteristic, either shale-like or crystalline in nature. Such material may be characterized by a shear wave velocity greater than 2,500 ft/second (760 m/second).

b. Stiff soil conditions where the soil depth is less than 200 ft (61 m) and the soil types overlying rock are stable deposits of sands, gravels, or stiff clays.

2. *Soil Profile Type B* is a profile with deep, cohesionless or stiff clay conditions, including sites where the soil depth exceeds 200 ft (61 m) and the soil types overlying rock are stable deposits of sands, gravels, or stiff clays.

3. *Soil Profile Type C* is a profile with soft to medium-stiff clays and sands characterized by 30 ft (9.1 m) or more of soft to medium-stiff clay with or without intervening layers of sand or other cohesionless soils.

4. *Soil Profile Type D* is a profile containing more than 40 ft (12.2 m) of soft clay characterized by a shear wave velocity less than 500 ft/second (152.4 m/second).

In locations where the soil profile type is not known in sufficient detail to determine the soil profile type, soil profile type C shall be assumed.

Table 6 Use factor I^*

1.25	Sole supply Fire protection Multiple supply and fire protection
1.0	Multiple supply and no fire protection

*An I of 1.25 shall be used unless otherwise specified by the purchaser.

For the condition where $T_w \geq 4.5$ seconds:

$$C_1 = \frac{0.75}{T_w^2} \qquad \text{(Eq 16b)}$$

T_w = first mode sloshing wave period, in seconds, which is determined as follows:

$$T_w = K_p D^{1/2} \qquad \text{(Eq 16c)}$$

Where:

K_p = factor from Figure 6 for the ratio of tank diameter, in feet, to maximum depth of water, in feet, D/H, or other consistent units

D = tank diameter, in feet

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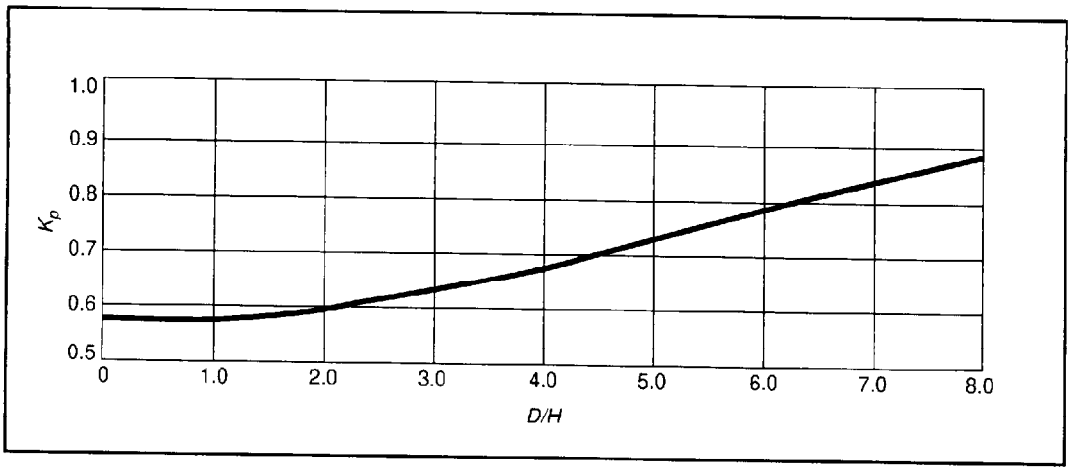

Figure 6 Curve for obtaining factor K_p for the ratio D/H

NOTE: The overturning moment determined by this formula is that applied to the bottom of the shell only. The tank foundation is subjected to an additional overturning moment due to lateral displacement of the tank contents. This may need to be considered in the design of some foundations, such as pile-supported concrete slabs.

12.3.2 *Effective mass of tank contents.*

12.3.2.1 The weight of the effective mass of the tank contents that moves in unison with the tank shell W_1 (Eq 15 and 16) and the weight of the effective mass of the first mode sloshing contents W_2 (Eq 15 and 16) may be determined by multiplying W_T (Eq 17) by the ratios W_1/W_T and W_2/W_T, respectively. These ratios may be obtained from Figure 7 for the ratio D/H,

Where:

W_T = total weight of tank contents, in pounds. This value is determined by the formula

$$W_T = 62.4GH\left(\frac{\pi D^2}{4}\right) = 49GHD^2 \qquad \text{(Eq 17)}$$

Where:

D = tank diameter, in feet
H = maximum depth of water in the tank, in feet
G = specific gravity (1.0 for water)

12.3.2.2 The heights X_1 and X_2 (Eq 16), from the bottom of the tank shell to the centroids of the lateral seismic forces applied to W_1 and W_2 (Eq 16), may be determined by multiplying H by the ratios X_1/H and X_2/H, respectively. These ratios may be obtained from Figure 8 for the ratio D/H.

12.3.2.3 The curves in Figures 7 and 8 are based on a modification of equations in "Nuclear Reactors and Earthquakes" (see Sec. 12.8, reference 1). Moment arms X_1 and X_2 are valid for tanks supported on ringwalls. For tanks supported on slabs, see reference 1 for additional overturning moment. Alternatively, W_1, W_2, X_1, and X_2 may

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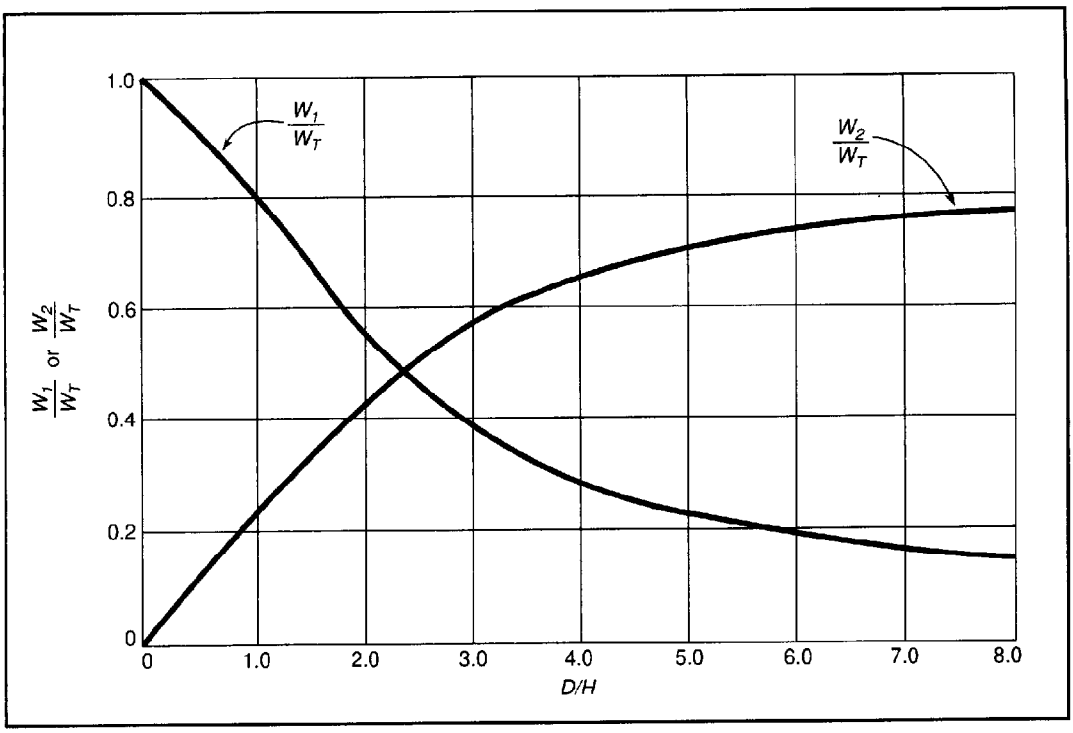

Figure 7 Curves for obtaining factors W_1/W_T and W_2/W_T for the ratio D/H

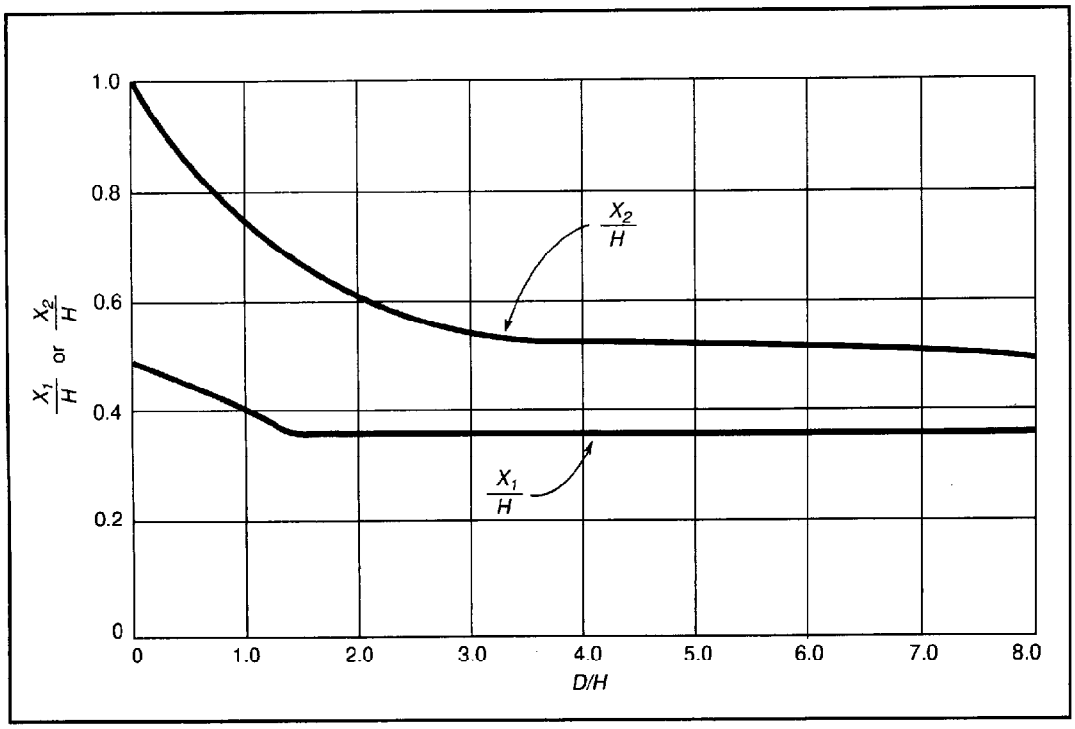

Figure 8 Curves for obtaining factors X_1/H and X_2/H for the ratio D/H

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be determined by other analytical procedures based on the dynamic characteristics of the tank. Where response spectra* are used, the acceleration of the two masses shall replace the seismic coefficient as follows:

$$A_{impulsive}, \left[\frac{(A_i)}{R_F}\right], \text{ replaces } (0.14)\frac{18ZI}{R_w} \text{ (in g's)}$$

$$A_{convective}, \left[\frac{(A_c)}{R_F}\right], \text{ replaces } \frac{18ZIC_1S}{R_w} \text{ (in g's)}$$

Where:

g = acceleration due to gravity, which is 32.2 ft/second^2
R_F = reduction factor (see Sec. 12.4.1)

The spectral velocity is related to the convective acceleration as follows:

$$S_v = 5.125A_cT_w, \text{ in ft/second} \qquad \text{(Eq 18)}$$

or

$$S_v = 92.25\frac{C_1ZIST_w}{R_w}, \text{ in ft/second} \qquad \text{(Eq 19)}$$

Where:

S_v = spectral velocity, in feet per second
A_i = impulsive acceleration, in g's, determined from the response spectrum
A_c = convective acceleration, in g's, determined from the response spectrum
T_w = first mode sloshing wave period, in seconds

The other symbols are previously defined in Sec. 12.3.1.

12.3.3 *Resistance to overturning.*

12.3.3.1 Resistance to the overturning moment at the bottom of the shell may be provided by the weight of the tank shell, weight of roof reaction on shell, W_{rs}, and by the weight of a portion of the tank contents adjacent to the shell for unanchored tanks, or by anchorage of the tank shell. For unanchored tanks, the portion of the contents that may be used to resist overturning is dependent on the width of the bottom annulus. The annulus may be a separate ring or an extension of the bottom plate if the required thickness does not exceed the bottom thickness. The weight of the annulus that lifts off the foundation shall be determined by the formula

*When tanks are located in an active fault zone capable of generating a maximum credible earthquake of Richter magnitude 7.0 or greater, consideration should be given to developing a response spectra for the site.

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$$w_L = 7.9t_b\sqrt{\sigma_y HG} \leq 1.28HDG \quad \text{(Eq 20)}$$

Where:

w_L = maximum weight of tank contents per foot of shell circumference that may be used to resist the shell overturning moment, in pounds per foot. Eq 20 applies whether or not a thickened annulus is used
t_b = thickness of the bottom annulus, in inches
σ_y = minimum specified yield strength of bottom annulus, in pounds per square inch
H = maximum depth of water, in feet
G = specific gravity (1.0 for water)
D = tank diameter, in feet

12.3.3.2 The bottom annulus may be thicker than the bottom shell course, but the thickness t_b, used to calculate seismic stability, shall not exceed the thickness of the bottom shell course. When the bottom annulus is thicker than the remainder of the bottom, the total width of the bottom annulus shall be equal to or greater than that determined by the formula

$$L \geq 0.216t_b\sqrt{\frac{\sigma_y}{HG}} \leq 0.035D, \text{ in feet} \quad \text{(Eq 21)}$$

Where:

L = total width of the bottom annulus measured from the inside of the shell, in feet, but is not to exceed $0.035D$

NOTE: If L exceeds $0.035D$, the tank must be anchored.

The other symbols are previously defined in this section, under Eq 20.

12.3.4 *Shell compression in unanchored tanks.*

12.3.4.1 The maximum longitudinal shell compression stress at the bottom of the shell when there is no uplift shall be determined by the formula

$$\sigma_c = \left(w_t + \frac{1.273M}{D^2}\right)\frac{1}{12t_s}(\text{psi}) \quad \text{(Eq 22)}$$

These terms are defined in this section, under Eq 16, 17, and 25.

NOTE: There is no uplift when the quantity resulting from Eq 23 is equal to or less than 0.785.

$$\frac{M}{D^2(w_t + w_L)} \leq 0.785 \quad \text{(Eq 23)}$$

12.3.4.2 The maximum longitudinal shell compression stress at the bottom of the shell when there is uplift shall be determined by the formula

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$$\sigma_c = \left[\frac{w_t + w_L}{0.6070 - 0.18667\left(\frac{M}{D^2(w_t + w_L)}\right)^{2.3}} - w_L \right] \frac{1}{12t_s} \text{ (psi)} \qquad \text{(Eq 24)}$$

NOTE: There is limited uplift when Eq 25 yields a quantity greater than 0.785 but equal to or less than 1.54.

$$0.785 < \frac{M}{D^2(w_t + w_L)} \leq 1.54 \qquad \text{(Eq 25)}$$

When Eq 25 yields a quantity greater than 1.54, the bottom annulus must be thickened (maximum thickness = t_s) or the tank must be anchored. In thickening the bottom annulus, the intent is not to force a thickening of the lowest shell course, thereby inducing an abrupt thickness change in the shell, but rather to impose a limit on the annulus ring thickness based on the shell design.

In Eq 22, 23, 24, and 25:

σ_c = maximum longitudinal shell compression stress, in pounds per square inch

t_s = thickness of bottom shell course, in inches

w_t = weight of the tank shell and portion of the roof reacting on the tank shell, in pounds per foot of shell circumference determined by the formula

$$w_t = \frac{W_s}{\pi D} + w_{rs} \qquad \text{(Eq 26)}$$

w_{rs} = roof load acting on shell in pounds per foot of shell circumference. Only permanent roof loads shall be included. Roof live load shall not be included.

The other symbols are previously defined in this section.

NOTE: The maximum longitudinal shell compression stress σ_c must be less than the earthquake allowable stress σ_e, which is determined in compliance with Sec. 12.3.7.4.

12.3.5 *Shell compression and anchor loads in anchored tanks.* When an anchored tank is required, the maximum longitudinal compression stress at the bottom of the shell shall be determined by Eq 22. The anchor tensile load is determined as follows:

$$T_B = S_L\left[\frac{1.273M}{D^2} - w_t\right] \qquad \text{(Eq 27)}$$

Where:

T_B = anchor tension, in pounds

S_L = anchor spacing, in feet

The other symbols have been previously defined in this section.

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12.3.6 *Hydrodynamic seismic hoop tensile stresses.* Hydrodynamic seismic hoop tensile stresses shall be determined by the following formulas.

1. When vertical acceleration is not specified,

$$\sigma_s = (N_i + N_c)/t \qquad \text{(Eq 28)}$$

for $D/H \geq 1.333$:

$$N_i = 11.35\left[\frac{ZI}{R_w}\right]GDH\left[\frac{Y}{H} - 0.5\left(\frac{Y}{H}\right)^2\right]\tanh\left(0.866\frac{D}{H}\right) \qquad \text{(Eq 29)}$$

For $D/H < 1.333$ and $Y < 0.75D$:

$$N_i = 6.98\left[\frac{ZI}{R_w}\right]GD^2\left[\frac{Y}{0.75D} - 0.5\left(\frac{Y}{0.75D}\right)^2\right] \qquad \text{(Eq 30)}$$

For $D/H < 1.333$ and $Y \geq 0.75D$:

$$N_i = 3.50\left[\frac{ZI}{R_w}\right]GD^2 \qquad \text{(Eq 31)}$$

For all values of D/H:

$$N_c = \frac{17.55\left[\frac{ZI}{R_w}\right]C_1SGD^2\cosh\left[\frac{3.68(H-Y)}{D}\right]}{\cosh\left[\frac{3.68H}{D}\right]} \qquad \text{(Eq 32)}$$

2. When vertical acceleration is specified,

$$\sigma_s = \frac{\sqrt{N_i^2 + N_c^2 + (N_h a_v)^2}}{t} \qquad \text{(Eq 33)}$$

Where:

σ_s = hydrodynamic hoop stress, in pounds per square inch
N_i = impulsive hoop force, in pounds per inch* of shell height, at the design point
N_c = convective hoop force, in pounds per inch* of shell height, at the design point

*Derived from reference 1 in Sec. 12.8. When a response spectra is specified that does not extend out to the period of the sloshing, it is acceptable to calculate spectral velocity by the formula in Sec. 12.3.2.3.

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N_h = hydrostatic force, in pounds per inch of shell height, at the design point

$$= 2.6GYD \qquad \text{(Eq 33a)}$$

a_v = vertical acceleration (decimal). This value shall be three fourths of the impulsive acceleration, unless otherwise specified

t = thickness of the shell ring under consideration, in inches (millimetres)

Y = distance from fluid surface, in feet (positive down) to the bottom of the ring or design point under consideration

The other symbols have been previously defined in this section.

The hydrodynamic hoop tensile stresses shall be added to the hydrostatic stress in determining the total stress.

12.3.7 *Additional considerations.*

12.3.7.1 If vertical acceleration is specified, the purchaser shall indicate the magnitude of acceleration, if different from that given in Sec. 12.3.6.

12.3.7.2 The purchaser shall specify the amount of freeboard to be provided for the sloshing wave. Freeboard is defined as the distance from the top capacity level to the lowest level of the roof framing. If the purchaser chooses to specify no additional freeboard, some loss of contents and roof damage may occur if the tank is completely full during an earthquake. The sloshing wave height may be calculated by the formula

$$d = 7.53D\left[\frac{ZIC_1S}{R_w}\right] \qquad \text{(Eq 34)}$$

Where:

d = wave height above top capacity level, in feet

The other symbols have been previously defined in this section.

12.3.7.3 Seismic design of roof framing and columns shall be made if specified by the purchaser. The purchaser shall specify the amount of live loads and vertical acceleration to be used in seismic design. Columns shall be designed for lateral water loads and acceleration as specified by the purchaser. Seismic beam-column design shall be based on the primary member allowable stresses, set forth in AISC (ASD), increased by one third for seismic loading.

12.3.7.4 Allowable shell plate stresses in tension for the material used shall be based on the stress allowable in Sec. 3. A one-third increase in basic allowable shell plate stress is permitted for seismic loadings.

In compression, the effect of internal liquid pressure on increasing buckling allowable stresses in Figure 9 shall be included with a safety factor of 2.0 in the design of unanchored tanks subjected to seismic loading (refer to reference 5 in Sec. 12.8).* The earthquake allowable stress is determined by the following formulas:

*The concept of increased stability due to internal pressure is supported by field observations and model tests. The increase in allowable stress due to pressure is permitted for a "once in a lifetime stress." Conservative non-pressure allowables are used for operating loads since consideration must be made for longevity, maintenance, settlement, tolerances, discontinuities, and so forth.

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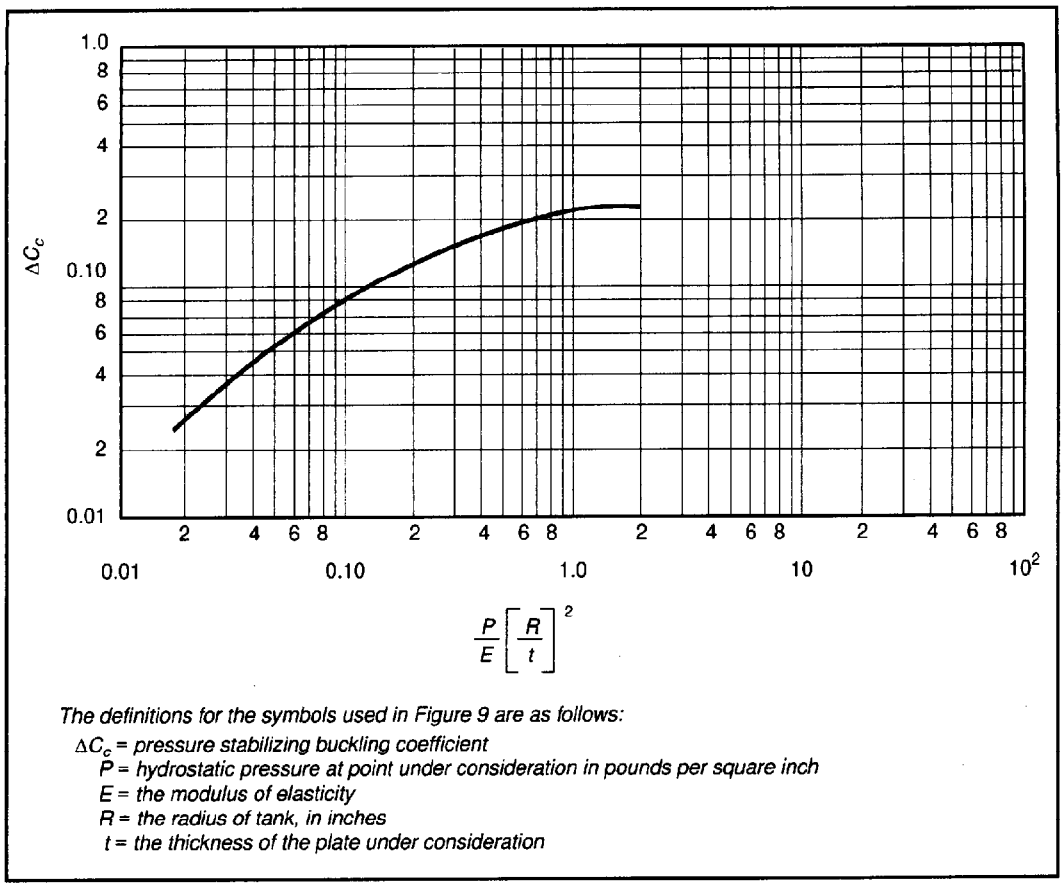

The definitions for the symbols used in Figure 9 are as follows:

ΔC_c = *pressure stabilizing buckling coefficient*
P = *hydrostatic pressure at point under consideration in pounds per square inch*
E = *the modulus of elasticity*
R = *the radius of tank, in inches*
t = *the thickness of the plate under consideration*

Figure 9 Increase in axial-compressive buckling-stress coefficient of cylinders due to internal pressure (for use with unanchored tanks)

For unanchored tanks:

$$\sigma_e = 1.333\left(f_s + \frac{\Delta\sigma_{cr}}{2}\right) \quad \text{(Eq 35)}$$

Where:

σ_e = earthquake allowable stress, in pounds per square inch
f_s = allowable compressive stress, in pounds per square inch, determined by the formula in Sec. 3.4.2
$\Delta\sigma_{cr}$ = critical buckling stress increase due to pressure, in pounds per square inch, determined by the formula

$$\Delta\pi_{cr} = \frac{\Delta C_c E t}{R} \quad \text{(Eq 36)}$$

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Where:

ΔC_c = pressure stabilizing buckling coefficient (see Figure 9)
E = modulus of elasticity, 29,000,000 psi
t = thickness of the plate under consideration, in inches
R = radius of the tank, in inches

For anchored tanks:

$$\sigma_e = 1.333 f_s \qquad \text{(Eq 37)}$$

12.3.7.5 Tank sliding. Ground-supported tanks full of product have not been found to slide off their foundation. When a sliding check is specified by the purchaser, a coefficient of friction equal to tan 30° can be assumed. The actual lateral base shear, V_{act}, shall be less than the allowable lateral base shear, V_{allow}.

$$V_{allow} = \tan 30°(W_s + W_r + W_1 + W_2)(1.0 - 0.4a_v) \qquad \text{(Eq 38)}$$

Where:

V_{allow} = allowable lateral shear in pounds
$V_{act} < V_{allow}$

NOTE: See Sec. 12.3.1 (Eq 15) for determination of V_{act}.

$$\frac{P}{E}[R/t]^2$$

Where:

ΔC_c = pressure stabilizing buckling coefficient (see Figure 9)
P = hydrostatic pressure at point under consideration, in pounds per square inch
E = modulus of elasticity
t = thickness of the plate under consideration, in inches
R = radius of the tank, in inches

NOTE: When $\frac{P}{E}[R/t]^2$ exceeds 2.0, inelastic buckling occurs. Design is beyond the scope of this standard.

Sec. 12.4 Local Seismic Data

When a spectral-response curve is provided for a given location, it may be used in place of acceleration and spectral velocity values in this section. A 2-percent damped curve is recommended for determining acceleration of a structure, and a 0.5-percent damped curve is recommended for determining acceleration of the sloshing liquid. The amplified acceleration shall be determined for the cantilever beam period of the shell and effective portion of the contained liquid.

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12.4.1 *Scaling down site response spectra.* Scaling down a site-specific response spectra is appropriate for ductile modes of failure, such as hoop tension. Nonductile modes of failure, such as elephant foot buckle at the base of ground-supported tanks may also be scaled down. Buckling loads that may result in total collapse of the structure shall not be scaled down. Scaling down will depend on the return period of the earthquake used to generate the response spectra. A reduction factor, R_F, of 2.5 shall be used for ground motion with a mean recurrence interval of 10,000 years. Where information is not available to accurately determine a recurrence level, the maximum credible ground motion based on seismology, geology, and seismic and geologic history of the site may be used to determine a site-specific response spectra. For lower recurrence spectra, the spectra may be scaled down, but in no case shall the final design acceleration be less than that calculated using values from Tables 3 through 6 and Eq 15 and 16.

Sec. 12.5 Piping Connections

A minimum 2 in. of flexibility in the vertical and tangential directions in either direction from the pipe centerline shall be provided for all piping attached to the shell.

12.5.1 *Bottom connection for unanchored flat-bottom tanks.* The bottom connection on an unanchored flat-bottom tank shall be located inside the shell a sufficient distance to minimize damage by uplift. At a minimum, the distance measured to the edge of the connection reinforcement shall be the width of the calculated unanchored bottom hold-down plus 12 in. (305 mm), as shown in Figure 10.

Sec. 12.6 Foundation Design

A one-third increase in allowable stress shall be permitted in foundation design.

12.6.1 *Anchored flat-bottom tank.* Ringwalls and footings for anchored flat-bottom tanks shall be proportioned to resist maximum anchor-bolt uplift and overturning bearing pressure. Water load directly over the ringwall and footing may be used to resist the maximum anchor bolt uplift, provided the ringwall and footing are designed to carry the eccentric loading. Water shall not be used to reduce the anchor bolt load.

12.6.2 *Unanchored flat-bottom tank.* Calculated toe pressure to satisfy equilibrium on unanchored flat-bottom tanks produces impractical ringwall dimensions.

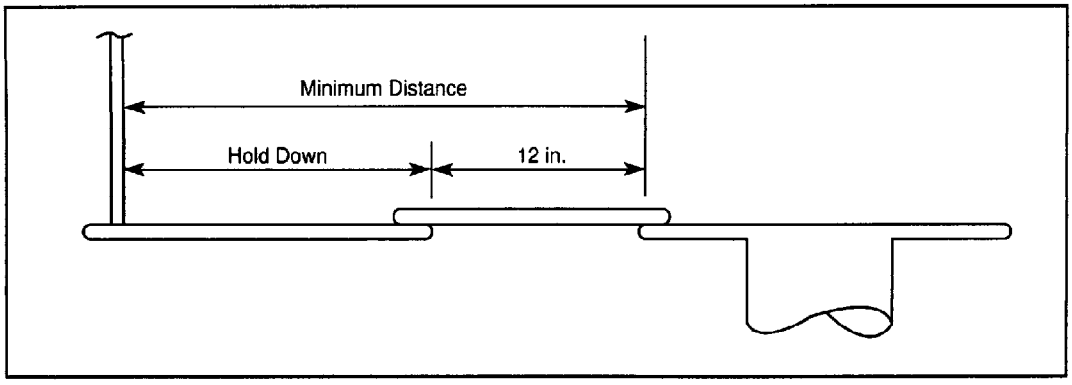

Figure 10 Bottom piping connection of an unanchored flat-bottom tank (12 in. = 304.8 mm)

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Some yielding of soil (settlement) may occur under the shell, requiring releveling of the tank after an earthquake. The foundations under flat-bottom tanks, even tanks resting directly on earth foundations, have fared well under seismic loadings. Therefore, the seismic loading does not alter the foundation design criteria or provide justifications for increased foundations for ring-bearing plates.* Design-bearing pressure should be determined using the same method as for an anchored tank condition. This assumption does not permit a larger R_w factor from Table 4. R_w shall be 3.5.

12.6.3 *Unanchored tank vaults.* If a vault or ringwall penetration exists, that portion under the shell shall be designed to carry the calculated shell load on its unsupported spans.

Sec. 12.7 Tabulation Forms for Seismic Data and Example

Figure 11A presents a blank tabulation form for seismic data to be completed by the purchaser. An example tabulation form and corresponding design calculations are presented below.

Example:

Determining the adequacy of using a 0.1495-in. (3.8-mm)-thick bottom shell course in a 21-ft (6.4-m) diameter by 24-ft (7.3-m) shell-height tank. The tank is located in seismic zone 4, and there is no soil information available. Assume the tank is to be anchored.

H_t = 24 ft (NOTE: In this example there is no freeboard, and the maximum depth of water H is the same as the shell H_t.)
D = 21 ft
G = 1.0
t_s = 0.1495 in. (bottom shell course thickness)
X_s = $H/2$, or 24/2 = 12 ft
W_s = 6,800 lb
W_r = 1,500 lb
w_{rs} = 15 lb/ft
D/H = 21/24 = 0.875

See completed tabulation form (Figure 11B) for seismic data for Z, R_w, I, and S, with values of 0.4, 4.5, 1.25, and 1.5, respectively.

Solution:

1. Overturning moment (see Sec. 12.3.1, Eq 16)

$$M = 18\frac{ZI}{R_w}[0.14(W_sX_s + W_rH_t + W_1X_1) + SW_2X_2C_1]$$

The unknown quantities for this equation are found as follows:

a. $W_1 = 0.82W_T$ (see Sec. 12.3.2.1 and Figure 7)

*A "ring-bearing plate" is a plate located under the shell to spread the unanchored shell compressive stress.

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NOTE: These specs are for	☐ Bidding	☐ Final	
Z—Zone coefficient (Table 3)			_____
R_w—Force reduction coefficient (Table 4)			_____
S—Site amplification factor (Table 5)			_____
I—Use factor (Table 6)			_____
Vertical acceleration (optional)	☐ Yes	☐ No	
Freeboard (optional) feet			_____
Following items pertain to roof:			_____
Seismic design of roof	☐ Yes	☐ No	
If yes checked above:			
Vertical acceleration, percent			_____
Live load included, pounds per square foot			_____
Column lateral wave load, pounds per square foot			_____
Column horizontal acceleration, percent			_____

Figure 11A Blank tabulation form

Example:

NOTE: These specs are for	☑ Bidding	☐ Final	
Z—Zone coefficient (Table 3)			0.4
R_w—Force reduction coefficient (Table 4)			4.5
S—Site amplification factor (Table 5)			1.5
I—Use factor (Table 6)			1.25
Vertical acceleration (optional)	☐ Yes	☑ No	
Freeboard (optional) feet			0
Following items pertain to roof:			_____
Seismic design of roof	☐ Yes	☑ No	
If yes checked above:			
Vertical acceleration, percent			_____
Live load included, pounds per square foot			_____
Column lateral wave load, pounds per square foot			_____
Column horizontal acceleration, percent			_____

Figure 11B Completed tabulation form for design example

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In this formula

$$W_T = \left(\frac{\pi D^2}{4}\right) H 62.4 \text{ (see Sec. 12.3.2.1, Eq 17)}$$

Substituting the known quantities

$$W_T = [(\pi \times 21^2)/4] \times 24 \times 62.4$$
$$= 518{,}710 \text{ lb}$$

$$W_1 = 0.82 \times 518{,}710$$
$$= 425{,}342 \text{ lb}$$

b. $W_2 = 0.20 W_T$ (see Sec. 12.3.2.1 and Figure 7)

Substituting the known quantities

$$W_2 = 0.20 \times 518{,}710$$
$$= 103{,}742 \text{ lb}$$

c. $X_1 = 0.42H$ (see Sec. 12.3.2.2 and Figure 8)

Substituting the known quantities

$$X_1 = 0.42 \times 24$$
$$= 10 \text{ ft}$$

d. $X_2 = 0.77H$ (see Sec. 12.3.2.2 and Figure 8)

Substituting the known quantities

$$X_2 = 0.77 \times 24$$
$$= 18.5 \text{ ft}$$

e. $C_1 = 1/(6T_w)$ when $T_w < 4.5$ seconds

or

$C_1 = 0.75/T_w^2$ when $T_w \geq 4.5$ seconds (see Sec. 12.3.1, Eq 16a and 16b)

In these formulas,

$T_w = K_p D^{1/2}$ (see Sec. 12.3.1, Eq 16c, and Figure 6)

Substituting the known quantities

$$T_w = 0.57 \times 21^{1/2}$$
$$= 2.61$$

the formula $C_1 = 1/(6T_w)$ governs, and substituting the known quantities,

$$C_1 = 1/(6 \times 2.61)$$
$$= 0.064$$

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Substituting the known quantities in the overturning moment formula

$$M = \frac{18(0.4)(1.25)}{4.5}[0.14(6{,}800 \times 12 + 1{,}500 \times 24 + 425{,}342 \times 10)$$

$$+ 1.5 \times 103{,}742 \times 18.5 \times 0.064] = 1{,}592{,}377 \text{ ft} \cdot \text{lb}$$

2. Shell compressive stress for anchored tank

$$\sigma_c = \left(w_t + \frac{1.273M}{D^2}\right)\frac{1}{12t_s} \text{ (see Sec. 12.3.5, Eq 22)}$$

The unknown quantity for this equation is found as follows:

$w_t = W_s/\pi D + w_{rs}$ (see Sec. 12.3.4.2, Eq 26)

Substituting the known quantities

$w_t = 6{,}800/\pi(21) + 15$

$= 118$ lb/ft

Substituting the known quantities in the shell compressive stress formula

$$\sigma_c = \left(118 + \frac{1.273 \times 1{,}592{,}377}{21^2}\right) \times \frac{1}{12(0.1495)}$$

$= 2{,}628$ psi

3. Earthquake allowable compressive stress

$$\sigma_e = 1.333 f_s \text{ (see Sec. 12.3.7.4, Eq 37)}$$

In this equation, try shell thickness $t = 0.1495$ in. The unknown quantity for Eq 37 is found as follows:

a. $$f_s = 15{,}000\left(\frac{2}{3}\right)\left(100\frac{t}{R}\right)\left[2 - \left(\frac{2}{3}\left(100\frac{t}{R}\right)\right)\right] \text{ (see Sec. 3.4.2)}$$

Substituting the known quantities

$$f_s = 15{,}000\left(\frac{2}{3}\right)\left(100\frac{0.1495}{10.5 \times 12}\right)\left[2 - \left(\frac{2}{3}\left(100\frac{0.1495}{10.5 \times 12}\right)\right)\right]$$

$= 2{,}279$ psi

Substituting the known values in the earthquake compressive stress formula (Eq 37)

$\sigma_e = 1.333(2{,}279)$

$\sigma_e = 3{,}038$ psi

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Conclusion:

Since the earthquake compressive stress of 3,038 psi is greater than the shell compressive stress of 2,628 psi, the shell thickness of 0.1495 in. is acceptable for an anchored tank.

Sec. 12.8 References

1. 1963. *Nuclear Reactors and Earthquakes.* Burbank, Calif.: Lockheed Aircraft Corporation, under a grant from the US Atomic Energy Commission. Tech. Info. Doc. 7024; Ch. 6 and Append. F.

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NOTE: Other suitable references in addition to these will also accomplish the intent of the seismic design of this section.

SECTION 13: STRUCTURALLY SUPPORTED ALUMINUM DOME ROOFS

Sec. 13.1 General

This section establishes minimum criteria for the design, fabrication, and erection of structurally supported aluminum dome roofs. Aluminum dome roofs can be used on any size tank erected in accordance with this standard. When this section is required by the purchaser, it supersedes conflicting requirements of other sections. All other requirements of AWWA D103 shall apply.

Sec. 13.2 Definition

The dome shall be a spherical structure conforming to the dimensions of the tank. The dome structure shall be a fully triangulated space truss complete with non-corrugated closure panels. The dome shall be clear span and designed to be self-supporting from the tank structure. The dome surface paneling shall be designed as a watertight system under all design load conditions. All raw edges of the aluminum panels shall be covered, sealed, and firmly clamped in an interlocking manner to prevent slipping or disengagement under all load conditions and temperature changes.

Sec. 13.3 Design Requirements

The tank shall be designed to support the aluminum dome roof. The roof manufacturer shall supply the tank manufacturer with the magnitude and direction of all the forces acting on the tank due to the roof loads and details of the roof-to-shell attachment. The tank shall be designed to support given roof loads and attachment details. Dissimilar metals shall be isolated to prevent galvanic corrosion. For new

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tanks, the tank manufacturer shall certify that the tank has been designed to support the aluminum dome roof. For existing tanks, the purchaser or purchaser's agent shall make such a verification. The aluminum dome roof shall be supported from the rim of the tank with primary horizontal thrust contained by an integral roof tension ring. Provisions shall be made in the design of the connection between the roof and tank rim to allow for thermal expansion. A minimum range of –40°F to +140°F (–40°C to +60°C) shall be used for design unless a greater range is specified by the purchaser.

Sec. 13.4 Materials

13.4.1 *General.* All materials furnished to meet the provisions of this section shall be new and shall comply with all the requirements of this section. All aluminum alloys, properties, and tolerances shall be as defined by the Aluminum Association's *Aluminum Standards and Data*. Unless specified by the purchaser, the aluminum dome roof materials shall have a mill finish.

13.4.2 *Structural frame.* All structural frame members shall be made from AA6061-T6 or a recognized alloy with properties established by the Aluminum Association.

13.4.3 *Roof panels.* Roof panels shall be fabricated from AA3000 series or AA5000 series aluminum with a minimum nominal thickness of 0.050 in. (1.27 mm).

13.4.4 *Bolts and fasteners.* All fasteners shall be AA7075-T73 aluminum or austenitic stainless steel or other materials as accepted by the purchaser. Only stainless steel fasteners shall be used to attach aluminum to steel.

13.4.5 *Sealant and gasket material.* All sealants shall be silicone compounds conforming to Fed. Spec. TT-S-00230 unless another material is required for suitability and compatibility when in contact with potable water. Sealants shall remain flexible over a temperature range of –80°F to +300°F (–62°C to +148°C) without tearing, cracking, or becoming brittle. Elongation, tensile strength, hardness, and adhesion shall not change significantly with aging or from exposure to ozone, ultraviolet light, or vapors from the water stored in the tank.

All preformed gasket material shall be made of silicone meeting Fed. Spec. ZZ-R-765D, class 2, grade 50, or a purchaser-approved equal, unless another material is required for compatibility with potable water stored in the tank.

13.4.6 *Skylight panels.* Skylight panels, if specified by the purchaser, shall be clear acrylic or polycarbonate with a minimum nominal thickness of 0.25 in. (6.4 mm).

Sec. 13.5 Allowable Stresses

13.5.1 *Aluminum structural members.* Aluminum structural members and their connections shall be designed in accordance with the Aluminum Association's *Specifications for Aluminum Structures*, except as modified by this section.

For members subjected to axial forces and bending moments due to load eccentricity or lateral loads, the combined member stresses shall be determined by adding the stress component due to axial load to the stress components that result from bending in both the major and minor axes.

Allowable shell buckling loads shall be determined in accordance with the following formula:

$$w = \frac{2{,}258 \times 10^6 (I_x A)^{1/2}}{(SF)R^2 L} \qquad \text{(Eq 39)}$$

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Where:

w = allowable load (pressure), in pounds per square foot
I_x = moment of inertia of strut about the strong axis, in inches^4
A = cross-sectional area of strut, in square inches
R = spherical radius of dome, in inches
L = average member length, in inches
SF = safety factor (1.65)

13.5.2 *Aluminum panels.* Aluminum panels shall be designed to support the loads specified in Sec. 13.6 without exceeding the allowable stresses specified in the Aluminum Association's *Specification for Aluminum Structures.* Panel attachment fasteners shall not penetrate both the panel and flange of the structural member.

13.5.3 *Bolts and fasteners.* For fasteners not listed in Table 7, the allowable stress in bolts and fasteners shall be in accordance with the Aluminum Association's *Specifications for Aluminum Structures* and the AISI *Stainless Steel Cold Formed Structural Design Manual for Aluminum and Stainless Steel Bolts,* respectively.

Hole diameters used for fasteners shall not exceed 1/16 in. (1.6 mm) plus the diameter of the fastener used.

Sec. 13.6 Design

13.6.1 *Detail drawings and calculations.* Detail drawings and calculations certified by a professional engineer experienced in the design of these structures shall be provided when specified by the purchaser (refer to Sec. 1.4).

13.6.2 *Principles of design.* The roof framing system shall be designed as a moment-resisting, three-dimensional space frame or truss with a membrane covering (roof panels) providing loads along the length of the individual members. The design shall consider the increased compression and minor axis bending induced in the framing members as a result of the tension in the roof panels. The design loads shall not exceed the allowable buckling loads set forth in Sec. 13.5.1. The actual stresses in

Table 7 Bolts and fasteners

Material	Allowable Tensile Stress*†		Allowable Shear Stress*†‡	
	psi	(*MPa*)	*psi*	(*MPa*)
Austenitic Stainless Steel (§)	30,000	(206.9)	18,000	(124.1)
Austenitic Stainless Steel (**)	42,000	(289.7)	25,000	(172.4)
AA2024-T4 Aluminum	26,000	(179.2)	16,000	(110.3)
AA7075-T73 Aluminum	28,000	(193.0)	17,000	(117.2)

NOTES:

*The root of thread area shall be used for calculating the strength of threaded parts.

†If the thread area is completely out of the shear area the cross-sectional area of shank may be used to determine the allowable shear load.

‡For wind and seismic loads, these values may be increased by one third.

§For stainless steel bolts with a minimum tensile strength of 90,000 psi (620.5 MPa).

**For stainless steel bolts with a minimum tensile strength of 125,000 psi (861.8 MPa).

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the framing members and panels under all design load conditions must be equal to or less than the allowable stresses.

The structural analysis shall include the effect of geometric irregularities such as dormer openings and perimeter support members.

13.6.3 *Design loads.* In addition to design loads specified in Sec. 3.2, the following loads shall be considered in the design of the aluminum dome roof.

13.6.3.1 Unbalanced loading. Reduce the live load by 50 percent over one-half the dome.

13.6.3.2 Panel design load. These loads do not act simultaneously with other design loads.

Two 250-lb (113.4-kg) loads concentrated on two separate 1 ft^2 (0.093 m^2) areas of any aluminum panel, or 60 psf (293 kg/m^2) distributed over the total panel area.

13.6.3.3 Wind pressures may also be based on certified wind tunnel test results.

13.6.3.4 The minimum wind load shall be the load resulting from a wind velocity of 100 mph (45 m/second) unless a different wind velocity is specified by the purchaser. Wind loading shall be determined in agreement with Sec. 3.2.4.

13.6.3.5 If the tank is designed for seismic loads, the roof shall be designed for a horizontal seismic force determined by using the procedures of Sec. 12.

13.6.3.6 The following load combinations shall be considered:

1. Dead load
2. Dead load + Uniform live load
3. Dead load + Unbalanced live load
4. Dead load + Wind load
5. Dead load + Uniform live load + Wind load
6. Dead load + Unbalanced live load + Wind load
7. Dead load + Seismic load

Sec. 13.7 Roof Attachment Details

The structure supports provided to support the aluminum dome roof shall be bolted or welded to the tank. The number of attachment points shall be determined by the roof manufacturer in consultation with the tank manufacturer to preclude overloading the tank shell. The attachment detail shall be suitable to transfer all roof loads to the tank shell, keeping local stresses within allowable limits.

13.7.1 *Roof supports.* The roof attachment points may incorporate a slide bearing with low-friction bearing pads to minimize the horizontal radial forces transferred to the tank. Alternatively, the roof may be attached directly to the tank and the top of the tank analyzed and designed to sustain the horizontal thrust transferred from the roof, including the thrust from differential thermal expansion and contraction.

13.7.2 *Separation of carbon steel and aluminum.* Aluminum shall be isolated from the carbon steel by an austenitic stainless steel spacer or an elastomeric isolator bearing pad, unless other methods are specified by the purchaser.

Sec. 13.8 Physical Characteristics

The maximum dome spherical radius shall be 1.4 times the diameter of the tank. The minimum dome spherical radius shall be 0.7 times the tank diameter unless otherwise specified by the purchaser.

13.8.1 *Roof accessories.* Roof accessories shall conform to the provisions of Sec. 5, as applicable.

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13.8.2 *Skylights.* Skylights, if specified by the purchaser, shall be furnished with a 4 in. (102 mm) or higher curb and shall be designed for the live and wind loads specified for the roof. The purchaser shall specify the total skylight area to be provided.

Sec. 13.9 Testing and Sealing

13.9.1 *Leak testing.* After completion, the roof seams shall be leak tested by spraying the outside with water from a hose with a minimum 50 psig (345 kPa) static head pressure at the nozzle. Potable water shall be used. The water must not be sprayed directly on any roof vents. Any water on the inside of the roof shall be evidence of leakage.

Sec. 13.10 Fabrication and Erection

The manufacturer of the roof and constructor shall perform the work described in this standard with qualified supervision that is skilled and experienced in the fabrication and erection of aluminum structures. The dome shall be erected in accordance with the manufacturer's instructions.

13.10.1 *Fabrication.* All roof parts shall be prefabricated for field assembly. Fabrication procedures shall be in accordance with Sec. 6 of the Aluminum Association's *Specifications for Aluminum Structures.*

13.10.2 *Welding.* The fabrication and design of welded aluminum parts shall be in accordance with Sec. 7 of the Aluminum Association's *Specifications for Aluminum Structures,* and ANSI/AWS D1.2, Structural Welding Code—Aluminum. All aluminum structural welds and components joined by welding shall be visually inspected and tested by the dye-penetrant method of examination in accordance with ANSI/AWS D1.2, Sec. 6.7.5. All structural welding of aluminum shall be performed prior to field erecting of the dome. A full set of satisfactory examination and qualification records shall be delivered to the purchaser if requested, prior to field erection.

13.10.3 *Shipping and handling.* Materials shall be handled, shipped, and stored in a manner that will not damage the surface of aluminum or the surface coating of steel.

13.10.4 *Workmanship.* The roof shall be installed so as to minimize internal stresses on the structure when bolted together, and to the supports. The basic component parts of the structure shall be erected with precise fit and alignment. Field cutting, trimming, relocating of holes, or the application of force to the parts to achieve fitup is not acceptable.

13.10.5 *Maintenance and inspection.* The manufacturer of the roof shall provide a maintenance and inspection manual for those items that may require maintenance or periodic inspection.

Sec. 13.11 Coatings

Aluminum dome roofs shall have a mill finish. If a color other than mill-finish aluminum is desired for aesthetic reasons, the exterior of the dome may be specified to have a factory-applied, baked-on finish.

Exterior coatings may be thermosetting, acrylic, silicone polyester, or fluorocarbon.

NOTE: No coatings are to be applied to the interior surfaces of the dome, either in the manufacturer's shop or in the field.

The coating shall meet the requirements of AAMA 605.1 for high-performance organic coating on architectural extrusions and panels.

The coating shall also meet the weathering requirements specified in ASTM D2244.

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APPENDIX A

Metric (SI) Equivalents

This appendix is for information only and is not a part of AWWA D103.

Metric units used are those of the International System of Units (SI), which is officially recognized by all industrial nations. This document may be supplemented by ASTM* E380, Metric Practice Guide.

Table A.1 lists selected SI conversions for the convenience of users of this standard.

Table A.1 Metric (SI) conversion factors

Property	To Convert US Customary Units From	To Metric (SI) Units	Multiply by*
Area	square inch (in.^{2})	millimetre squared (mm^2)	6.451 600*E + 02
		metre squared (m^2)	6.451 600*E – 04
	square foot (ft^2)	metre squared (m^2)	9.290 304*E – 02
Force	pound–force (lbf)	newton (N)	4.448 222 E + 00
	kip (1,000 lbf)	newton (N)	4.448 222 E + 03
Force/Area	pound-force/foot^2 (lbf/ft^2)	newton/metre^2 (N/m^2)	4.788 026 E + 01
Impact strength	foot-pound force (ft•lbf)	joule (J)	1.355 818 E + 00
Linear dimension	inch (in.)	millimetre (mm)	2.540 000*E + 01
	foot (ft)	millimetre (mm)	3.048 000*E + 02
Mass/Volume	pound–mass/cubic foot (lb/ft^3)	kilogram/metre^3 (kg/m^3)	1.601 846 E + 01
Temperature	degrees Fahrenheit (°F)	degrees Celsius (°C)	°C = (°F –32)/1.8
Tensile strength	pounds per inch^2 (psi)	pascal (Pa)	6.894 757 E + 03
	kips per inch^2 (ksi)	kilopascal (kPa)	6.894 757 E + 00
		megapascal (MPa)	6.894 757 E + 00
Velocity	miles per hour (mph) (US statute)	metre per second (m/second)	4.470 400*E – 01
Volume	gallon (gal) (US liquid)	metre cubed (m^3)	3.785 412 E – 03

*An asterisk (*) after the sixth decimal place indicates that the conversion factor is exact and that all subsequent digits are zero. The number is followed by the letter E (exponent), a plus or a minus symbol, and two digits that indicate the power of 10 by which the number must be multiplied to obtain the correct value.

*American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

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Erratum to ANSI/AWWA D110-95 Standard for Wire- and Strand-Wound, Circular, Prestressed Concrete Water Tanks

(January 2001)

Corrections to text:

P. 32, Sec. 4.3.1(3), revised as follows:

3. The impulsive coefficient C_I is determined from Eq 4-7. However, C_I need not exceed 2.75.

$$C_I = \frac{1.25S}{T_I^{2/3}} \qquad \text{(Eq 4-7)}$$

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Addendum to ANSI/AWWA D110-95

Standard for Wire- and Strand-Wound Circular-Prestressed Concrete

(Approved by the AWWA Board of Directors on June 23, 1996.)

P. 32, Sec. 4.3.1(4), revise as follows:

"(4) The tank's natural period T_I may be determined by a rational analysis that considers the weight of the tank wall and roof and effective weight W_I of the tank contents. The tank's natural period T_I shall be limited to 0.3 s or less for Sec. 4.2.1, Figure 4A tanks. For Sec. 4.2.1, Figure 4B and 4C tanks, T_I shall be determined from Eq 4-8. Refer to Sec. 4.1.2 for definition of symbols.

$$T_I = \sqrt{\frac{4\pi (W_S + W_R + W_I)}{g\, r\, k}} \qquad \text{(Eq 4-8)}$$

P. 35, Sec. 4.3.2, replace with the following:

"4.3.2 *Application of site response spectrum.* Where site-specific response spectra are used, the accelerations of the two masses shall replace the seismic coefficient as follows:

A_I replaces ZIC_I (in g) in Eq 4-1, 4-4, and 4-24, providing the following alternative equations:

$$V_I = \frac{A_I}{R_I}(W_S + W_R + W_I) \qquad \text{(Eq 4-1A)}$$

$$M_I = \frac{A_I}{R_I}(W_S X_S + W_R H_t + W_I X_I) \qquad \text{(Eq 4-4A)}$$

$$N_I = \frac{A_I}{\pi R_I}\left(\frac{W_S}{2} + W_R + W_I\right) \qquad \text{(Eq 4-24A)}$$

Similarly, $\sqrt{3.375}\ \frac{D_c}{r}\ \tanh\ (\sqrt{3.375}\ H/r)$ replaces ZIC_c (in g) in Eq 4-2, 4-5, 4-25, 4-28, and 4-29.

Refer to Sec. 4.1.2 for definition of symbols.

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For tanks with a Sec. 4.2.1, Figure 4A base joint, the natural period T_I shall be taken as the period in the range of 0.0 s to 0.3 s that gives the largest base shear, unless a more precise determination of period is performed.

The zone coefficients Z represent, within the accuracy that can be expected of such a system, the peak ground accelerations that have a 10 percent chance of being exceeded in 50 years. When multiplied by an importance factor I of 1.25, the probability of being exceeded drops to 5 percent. Similar probabilities should be used for site-specific response spectra. The results obtained by using site-specific response spectra shall not be less than those determined by the zone-based Eq 4-1, 4-2, 4-4, 4-5, 4-24, 4-28, and 4-29."

P. 37, Sec. 4.5.3, revise Eq 4-24, with the following:

"4.5.3 *Equivalent axisymmetric hoop loads.* Hydrodynamic seismic membrane hoop tensile stresses in the circumferential direction, radial shear, and vertical bending moments shall be determined by applying the equivalent axisymmetric hoop loads due to the response of the mass of the tank roof and shell (wall) combined with the equivalent axisymmetric hoop load due to the response of the mass of the tank contents given by Eq 4-24, 4-25, 4-26, and 4-27. The maximum radial force, summed over the full height of the tank wall (see the last two paragraphs in this section for the vertical distribution of these forces) for each component, may be obtained by dividing the following equivalent axisymmetrical hoop loads by the radius:

$$N_I = \frac{ZIC_I}{\pi R_I}\left(\frac{W_S}{2} + W_R + W_I\right) \qquad \text{(Eq 4-24)}$$

NOTE: The roof weight W_R need not be included in Eq 24 for tanks with shear connections between the wall and roof that only transfer forces tangential to the wall.

$$N_C = \frac{ZIC_C}{R_C}(W_C)\left(\frac{8}{9\pi}\right) \qquad \text{(Eq 4-25)}$$

$$N_V = \frac{\ddot{u}_V \gamma H^2 R}{2} \qquad \text{(Eq 4-26)}$$

$$N_T = \sqrt{N_I^2 + N_C^2 + N_V^2} \qquad \text{(Eq 4-27)}$$

The vertical distribution of the impulsive hoop loads, resulting from the response of the tank contents, shall be Housner's (see appendix A, reference 5) impulsive pressure distribution, or a trapezoid that approximates this distribution, increasing linearly from top to bottom. The centroid of the impulsive hoop load distribution shall be located at a height from the bottom of the tank shell equal to the centroid X_I of the impulsive portion W_I of the tank contents. The impulsive hoop loads shall not be distributed over a height greater than the depth of the water H.

The vertical distribution of the convective hoop loads, due to the response of the tank contents, shall be Housner's convective pressure distribution, or a trapezoid that approximates this distribution, decreasing linearly from top to bottom. The centroid of the convective hoop load distribution shall be located at a height from the bottom of the tank shell equal to the centroid X_C of the convective portion W_C of the tank contents. The convective hoop loads shall not be distributed over a height greater than the depth of water H.

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The vertical distribution of the vertical acceleration hoop loads shall be a triangular distribution with the maximum at the bottom. The vertical acceleration loads shall not be distributed over a height greater than the depth of the water *H*.

For purposes of calculating the combined effects on the tank wall and other components, the impulsive, convective, and vertical acceleration loads shall be combined by taking the square root of the sum of the squares of the three components. When determining the required area of circumferential prestressed reinforcement for a given increment of wall height, the square root of the sum of the squares of the three seismic components taken at the mid-height of the increment shall be added to the hydrostatic load at the mid-height of the increment and divided by the allowable stress under seismic loading."

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ANSI/AWWA D110-95
(Revision of ANSI/AWWA D110-86)

AWWA STANDARD

FOR

WIRE- AND STRAND-WOUND, CIRCULAR, PRESTRESSED CONCRETE WATER TANKS

AMERICAN NATIONAL STANDARD

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AMERICAN WATER WORKS ASSOCIATION

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Foreword

This foreword is for information only and is not a part of AWWA D110.

I. Introduction

I.A. *Background.* The New England Water Works Association (NEWWA) established a committee in 1958 to prepare a standard specification for the design and construction of prestressed concrete water-storage tanks. The committee submitted a suggested specification to NEWWA in October 1962 as a guide to those in the water industry who wished to consider the use of these tanks.

American Concrete Institute (ACI) Committee 344 concluded eight years of committee work with a report titled *Design and Construction of Circular Prestressed Concrete Structures,* published in the *ACI Journal* in September 1970. This report referred primarily to wire-wound tanks.

I.B. *History.* In the December 1972 issue of Journal AWWA, the applicability of the ACI report to water containment structures was discussed in four articles. As a result of these articles and continued discussion on the subject, a standards committee was authorized by the American Water Works Association (AWWA) to develop an AWWA standard for circular, prestressed concrete water tanks.

An AWWA Standards committee on circular, prestressed concrete water tanks was appointed and held its first meeting June 19, 1974. During its first two years, the committee studied the various types of prestressed tanks then in service or under construction and determined that most were of the wire-wound type. Therefore, the committee in 1976 was directed to limit its scope to the wire- and strand-wound prestressed tank wall design. The first edition of this standard incorporated the work of ACI Committee 344 and contained additional requirements and recommendations, specifically for potable and process water, and for wastewater containment structures. The new standard, AWWA D110-86, Standard for Wire-Wound Circular Prestressed-Concrete Water Tanks, was approved by the AWWA Board of Directors on June 22, 1986, and had an effective date of June 1, 1987. The standard has been in use since approval by the American National Standards Institute (ANSI) on Mar. 3, 1987.

The first revision of this standard was initiated by the AWWA Standards Committee during 1990 in accordance with AWWA Standards Council policy.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF) to develop voluntary third-party consensus standards and a certification program for all direct and indirect drinking water additives. Other members of the consortium included the American Water Works Association Research Foundation (AWWARF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.* Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate

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the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.
2. Specific policies of the state or local agency.
3. Two standards developed under the direction of NSF, ANSI*/NSF† 60, Drinking Water Treatment Chemicals—Health Effects, and ANSI/NSF 61, Drinking Water System Components—Health Effects.
4. Other references, including AWWA standards, *Food Chemicals Codex, Water Chemicals Codex*,‡ and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with ANSI/NSF 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Appendix A, "Toxicology Review and Evaluation Procedures," to ANSI/NSF 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Appendix A procedures may not always be identical, depending on the certifier.

AWWA D110 does not address additives requirements. Thus, users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.
2. Determine the status of certifications by all parties offering to certify products for contact with, or treatment of, drinking water.
3. Determine current information on product certification.

II. Special Issues

II.A. *Intent*. This standard reflects a committee consensus of industry practice concerning the design, detailing, and construction of circular, prestressed concrete water tanks of several types, with or without vertical prestressing of the tank core wall. The horizontal prestressed reinforcement of the tank wall is accomplished by the application of helically wound high-tensile-stress wire or strand under controlled tension on the surface of the core wall, protected by shotcrete cover coats.

Recommended criteria and guidelines are presented to assist engineers in the design, construction, and inspection of tanks with shotcrete, cast-in-place concrete, or precast circular concrete core walls, with or without internal steel diaphragms, based on the successful application of these concepts in practice and the detailed experience of committee members. Engineering principles are tied to existing codes where applicable.

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*American National Standards Institute, 11 W. 42nd St., New York, NY 10036.

†NSF International, 3475 Plymouth Rd., Ann Arbor, MI 48106.

‡Both publications available from National Academy of Sciences, 2102 Constitution Ave. N.W., Washington, DC 20418.

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The intent is also to assist the designer and constructor by sharing information on the unique aspects in analysis and construction that are encountered in these types of structures.

II.B. *Limitations.* Because of the wide range of site-specific environments, foundation conditions, loadings, and construction conditions throughout North America, this standard should not be expected to apply universally nor to produce a cost-effective and completely maintenance-free structure in every situation. In adapting this standard to obtain the structure's expected service life for the actual conditions that are anticipated, the purchaser and the designer of the tank are advised to study carefully all factors affecting the structure during its anticipated service life.

III. Use of This Standard. AWWA has no responsibility for the suitability or compatibility of the provisions of this standard to any intended application by any user. Accordingly, each user of this standard is responsible for determining that the standard's provisions are suitable for and compatible with that user's intended application.

III.A. *Industry Practice and Assumptions.* It is not the purpose of this standard to either define or recommend contractual relationships or to stipulate contractual obligations, both of which are the responsibility of the purchaser. Generally, purchasers may solicit competitive bids for wire- and strand-wound circular prestressed concrete tanks by one of two methods.

Under the first method, a qualified engineer is retained by the purchaser to design the structure and prepare construction drawings, specifications, and other contract documents. Competitive bids are then solicited from constructors and suppliers for construction of the tank. In this standard, these are referred to as *purchaser-furnished designs.*

Under the second method, the purchaser prepares performance specifications that require bidding constructors to prepare detailed project designs and specifications and construct the tank according to the approved design. In this standard, these are referred to as *design-construct projects.*

While the division of information that must be covered in the purchaser's specifications for execution of each project type differs substantially, depending on who is responsible for the tank design, the information that must be supplied by the purchaser to successfully apply this standard is essentially the same.

AWWA D110-95 does not address matters related to site selection and property acquisition. It is assumed that the purchaser will have conducted sufficient background work in the form of water system studies, predesign surveys, subsurface investigations, preliminary design work, etc., to establish the desired tank site, volume, operating water depth, and elevations. Further, it is assumed that the purchaser will have acquired the property, easements, and rights-of-way necessary for construction of site access, the tank structure, and associated water pipelines connecting the tank to the water system and drainage, if required. Specifically, it has been assumed that the purchaser will arrange for or provide the following as necessary or appropriate:

1. The site on which the tank is to be built, with adequate space to permit the constructor to erect the structure using customary methods.

2. A predesign site survey and preparation of a site plan showing existing topography, property lines, approximate tank centerline location, setback, encumbrances, details of special construction features, and extent of final site grading.

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3. A site geotechnical survey and foundation report, including logs of borings and test pits, soil densities, and other pertinent soil and geological information; construction criteria for any backfill that may be necessary at a particular site; and foundation design criteria prepared by a registered professional engineer specializing in soil mechanics, including allowable bearing loads, anticipated total and differential settlements, and the seismic soil profile type.

4. Structural loading conditions, including, but not limited to, snow, wind, seismic, hydrostatic uplift, and other live loads depending on the tank's intended use; the amount of earth cover over the tank, if any; the height of backfill against the tank wall, if any; and any other special loading conditions that are anticipated or special criteria on which the tank design is to be based. If, for example, the tank is located in a high-intensity earthquake area and must continue to serve without damage, the purchaser may specify an importance factor for earthquake design as described in Sec. 4.2.1 or provide design values for the peak horizontal ground acceleration and for the spectrum velocity. In cases where the static and dynamic earth pressures resulting from seismic shaking must be designed for, the purchaser shall provide the required geotechnical data to evaluate these pressures in the tank design. If the tank is to be located in seismic zones 3 or 4, additional information shall be provided in the soils report as discussed in Sec. 4.

5. Requirements for subdrainage and overflow collection systems.

6. Delivery of electric power and water service to the site.

III.B. *Purchaser Options and Alternatives.* The items that follow are either required information or alternative options in the standard that should be considered and covered in the purchaser's specifications, unless the purchaser intends that the choice for a particular option be left to the tank designer's discretion.

1. The standard to be used, that is, AWWA D110-95, Standard for Wire- and Strand-Wound, Circular, Prestressed Concrete Water Tanks.

2. The required capacity of the tank and desired height–diameter relationship.

3. The required elevation of the overflow weir and freeboard requirements.

4. The type of roof and type or types of tank wall. Basic wall types are listed in Sec. 1.1.1. Roof structures may be shotcrete or concrete domes as described in Sec. 3.6, nonprestressed concrete flat slabs supported by columns as described in Sec. 3.7.1.1, or other types of roofs selected by the purchaser. Preference for wet mix or dry mix for the tank wall or shotcrete cover coats, as specified in Sec. 2.1.2.2.

5. Maximum filling and emptying (overflow) rates required.

6. Size, material, arrangement, and location for the overflow pipe.

7. Size, material, location, details, cover depths, and limits of responsibility for all other pipe connections.

8. Requirements for subdrainage and overflow collection systems.

9. Finish grade relative to the tank foundation. (Whether or not the wall is to be completely exposed, partially buried, or completely buried.)

10. Tank appurtenances required.

a. Whether or not a removable silt stop is required and/or baffles are to be provided for circulation.

b. Size, material, and location of vents, access hatches, ladders, stairs, and manways; and locking and safety devices required.

c. Requirements for a water-level gauge or pressure sensor.

d. Specifications for any additional accessories to be provided.

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11. Special exterior wall coatings or architectural treatment, if any.
12. Seismic information required.
a. Zone classification (Table 2 and Uniform Building Code*).
b. Importance factor (Table 3).
c. Soil profile coefficient (Table 5) from geotechnical survey report provided by the purchaser.
13. Special requirements, including federal, state, and local regulations, labor, and others.
14. Information on access to the site for the constructor's equipment and for supply of construction materials.
15. Availability and characteristics of electric power and source of water for construction.

III.C. *Modification to Standard.* Any modification to the provisions, definitions, or terminology in this standard must be provided in the purchaser's specifications.

IV. Major Revisions. This second edition of the standard has been edited throughout and includes revisions to standard definitions and terms adopted as Standards Council policy to achieve a higher degree of consistency among the standards produced by AWWA standards committees. This foreword has been arranged to address specific items in conformance with this policy.

Provisions for earthquake-induced forces, formerly attached to the standard as appendix A, provided for information only and not as a part of AWWA D110 in the first edition, has been incorporated into the standard as Sec. 4 and updated in accordance with experience and current practice.

The technical revisions to the standard reflect current thinking and construction practices. These include

1. Addition of a type IV core wall tank consisting of cast-in-place concrete with a steel diaphragm imbedded at the exterior face (Sec. 1.1.1).
2. Limitation of recommended use of the standard to containment of potable water and nonaggressive raw water (Sec. 1.1.3).
3. Clarification of terms to differentiate between wire- and strand-wound tanks addressed by this standard and tanks with a wall circumferentially prestressed using anchored tendons.
4. References to ASTM† A227 for prestressing wire or strand and to ASTM A586 and ASTM A603 for steel wire structural strand and wire rope have been deleted. (Sec. 1.3).
5. References to test methods ASTM C882, ASTM D395, ASTM D412, and ASTM D2240 have been deleted as they are referenced in the appropriate standard. Fed. Spec. TT-S-227 polysulfide sealant has also been deleted (Sec. 1.3).
6. References to ASTM standards A615, A641, A722, C920, and C1107 and to Fed. Spec. SS-S-210A have been added (Sec. 1.3).
7. For type II shotcrete core-wall tanks with a steel diaphragm, the requirement that the diaphragm be continuous for the full height of the tank, as currently practiced, has been added (Sec. 2.4.1.3).

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*Available from International Conference of Building Officials (ICBO), 5360 S. Workman Mill Road, Whittier, CA 90601.

†American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

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8. Use of noncorrosive and noncontaminating chemical grout has been deleted and prohibition of the use of metallic nonshrinking aggregate grout for concrete repair has been added (Sec. 2.1.3 and Sec. 2.1.5).

9. The alternative approach of providing an initial prestress in the tank wall of 35,000 psi (240 MPa) in excess of the final prestress required for internal water pressure on the tank core wall with a minimum residual horizontal compression of 50 psi (345 kPa) in the core wall with the tank filled to the maximum overflow level has been deleted (old Sec. 3.4.2.3).

10. Rational design criteria for a dome tank cover has been modified to conform to standard practice (Sec. 3.6).

11. A requirement for a minimum 6-in. (150-mm) thick granular base material under a membrane floor has been added (Sec. 3.8.5).

12. Shotcrete floors have been deleted (Sec. 3.8.2).

13. A new section on tank appurtenances and accessories has been added (Sec. 3.11).

14. Requirements for hot-weather and cold-weather concreting and shotcreting have been clarified and modified (Sec. 5.2.1 and Sec. 5.3.1).

15. The allowable leakage for tank acceptance has been reduced to 0.05 from 0.1 percent of the tank capacity for a 24-h period (Sec. 5.13.2).

V. Comments. If you have any comments or questions about this standard, please call the AWWA Standards and Materials Development Department, (303) 794-7711, ext. 6283, FAX (303) 795-1440, or write to the department at 6666 W. Quincy Ave., Denver CO 80235.

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ANSI/AWWA D110-95
(Revision of ANSI/AWWA D110-86)

AWWA STANDARD FOR

WIRE- AND STRAND-WOUND, CIRCULAR, PRESTRESSED CONCRETE WATER TANKS

SECTION 1: GENERAL

Sec. 1.1 Scope

1.1.1 *Intent of standard.* The intent of this standard is to cover current recommended practice for the design, construction, inspection, and maintenance of wire- and strand-wound, circular, prestressed concrete water-containing structures with the following four types of core walls:

type I—cast-in-place concrete with vertical prestressed reinforcement
type II—shotcrete with a steel diaphragm
type III—precast concrete with a steel diaphragm
type IV—cast-in-place concrete with a steel diaphragm

1.1.2 *Items not covered by standard.* This standard does not cover bonded or unbonded horizontal tendons for prestressed reinforcement of the tank wall, floor, or roof.

1.1.3 *Tank contents.* This standard applies to containment structures for use with potable water or raw water of normal temperature and pH commonly found in drinking water supplies. It is not intended for use in the design of containment structures for highly aggressive waters or high-temperature waters without special consideration being given to their effects on the structure; nor is it intended that the standard be used for the design of structures for wastewater, bulk dry storage, chemical storage, or storage of slurries.

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Sec. 1.2 Definitions

In this standard, the following definitions will apply:

1.2.1 *Parties:* The persons, companies, or organizations generally involved in the purchase, design, and construction of circular, prestressed concrete tanks including:

1. *Bidder:* A party from whom bids for construction of the tank are solicited or received by the purchaser.

2. *Constructor:* The party that furnishes the work and materials for placement or installation in providing the tank for the purchaser.

3. *Design-constructor:* A firm that specializes in, designs, and constructs prestressed concrete tanks.

4. *Manufacturer:* A party that manufactures, fabricates, or produces materials or products.

5. *Prestresser:* The person, company, or organization that applies the prestressing forces to the tank.

6. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed in the design and construction of the tank.

7. *Purchaser's engineering agent:* The registered professional engineer representing the purchaser in the design of the tank and/or during its construction.

1.2.2 *Capacity:* The net volume of contents that may be removed from a tank filled to the overflow level.

1.2.3 *Core wall:* That portion of the concrete or shotcrete wall that is circumferentially prestressed.

1.2.4 *Base and top-of-wall joints:* Connections between the base of the tank's core wall and its foundation or floor slab and between the top of the wall and roof slab or dome. Types of wall-base joints may be generally defined as follows:

1. *Unanchored and uncontained, free:* Minimal restraint of radial translation and rotation.

2. *Anchored flexible:* Minimum restraint of radial translation and rotation, employing strand anchor cables between the joint components to resist tangential displacement.

3. *Reinforced-nonsliding, fixed:* Considerable or full restraint of radial translation and rotation.

4. *Changing restraint:* A wall-base joint may be of a different type during and after prestressing. An example is a joint that is unrestrained during horizontal prestressing of the wall, but is hinged after prestressing. The change in joint type is a result of grout installation that prevents radial translation after prestressing.

Types of wall-roof joints in general use may be defined as follows:

1. *Separated:* Minimal restraint of radial translation and rotation.

2. *Hinged or pinned:* Full restraint of radial translation; negligible restraint of rotation.

3. *Reinforced nonsliding:* Fixed for restraint of radial translation and rotation.

1.2.5 *Membrane floor:* A thin, highly reinforced, low-moment-resistant, concrete slab-on-grade designed to be a flexible watertight floor system.

1.2.6 *Mortar and grout:* Includes the following types:

1. *Cement mortar:* Generally, a mixture of sand, cement, and water of specified proportions.

2. *Epoxy mortar:* A mixture of epoxy resin, catalyst, and fine aggregate for repair of concrete.

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3. *Nonshrink grout:* A shrinkage-compensating, expansive cement grout used for concrete repair and patching of form-tie holes.

4. *Cement grout:* A portland cement and water mixture of pourable consistency (without segregation of constituents) used to bond and provide corrosion protection to prestressed tendons in a duct.

5. *Epoxy grout:* An epoxy-resin system used to bond and provide corrosion protection to vertical prestressed tendons in a duct.

6. *Epoxy bonding agent:* An epoxy resin normally used in repair processes to bond fresh plastic concrete mix, cement mortar, or epoxy mortar to hardened concrete.

1.2.7 *Prestressed concrete:* Concrete in which internal compressive stresses of such magnitude and distribution are introduced that the tensile stresses resulting from the service loads are counteracted to the desired degree; circumferential prestress of the tank wall is introduced herein by the helical application of high-strength steel wire or strand under controlled tension and vertical prestress by posttensioned, high-strength steel bar or strand tendons.

1.2.8 *Prestressed reinforcement:* High-strength steel used to prestress the concrete or shotcrete of the tank wall or dome roof edge ring, commonly single wires, seven-wire strands, or bars.

1. *Wire:* High-strength, cold-drawn steel wire used for prestressed reinforcement.

2. *Strand:* A symmetrically arranged and helically twisted assembly, commonly of seven high-strength steel wires, used for prestressed reinforcement or as nonprestressed earthquake cables.

3. *Tendon:* High-strength strand or bar, including end anchorages, used to impart vertical prestress to the tank wall.

1.2.9 *Duct:* Tubing for forming internal voids in the core wall for placement of vertical prestressed reinforcement.

1.2.10 *Shotcrete:* Pneumatically applied wet- or dry-mix mortar or concrete used for the core wall or as embedment and protection of the circumferential prestressed wall reinforcement, including

1. *Wire coat:* Initial application of shotcrete over the prestressed wire or strand.

2. *Cover coat:* Shotcrete applied over the wire coat of the outer layer of prestressed wire or strand.

3. *Finish coat:* The final layer of cover coat, usually placed for improved appearance.

1.2.11 *Specifications:* A statement describing the structure to be provided and containing the details of construction materials, methods, or contractor performance required in conjunction with the construction drawings and other contract documents for the structure.

1.2.12 *Standpipe:* A cylindrical structure for water storage, based at or below grade and having a wall height greater than its diameter. Standpipes are considered a special type of tank because of generally more critical loading conditions. Use of this standard in the design and construction of standpipes is not, however, precluded.

1.2.13 *Tank:* A cylindrical structure for water storage, based at or below grade. In general, this term shall refer to a structure having a wall height equal to or less than its diameter.

1.2.14 *Waterstop:* An impervious barrier installed to prevent passage of water through a construction or expansion joint between adjacent elements of concrete or shotcrete construction.

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1.2.15 *Wire or strand winding:* The helical application of a continuous wire or strand for circumferentially prestressing the wall or dome ring of a circular tank.

Sec. 1.3 References

References identified refer to the latest revision available, unless otherwise specifically noted by date. Standards referenced herein shall comply with the appropriate documents and test methods included and referenced in the listed standard. The following is a list of references used in this AWWA standard:

AASHTO*T-260—Standard Method of Sampling and Testing for Total Chloride Ion in Concrete and Concrete Raw Materials.

ACI† 301—Specifications for Structural Concrete for Buildings.

ACI 302.1R—Guide for Concrete Floor and Slab Construction.

ACI 304R—Guide for Measuring, Mixing, Transporting, and Placing Concrete.

ACI 305R—Hot Weather Concreting.

ACI 306R—Cold Weather Concreting.

ANSI‡/ACI 308—Standard Practice for Curing Concrete.

ACI 318—Building Code Requirements for Reinforced Concrete and Commentary (ACI 318R).

ACI 344R-W—Design and Construction of Circular Wire- and Strand-Wrapped Prestressed Concrete Structures.

ACI 347R—Guide to Formwork for Concrete.

ACI 350R—Environmental Engineering Concrete Structures.

ACI 503.2—Standard Specification for Bonding Plastic Concrete to Hardened Concrete with a Multi-Component Epoxy Adhesive.

ACI 506R—Guide to Shotcrete.

ACI 506.2—Specifications for Materials, Proportioning, and Application of Shotcrete.

ACI 515.1R—Guide to the Use of Waterproofing, Dampproofing, Protective and Decorative Barrier Systems for Concrete.

ACI SP-2—ACI Manual of Concrete Inspection.

ANSI/ASCE§ Standard 7-88—Minimum Design Loads for Buildings and Other Structures.

ASTM**A366/A366M—Standard Specification for Steel, Sheet, Carbon, Cold-Rolled, Commercial Quality.

ASTM A416—Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete.

ASTM A421—Standard Specification for Uncoated Stress-Relieved Steel Wire for Prestressed Concrete.

ASTM A475—Standard Specification for Zinc-Coated Steel Wire Strand.

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*American Association of State Highway and Transportation Officials, 444 N. Capitol St., N.W., Suite 249, Washington, DC 20001.

†American Concrete Institute, Redford Station, P.O. Box 19150, Detroit, MI 48219.

‡American National Standards Institute, 11 W. 42nd St., New York, NY 10036.

§American Society of Civil Engineers, 345 East 47th St., New York, NY 10017-2398.

**American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

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ASTM A525/A525M—Standard Specification for General Requirements for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process.

ASTM A615/A615M—Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement.

ASTM A641/A641M—Standard Specification for Zinc-Coated (Galvanized) Carbon Steel Wire.

ASTM A648—Standard Specification for Steel Wire, Hard Drawn for Prestressing Concrete Pipe.

ASTM A722—Standard Specification for Uncoated High-Strength Steel Bar for Prestressing Concrete.

ASTM A821—Standard Specification for Steel Wire, Hard Drawn for Prestressing Concrete Tanks.

ASTM A882/A882M—Standard Specification for Epoxy-Coated Seven-Wire Prestressing Steel Strand.

ASTM C881—Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete.

ASTM C920—Standard Specification for Elastomeric Joint Sealants.

ASTM C1107—Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink).

ANSI/ASTM D695/D695M—Standard Test Method for Compressive Properties of Rigid Plastics.

ASTM D1056—Standard Specification for Flexible Cellular Materials—Sponge or Expanded Rubber.

ASTM D1556—Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.

ASTM D1557—Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft) (2,700 kN-m/m).

ASTM D1752—Standard Specification for Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction.

ASTM D2000—Standard Classification System for Rubber Products in Automotive Applications.

ANSI/AWWA C652—Standard for Disinfection of Water Storage Facilities.

Fed Spec.* SS-S-210A—Sealing Compound for Preformed Plastic, for Expansion Joints and Pipe Joints.

Handbook of Molded and Extruded Rubber.†

Uniform Building Code.‡

Post-Tensioning Manual.§ Fifth edition, 1990.

US Army Corps of Engineers Spec.* CRD-C572—Specification for PVC Waterstop.

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*Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120.

†Goodyear Tire and Rubber Company, 1144 E. Market, Akron, OH 44316.

‡International Conference of Building Officials (ICBO), 5360 S. Workman Mill Road, Whittier, CA 90601.

§Post-Tensioning Institute, 1717 W. Northern Ave., Suite 218, Phoenix, AZ 85021.

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SECTION 2: MATERIALS

Sec. 2.1 Concrete and Shotcrete

2.1.1 *General.* The quality of concrete or shotcrete is of great importance to its structural integrity and watertightness. Therefore, care shall be taken throughout the tank construction to maintain close quality control of the materials, proportions, forming, embedded items, placement, finishing, curing, and other details of the work. Concrete or shotcrete in potable-water tanks in contact with water shall

1. Be dense and low in permeability to retain water, to prevent contamination of the tank contents, and to avoid unsightly efflorescence and spalling.
2. Provide a noncorrosive environment for nonprestressed steel reinforcement, steel diaphragms, and prestressed steel reinforcement.
3. Provide a surface that is smooth and well formed to facilitate cleaning and reduce maintenance. Ordinary wall finish for concrete and a lightly broomed finish for shotcrete and precast panels are acceptable provided good workmanship standards are observed.

2.1.2 *Concrete and shotcrete materials.* Concrete and shotcrete materials shall conform to the recommendations of ACI 301, 350R, and 506.2 as modified herein. The mix proportions shall be submitted to the purchaser and shall meet the strength requirements of the purchaser's specifications. For corrosion protection of the steel reinforcement, concrete or shotcrete used in the core wall, top slab, or dome, and shotcrete for covering prestressed wire or strand, shall not contain water-soluble chloride ions in excess of 0.06 percent of the weight of the cement in the mix as determined by AASHTO T-260.

Concrete subjected to freeze–thaw cycling shall be air entrained in accordance with ACI 301. Wet-mix shotcrete for dome roofs in areas subjected to freeze–thaw cycles shall be air entrained with an air content of 5 to 8 percent at the pump. Dry-mix shotcrete shall not be used in domes subject to freezing cycles.

2.1.2.1 Shotcrete wire coat used for covering prestressed wire or strand shall consist of not more than three parts sand to one part portland cement by weight; additional coats of shotcrete shall consist of not more than four parts sand to one part portland cement by weight.

2.1.2.2 Either the wet-mix or dry-mix process referred to in ACI 506R may be used for shotcreting unless the specifications require the use of a specific process. Shotcrete shall be proportioned for a 28-day strength equal to that for which the core wall is designed, but not less than 4,000 psi (28 MPa) unless otherwise specified.

2.1.3 *Cement mortar.* Mortar used for repair of concrete, encasement of waterstop, and for patching form tie holes shall consist of not more than three parts sand to one part portland cement by weight and shall conform to the requirements of ACI 301. Mortar shall not contain water-soluble chloride ions in excess of 0.06 percent of the weight of the cement in the mortar. Shrinkage-compensating mortars (nonshrink grout) shall be of the nonmetallic type as specified in Sec. 2.1.5.

2.1.4 *Cement grout.* Cement grout used for grouted or bonded vertical tendons in ducts shall contain not more than 0.45 parts water to one part portland cement by weight (approximately 4.5 gal [17 L] per sack of cement) and shall not contain water-soluble chloride ions in excess of 0.06 percent of the weight of the cement in the grout. Cement grout for tendons shall contain admixtures to reduce bleeding and grout settlement, and shall be used in accordance with the manufacturer's recommendation for this application.

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2.1.5 *Nonshrink grout.* Nonshrink cement grout used for repair of honeycomb and other concrete repair and for patching form tie holes shall be a nonhydrogen-gas-liberating, nonmetallic grout meeting all of the requirements of ASTM C1107, grade A or C, for nonshrink grout. This grout is not to be used for bonding of prestressed tendons, or in contact with the wire or strand prestressed reinforcement.

Sec. 2.2 Mixing Water

Mixing water shall conform to the requirements of ACI 318.

Sec. 2.3 Admixtures

Admixtures shall comply with the requirements of ACI 301 or ACI 506.2 and shall not contain more than trace amounts of chlorides, fluorides, sulfides, or nitrates because of their possible corrosive effect on the prestressed reinforcement. Materials in contact with potable water shall not impart taste, odor, or toxic chemicals to the water. All admixtures used in the concrete shall be compatible.

Sec. 2.4 Reinforcement

2.4.1 *Nonprestressed reinforcement.*

2.4.1.1 Deformed billet-steel bars; epoxy-coated steel bars; fabricated deformed steel bar mats; and steel welded-wire fabric, plain or deformed, for concrete reinforcement shall conform to the requirements of ACI 318 and the applicable ASTM standards referenced therein.

2.4.1.2 Strand for earthquake cables shall meet the requirements of ASTM A416, for seven-wire prestressing steel strand. The strand shall be protected with a fusion-bonded epoxy coating, grit-impregnated on the surface, conforming to ASTM A882/A882M, or it shall be galvanized. Galvanized strand shall meet the requirements of ASTM A416 prior to galvanizing. The zinc coating for galvanizing shall meet the requirements of ASTM A641/A641M or ASTM A475, with a minimum weight per unit area of uncoated wire surface of class A of these standards.

2.4.1.3 Steel-sheet diaphragms for use as impervious membranes in the walls of prestressed concrete tanks shall be vertically ribbed with adjacent and opposing channels. The base of the channels (see Figure 1) shall be wider than the throat, thus providing a mechanical keyway anchorage between the inner and outer concrete or shotcrete. Uncoated steel sheet shall comply with ASTM A366, and hot-dipped galvanized sheet shall comply with ASTM A525. Diaphragm steel thickness shall be a minimum of 0.017 in. (0.43 mm). Weight of zinc coating, where specified, shall be not less than G 90 of Table 1 of ASTM A525. The diaphragm sheets shall be continuous for the full height of the tank.

2.4.2 *Prestressed reinforcement.*

2.4.2.1 Uncoated prestressing wire and strand shall conform to the requirements of ACI 318 and the following applicable ASTM standards: hard-drawn steel wire to be helically wrapped, maintaining tension by mechanical means, shall conform to the requirements of ASTM A821; ASTM A648, class II; or ASTM A421, type WA. Steel wire, hard-drawn to be helically wrapped on the structure employing a wire drawing die for back tension, shall conform to the requirements of ASTM A821. Steel prestressing strand shall conform to the requirements of ASTM A416.

2.4.2.2 Galvanized prestressing wire and strand to be helically wrapped and tensioned shall meet the requirements of ASTM A821; ASTM A648, class II; or ASTM A421, type WA, for wire, and ASTM A416 for strand. Zinc coating for galvanizing

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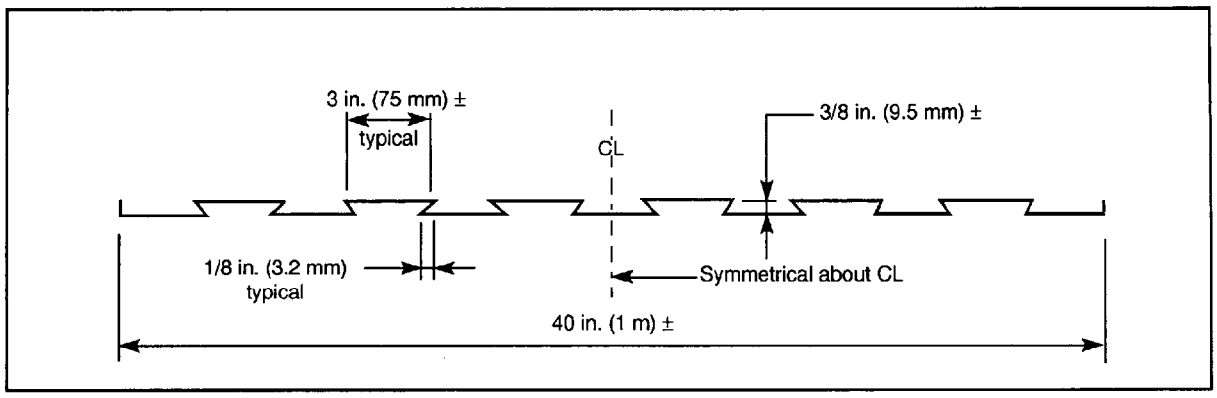

Figure 1 Example diaphragm sheet

shall meet the requirements of ASTM A641/A641M or ASTM A475, with a minimum weight per unit area of uncoated wire surface of 0.85 oz/ft^2 (259 g/m^2) or of class A of these standards.

Where galvanized wire is stressed on the structure by drawing through a die, the zinc coating remaining after stressing shall be a minimum of 0.50 oz/ft^2 (150 g/m^2) of wire surface.

2.4.2.3 Splices for horizontal prestressed reinforcement shall be ferrous material compatible with the reinforcement and shall develop the full strength of the wire or strand. Anchor clamps and other accessories in contact with the prestressing elements may be galvanized or epoxy-coated iron or steel. Wire splice and anchorage accessories shall not weaken or otherwise compromise the prestressed reinforcement.

2.4.2.4 Tendons for vertical prestressed reinforcement of cast-in-place concrete core walls shall consist of high-strength strand or bars conforming to the requirements of ACI 318 and the material requirements of ASTM A416 or ASTM A722. Tendon anchorages may be galvanized or epoxy coated for additional corrosion protection.

2.4.3 *Steel corrosion inhibitor.* Temporary corrosion protection of vertical prestressed reinforcement left in the ducts for more than 10 days prior to grouting shall be provided by volatile or vapor-phase inhibitors. These inhibitors are applied in solid form (a fine white powder) or liquid form that vaporizes and coats the surface of the prestressing steel with a stable organic nitrate that prevents corrosion by passivating the metal. The corrosion inhibitor shall have no deleterious effect on the steel or bond strength between the cement or epoxy-resin grout and steel, and shall not prevent future corrosion protection of the prestressing steel by the grout.

Sec. 2.5 Elastomeric Materials

2.5.1 *Waterstops.* Waterstops shall be composed of plastic or other materials suitable for the intended use.

2.5.1.1 Plastic waterstops. Plastic waterstops shall be of virgin polyvinyl chloride meeting the requirements of CRD-C572. Splices shall be made in accordance with the manufacturer's recommendations, subject to review by the purchaser. Tests assuring conformity to the specification shall either be made on material delivered to the jobsite or be certified by an independent testing laboratory. Plastic waterstops shall be ribbed and shall have a minimum ultimate tensile strength of 1,750 psi (12.17 MPa), ultimate elongation of 300 percent, and a shore hardness of 70 to 80 durometer.

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2.5.2 *Bearing pads.* Bearing pads used in the floor-to-wall and wall-to-roof joints shall consist of neoprene, natural rubber, or polyvinyl chloride.

2.5.2.1 Neoprene bearing pads shall have a minimum ultimate tensile strength of 1,500 psi (10.5 MPa), a minimum elongation of 500 percent, a maximum compressive set of 50 percent, and a hardness of 40 to 50 durometer in accordance with ASTM D2240. Neoprene bearing pads shall contain only virgin crystallization-resistant polychloroprene as the raw polymer and the physical properties shall comply with ASTM D2000, line call out 2BC415A14B14 for 40 durometer material.

2.5.2.2 Natural-rubber bearing pads shall contain only virgin natural polyisoprene as the raw polymer, and the physical properties shall comply with ASTM D2000, line call out 4AA420A13.

2.5.2.3 Polyvinyl chloride for bearing pads shall meet the requirements of CRD-C572 for tanks in cold-weather regions.

2.5.3 *Sponge filler.* Sponge filler shall be closed-cell neoprene or rubber conforming to ASTM D1752, type 1, or to the requirements of ASTM D1056, types 2A1 through 2A4.

Sec. 2.6 Duct Material

2.6.1 *Grouted tendons.* Duct material for grouted vertical wall tendons shall be flexible or semiflexible steel or polyvinyl chloride pipe or tubing and shall be sufficiently strong to retain its shape and location during placement and vibration of the concrete. Inside diameter of the duct to be filled with portland-cement grout shall be a minimum of 3/8 in. (9.5 mm) greater than the nominal diameter of the bar tendon, or the inside area of the duct shall be twice the area of the prestressed strand tendon. If the duct is to be filled with pumped epoxy, the annular space around the tendon may be reduced to the minimum size that will permit easy insertion of the tendon. Ducts shall be so constructed and sealed as to positively prevent the entrance of cement paste from the concrete and shall be equipped with suitable fittings and tubing at the base and top for flushing and pumping the grout or epoxy.

2.6.2 *Bonded tendons.* Duct material for fully bonded vertical tendons shall be semiflexible steel or corrugated polyvinyl duct. In addition to the requirements of Sec. 2.6.1, the duct shall be capable of transferring the stress from the tendon by bond or shear through the duct to the concrete along its full length.

Sec. 2.7 Concrete and Shotcrete Coatings

2.7.1 *Above grade.* In some cases, such as tanks located in areas subject to salt spray or other corrosive environments, coatings may be desired to seal the exterior surface of above-grade concrete and shotcrete dome roofs and shotcrete protection for the circumferential prestressed reinforcement. Coatings suitable for sealing the exterior of the tank shall be permeable to water vapor. Suitable coatings include rubber base (polyvinyl chloride–latex and polymeric vinyl–acrylic), acrylic elastomer and acrylic emulsion paints, and cementitious waterproofing compounds.

2.7.2 *Below grade.* Coatings are recommended for sealing the exterior surface of below-grade tanks where additional protection against aggressive soils is required. Coatings suitable for sealing the exterior of the tank wall include coal-tar epoxies and bitumastic compounds specifically formulated for this purpose.

2.7.3 Additional information on exterior coatings and seal coats for aggressive environments may be found in ACI 515.1R.

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Sec. 2.8 Sealants and Joint Fillers

2.8.1 *Sealant for steel diaphragm joints.* Joints shall be sealed with polysulfide or polyurethane sealant, epoxy sealant, or double folded with a mechanical seamer, and shall be watertight under full tank head.

2.8.2 Polysulfide sealant shall be a two- (or more) component elastomeric compound of the appropriate type meeting the requirements of ASTM C920, type M, and shall have permanent characteristics of bond-to-metal or concrete surfaces, flexibility, and resistance to extrusion due to hydrostatic pressure. Air-cured sealants shall not be used. The grade and class shall be appropriate for the intended use as recommended by the manufacturer.

2.8.3 Polyurethane elastomeric sealant used in interior tank construction joints and movement joints at the base of the wall, or in floor or roof slab joints shall meet the requirements of ASTM C920, class 25, of appropriate type and grade for permanent bond-to-concrete surfaces, flexibility, and resistance to extrusion due to hydrostatic pressure. The sealant shall be multicomponent type M, of grade P for pourable, and grade NS for nonsag or gunnable. Sealant shall not impart taste, odor, or toxic chemicals to potable water.

2.8.4 Preformed bitumen compound plastic joint filler for use in exterior movement joints shall be of the appropriate type conforming to Fed. Spec. SS-S-210A. Such filler or sealing compound shall not be used in interior floor, wall, or roof joints in contact with potable-water tank contents, or where the material may leach into the tank contents.

2.8.5 Epoxy sealants shall be suitable for bonding to concrete, shotcrete, and steel, and shall be suitable for sealing the vertical joints between sheets of steel diaphragms. Epoxy sealants shall conform to the requirements of ASTM C881, type III, grade 1, and shall be a 100 percent solids, moisture-insensitive, low-modulus epoxy system. When pumped, maximum viscosity of the epoxy should be 10 poises (1 Pa·s) at 77°F (25°C), or shall be otherwise acceptable to the purchaser.

2.8.6 Polyurethane filler used to fill voids between components in the wall-base joint and seal around waterstops, base pads, seismic cable sleeves, and sponge fillers shall meet the requirements of ASTM C920, class 25, for single-component sealer type S, grade P or NS, as appropriate for the intended use.

Sec. 2.9 Epoxy Bonding Agent

Epoxy resin used for increasing the bond of fresh, plastic concrete or mortars to hardened concrete shall be a two-component, 100 percent solids, moisture-insensitive epoxy adhesive meeting the requirements of ASTM C881, type II, grade 2, as specified in ACI 503.2. The bonding agent shall produce a bond strength, as determined by ASTM C882, greater than 1,500 psi (12.2 MPa) 14 days after the plastic concrete is placed. Epoxy in contact with potable water shall not impart taste or odor, or leach toxic trace elements into the water.

Sec. 2.10 Epoxy Mortar and Grout

2.10.1 Epoxy mortar used for concrete repair shall be a noncorrosive and noncontaminating mixture of epoxy resin, catalyst, and fine aggregate proportioned in strict accordance with the manufacturer's instructions for the product and its intended use.

2.10.2 Epoxy-resin grout used for corrosion protection of prestressed vertical tendons or for bonding the reinforcement within the duct shall be a two-component,

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moisture-insensitive, resin bonding system conforming to ASTM C881, of the type, grade, and class recommended by the manufacturer as suitable for these applications.

Sec. 2.11 Form Coatings

The form coating for concrete surfaces that will be in contact with potable water or that may leach trace elements into potable-water tank contents shall be of an organic base and shall be nonstaining and nontoxic.

SECTION 3: DESIGN

Sec. 3.1 Notation*

Symbols used in various equations presented in Sec. 3 are defined as follows:

A_{ds} = total area of prestressing wires or strand for dome ring (area, in.^{2}), see Sec. 3.6.5.1
d = distance from face of support (linear, in.)
E_c = short-term modulus of elasticity of concrete or shotcrete (force per unit area, psi)
f'_c = specified 28-day compressive cylinder strength of concrete or shotcrete (force per unit area, psi). (Refer to Sec. 5.3.4 for control of shotcrete strength)
f_c = permissible compressive concrete or shotcrete stress (force per unit area, psi)
f'_{ci} = specified compressive cylinder strength of concrete or shotcrete (Refer to Sec. 5.6.2.5) at time of prestressing (force per unit area, psi)
f_{pu} = specified ultimate tensile strength of steel prestressing wire, strand, or high-strength bars (force per unit area, psi)
f_{se} = effective stress in prestressed reinforcement after losses (force per unit area, psi)
f'_{si} = allowable initial stress in prestressed reinforcement before losses (force per unit area, psi)
f_t = flexural tensile stress in extreme fiber of the core wall (force per unit area, psi)
l_d = development length for bond (linear, in.)
L = unit live load on dome shell (force per unit area, lb/ft^2)
P_{fw} = final prestressing force for water load (force, lb)
P_u = factored (uniformly distributed) unit dead and live design load on dome shell (force per unit area, lb/ft^2)
r_d = mean radius of dome shell (linear, ft)
r_i = average maximum radius of curvature over a dome imperfection area (linear, ft)
t_c = core-wall thickness (linear, in.)
t_d = dome-shell thickness (linear, in.)
u = nominal bond stress in concrete or shotcrete (force per unit area, psi)

*Caution should be used to be consistent throughout with use of units.

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V_c = nominal shear stress in concrete or shotcrete (force per unit area, psi)
V_{max} = maximum shear stress in reinforced section (force per unit area, psi)
W = total dead and live load on dome, exclusive of dome ring (force, lb)
β_c = buckling reduction factor for creep, nonlinearity, and cracking of concrete
β_i = buckling reduction factor for geometrical imperfections from a true spherical surface, such as local increases in radius
ω = half central angle of dome shell (degrees)
ϕ = strength reduction factor

Sec. 3.2 Design Method

Tank design shall be based on elastic analysis methods and shall take into account effects of all loads and prestressing forces during and after tensioning, and conditions of edge restraint at wall junctions with floor and roof. Stresses shall not exceed allowable service stresses described in Sec. 3.4. Consideration shall also be given to the effects of all loads and load combinations, including stresses induced by temperature and moisture gradients. The recommendations herein pertain to service-load conditions and serviceability requirements. For many effects, the service-load design is more conservative than the strength design. However, to ensure the safety of the structure, the design must also meet the strength requirements of ACI 318. All applicable sections of the latest edition of ACI 318, including supplements and the chapters describing precast and prestressed concrete, shall be followed except when supplemented or modified by provisions of this standard.

Sec. 3.3 Design Loads

Loads indicated in this section are those most frequently encountered in prestressed concrete tank design and shall be included in the design calculations. Loadings, including prestressing forces and their placement, shall follow governing codes.

3.3.1 *Wall design loads.*

3.3.1.1 Internal pressure—the pressure from water at maximum overflow level.

3.3.1.2 Backfill loading—the lateral pressure from earth backfill, symmetrical or asymmetrical. Net lateral loads, including those due to unequal backfill, shall be determined by rational methods of soil mechanics based on foundation and soils investigations. Surcharge loads on backfilled surfaces shall be considered.

Backfill pressure shall not be used to reduce the amount of prestressing force required for resisting internal water pressure. Backfill forces shall be based on soil parameters established by a professional engineer experienced in soils.

3.3.1.3 Minimum design loadings for wind and earthquake. These loadings shall conform to requirements of local building codes and the provisions of the seismic sections of the ICBO *Uniform Building Code* or ANSI/ASCE Standard 7-88. Seismic design criteria for prestressed concrete tanks are set forth in Sec. 4 as appropriate.

3.3.1.4 Effects of construction, including loads resulting from equipment, materials, and construction methods to be used.

3.3.1.5 External hydrostatic pressure on the floor and wall, if any.

3.3.1.6 Appurtenance loads.

3.3.1.7 Operating loads and system surges.

3.3.1.8 Thermal and moisture gradients as follows:

1. Radially, through the thickness of the wall.
2. Vertically, that occur between the buried and exposed portion of the wall.

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3. Between the wall and roof or floor.

3.3.1.9 Effects on the wall due to application of prestressing forces, including those due to nonlinear distribution of prestressing forces temporarily induced during the stressing operations and in the completed structure.

3.3.2 *Roof design loads.*

3.3.2.1 Dead loads, including sustained surcharges.

3.3.2.2 Earth, snow or ice, and other live loads.

3.3.2.3 Construction loads.

3.3.2.4 Wind loads.

3.3.2.5 Earthquake loads.

3.3.2.6 Appurtenance loads.

3.3.2.7 Operational loads, if any.

3.3.2.8 Roof openings.

3.3.3 *Floor design loads.*

3.3.3.1 Dead loads.

3.3.3.2 Water loads.

3.3.3.3 Earthquake loads.

3.3.3.4 Uplift due to groundwater or expansive soils.

3.3.3.5 Radial forces from the base of the tank wall.

3.3.3.6 Differential and total settlement.

3.3.4 *Control of loads.* Consideration shall also be given to the following load control techniques and their safety margins:

3.3.4.1 Overflow systems.

3.3.4.2 Venting.

3.3.4.3 Internal freeboard to provide room for sloshing during an earthquake.

3.3.4.4 Perimeter and underfloor drainage systems to limit hydrostatic pressures.

3.3.4.5 Provisions for drainage of surface water from earth backfill and roof runoff away from the structure, or use of a free-draining granular backfill adjacent to the wall, should be considered for reducing lateral loading on the exterior face of the tank wall.

Sec. 3.4 Allowable Stresses

3.4.1 *Concrete and shotcrete.* Service-load stresses shall be limited to provide protection against leakage into or out of the tank and against corrosion of the reinforcement. Concrete cracking shall not be allowed under predominantly axial stresses. Cracking under predominantly flexural stresses shall be controlled to limit crack depth and width. The stresses for concrete and shotcrete shall not exceed the values indicated in Table 1.

3.4.2 *Prestressed reinforcement.*

3.4.2.1 Maximum permissible initial stress f_{si} in any wire or strand on the wall, or in vertical threaded bar prestressed reinforcement shall not exceed 0.75 f_{pu}. Maximum initial stress for anchored strands in vertical prestressed reinforcement, after anchorage losses, shall not exceed 0.70 f_{pu}.

3.4.2.2 Long-term stress losses due to shrinkage and creep of concrete or shotcrete, and relaxation in prestressed reinforcement shall be calculated in accordance with the recommendations in Reference 18.6 of ACI 318 or assumed to be 25,000 psi (170 MPa). Calculation of stresses due to thermal and moisture gradients may normally be ignored if the initial prestress provides for these long-term losses and, in addition, produces a residual horizontal compression in the concrete or shotcrete core wall, with

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Table 1 Allowable stresses in concrete and shotcrete

Description	Notation	Allowable Stresses*
Compression: Horizontal or vertical in extreme fiber.	f_c	0.55 f_c' initial; 0.45 f_c' final.
Tension: Vertical, in extreme fiber of all nondiaphragm tanks. All nondiaphragm tanks shall be vertically prestressed.	f_t	Vertical flexural tensile stresses to be reduced to zero by vertical prestressing as in Sec. 3.5.3 or taken by the auxiliary nonprestressed reinforcement at the stresses in paragraphs of Sec. 3.4.3.
Tension: Vertical in diaphragm tanks.	f_t	100 percent of the tensile force shall be taken by the reinforcing steel and/or diaphragm at the stresses specified in the paragraphs of Sec. 3.4.3.
Shear: As a measure of diagonal tension at a distance d from the face of the support, psi.		
Members with no web reinforcement.	V_c	$1.1\sqrt{f_c'}$
Members with vertical or inclined web reinforcement.	V_{max}	$5\sqrt{f_c'}$ (Increased stress allowed for properly designed reinforcement.)
Slabs with footings—peripheral shear.	V_c	$2\sqrt{f_c'}$
Bond: Development length and bonding reinforcement:		
Deformed bars and welded wire fabric.	l_d	Development length l_d shall be computed as a measure of bond resistance in accordance with recommendations of ACI Committee 318.
Steel diaphragm	u	$2.5\sqrt{f_c'}$ (See Sec. 3.4.3.3.)

*Coefficients shown are for values of f_c' expressed in pounds per square inch (psi). Refer to Sec. 3.1 for definition of symbols in notations.

the base free to move radially, of not less than 200 psi (1.4 MPa) above ground tapering linearly to 50 psi (340 kPa) at 6 ft (1.8 m) below ground with the tank filled to the maximum overflow level. For restrained base-joint construction, the equivalent prestress force shall be provided as if the base were free to move radially.

3.4.2.3 Maximum design stress in prestressed wire, strand, or high-strength bars f_{se} for structures subject to full design load, after deduction of the above allowances for stress losses, shall not exceed 0.65 f_{pu}.

3.4.3 *Nonprestressed reinforcement.*

3.4.3.1 Nonprestressed reinforcement shall be designed in accordance with the requirements of Alternate Design Method, in ACI 318. The strength requirements of ACI 318 shall also be satisfied. Since crack control is of paramount importance to prestressed concrete structures, more conservative allowable steel stresses are recommended than used in building construction, and additional nonprestressed reinforcement is often used in areas of localized stress to control cracking and preclude the contained liquid from reaching the prestressing elements. Low stress in reinforcement at service loads is good insurance against undesirable performance of these structures. Recommended maximum stresses and spacing for deformed bars, as provided in ACI 350R, shall not be exceeded.

3.4.3.2 Nonprestressed reinforcement may consist of bars or welded wire fabric. The area of steel-sheet wall diaphragm parallel to the direction of its channels (vertical)

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may also be used to contribute to the vertical reinforcement of the wall provided the diaphragm is located close enough to the inside or outside surface to effectively control cracking due to vertical bending moments.

3.4.3.3 For diaphragm-type tanks, the allowable tensile stress in the diaphragm shall not exceed 18,000 psi (120 MPa). Design shall otherwise be in accordance with the requirements of ACI 350R.

3.4.3.4 Nonprestressed steel reinforcement shall not be used to resist any portion of circumferential tension in the wall. It may be used to resist circumferential tension in the dome-roof edge ring due to roof live load as provided in Sec. 3.6.5.2.

Sec. 3.5 Wall Design

3.5.1 *Design calculations.* Wall design shall be based on elastic cylindrical-shell analyses for stresses and deformations due to loads outlined herein. The design calculations made by either the purchaser's engineer, a retained consultant, or the design-construct contractor shall be made a matter of record, available at the request of the purchaser and approving authority.

3.5.2 *Circumferential prestressing force.* Circumferential prestressed reinforcement shall be furnished to resist all forces due to internal loads, after accounting for all stress losses and for residual compression.

3.5.2.1 The minimum final circumferential prestressing force to contain the water load at any point on the wall shall include provision for the calculated forces for thermal and moisture gradients or allowance for a minimum residual compression of 200 psi (1.4 MPa) for the aboveground portion of the tank wall, tapering linearly to 50 psi (340 kPa) at 6 ft (1.8 m) below grade as specified in Sec. 3.4.2.2. For empty open-top tanks, the final horizontal prestress force, after losses, shall provide 400 psi (2.8 MPa) minimum compression in the concrete or shotcrete core wall at any point on the wall. For a tank covered with a concrete roof that is monolithic with or bears on and restrains the top of the wall, the final horizontal prestress force, after losses, for the empty tank shall provide 240 psi (1.7 MPa) minimum compression at any point in the core wall when free joints are assumed at the top and bottom.

3.5.3 *Vertical prestressing force.*

3.5.3.1 In nondiaphragm tanks, vertical prestressed reinforcement shall be provided to produce, after allowance for prestress losses, a minimum axial average compression of 200 psi (1.4 MPa) in the concrete core wall. Looped strand tendons shall not be used. Vertical tendons shall have end anchors at the top and bottom of the wall. The maximum spacing of vertical tendons shall not exceed seven times the wall thickness or 50 in. (1.3 m), whichever is less. Auxiliary nonprestressed steel reinforcement shall be provided to resist part of the vertical bending moments resulting from edge restraint, differential dryness and temperature, and other applied loads. For example, vertical nonprestressed reinforcement may be required at the lower portion of the wall (inside face) to control concrete tension as the circumferential prestressing is applied.

3.5.4 *Core-wall thickness.* The thickness of the concrete or shotcrete core wall t_c, prior to prestressing, shall be such that membrane shell stresses are within the allowable stresses; the minimum dimensional limits are as follows:

8 in. (200 mm) for type I core walls,
3 ½ in. (90 mm) for type II core walls,
4 in. (100 mm) for type III core walls, and
7 in. (180 mm) for type IV core walls.

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3.5.4.1 For tanks with unusual dimensions, unusual vertically applied loads, or other unusual loading, minimum wall thickness shall be based on analyses that include an evaluation of wall stability, buckling, and moments introduced by prestressing and other forces.

3.5.4.2 For core walls with a diaphragm, the diaphragm shall be embedded with a minimum of 1.0 in. (25 mm) interior cover. For all core walls incorporating a diaphragm at the exterior face of the wall, at least 0.5 in. (13 mm) of shotcrete cover shall be applied to the exterior of the steel diaphragm prior to wire or strand wrapping to fill the diaphragm channels or flutes and preclude wrapping the horizontal prestressed reinforcement directly on the exposed steel diaphragm.

3.5.5 *End restraint.* Restraint of the wall at either the base or roof causes significant vertical bending stresses that must be evaluated and included in the design.

3.5.5.1 Wall-joint details. The designer shall consider all wall boundary conditions resulting from the construction-joint details to be used at the top and bottom of the wall. Particular attention shall be given to restraint of translation and rotation, which varies depending on whether the joint is monolithic, allowed to slide (friction force), or allowed to move by deforming an elastomeric pad (rigidity of the pad) (see Sec. 4.2.1). Use appropriate values of recognized test data and record the values in the project calculations. For guidance to the designer, the *Handbook of Molded and Extruded Rubber,* second edition, provides data on rubber pads for various durometers of hardness and shape factors.

3.5.6 *Vertical nonprestressed reinforcement.*

3.5.6.1 Tank core walls reinforced vertically with only nonprestressed steel reinforcing shall contain a suitable watertight steel diaphragm. In the diaphragm wall, nonprestressed reinforcement shall be used to resist the vertical flexural tension caused by edge restraints when either internal water pressure, external loadings, or circumferential prestressing are applied. The diaphragm may preclude the necessity for additional nonprestressed reinforcement in free base tanks and for effects resulting from temperatures and moisture gradients where the wall is a thin section and temperature conditions are not extreme. A minimum vertical-reinforcement ratio of 0.0025 on each face of the wall section shall be provided by the diaphragm and auxiliary nonprestressed reinforcement.

3.5.6.2 Maximum tensile stress for regular nonprestressed steel reinforcement used to resist vertical bending stresses due to service loads shall be 18,000 psi (120 MPa) for grades 40, 50, and 60. Bar size shall be no greater than 3/4 in. (19 mm) (No. 6) and bar spacing shall not exceed 12 in. (300 mm). The cross-sectional area of the steel diaphragm used in a tank core wall may be included as part of the nonprestressed vertical steel reinforcing requirements provided that the steel stress does not exceed 18,000 psi (120 MPa) and the diaphragm is close enough to the face of the wall to control cracking due to bending moments in the wall.

3.5.6.3 The minimum concrete or shotcrete interior cover over steel diaphragms, welded wire fabric, and bar reinforcement shall be not less than 1 in. (25 mm) or one and a half times the diameter of nonprestressed steel deformed bars, whichever is greater. Cover for vertical tendon anchorages shall not be less than 2 in. (50 mm). For containment of aggressive water, additional cover shall be provided for the reinforcement.

3.5.7 *Seismic forces.* Forces and moments resulting from seismic accelerations of water loads, dead loads, and external loads shall be taken into account in the design, except where the tank is to be constructed in a zero seismic zone area. The

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design shall include the construction details to be provided at the top and base of the wall. Seismic cables, shear keys, dowels, elastomeric pads with or without confinement ring joints, and monolithic joints are examples of systems available to resist these forces. Stresses and deflections produced by seismic effects in all components shall be controlled. These may be determined and evaluated using the provisions in Sec. 4.

3.5.8 *Shear forces.* Reinforcement of joints must be sufficient to resist the following loads and any combination thereof:

1. Water.
2. Backfill.
3. Seismic.
4. Prestressing.
5. Other.

3.5.9 *Bearing pads.* In order to minimize vertical bending moments in the wall, it is important to keep the hardness in the range of 30 to 50 durometers and the pad thickness under the wall at a ¾-in. (18-mm) minimum. When a pad is required between the wall and roof, it shall have a minimum thickness of ½ in. (13 mm). The required pad area is determined after considering the vertical load, percent compression, and allowable deformation of the pad.

Sec. 3.6 Dome-Roof Design

3.6.1 *General.* A number of different types of concrete and shotcrete dome designs have been successfully used as covers for prestressed concrete tanks. The most common types used today in the United States are spherical shells of cast-in-place or precast concrete. The joint between the dome edge ring and the top of the wall may be "fixed" by extension of the wall reinforcement to restrict radial translation and rotation, "pinned" to restrain against translation, or "separated" by an elastomeric bearing pad to minimize restraint of both translation and rotation (see Figure 2).

The dome roof may also be constructed of doubly curved, precast concrete panels. The panels are connected at cast-in-place intermediate circumferential rings and a dome edge ring. The pinned-type joint of Figure 2B is generally used with precast concrete and cast-in-place domes and the other two types of joints with cast-in-place domes. Provision must be made in the design of the fixed connection of Figure 2A for the effects of stress transfer from the dome to the wall and from the wall to the dome as discussed in Sec. 3.6.4. When the dome ring is separated from the tank wall, as in Figure 2C, the joint design may require means to prevent lateral displacement of the dome due to seismic activity, as discussed in Sec. 3.6.5.5.

3.6.1.1 Most concrete or shotcrete domes built in the United States are low-rise spherical shells with rise-to-span ratios between 1:12 and 1:8. Domes with greater rise-to-span ratios than 1:8 present a problem in placement and finishing at the edge without use of a top form, and ratios of 1:12 or less require larger edge ring prestress and are generally less economical. A rise-to-span ratio of 1:10 is typical.

3.6.1.2 Consideration shall be given in the dome design for severe exposure conditions and condensation on the underside of the roof. For this reason, dry-mix shotcrete shall not be used in construction of domes in areas subject to freeze–thaw cycles.

3.6.1.3 The cast-in-place concrete, precast concrete, and shotcrete dome designs described herein are for typical dome roofs commonly used in current practice. It is not the intent of this standard to preclude other dome-to-wall connections and alternative

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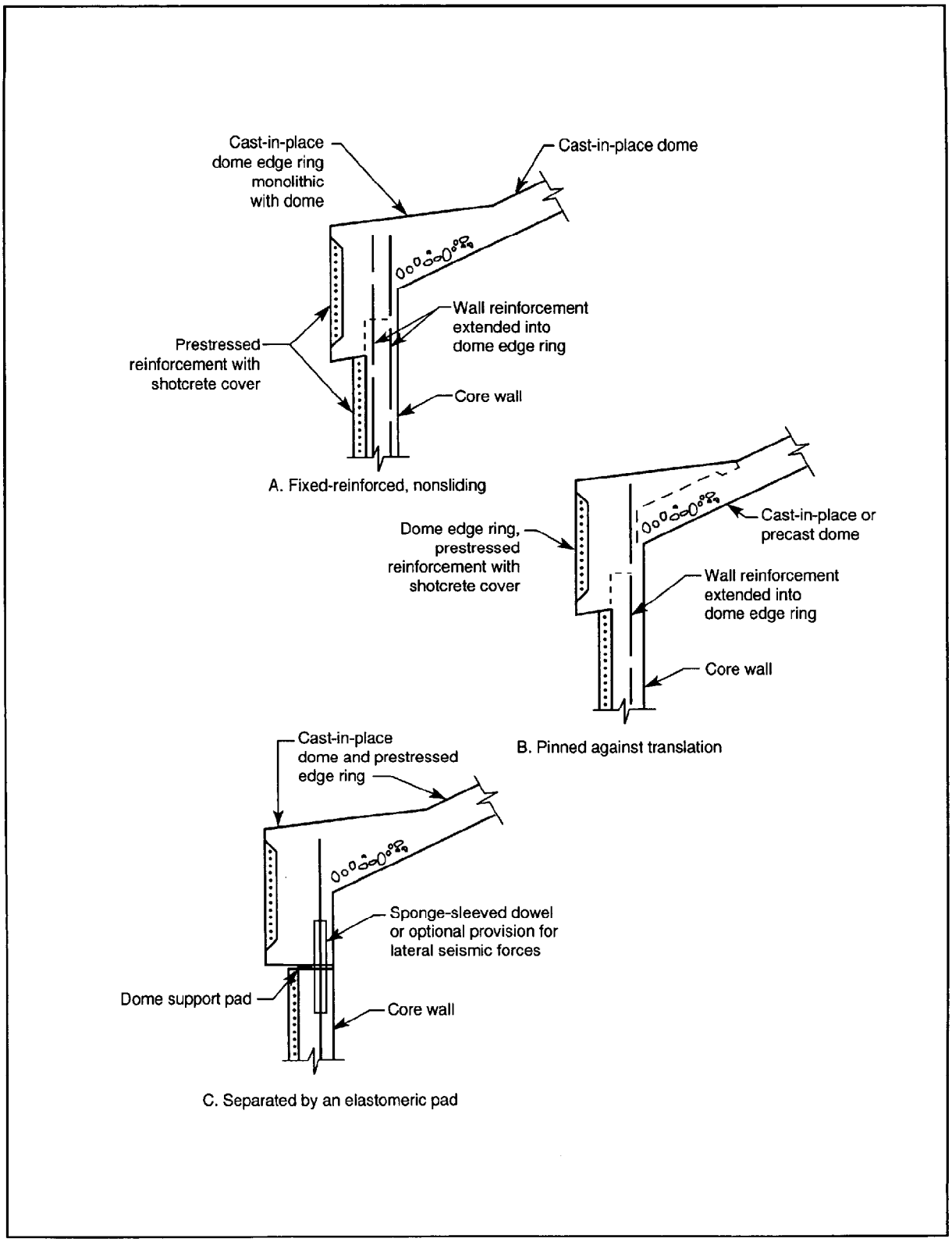

Figure 2 Joints between wall and dome edge ring

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cast-in-place dome designs that are in conformance with currently accepted standards, and that have been developed and successfully used in the United States.

3.6.2 *Design method.* Concrete or shotcrete dome roofs shall be designed on the basis of elastic shell analysis. A circumferentially prestressed dome edge ring or its equivalent shall be provided at the base of the dome shell if required to resist the horizontal component of the dome thrust.

3.6.3 *Thickness and reinforcement.* Dome shell thickness is governed by either buckling resistance, by minimum thickness for practical construction, or by corrosion protection of the reinforcement. Minimum thickness of concrete or shotcrete domes shall not be less than 3 in. (75 mm).

3.6.3.1 A method for determining the minimum thickness of a concrete spherical dome shell to provide adequate buckling resistance is given in appendix A, Zarghamee and Heger (1983). This method is based on the elastic theory of dome shell stability with consideration of the effects of creep, imperfections, and experience with existing tank domes having large radius-to-thickness ratios. Based on these criteria, the minimum recommended dome thickness for buckling may be determined from Eq 3-1.

$$\min\ t_d = r_d \sqrt{\frac{1.5P_u}{\phi\,\beta_i\,\beta_c\,E_c}} \qquad \text{(Eq 3-1)}$$

Refer to Sec. 3.1 for definition of symbols.

The conditions that determine the factors β_i and β_c are discussed in Zarghamee and Heger (1983). The values for these factors, which are given below, are recommended for use when domes are designed for conditions where live load is 12 lb/ft^2 (575 MPa) or more, water is stored inside the tank, dome thickness is 3 in. (75 mm) or more, f'_c is 3,000 psi (20.7 MPa) or more, normal-weight aggregates are used, and dead load is applied (i.e., shores removed) not earlier than seven days after concrete placement, with curing as required in ACI 301. Recommended values for the terms for such domes are

P_u = the minimum load factors given in ACI 318 for dead and live (snow) load, L

ϕ = 0.7

β_i = $(r_d/r_i)^2$, where r_i = averaged maximum radius of curvature over a dome imperfection area with a diameter of 2.5 $(r_d t_d)^{0.5}$

In the absence of other criteria, the maximum r_i may be taken as 1.4 r_d and in this case

β_i = 0.5

β_c = $0.44 + 0.003L$ for live loads between 12 and 30 lb/ft^2

β_c = 0.53 for live loads of 30 lb/ft^2 or greater

E_c = 57,000 $(f'_c)^{0.5}$ for normal-weight concrete or shotcrete

Precast concrete panel dome shells may be used in dome construction provided they are watertight and the designer makes allowance for joints between panels that are not equivalent in thickness, strength, or resistance to buckling to a monolithic shell.

3.6.3.2 The area of reinforcing steel in a dome, excluding the dome ring, shall be not less than 0.25 percent of the concrete cross-sectional area (0.0025 bt_d) in both the circumferential and radial directions. The reinforcement shall be placed approximately at the mid-depth of the shell, except in the edge region, where two layers of reinforcement shall be used in the radial direction.

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3.6.4 *Dome edge region.* The edge region of the dome and the top region of the wall are subject to bending stresses that arise because deflections at the intersection of the dome ring and cylindrical wall differ from the membrane condition due to the dome and wall prestress and loading conditions. These stresses can be reduced to levels that do not impair tank performance by the proper design of the dome-wall joint as described in this section. Factors that affect bending stresses are type of joint (reinforced nonsliding, pinned, or separated), size of dome ring, initial prestress force on the ring and on the adjacent wall, and the thickness of the dome edge region. The edge effects may require thickening of the dome near its edge, radial reinforcement in the top and bottom of the dome edge region, and vertical reinforcement in each face of the upper tank wall.

3.6.5 *Dome edge ring.* Circular prestressing of the dome edge ring is used to eliminate or control circumferential tension in the dome ring and to minimize edge bending effects in the dome and upper region of the tank wall.

3.6.5.1 Unless a more accurate analysis is made, the area of prestressing steel to resist total dead and live load W shall be taken as

$$A_{ds} = \frac{W \cot\omega}{2 \pi f_{se}} \qquad \text{(Eq 3-2)}$$

See Sec. 3.1 for definition of symbols.

3.6.5.2 Prestressing force may be provided to counteract only that tension due to dead load plus all losses. If prestressing for less than the full live load is used, sufficient area of prestressing steel must be maintained at reduced stress, or additional nonprestressed reinforcing shall be added to provide strength in accordance with the requirements of ACI 318. Prestressing in excess of that required for dead-load thrust increases bending and compression stresses in the dome ring, in adjacent regions of the dome, and in the upper part of the wall when it is monolithic with the ring.

3.6.5.3 The dome edge ring is often proportioned such that the initial nominal compressive stresses are limited within a range of 400 psi (2.8 MPa) to 1,000 psi (7 MPa) based on the net cross section of the ring, excluding haunches or adjacent wall.

3.6.5.4 Nonprestressed reinforcing steel shall be used in the dome ring to control shrinkage and temperature effects prior to prestressing. The minimum area of circumferential steel shall be 0.0025 times the cross-sectional area of the dome ring.

3.6.5.5 When the dome ring is separated from the tank wall, as in Figure 2C, positive means, such as keyways, flexible seismic cables, or doweling, shall be provided to prevent excess lateral displacement of the dome in the event of seismic activity. Where such a detail is used, the joint shall be designed to accommodate controlled radial movement at the top of the wall during circumferential prestressing and fluctuations in water level.

3.6.5.6 All roof-wall joints shall be designed to prevent dome roof runoff from penetrating the interface between the core wall and the circumferential prestressed wall reinforcement.

Sec. 3.7 Other Roof Designs

3.7.1 *General.* Other types of roof structures constructed of concrete, steel, aluminum, and fiberglass-reinforced plastic may be used if designed in conformance with currently accepted standards. The design shall provide a weathertight roof to prevent leakage and contamination of the tank contents. Consideration shall be

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given for severe exposure conditions and condensation on the underside of the roof. Concrete slab roofs shall be reinforced to resist temperature-gradient stresses. The design shall include crack control to prevent leakage and corrosion of the reinforcement. Nonprestressed cast-in-place or precast concrete slab roofs for potable-water tanks shall have a minimum slope of 1½ percent, or a suitable coating or membrane shall be provided to prevent liquids from leaking into the tank and contaminating the contents.

3.7.1.1 Nonprestressed steel-reinforced concrete flat slabs shall conform to the applicable requirements of ACI 350R, with special attention to crack control.

Sec. 3.8 Floor Design

The floor may be either structural or membrane type.

3.8.1 *Structural floors.* Structural floors that are properly reinforced for supporting the tank contents, for resisting maximum hydrostatic uplift forces, for locations with expansive soils, or for other unusual foundation conditions may be used where conditions warrant. Structural reinforced-concrete floors used for these purposes shall be designed in accordance with the requirements of ACI 318 and ACI 350R with special attention to crack control. Under some conditions, anchorage to underlying foundation strata or a sufficiently heavy concrete floor system can provide a satisfactory solution to hydrostatic uplift.

3.8.2 *Membrane floors.* In cast-in-place concrete membrane floors, loads are assumed to be transmitted to the subbase directly through the membrane. Minimum thickness of the membrane shall be 4 in. (100 mm). Floors shall be placed continuously in sections as large as practicable to decrease the length of construction joints and potential leakage problems related to their presence. Precautions shall be taken with large floor sections to limit long-term shrinkage by using concrete with a properly controlled water–cement ratio, adequate reinforcement, and proper curing conditions. Hydrostatic uplift when the tank is empty or when the tank water level is lowered during operation shall be precluded by adequate surface drainage, a perimeter drain around the tank wall foundation, and underdrainage, if necessary.

3.8.3 *Watertightness.* Where construction or expansion joints are provided in floors, waterstops shall be used to ensure watertightness under a head of water equal to the height of the tank (see Figure 3). In expansion joints, an acceptable joint sealant shall be used in addition to the waterstop to prevent entry of foreign material into the joint and to ensure its performance.

The slab at the joint may be thickened to allow additional space for the waterstop and reinforcement. For a restrained joint, the reinforcement shall be continuous through the joint. Additional nonprestressed reinforcement shall be provided in the thickened portion of slab plus 2 ft (0.75 m) of the subsequently placed membrane slab parallel to the construction joint to control cracking. Alternate designs with nonrestrained (unbonded) joints are acceptable provided the watertightness criteria are met.

Subgrade rigidity and uniformity shall be carefully controlled to limit differential vertical movement at joints. For crack control in the floor, the minimum reinforcement in each direction in the horizontal plane shall be 0.5 percent of the concrete area. Where the wall-base shear is transferred into radial tension in the slab, additional reinforcement shall be provided as required. Expansion joints shall not be used in floors of tanks in seismic zones 2B or higher, unless special precautions are taken to ensure adequate performance of the joint under seismic loadings.

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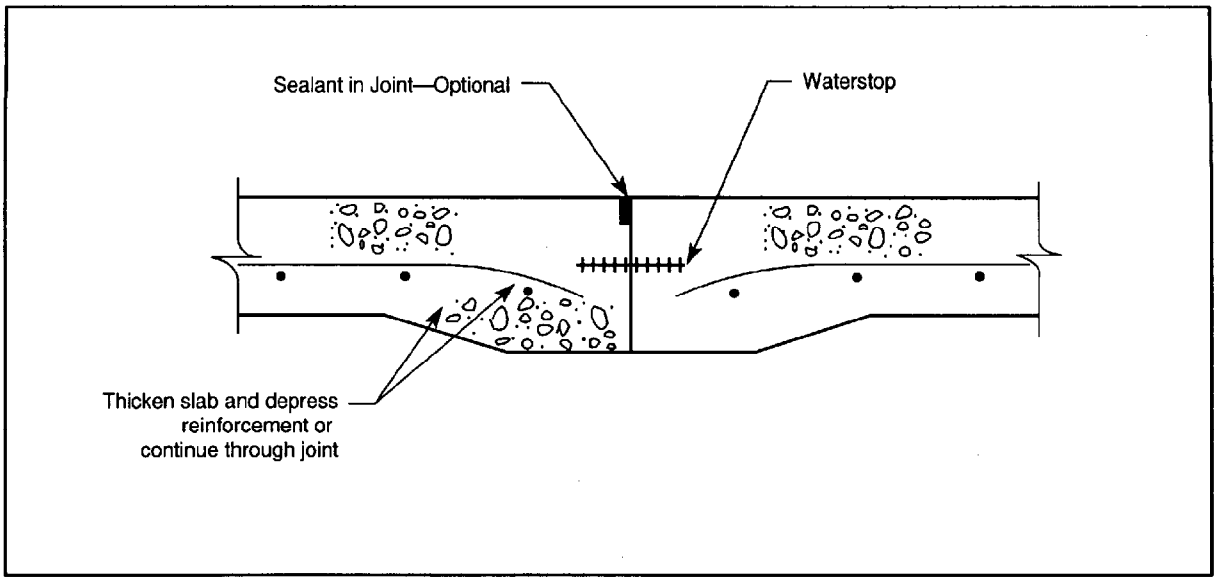

Figure 3 Typical floor-slab construction joint

3.8.4 *Subgrade.* The subgrade for membrane floors shall have adequate bearing capacity to sustain the weight of the tank, fluid contents, and roof load. The floor slab shall not be constructed directly on the natural subgrade soil or rock unless it is uniform and compact.

3.8.4.1 The subgrade for membrane floors must be of uniform density and compressibility to minimize differential settlement of the floor and footings. Disturbed subgrade or loosely consolidated soil or foundation material shall be removed and replaced with suitable compacted soil, or it shall be compacted in place. Compaction shall achieve a density of at least 95 percent of the maximum laboratory density determined by ASTM D1557. Field tests for measurement of in-place density shall be in accordance with ASTM D1556. Overexcavation and replacement with compacted imported material may be required if foundation soils are unsatisfactory for the imposed loadings or do not provide uniform support.

3.8.4.2 The subgrade for all types of floors shall be so designed that leakage through the floor will not cause erosion and settlement in excess of that provided for in the design or will not cause other types of failure.

3.8.5 *Floor base.* Use of a clean, well-compacted granular base with a minimum thickness of 6 in. (150 mm) shall be used for tanks when the natural subgrade does not meet drainage requirements or is difficult to prepare for floor construction. Gradation should be selected to permit free drainage without loss of fines. When suitable base material is not available, the use of geotextile fabrics shall be used.

3.8.5.1 Where site conditions indicate the possibility of hydrostatic uplift of the floor, a properly designed structural floor shall be used or adequate drainage of the floor base shall be provided to relieve the hydrostatic pressure and remove the water from the site. Drainage to a manhole or other drainage structure where the flow can be observed and measured is recommended. The receiving structure shall be below the level of the floor slab to guard against surcharge and backflow to the floor base.

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Sec. 3.9 Footing Design

3.9.1 *Wall footings.* When separated wall–floor connections are used at the base of the wall, a continuously reinforced concrete footing, either as a thickened floor edge region, an inverted footing, or one separated from the floor, shall be provided to distribute the vertical loads at the base of the wall to the underlying foundation material. A suitable waterstop shall be provided in all such separated wall-base joint connections. Reinforced nonsliding wall-base tanks shall employ a thickened and reinforced floor edge region to distribute wall loads to the foundation. Foundation for membrane floors and footings shall be of uniform compaction and bearing value to support the structure without differential settlement that may damage the structure. Footings and integral floor slab shall be designed to resist the entire radial and tangential shears from the wall.

3.9.2 *Column footings.* Column footings shall be designed in accordance with ACI 350R and may be an integral part of the membrane floor. Separation of the column footing from the floor requires the use of submerged joints that increase the potential for leakage. Where footings are placed below the floor slab and integral with it, additional reinforcing may be required to control cracking due to restriction of slab movement during curing and temperature or moisture changes. Inverted footings above the slab avoid this condition, but may entrap sediment and impede normal washdown and cleaning maintenance. Transitions in floor thickness should be gradual and additionally reinforced for flexural stresses and control of shrinkage cracking and leakage.

Sec. 3.10 Columns

Columns shall conform to the requirements of ACI 318, including supplements thereto. Minimum concrete cover over principal reinforcement shall be 2 in. (50 mm).

Sec. 3.11 Tank Appurtenances

This section is intended only to provide guidance to the purchaser and the designer in the functional aspects of appurtenances to be considered in the tank design.

The tank appurtenances and accessories to be provided shall be in accordance with ANSI and OSHA standards and the special requirements of governing agencies responsible for health and safety in the locality where the tank is to be constructed.

3.11.1 *Inlet and outlet piping arrangement.* Disinfectant contact time and residual should be considered in the design. Baffles or directional inlets may be required to achieve water quality objectives. This is particularly important for large tanks or where the daily fluctuations in water level do not provide adequate circulation.

3.11.1.1 The inlet and outlet pipes should be controlled by valves outside the tank that can be closed for tank inspection and maintenance.

3.11.1.2 The outlet connection should allow water to flow out of the tank with minimum head loss. This is especially important when the tank is used as suction storage for a pumping station and allowable head loss is limited. The outlet connection is generally depressed below the base of the tank wall, and its entrance may be flared to reduce head loss.

Where sediment from residual turbidity may accumulate in the tank during use, a removable silt stop may be placed on the outlet to prevent its entry into the outlet pipe during periods of high draft.

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3.11.1.3 Concrete encasement of all inlet–outlet piping placed under the floor slab is recommended for added corrosion protection and to ensure against leakage during the useful life of the structure. Flexible joints should be provided outside the wall footing to accommodate any movement due to differential settlement or seismic activity.

3.11.2 *Tank overflow and drain.*

3.11.2.1 The tank overflow system must normally be designed to pass the maximum filling rate. The overflow weir, flared inlet, or vortex breaker should be sized to pass the design flow at the maximum static water surface permitted in the wall and roof design. The freeboard specified in Sec. 4.10 is measured from the maximum static water surface to the underside of the roof slab or dome roof at its intersection with the inside face of the wall.

The overflow line should extend to a point outside the wall where it can freely discharge without unacceptable consequences and terminate with a screen, flap valve, or other device for preventing access by small animals into the tank through the overflow.

3.11.2.2 A washdown piping connection from the supply system with washdown piping and valved hose connection inside the tank or outside adjacent to the tank access ladder may be desirable design features for large-diameter tanks. Temporary pumping may be required for effective washdown pressure. Uniformly sloping the floor from its high point to the drain will facilitate wash down and cleaning.

3.11.2.3 A tank drain line, valved outside the tank, is normally provided to dispose of washdown water during inspection and cleaning. The drain line may be taken from the effluent line, if the effluent line starts at the low point in the tank floor.

There may be circumstances where an underdrain system is required to prevent hydrostatic uplift under the tank floor when the tank is emptied. If the tank may be subjected to hydrostatic uplift that cannot be relieved by a gravity drain system, an alarm system and/or automatic means of pumping down the water table to prevent groundwater entry into the tank on drawdown must be provided, or the tank floor designed to accommodate the uplift.

3.11.2.4 A pressure sensor may be provided and calibrated to the depth of water in the tank if remote level sensing or recording is required by the purchaser. Sampling connections of suitable size for accurately monitoring the quality of water in potable water tanks are also desirable features.

3.11.3 *Roof opening, hatches, and ventilators.*

3.11.3.1 All roof openings, including personnel and equipment hatches, sampling points, and ventilators should be constructed so as to prevent leakage into the tank and locked to resist unauthorized entry and vandalism.

All roof openings should be atop curbs at least 4 in. (100 mm) high. All covers should turn down at least 2 in. (50 mm) over the curbs. All frames and covers should be galvanized steel, fiberglass, or aluminum at least $3/16$ in. (5 mm) thick. Personnel hatches shall be at least $2\frac{1}{2}$ ft (0.76 m) square and provided with protective handrails conforming to OSHA specifications, if required.

3.11.3.2 Roof ventilators should be provided to admit air at a flow rate equal to the maximum tank outflow rate at pressure differentials not exceeding 2.0 in. (50 mm) of water column (equivalent to a 10 lb/ft^2 [4.79 kPa] loading on the roof or dome). The exhaust capacity of the ventilator must be at least equal to the design fill rate of the tank.

Ventilator screens should be protected from vandalism, but must be accessible for inspection and cleaning to remove insects or airborne lint, pollen, or dust.

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3.11.4 *Ladders and stairs.* All access ladders shall conform to OSHA requirements. Galvanized or painted steel may be suitable for outside ladder construction, but more corrosion-resistant structural materials, such as aluminum, stainless steel, and fiberglass-reinforced plastic, are recommended for interior ladder construction. Flat steel bar stock, steel pipe, and aluminum tubing have been commonly used for ladder stringers. Normal rung spacing is 12 in. (300 mm), and distance from the floor or landing to the bottom rung of inside ladders should be the same as the rung spacing.

Flat bar ladder stringers should be punched to receive rungs. Rungs and brackets should be welded to stringers. Stringers should be at least ⅜ by 2½ in. (10 by 63 mm), and rungs should be at least 1 in. (25 mm) in diameter. Brackets may be made of the same bar size as the stringers. Ends of ladder stringers should be rounded.

Outside ladders should be provided with hinged plate covers or other devices, extending far enough above ground to discourage unauthorized climbers. The cover or other device would be unlocked and swung aside for entry by authorized personnel.

Outside stairs should be fitted with handrails and landings at intervals specified by OSHA.

3.11.5 *Wall manholes.* When wall manholes in prestressed concrete tank walls are specified, the transfer or prestress forces around the wall opening may be handled by the use of stress plates or the banding of the circumferential prestressed reinforcement above and below the opening. Special consideration must be given to localized wall stresses, the spacing and protection of the prestressed reinforcement, and waterstop integrity.

3.11.6 *Architectural treatments.* Special architectural treatments are frequently used to enhance the appearance of prestressed tanks, including pilasters, brick, or precast facing panels and special finishes applied over the shotcrete cover coat. Care must be exercised in the selection and installation of anchorages and attachments for pilasters and wall facings to isolate them from contact with the prestressed reinforcement and eliminate the potential for corrosion of the reinforcement.

SECTION 4: PROVISIONS FOR EARTHQUAKE-INDUCED FORCES

Sec. 4.1 Introduction

4.1.1 *Design method.* The seismic design procedure for wire- or strand-wound, circular, prestressed concrete tanks may be the effective-mass method or a more accurate analysis method for seismic design (see appendix A). The effective-mass method recognizes the reduction in seismic load due to the sloshing of the contained liquid. The procedure outlined in Sec. 4.3 is based on this method. No seismic design is required for tanks located in seismic zone classification 0.

The user of this standard is directed to appendix A for references providing background on the theory of plates and shells and for other general reference material commonly used in the design of liquid containment structures subjected to earthquake-induced forces.

4.1.2 *Notation.* Symbols used in the various equations presented in Sec. 4 are defined as follows:

A = area of cable or strand, in in.^{2} (mm^2)

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A_I = the peak amplified acceleration consistent with the impulsive period at 5.0 percent damping, in units of gravitational acceleration (g); see definition for g below and Sec. 4.3.2

B = fraction of site horizontal acceleration to be used in vertical acceleration calculation, see Sec 4.5.1

C_C = convective coefficient, see Sec. 4.3.1(6)

C_I = impulsive coefficient, see Sec. 4.3.1(3)

C_V = coefficient of vertical acceleration, see Sec.4.5.1

d = slosh height, in ft (m); see Sec. 4.10

D = inside tank diameter, in ft (m)

D_c = the spectral displacement consistent with the convective period at 0.5 percent damping, in ft (m); see Sec. 4.3.2

E = modulus of elasticity of cable or strand, in lb/in./in. (grams/mm/mm)

E_c = modulus of elasticity of concrete, in lb/in./in. (grams/mm/mm)

G = shear modulus of elastomeric pad, in lb/in./in. (grams/mm/mm)

g = acceleration due to gravity, 32.2 ft/s^2 (9.80665 m/s^2)

H = maximum depth of water acting on the tank shell, in ft (m)

H_t = distance from the center of gravity of roof to the tank floor, in ft (m)

I = importance factor from Table 3

K_p = the factor from Figure 6 for the ratio of inside tank radius, in ft (m), to maximum depth of water, r/H, in ft (m)

k = spring stiffness per unit length of circumference for cable or elastomeric pad, or both, in lb/ft/ft (grams/m/m); see Sec. 4.3.1(5)

L_c = length of cable assumed to stretch, taken as sleeve length plus 35 times strand diameter, in in. (mm)

L_p = length of bearing pad along circumference, in in. (mm); see Sec. 4.3.1(5)

M_C = overturning moment applied to the bottom of tank shell due to convective forces, in lbf• ft (N• m); see Sec. 4.3.1(2)

M_I = overturning moment applied to the bottom of tank shell due to impulsive forces, in lbf• ft (N• m); see Sec. 4.3.1(2)

M_T = total overturning moment applied to the bottom of tank shell, in lbf• ft (N• m); see Sec. 4.3.1(2)

N_C = equivalent axisymmetric convective circumferential hoop load, in lb (kg); see Sec. 4.5.3

N_I = equivalent axisymmetric impulsive circumferential hoop load, in lb (kg); see Sec 4.5.3

N_T = total equivalent axisymmetric circumferential hoop load, in lb (kg); see Sec 4.5.3

N_V = hoop load due to vertical acceleration, in lb (kg); see Sec. 4.5.3

P_c = maximum vertical shell compressive force, in lbf/ft (kg/m) of shell circumference; see Sec. 4.4.5

P_t = maximum vertical shell tensile force or the minimum vertical shell compressive force, in lb/ft (kg/mm) of shell circumference; see Sec. 4.4.6

r = inside radius of tank wall, in ft (m)

R_I = impulsive structure coefficient, from Table 4

R_C = convective structure coefficient, from Table 4

R_V = structure coefficient for vertical acceleration, see Sec. 4.5.1

S = soil profile coefficient (site amplification factor) from Table 5

S_c = spacing between the cable sets, in in. (mm)

S_p = spacing of elastomeric pads, in in. (mm); see Sec. 4.3.1(5)

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T_I = natural period of tank and impulsive contents, in seconds; see Sec. 4.3.1(4)
T_c = the first-mode sloshing wave period, in seconds; see Sec. 4.3.1(6)
t = thickness of elastomeric pad after precompression due to dead load, in in. (mm)
t_b = tank core wall thickness at the base, in in. (mm)
$\ddot{u}_V$ = vertical acceleration, in ft/s^2 (m/s^2); see Sec. 4.5.1
V_C = base shear at the bottom of the tank shell due to convective force, in lb (kg); see Sec. 4.3.1(1)
V_I = base shear at the bottom of the tank shell due to impulsive forces, in lb (kg); see Sec. 4.3.1(1)
V_T = total base shear at the bottom of the tank shell, in lb (kg)
W_C = weight of effective mass of the first-mode sloshing contents of the tank, in lb (kg); see Sec. 4.3.1(7)
W_I = weight of effective mass of tank contents that moves in unison with the tank shell, in lb (kg); see Sec. 4.3.1(7)
W_R = total weight of the tank roof, plus a portion of snow or other roof live load, in lb (kg)
W_S = total weight of the tank wall (shell), in lb (kg)
W_T = the total weight of tank contents, in lb (kg); see Sec. 4.3.1(7)
w = width of elastomeric bearing pad in radial direction, in in. (mm)
w_t = weight of the tank, in lb/ft (kg/m) of shell circumference; see Sec. 4.4.5
X_C = height from the bottom of the tank shell to the centroid of W_C, in ft (m); see Sec. 4.3.1(8)
X_I = height from the bottom of the tank shell to the centroid of W_I, in ft (m); see Sec 4.3.1(8)
X_S = height from bottom of tank shell to center of gravity of the shell, in ft (m); see Sec. 4.3.1(2)
Z = zone coefficient from Table 2
α = angle of cable or strand with horizontal, in degrees
γ = unit weight of water, 62.4 lb/ft^3 (999.55 kg/m^3)
μ = coefficient of friction, see Sec. 4.7.1

Sec. 4.2 Seismic Design Categories

4.2.1 *Wall-base joint types.* For purposes of seismic design, externally wrapped, prestressed, concrete water-storage tanks currently in use can be classified into tanks with the following three types of joints between the wall and the foundation:

1. Reinforced nonsliding base. Tanks with a substantially fixed joint between the wall and the foundation (Figure 4A) that are tied to the footing and floor by adequate steel reinforcement.

2. Anchored flexible base. Tanks with an anchored flexible joint between the wall and the foundation. Anchorage is achieved by diagonal strand seismic cables embedded in the wall and in the footing, as shown in Figure 4B, which resist tangential movements but permit only limited radial movements of the wall.

3. Unanchored and uncontained flexible base. Tanks with an unanchored and uncontained flexible joint between the wall and the foundation; flexibility is achieved by an elastomeric bearing pad (Figure 4C).

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Table 2 Zone coefficient

Seismic Zone Classification*	Zone Coefficient Z
1	0.075
2A	0.15
2B	0.20
3	0.30
4	0.40

*The Uniform Building Code (UBC) assigns seismic zone classifications for areas both outside and within the United States as illustrated by the seismic zone map of Figure 5. These classifications are periodically updated based on data from site-specific seismic events. Many state and local building codes have also adopted governing seismic zone classifications more stringent than those designated by the UBC.

For determination of the seismic zone classification for the project location, the user of this standard should refer to the latest revision of the UBC or to equivalent local building codes for the design peak ground acceleration.

The unanchored and uncontained flexible base joint of Figure 4C has generally proved adequate for use in seismic zones 2A and below, although it is recommended that adequacy should be investigated for questionable site-specific conditions or importance factors greater than 1.0 (see Tables 2 and 3).

Table 3 Importance factor

Tank Use	Importance Factor I
Tanks that must remain usable to provide emergency service, with slight structural damage and insignificant leakage after an earthquake	1.25
Tanks that must remain usable, but may suffer repairable structural damage, and can be taken out of service, inspected, and repaired at some convenient time after an earthquake	1.0

Table 4 Structure coefficient for type of tank

Structure	Structure Coefficient	
	R_I	R_C
Tanks with a reinforced nonsliding base (Fig. 4A)	2.75	1.0
Tanks with an anchored flexible base (Fig. 4B)	4.5	1.0
Tanks with an unanchored and uncontained flexible base (Fig. 4C)	2.0	1.0

Tanks with hinged bases or unanchored and containing flexible bases, while used in the past, are no longer used in current practice in wire- and strand-wound tank construction.

4.2.2 *Applicability of base joint types.* Tanks to be located in seismic zones 2B, 3, and 4 (see Table 2 and associated footnote) shall use a Sec. 4.2.1, Figure 4A or Figure 4B type joint that anchors the wall to the foundation to prevent or restrict wall displacement during a seismic event. The fixed base joint described in Sec. 4.2.1(1), Figure 4A, has been used in seismic zones 3 and 4 primarily in tanks of 2.0 mil gal (7.57 ML) capacity or smaller, whereas the radially freed but anchored flexible base joint described in Sec. 4.2.1(2), Figure 4B, has been used in tanks of all sizes. The fixed base is not recommended for larger tanks in seismic zones 3 and 4 without

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Table 5 Soil profile coefficient

Soil Profile Coefficient*	Soil Profile Type			
	A	*B*	*C*	*D*
S	1.0	1.2	1.5	2.0

*The following is an explanation for the determination of the soil profile coefficient. The soil profile coefficient shall be specified by the purchaser. Site effects on tank response shall be established based on the following soil profile factors:

1. *Soil profile type A* is a profile with
   a. A rock-like material characterized by a shear wave velocity greater than 2,500 ft/s (764 m/s) or by other suitable means of classification.
   b. Stiff or dense soil condition where the soil depth is less than 200 ft (61 m).
2. *Soil profile type B* is a soil profile with dense or stiff soil conditions where the soil depth exceeds 200 ft (61 m).
3. *Soil profile type C* is a soil profile 70 ft (21 m) or more in depth and containing more than 20 ft (6 m) of soft to medium-stiff clay but not more than 40 ft (12 m) of soft clay.
4. *Soil profile type D* is a soil profile containing more than 40 ft (12 m) of soft clay characterized by a shear wave velocity less than 500 ft/s (153 m/s).
5. For tanks in seismic zones 3 and 4 and for tanks having an importance factor greater than unity, the soil profile shall be determined by a geotechnical investigation. In other locations, where the soil profile is not known in sufficient detail to determine the soil profile type, soil profile C may be assumed. Soil profile type D need not be assumed unless there is reasonable evidence that it exists, or its presence is established by geotechnical data.

full consideration and adequate reinforcement to counteract the base shear and vertical bending moments induced in the wall and its interaction with the footing and floor slab.

4.2.3 *Wall-to-roof joint connection.* Any of the above categories of tanks may have, at the wall-to-roof connection, a joint that is substantially fixed, has flexible or rigid ties, or that has no ties (elastomeric pad only). A joint with an elastomeric pad and without ties shall be contained to preclude excessive lateral displacement between the roof and the wall. The tank design shall have provisions that prevent the upward displacement of the roof with respect to the wall due to the height of the sloshing wave and vertical accelerations (see Sec. 4.10).

The designer should also consider increasing the zone coefficient in the vicinity of known faults where peak ground accelerations have been observed or may be anticipated in excess of those that have a 10 percent chance of exceedance in 50 years (see Sec. 4.3.2).

Sec. 4.3 Seismic Design Loads

4.3.1 *Effective-mass procedure for determining base shear and overturning moment due to seismic effects.* The effective-mass procedure considers the following two response modes of the tank and its contents: (1) the impulsive mode, which is the high-frequency amplified response to lateral ground motion of the tank shell and roof together with that portion of the liquid contents that moves in unison with the shell, and (2) the convective mode, which is the low-frequency amplified response of a portion of the liquid contents in the fundamental sloshing mode. The design requires the determination of the hydrodynamic mass associated with each mode and the lateral force and overturning moment applied to the shell resulting from the response of the masses to lateral ground motion. Because the two different response modes are not maximized at the same time, the root mean square can be used for combining forces and moments resulting from the two response modes.

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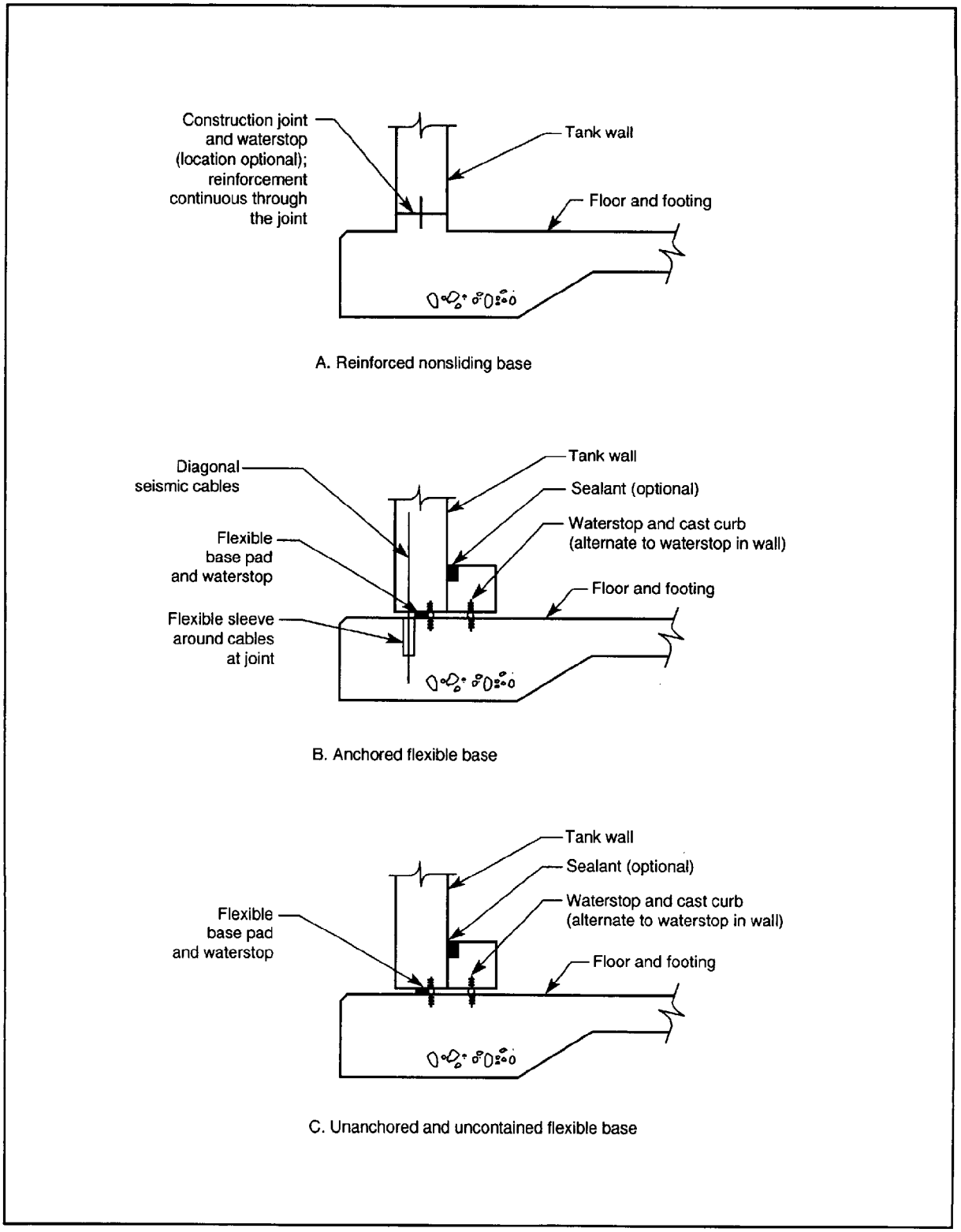

Figure 4 Types of joints used between the wall and its foundation

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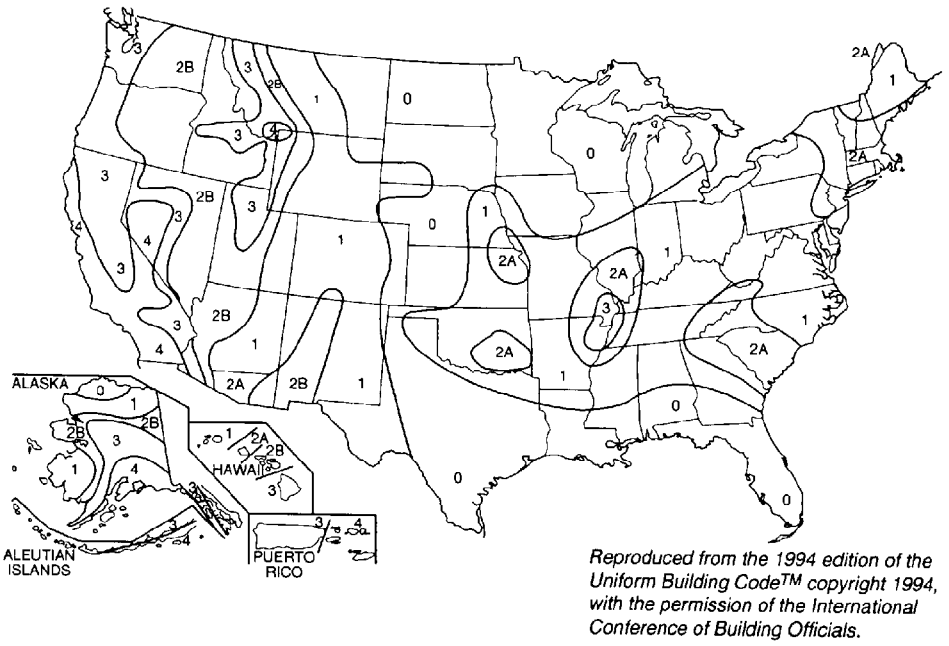

Figure 5 Seismic zone map of the United States (see notes accompanying Table 2)

1. The lateral or horizontal base shear due to seismic forces applied at the bottom of the tank wall shall be determined by Eq 4-1, 4-2, and 4-3. Refer to Sec. 4.1.2 for definition of symbols.

$$V_I = \frac{ZIC_I}{R_I}(W_S + W_R + W_I) \qquad \text{(Eq 4-1)}$$

$$V_C = \frac{ZIC_C}{R_C} W_C \qquad \text{(Eq 4-2)}$$

$$V_T = \sqrt{V_I{}^2 + V_C{}^2} \qquad \text{(Eq 4-3)}$$

In the case of Figures 4A and 4B bases, the wall design shall provide for 100 percent of the base shear V_T to be transferred tangentially. In addition to providing for 100 percent of the base shear to be transferred tangentially as noted above, for Figure 4A bases, the maximum radial base shear at 0° from the direction of the earthquake, along with the corresponding vertical bending moments and hoop forces, shall also be provided for in accordance with Sec. 4.5.3.

In the case of Figure 4B bases with diagonal seismic cables between the footing and the wall, the wall design shall provide for 100 percent of the base shear to be transferred tangentially. In addition, for Figure 4B bases, the maximum hoop forces at 0° from the direction of the earthquake shall also be provided for in accordance with Sec. 4.5.3.

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2. The overturning moment due to seismic forces applied at the bottom of the tank wall shall be determined by Eq 4-4, 4-5, and 4-6. Refer to Sec. 4.1.2 for definition of symbols.

$$M_I = \frac{ZIC_I}{R_I}(W_S X_S + W_R H_t + W_I X_I) \quad \text{(Eq 4-4)}$$

$$M_C = \frac{ZIC_C}{R_C} W_C X_C \quad \text{(Eq 4-5)}$$

$$M_T = \sqrt{M_I{}^2 + M_C{}^2} \quad \text{(Eq 4-6)}$$

3. The impulsive coefficient C_I is determined from Eq 4-7. However, C_I need not exceed 2.75.

$$C_I = \frac{1.25S}{T_I^{2/3}} \quad \text{(Eq 4-7)}$$

4. The tank's natural period T_I may be determined by a rational analysis that considers the weight of the tank wall and roof and effective weight W_I of the tank contents. For calculating the impulsive coefficient C_I, it shall be assumed that the period of the tank and its impulsive contents is 0.3 s or less for tanks with a reinforced nonsliding base (Figure 4A) unless substantiated to be longer. For tanks with anchored flexible bases (Figure 4B) and tanks with unanchored and uncontained flexible bases (Figure 4C), T_I may be determined from Eq 4-8. However, T_I shall not exceed 1.0 s for Figure 4B tanks, nor 2.0 s for Figure 4C tanks. Refer to Sec. 4.1.2 for definition of symbols.

$$T_I = \sqrt{\frac{4\pi (W_S + W_R + W_I)}{g\, r\, k}} \quad \text{(Eq 4-8)}$$

5. For tanks with a Figure 4B, base-joint type, the spring stiffness k is determined from Eq 4-9. Refer to Sec. 4.1.2 for definition of symbols. In Eq 4-9 and 4-10, for a tank with a continuous bearing pad, the ratio L_p/S_p= 1.0. For a tank with a series of bearing pads, for example, having lengths of 6 in. (150 mm) spaced at 12 in. (300 mm) on centers, L_p/S_p = 0.5.

$$k = 144\left[\frac{(AE)\cos^2\alpha}{L_c S_c} + \frac{2G\, w\, L_p}{tS_p}\right] \quad \text{(Eq 4-9)}$$

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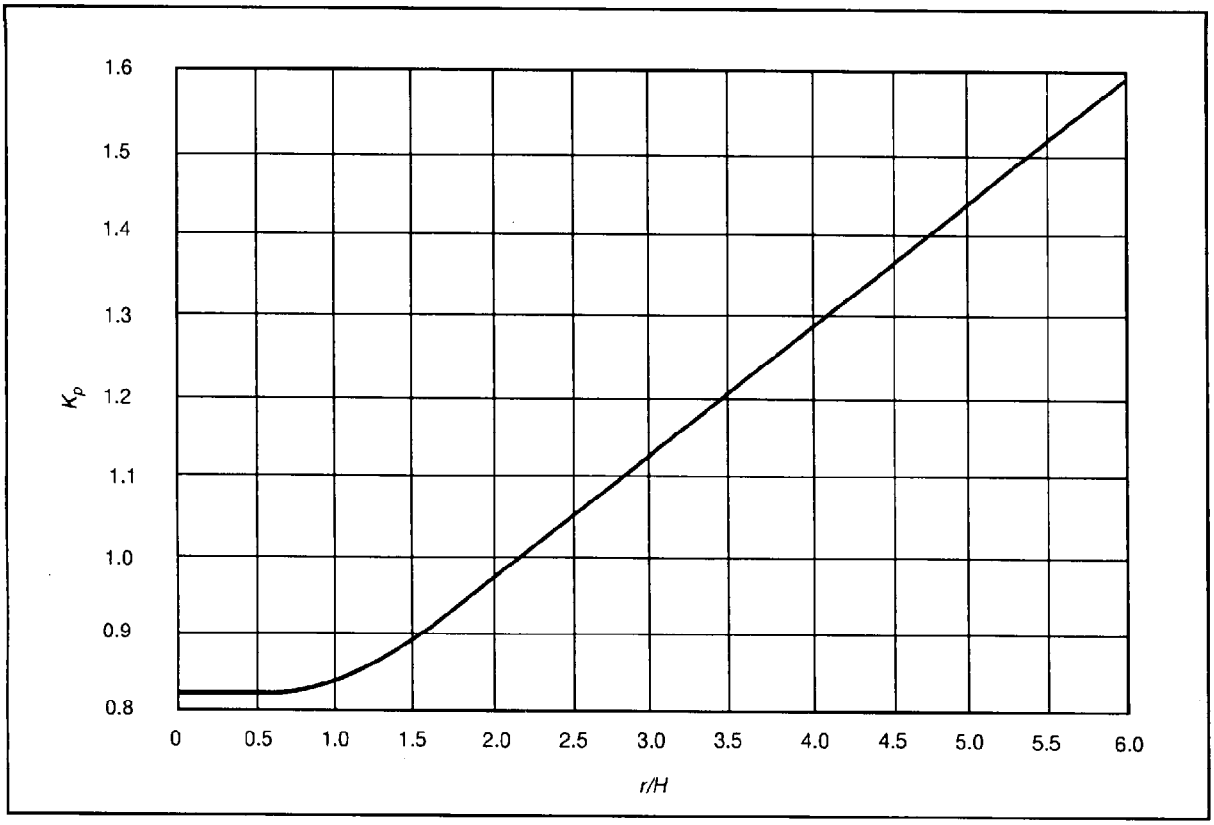

Figure 6 Curve for obtaining factor K_p for the ratio r/H

For tanks with Figure 4C base-joint type, k is determined from Eq 4-10.

$$k = \left[144 \frac{2G\,w\,L_p}{tS_p}\right] \qquad \text{(Eq 4-10)}$$

NOTE: Eq 4-9 and 4-10 were derived without including the effects of the flexibility of the tank shell and the wall-to-roof connection. These effects may be important under some circumstances.

6. The convective coefficient C_C is determined from Eq 4-11. Refer to Sec. 4.1.2 for definition of symbols.

$$C_C = \frac{4S}{T_c{}^2} \qquad \text{(Eq 4-11)}$$

The first-mode sloshing wave period T_c is determined from Eq 4-12 and K_p is obtained from Figure 6.

$$T_c = K_p \sqrt{r} \qquad \text{(Eq 4-12)}$$

or

$$T_c = \sqrt{\frac{r}{1.5 \tanh\left(\sqrt{3.375}\, H/r\right)}}$$

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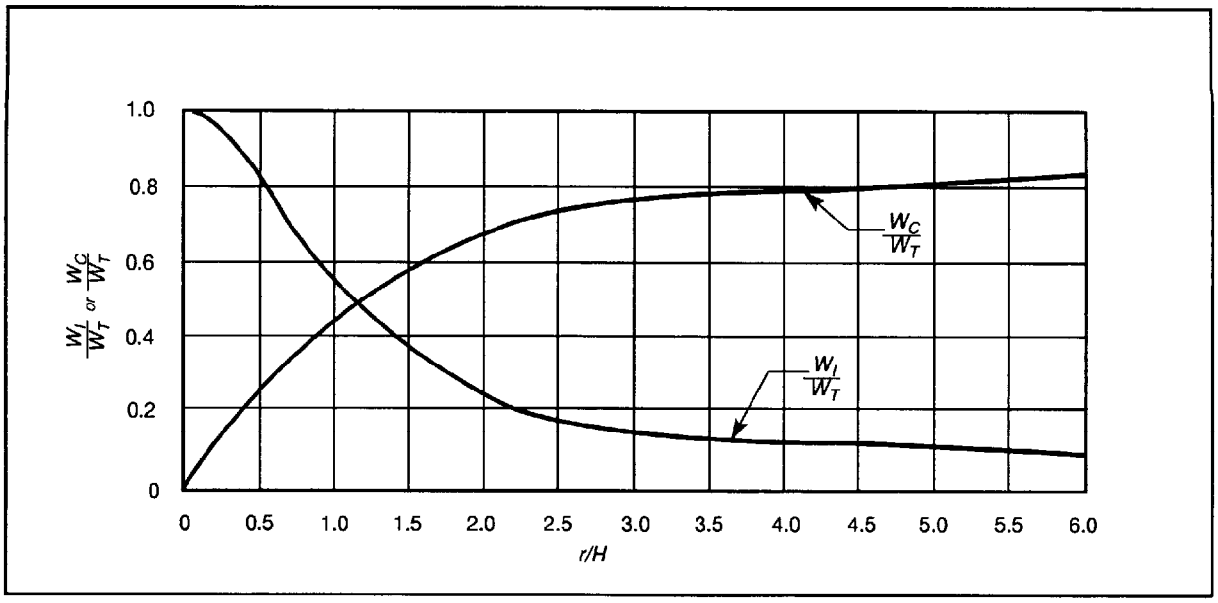

Figure 7 Curves for obtaining factors W_I/W_T and W_C/W_T for the ratio r/H

7. Effective mass of tank contents. The weight of the impulsive mass of the tank contents that moves in unison with the tank shell W_I and the weight of the convective mass of the first-mode sloshing contents W_C may be determined by multiplying W_T by the ratio W_I/W_T and W_C/W_T, respectively, obtained from Figure 7 for the ratio r/H of the tank, or from Eq 4-14 and 4-15.

The total weight of the tank contents W_T is determined from Eq 4-13. Refer to Sec. 4.1.2 for definition of symbols.

$$W_T = \gamma \pi r^2 H \qquad \text{(Eq 4-13)}$$

$$\frac{W_I}{W_T} = \frac{\tanh (\sqrt{3}\ r/H)}{(\sqrt{3}\ r/H)} \qquad \text{(Eq 4-14)}$$

$$\frac{W_C}{W_T} = \frac{\sqrt{3.375}\ r \tanh \sqrt{3.375}\ H/r}{4H} \qquad \text{(Eq 4-15)}$$

8. The heights X_I and X_C from the bottom of the tank shell to the centroids of the lateral seismic forces applied to W_I and W_C may be determined by multiplying H by the ratios X_I/H and X_C/H, respectively, obtained from Figure 8 for the ratio r/H or from Eq 4-16 and 4-17.

When $r/H \leq 0.6667$, then

$$\frac{X_I}{H} = [\,0.50 - 0.1875\ (r/H)\,] \qquad \text{(Eq 4-16)}$$

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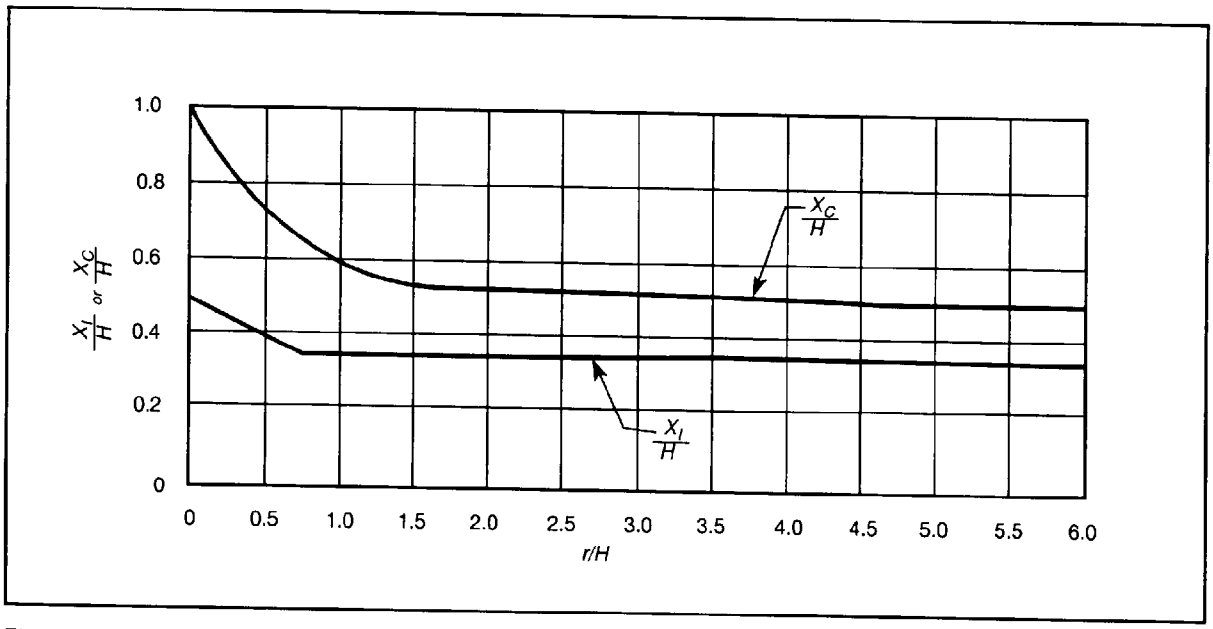

Figure 8 Curves for obtaining factors X_I/H *and* X_C/H for the ratio r/H

When $r/H >= 0.6667$, then

$$\frac{X_I}{H} = 0.375$$

For all values of r/H,

$$\frac{X_C}{H} = 1 - \left[\frac{\cosh \sqrt{3.375}\, H/r - 1}{(\sqrt{3.375}\, H/r) \sinh (\sqrt{3.375}\, H/r)}\right] \qquad \text{(Eq 4-17)}$$

9. The curves in Figure 7 and Figure 8 are based on equations in Chapter 6 and Appendix F of *Nuclear Reactors and Earthquakes* (see US Nuclear Regulatory Commission [1963] in appendix A). Alternately, W_I, W_C, X_I, and X_C may be determined by other analytical procedures based on the dynamic characteristics of the tank.

4.3.2 *Application of site response spectrum.* Where site-specific response spectra are used, the accelerations of the two masses shall replace the seismic coefficient as follows:

A_I replaces ZIC_I (in units of gravitational acceleration [g]) in Eq 4-1, 4-4, and 4-24, and $\sqrt{3.375}\, \frac{D_c}{r} \tanh (\sqrt{3.375}\, H/r)$ replaces ZIC_c (in g) in Eq 4-2, 4-5, 4-25, 4-28, and 4-29.

Refer to Sec. 4.1.2 for definition of symbols.

For tanks with a Figure 4A base joint, the natural period T_I shall be taken as the period in the range of 0.0 to 0.3 s that gives the largest base shear, unless a more precise determination of period is performed.

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The zone coefficients Z represent, within the accuracy that can be expected with such a system, the peak ground accelerations that have a 10 percent chance of exceedance in 50 years. When multiplied by an importance factor I of 1.25, the probability of exceedance drops to 5 percent. Similar probabilities should be used for site-specific response spectra. The results obtained by using site-specific response spectra shall not be less than those determined by the zone-based Eq 4-1, 4-2, 4-4, 4-5, 4-24, 4-28, and 4-29.

Sec. 4.4 Vertical and Horizontal Forces

4.4.1 *Application at joints.* Wall-roof joints and wall-floor joints shall be designed to resist the horizontal and vertical forces they transmit due to the earthquake and gravity loads acting simultaneously.

4.4.2 *Effects on tank components.* Roofs, walls, and floors shall be investigated for strength and stability under tensile and compressive hoop forces, vertical bending moments, radial and/or tangential shear forces, and overturning moment resulting from earthquake-induced impulsive and convective forces and from gravity loads acting simultaneously. The impulsive and convective forces shall be converted to their maximum pressure and then this maximum pressure shall be used to analyze the wall as though it were axisymmetric for purposes of finding the maximum hoop forces, radial shears (Figure 4A tanks), and vertical bending moments (see Sec. 4.5.3).

4.4.3 *Seismic cables.* For tanks with Figure 4B bases, the strength of seismic cables and their anchorage in the tank wall and foundation shall also be investigated under tensile forces resulting from earthquake-induced base shear and overturning moment.

4.4.4 *Base-pad design considerations.* For tanks with Figures 4B and 4C bases, the strength of base pads shall also be investigated under shear and compressive forces resulting from earthquake-induced base shear, overturning moment, and gravity loads acting simultaneously. The base pads for tanks with Figure 4C bases shall be designed to resist the total earthquake-design base shear. Maximum total base-pad frictional resistance shall not exceed $\mu\ (W_S + W_R)$, where μ is the coefficient of friction, unless adequate shear keys or other positive mechanical means of attachment are provided to transfer the shear forces from the concrete to the base pads. However, such frictional resistance can be considered only if vertical accelerations have also been calculated and the gravity dead loads reduced by the effects of the vertical accelerations.

4.4.5 *Vertical forces at wall base.* The maximum vertical compressive and tensile forces, P_c and P_t, respectively, at the bottom of the tank wall due to gravity load and earthquake-induced overturning moment shall be determined from Eq 4-18 and 4-19. Refer to Sec. 4.1.2 for definition of symbols.

$$P_c = w_t \left[1 + 1.273 \frac{M_T}{D^2 w_t} \right] \qquad \text{(Eq 4-18)}$$

$$P_t = w_t \left[1 - 1.273 \frac{M_T}{D^2 w_t} \right] \qquad \text{(Eq 4-19)}$$

The weight of the tank w_t, in pounds per foot of shell circumference, shall be determined from Eq 4-20.

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$$w_t = \frac{W_s + W_R}{\pi D} \qquad \text{(Eq 4-20)}$$

4.4.6 *Cable anchorage force.* The maximum vertical compressive force at the bottom of the tank wall due to gravity load and earthquake-induced base shear in tanks with Figure 4B bases shall include the vertical component of force in the anchor cables.

Sec. 4.5 Other Effects

4.5.1 *Vertical acceleration.* The tank shall be designed for vertical acceleration. Unless the use of a greater vertical acceleration is specified or agreed on by the purchaser, the vertical acceleration $\ddot{u}_V$ shall be determined from Eq 4-21. In seismic zones 3 and 4, $\ddot{u}_V$ shall be no less than one half of the horizontal acceleration.

$$\ddot{u}_V = \frac{ZIC_V}{R_V} B \qquad \text{(Eq 4-21)}$$

The value of B shall be 0.25 for seismic zones 1, 2A, and 2B; 0.50 for zone 3; and 0.60 for zone 4. The value of R_V (the structure coefficient for vertical acceleration) shall be 3.0 and C_V (the coefficient of vertical acceleration) is determined from Eq 4-22. C_V, however, need not exceed 2.75.

$$C_V = \frac{1.25S}{T_V^{2/3}} \qquad \text{(Eq 4-22)}$$

The natural period of the tank T_V may be determined from Eq 4-23.

$$T_V = 2\pi\sqrt{\frac{\gamma DH^2}{24\, g t_b E_c}} \qquad \text{(Eq 4-23)}$$

4.5.2 *Combining acceleration effects.* The strength and stability of walls, floors, and roofs shall be adequate to withstand the effects of both the design horizontal acceleration and the design vertical acceleration. Effects of maximum horizontal and vertical acceleration shall be combined by the root-sum-square method.

4.5.3 *Equivalent axisymmetric hoop loads.* Hydrodynamic seismic membrane hoop tensile stresses in the circumferential direction; radial shear; and vertical bending moments shall be determined by applying the equivalent axisymmetric hoop loads due to the response of the mass of the tank roof and shell (wall) combined with the equivalent axisymmetric hoop load due to the response of the mass of the tank contents given by Eq 4-24, 4-25, 4-26, and 4-27. The maximum radial force, summed over the full height of the tank wall (see the last two paragraphs in this section for the vertical distribution of these forces) for each component, may be obtained by dividing the following equivalent axisymmetrical hoop loads by the radius.

$$N_I = \frac{ZIC_I}{R_I} (W_S + W_R + W_I) \left(\frac{1}{\pi}\right) \qquad \text{(Eq 4-24)}$$

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$$N_C = \frac{Z I C_C}{R_C} (W_C) \left(\frac{8}{9\pi}\right) \quad \text{(Eq 4-25)}$$

$$N_V = \frac{\ddot{u}_V \gamma H^2 R}{2} \quad \text{(Eq 4-26)}$$

$$N_T = \sqrt{N_I{}^2 + N_C{}^2 + N_V{}^2} \quad \text{(Eq 4-27)}$$

The vertical distribution of the impulsive hoop loads, resulting from the response of the tank contents, shall be Housner's impulsive pressure distribution (Housner 1954), or a trapezoid that approximates this distribution, increasing linearly from top to bottom. The centroid of the impulsive hoop-load distribution shall be located at a height from the bottom of the tank shell equal to the centroid X_I of the impulsive portion W_I of the tank contents. The impulsive hoop loads shall not be distributed over a height greater than the depth of the water H.

The vertical distribution of the convective hoop loads, due to the response of the tank contents, shall be Housner's convective pressure distribution (Housner 1954), or a trapezoid that approximates this distribution, decreasing linearly from top to bottom. The centroid of the convective hoop-load distribution shall be located at a height from the bottom of the tank shell equal to the centroid X_C of the convective portion W_C of the tank contents. The convective hoop loads shall not be distributed over a height greater than the depth of water H.

The vertical distribution of the vertical-acceleration hoop loads shall be a triangular distribution with the maximum at the bottom. The vertical-acceleration loads shall not be distributed over a height greater than the depth of the water H.

For purposes of calculating the combined effects on the tank wall and other components, the impulsive, convective, and vertical-acceleration loads shall be combined by taking the square root of the sum of the squares of the three components. When determining the required area of circumferential prestressed reinforcement for a given increment of wall height, the square root of the sum of the squares of the three seismic components taken at the midheight of the increment shall be added to the hydrostatic load at the midheight of the increment and divided by the allowable stress under seismic loading.

Sec. 4.6 Maximum Allowable Stresses and Reinforcement Requirements

4.6.1 *Maximum combined stresses.* Except as provided in Sec. 4.6.5, forces or stresses in the tank caused by the seismic loads given in this section, combined with all other loads that can act simultaneously, shall not exceed 1.25 times the allowable stresses given in Sec. 3.4.

4.6.2 *Reinforcement for flexural tension.* Whenever seismic effects, combined with other load effects that can act simultaneously, induce flexural tension stresses in the tank wall, bonded nonprestressed vertical reinforcement shall be provided within 1 to 2 in. (25 to 50 mm) of the tension faces of the wall. The area of this reinforcement shall be sufficient to resist the entire net flexural tension force. Maximum spacing of bonded reinforcement shall be three times the wall thickness or 12 in. (300 mm), whichever is greater.

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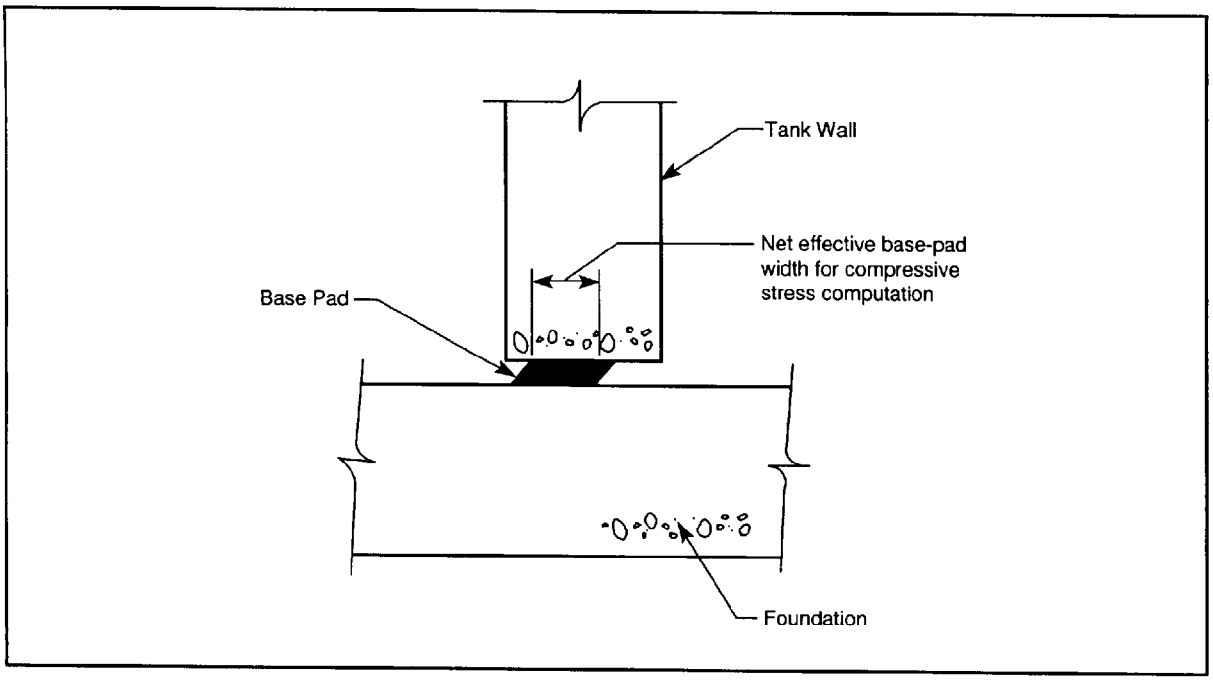

Figure 9 Net effective base-pad width after shear deformation

4.6.3 *Prestressing tensile stress.* For all tanks, the resultant tensile stress in the horizontal prestressed reinforcement under the combined effects of hydrostatic and hydrodynamic fluid pressure shall be not greater than $0.75f_{pu}$, where f_{pu} is the specified ultimate tensile strength of the wire or strand. The prestressed reinforcement shall be assumed to resist the entire net tension.

4.6.4 *Seismic-cable stress.* Maximum seismic-cable tensile stress shall not exceed $0.75f_{pu}$, where f_{pu} is the specified ultimate tensile strength of the strand.

4.6.5 *Base pad.* Maximum base-pad shear and compressive stresses shall not exceed the limits for occasional loading recommended by the manufacturer. The minimum width-to-thickness ratio for all pads and the minimum length-to-thickness ratio for discontinuous pads shall be 3.0. The net effective pad width after shear deformation (Figure 9) shall be used to compute the maximum compressive stress on the base pad.

Sec. 4.7 Maximum Allowable Coefficient of Friction

4.7.1 *Base-joint friction.* The coefficient of friction μ between concrete and an elastomeric pad shall not be less than 0.5 to compute maximum allowable base-pad, service-load, frictional resistance.

Sec. 4.8 Serviceability Requirements

4.8.1 *Uplift limitation.* Tanks without vertical or diagonal ties between the wall and footing shall not be permitted to have tension due to uplift from earthquake-induced overturning moment. For no uplift, the overturning moment M must be less than or equal to $r(W_S+W_R)$.

4.8.2 *Waterstop integrity.* For tanks with Figure 4B and 4C bases, the relative displacement between the tank shell and the foundation due to the combined effects of earthquake-induced base shear, gravity loads, and vertical accelerations shall not

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exceed the capability of the waterstop to accommodate radial and tangential movement without leakage. Friction between the bearing pad and the wall base shall not be relied on to reduce the tangential displacements of the wall base in seismic zones 2B, 3, and 4.

4.8.3 *Seismic-cable sleeves.* For tanks with a Figure 4B base, compressible sponge rubber sleeves shall be used over the seismic cable through the base joint as specified to allow controlled radial wall movement.

Sec. 4.9 Foundation Design

4.9.1 *General.* Foundations shall be designed to resist gravity loads and the horizontal and vertical forces due to seismic forces induced by the design earthquake, acting simultaneously. Foundations for anchored flexible base tanks shall be designed to resist the seismic-cable uplift forces resulting from the earthquake-induced total shear, overturning moment, and gravity loads acting simultaneously. Foundations for all tanks shall be designed to resist the compressive forces resulting from the earthquake-induced overturning moment and gravity loads acting simultaneously.

4.9.2 *Soil stress.* A one-third increase in allowable soil stresses is permitted for load combinations that include seismic loads.

4.9.3 *Overturning moment.* The overturning moment in Sec. 4.3.1(2) is that applied to the base of the tank shell. The foundation is subjected to an additional moment due to the sloshing of the tank contents and the effect of dynamic fluid pressure on the tank bottom (see US Nuclear Regulatory Commission [1963] in appendix A) as well as an additional moment equal to the base shear times the vertical distance between the shell base and the resultant of the lateral soil load on the foundation.

The overall stability of the tank shall be investigated under maximum governing load combinations, including those due to seismic forces, and the stability against overturning achieved with a safety factor of 1.5 or greater. Under these conditions, the maximum soil stress under the foundation shall not exceed the allowable stress in Sec. 4.9.2. The tank foundation shall be designed for the resulting shear, flexure, and deflection.

Sec. 4.10 Minimum Freeboard

During a seismic event, the maximum water-surface displacement (sloshing height) may impinge on the underside of the roof slab. The anticipated unrestrained sloshing height shall be computed by Eq 4-28 or 4-29. If sufficient freeboard height is not provided to prevent uplift forces due to sloshing, the tank roof and its connections shall be designed for the uplift forces. The uplift forces generated by the restraint of sloshing shall be computed as the hydrostatic force produced by the liquid restrained from sloshing. The connection of the roof to the wall shall be designed for the resulting forces, and restraint provided if the uplift sloshing force exceeds 90 percent of the roof dead load on the wall.

$$d = ZIC_c r \qquad \text{(Eq 4-28)}$$

but need not exceed

$$d = \frac{3\, r \coth\left(\sqrt{3.375}\, H/r\right)}{\dfrac{6T_c^{\,2}}{ZIC_c\, r} - \sqrt{54}} \qquad \text{(Eq 4-29)}$$

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Sec. 4.11 Design for Seismic Effects of Backfill

The dynamic seismic forces due to the backfill surrounding the tank, if any, shall be taken into account according to the soil-structure interaction criteria provided by the geotechnical engineer.

In a buried tank, the dynamic backfill forces shall not be relied on to reduce the dynamic effects of the water in the tank.

SECTION 5: CONSTRUCTION PROCEDURES

Sec. 5.1 Scope

The requirements for placing, finishing, and curing concrete and shotcrete shall be in accordance with the requirements of ACI 301, ACI 302.1R, ACI 304R, ACI 305R, ACI 306R, ACI 308, ACI 318, ACI 347R, ACI 350R, ACI 506R, and ACI 506.2, as modified herein, and additional requirements related specifically to wire- and strand-wound, circular, prestressed tank construction not included in these references.

Sec. 5.2 Concrete

5.2.1 *Weather limitations.*

5.2.1.1 Unless specifically authorized in writing, concrete shall not be placed during cold weather when the ambient temperature is below 35°F (2°C), even if the temperature is rising, or below 40°F (4°C) and falling, and when the concrete is likely to be subjected to freezing temperature before the concrete compressive strength has reached 500 psi (3.5 MPa). Most well-proportioned concrete will reach this strength when the temperature has been maintained at 50°F (10°C) into the second day after placement. Cold-weather concreting shall be in accordance with ACI 306R and ACI 301. The materials shall be heated so that the temperature of the concrete, when deposited, shall be not less than 50°F (10°C), or as otherwise indicated in ACI 306R, or more than 70°F (21°C). All methods and equipment for heating and for protecting concrete in place shall be subject to review by the purchaser.

5.2.1.2 During hot-weather concreting, cooling of water and aggregate shall be in accordance with the recommendations of ACI 305R.

5.2.1.3 Placement of concrete during periods of low humidity or high winds shall meet the requirements of ACI 301 and ACI 305R, particularly when large surface areas are to be finished. In any event, all concrete surfaces exposed to drying wind shall be covered with polyethylene sheets or acceptable wet covering immediately after finishing and shall be water cured in accordance with the requirements of ACI 308, continuously from the time the concrete has taken initial set. Water curing by ponding is the recommended method for curing water tank floors and shall be employed whenever practicable.

Curing compounds may be used in conjunction with water curing, provided they are compatible with coatings that may later be applied, or providing they are degradable or will be removed prior to the application of shotcrete or seal coatings. Curing compounds should not be permitted, under most circumstances, in lieu of water curing except for vertical surfaces such as cast-in-place core walls. Curing compounds used on the interior surfaces of tanks shall contain no constituents that will impart taste or odor, or other toxic chemicals to the water.

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5.2.2 *Foundation preparation.* If the tank is to be constructed on undisturbed earth, all deleterious material should be removed during excavation for the tank floor and wall and column foundations. Confirm that the subgrade foundation material and its compaction are as specified in Sec. 3.8.4 and Sec. 3.9 for the tank construction. Under no circumstances should the earth be plowed, scraped, or dug by machinery in such a way that will result in the disturbance of material below grade, unless the earthwork specifications require its compaction in place or that it be removed and replaced with compacted imported material.

5.2.3 *Floor placement.* Check all reinforcing steel immediately prior to placing concrete to verify that the steel is properly positioned, adequately supported, and will have the specified concrete cover. If nonmetallic spacers (e.g., concrete "dobies" or plastic pads) are used between reinforcing bars and subgrade, verify that they are of adequate size, density, and number. Foot traffic should not be allowed on the reinforcing steel during the placing of the concrete unless the supports and ties are designed for that purpose. Temporary walkways for concrete placement should be adequately supported on the base material or formwork.

Concrete-membrane floors shall be cast continuously, without cold joints and, where practicable, without construction or expansion joints. Structural floors shall be cast continuously in sections of such size that once any placement begins, it will be completed without interruption. Waterstops shall be provided for all construction and expansion joints in concrete floor slabs. The free edge of a horizontal elastomeric waterstop shall be folded back until the concrete has been placed beneath it and compacted. The waterstop shall then be released and the concrete placement continued over it. Care shall be taken to avoid a downward deflection of the waterstop after it has been folded down on the previously placed and compacted concrete. Thickening the floor slab at the joint to a minimum of 8 in. (200 mm) will facilitate proper placement of the waterstop, but it may also contribute to shrinkage stresses that will require additional steel reinforcement in the thickened section. All top floor surfaces shall be to the line, grade, and finish specified.

Adequate curing of floors is critical to their proper construction and watertightness. During hot weather, floors shall be water cured in accordance with the requirements of ACI 308. In the absence of hot weather, water curing in accordance with ACI 308 shall be the preferred curing method, although membrane-forming curing compounds may be used in accordance with ACI 308 where conditions make it impractical to use water curing.

5.2.4 *Cast-in-place walls and columns.* Concrete cast-in-place walls and columns shall be placed in accordance with the requirements of ACI 301 or ACI 304. Each vertical segment of the tank wall shall be placed in a single continuous operation without horizontal joints. An enriched fine-aggregate mix shall be used at the base of columns and the base of the wall to improve embedment of the horizontal base waterstop and the reinforcement and bottom anchorages of vertical prestressing units. Care should be taken to assure subsequently placed concrete is vibrated into the enriched mixture.

5.2.4.1 Concrete shall be conveyed from mixer to forms by methods that minimize segregation or loss of ingredients. Concrete shall be deposited, as nearly as practicable, in its final position horizontally. There shall be no free vertical drop greater than 8 ft (2.4 m), except when starting a wall placement, in which case the free vertical drop of concrete shall not be more than 4 ft (1.2 m).

5.2.4.2 Concrete shall be placed before initial set has occurred and, unless otherwise acceptable to the purchaser, not later than 1½ h after adding water to the

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mix when the air temperature is at 85°F (29°C) or above. This time period may be extended to a maximum of 2½ h provided the purchaser is satisfied that admixtures in sufficient quantity can extend the setting time of the concrete without adverse effects on the strength and quality of the concrete. When the air temperature is below 85°F (29°C), the 1½ h period may be extended by 1 min for each degree fahrenheit the air temperature is below 85°F (29°C). The time for placement shall not exceed a maximum of 2½ h after the water has first been added to the aggregate–cement mix.

5.2.4.3 Concrete shall not be placed in water, nor shall water be allowed to rise over freshly placed concrete, until after the concrete has set sufficiently to prevent damage to the mix or finish.

5.2.4.4 The forms shall be cleaned and coated with an approved nonstaining, nontoxic, bond release form oil before erection as specified in ACI 301. Concrete shall not be placed until all reinforcement is securely and properly fastened in position, the form ties at construction joints have been retightened, and all sleeves, hangers, pipe, bolts, and other items required to be embedded in the concrete have been placed and anchored. Exposed concrete edges, except vertical wall joints, shall have a ¾-in. (19-mm) chamfer.

5.2.4.5 Concrete shall be deposited in approximately horizontal layers or lifts not to exceed 24 in. (0.6 m) in depth. Before a new lift is placed, the concrete in the last lift shall be thoroughly and systematically vibrated. The vibrator shall penetrate the upper two lifts and shall be slowly pulled up. In other words, each lift before the final lift shall be vibrated twice. The final lift shall also be vibrated twice. Casting and vibrating of walls shall be done through form openings 18 in. by 18 in. (0.46 m by 0.46 m) minimum, located on one side of the wall.

5.2.4.6 All top surfaces shall be to line and grade and, unless otherwise specified, shall receive a smooth steel-trowel finish.

5.2.4.7 Walls shall be cured in accordance with the requirements of ACI 308.

5.2.4.8 All honeycombed concrete or concrete not meeting the requirements of ACI 301 shall be removed to sound concrete and repaired in accordance with ACI 301.

5.2.5 *Construction joints for cast-in-place concrete.*

5.2.5.1 Prior to the start of construction, the constructor shall submit for review layouts and details of all proposed joints in walls, floors, and footings, unless these details are shown on the contract drawings.

5.2.5.2 Spacing of vertical construction joints in concrete walls shall generally not exceed 60 ft (18 m). Shear keys, sleeved dowels, or continuous reinforcement shall be used in the joint to prevent radial displacement of adjacent wall panels or sections prior to prestressing. The face of the vertical joint where the horizontal nonprestressed-steel reinforcement is discontinuous at the joint shall be coated with bond breaker prior to placement of concrete for the adjacent wall section. All vertical construction joints in nondiaphragm tank walls shall have a suitable waterstop in the joint between the water and the prestressing wire or strand. Details of all joints shall be shown on the drawings. Joints between any two adjacent elements of the floor, wall, flat roof, and wall footing, and between floor and wall or between the wall and its footing, shall contain a suitable waterstop unless otherwise approved on the construction drawings submitted for the structure.

5.2.6 *Precast-concrete-panel wall.* Concrete for each precast panel shall be placed in one continuous operation.

5.2.7 *Precast-wall-panel erection.* The precast panels shall be erected to the correct vertical and circumferential alignment. The edges of adjoining panels shall

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not vary inwardly or outwardly from one another by more than ⅜ in. (9.5 mm) and shall be placed to the tank radius, within like tolerance.

5.2.8 *Vertical joints between precast panels.* The edges of the diaphragms of adjoining panels shall be joined or lapped to form a watertight barrier. A steel sheet with lapped joints between diaphragm and steel sheet sealed with an elastomeric or epoxy sealing compound may be used to secure a watertight joint. The lapped joints between diaphragm sheets within each precast panel shall preferably be sealed by lock seaming with a roll form machine. The vertical slots between panels shall be filled with cast-in-place concrete, cement–sand mortar, or shotcrete compatible with the details of the joint. The strength of the concrete, mortar, or shotcrete shall be equal to that specified for concrete in the wall panels.

5.2.9 *Placement details for concrete in roofs.* Prior to construction, the constructor shall submit for review the proposed placement details and procedures, including the location and type of construction joints, unless these details and procedures are specified by the purchaser.

Sec. 5.3 Shotcrete

5.3.1 *Weather limitations.*

5.3.1.1 Placement of shotcrete may start without special protection when the ambient temperature is 35°F (2°C) and rising, but shall be suspended when the ambient temperature is 40°F (4°C) and falling. Placement of shotcrete when the ambient temperature is below 35°F (2°C) and rising, or below 40°F (4°C) and falling, shall be considered cold-weather shotcreting and shall not be allowed unless specifically authorized by the purchaser. Shotcrete shall not be placed on frozen surfaces. Cold-weather shotcreting shall be in accordance with ACI 306R and ACI 301. The materials shall be heated in order that the temperature of the shotcrete, when deposited, shall be not less than 50°F (10°C), or as otherwise recommended in ACI 306R, or more than 70°F (21°C). All methods and equipment for heating and for protecting shotcrete in place shall be subject to review by the purchaser.

5.3.1.2 For shotcrete placed during extremely hot weather, the aggregate shall be cooled by frequent spraying with water in such a manner as to use the cooling effect of evaporation without raising the moisture content above the level suitable for mixing and placement. During such periods, an acceptable placement schedule shall be arranged in a manner that will provide time for the temperature of the previously placed coat to begin to drop. The mixing water shall be the coolest available at the site, insofar as practicable. Hot-weather shotcreting shall be in accordance with the requirements of ACI 301 and the recommendations of ACI 305R.

5.3.1.3 Placement of shotcrete during periods of low humidity or high winds shall meet the requirements of ACI 301 and the recommendations of ACI 305R, particularly when large surface areas are to be placed. Roof domes and wall surfaces exposed to drying wind shall be water cured continuously in accordance with the requirements of ACI 308 from the time the shotcrete has taken initial set. Curing compounds may be used to assist in curing, but shall not be used in lieu of water curing, or on surfaces that are to receive additional shotcrete coatings.

5.3.2 *Placing and finishing.*

5.3.2.1 Dense, impermeable shotcrete is required for dome roofs in severe exposure conditions where condensation may occur on the underside of the roof. For this reason, dome roofs of dry-mix shotcrete shall not be used in areas subjected to freeze–thaw cycles. Where shotcreted dome roofs are allowed, roof shell thickness shall be controlled by positive methods, allowing a variation of +½ in. (13 mm). Dome thickness

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shall not be less than specified. Dome joints shall be of the butt type, trimming the edge of that portion of the shotcrete above the mesh or bar reinforcement perpendicular to the form. The portion below shall be as close to perpendicular as placing techniques permit. The exposed joint shall be cleaned carefully with an air and water blast, and all loose material removed before placing the next section of shotcrete. Special attention should be given to the prevention of sand-pocket formation. Shotcrete dome roofs shall be continuously water cured in accordance with the requirements of one of the methods described in ACI 308.

5.3.2.2 Shotcrete walls shall be built up of individual layers of shotcrete no more than 2 in. (50 mm) thick. No less than two coats to a minimum total thickness of 1 in. (25 mm) shall be provided over the diaphragm on the inside of the tank. Under aggressive (corrosive) water conditions, additional protection shall be provided for the diaphragm.

5.3.2.2.1 Prior to placement of shotcrete, the constructor shall submit for the purchaser's review details of thickness-control procedures and aids. During application of shotcrete coats, the constructor shall demonstrate the effectiveness of the control procedures being used.

5.3.2.2.2 Shotcrete core-wall thickness shall be controlled by the use of vertical shooting wires (or line).

5.3.2.2.3 Vertical shooting wires (or line) for manual placement of shotcrete shall be installed under tension and spaced no more than 3 ft (0.9 m) apart to establish uniform and correct wall thicknesses. For machine-applied shotcrete, the shooting wires may be placed farther apart, as demonstrated by consistent and uniform application. Wires of 18- to 20-gauge (0.0475- to 0.0348-in. [1.21- to 0.88-mm]) high-tensile-strength steel or 150-lb (68-kg) test monofilament line shall be used. Shooting wires shall not be imbedded in the shotcrete surface. Should this occur, they shall be snapped loose. Shooting wires shall scribe the contour of the tank core wall from top to bottom, and shall not be removed until the cover-coat thickness has been confirmed by the purchaser's agent to be as specified. The specified finish may then be applied.

5.3.2.2.4 Shotcrete finish for the exterior wall surface may be any of the finishes in Sec. 5.3.3.5, as specified. Shotcrete finish for the inside-core-wall surface shall be smooth and well formed to facilitate cleaning of the tank and to reduce maintenance. The surface shall be a natural shotcrete finish followed by light brooming to remove pitting and surface roughness.

5.3.3 *Shotcrete protection of prestressed wire or strand.*

5.3.3.1 The primary purpose of the shotcrete wire and cover coats is for protection of the prestressed reinforcement against corrosion, both from the external environment and from materials used in the tank construction. Section 2.1.2 requires limiting the water-soluble chloride ion content in the concrete or shotcrete covering prestressed wire or strand to 0.06 percent of the weight of the cement in the mix. This requirement shall be adhered to rigidly.

Shotcrete for covering wire or strand shall be tested for water-soluble chloride content in accordance with the requirements of AASHTO T-260, unless previous test results substantiate that the allowable content will not be exceeded. Testing may be conducted on either the individual shotcrete ingredients or samples of the hardened shotcrete. Where local aggregates produce a mix that exceeds the 0.06 percent limitation, washing will normally reduce the chloride ion content to within acceptable limits for shotcrete placement; otherwise, aggregates must be imported.

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5.3.3.2 Before beginning prestressing, voids or other defects on the core wall shall be repaired with mortar. Dust, efflorescence, oil, and other foreign material shall be removed from surfaces to be shotcreted. Concrete core walls shall have a bondable surface; attaining this will require sandblasting of the outside wall surface before wrapping. Sandblasting of concrete shall result in a heavily pitted bondable surface. Prior to wire or strand winding, and again before applying shotcrete cover coats, such materials as dirt, loose sand, and dust shall be removed from the wall surface and wire or strand, and the surface thoroughly dampened. Hardened shotcrete surfaces may be prepared by an air/water jet immediately before the next shotcrete coat is applied.

5.3.3.3 Each layer of circumferential prestressing shall be covered with a coat of fine-aggregate shotcrete wire coat as soon as practicable after prestressing. Nozzle distance and wetness of mix are equally critical to satisfactory encasement of prestressing wire or strand. The shotcrete shall be applied wet but not dripping.

5.3.3.3.1 Shotcrete shall be applied with the nozzle held at a small, upward angle, not exceeding 5°, and shall be constantly moved in a smooth motion during application, with the nozzle pointing in a radial direction toward the center of the tank. The nozzle distance from the prestressing shall be such that shotcrete does not build up or cover the front face of the wire or strand before the spaces behind and between the prestressing elements are filled. If the nozzle is held back too far, the shotcrete may deposit on the face of the prestressing elements at the same time that it is building on the core wall, thereby creating voids behind the wires or strand.

5.3.3.3.2 The appearance of a clearly defined pattern of continuous horizontal ridges at the prestressing elements after they are covered is an indication of insufficient shotcrete cover or of poor application and probable voids. If this occurs, the application of the wire coat shall be immediately suspended and the work carefully inspected by the purchaser. Corrective measures shall be implemented and completed prior to resuming the shotcreting operations. All improperly deposited shotcrete shall be removed prior to its final set and the shotcreting procedure corrected. The shotcreting procedure may be corrected by adjusting the nozzle distance and orientation perpendicular to the wall, or by adjusting the water content of the shotcrete mix. All shotcrete overspray shall be removed from the wall. The shotcreted surface shall be broomed and roughened, if needed, to ensure the proper bond of the subsequent applications. Rebound materials shall be removed from the work and shall not be reused in shotcreting.

5.3.3.3.3 Subsequent layers of circumferential prestressing and shotcrete wire or cover coats may be applied as soon as the underlying coat has developed sufficient bond and compressive strength to avoid damage.

5.3.3.3.4 Wire coat thickness shall be sufficient to provide a clear cover over the wire or strand of at least ¼ in. (6 mm) and in no case less than the diameter of the wire or strand.

5.3.3.4 Shotcrete shall be applied to provide a total thickness of not less than 1 in. (25 mm) over the last layer of wire or strand. The first coat placed over the wire shall be wire coat and the remaining cover coat(s) shall be wire or finish coat(s) applied as soon as possible after application of the last layer of wire coat. Intermediate cover coats and the finish coat shall be placed in thickness not exceeding 1 in. (25 mm).

Shotcrete cover coats shall be cut back 1 in. (25 mm) above the top of the footing or floor slab where movement may occur between the wall and floor or footing. Similarly, shotcrete shall be trimmed back from movable joints between the wall and

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roof. Vertical shooting wires as specified in Sec. 5.3.2.2.3 shall be used to ensure positive control of the thickness.

5.3.3.5 One of the following shotcrete finishes shall be provided, as specified:

1. Natural gun.
2. Broomed.
3. Wood float.
4. Rubber float.

5.3.3.6 All exposed shotcrete coatings shall be kept moist for at least seven days. Each time a new wire or finish coating is applied, covering an underlying coat, a new seven-day curing period begins for the new coating, superseding the curing schedule on the prior shotcrete coating since its cure will proceed concurrently. Moist curing shall be started as soon as possible without damaging the shotcrete. Curing shall be by fog spraying or sprinkling and covering so as to keep the surface continuously damp, or by use of wetted burlap or cotton mats as specified in ACI 308. Curing by other means shall not be allowed. Curing may only be interrupted for subsequent application of prestressing and shotcreting that is to be applied prior to the end of the day. Remove any laitance that appears on the shotcrete surface after the curing period by using light sandblasting, air/water blasting, or other method acceptable to the purchaser.

5.3.4 *Control testing.* Quality control of shotcrete shall be in accordance with the applicable requirements of ACI 506R.

5.3.5 *Automated application.* In lieu of manually applied shotcrete, shotcrete may be applied by nozzles mounted on power-driven machinery located a uniform distance from the wall surface, traveling at a uniform speed around the wall circumference to provide the required coatings.

Sec. 5.4 Forming

5.4.1 *General.* Formwork shall meet the requirements of ACI 347R and ACI 301 unless modified by the purchaser in the project specifications.

5.4.2 *Wall form ties.* Form ties for wood forms shall have waterstops and shall be of the "snap-off breakback" type with conical- or spherical-type inserts 5/8 in. (16 mm) or more in depth. Flat bar ties used with steel form panels shall have plastic or rubber inserts to form a hole at least 1 in. (25 mm) deep for patching.

As soon as possible after the forms are removed, the tie holes on the interior wall surface shall be packed with nonmetallic, nonshrink, or epoxy mortar grout as specified in Sec. 2.1.5 and Sec. 2.10.1. The holes on the exterior of the wall shall be dry packed with portland-cement mortar as specified in Sec. 2.1.3.

Through bolts used for form ties shall be tapered for ease of removal and patching. If through bolts are used, the bolts shall be removed and the holes cleaned by sandblasting or wire brushing to remove all grease, bond breaker, or laitance. Bolt holes shall be vinyl plugged and patched with nonshrink or epoxy mortar grout in accordance with approved details. The outer 1 in. (25 mm) of the hole shall be patched with portland-cement grout that will provide a neutral or alkaline contact with the circumferential prestressing wire and strand.

5.4.3 *Dome-roof forms.* Dome forms shall be designed to resist all forces acting with respect to its sloped surfaces. The bracing required will be determined by the sequence of concrete or shotcrete placement and the rate at which it is placed. It is important to maintain proper curvature of the shell to avoid flat spots. Except for the outermost set of forms, formwork for concrete or shotcrete domes shall not be

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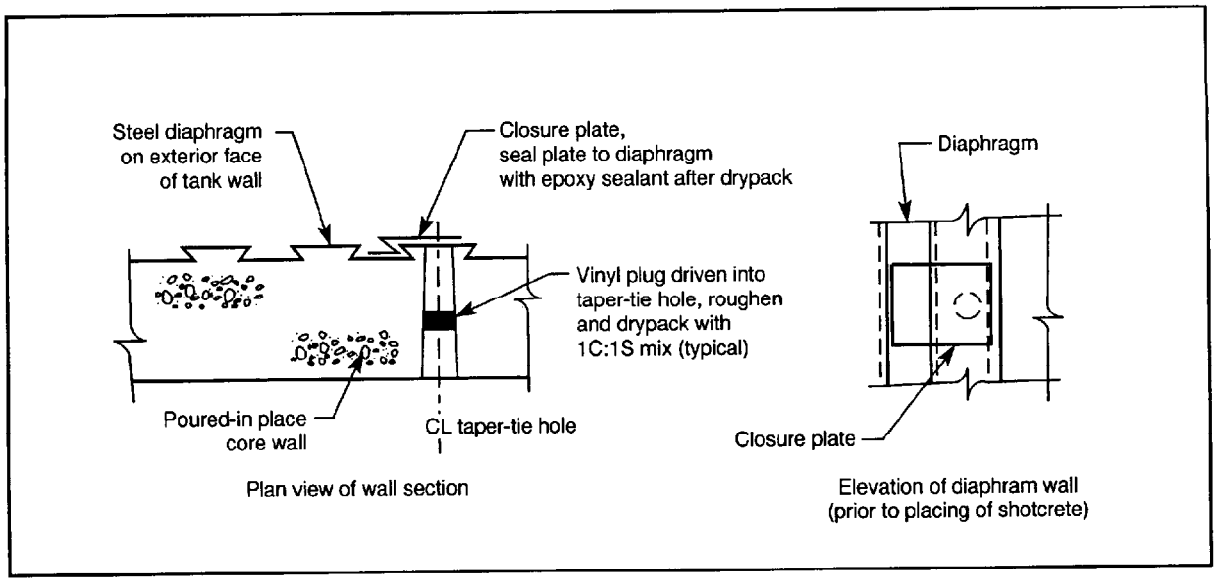

Figure 10 Diaphragm patching detail for type IV tank core wall

removed until the concrete or shotcrete is of sufficient strength and a circumferential prestressing force sufficient to support the dead load and a nominal construction live load has been applied to the dome edge ring.

5.4.4 *Metal diaphragms.* All vertical joints between metal diaphragms shall be sealed to form watertight joints without voids. When the diaphragm form performs as a vertical form (type II core wall), it shall be braced and supported in a manner sufficient to eliminate vibrations that would cause sloughing of the shotcrete during application. When it is necessary to penetrate the diaphragm, such as for installation of form ties in type IV core wall tanks, the penetrations shall be covered and sealed with epoxy after removal of the ties and patching of the tie holes. The patching shall result in a watertight barrier that will withstand water pressure the full height of the tank (see Figure 10).

Sec. 5.5 Nonprestressed-Steel Reinforcement and Vertical Tendons

5.5.1 *General.* Steel reinforcement shall be placed in conformance with ACI 301. For those tanks with vertical posttensioning tendons in the wall, and where the design requires radial movement of the wall with relation to the footing, the posttensioning units shall be supported prior to concrete or shotcrete placement in such a way that this wall movement will not be restricted. The posttensioning units shall be supported from the nonprestressed circular reinforcement, from the wall forms, or on plastic or mortar pads placed on the elastomeric bearing pad.

5.5.2 *Concrete and shotcrete cover.* The minimum cover over steel diaphragms, welded-wire fabric reinforcement, and tendon anchorages shall be as specified in Sec. 3.5.6.3.

Sec. 5.6 Prestressing

5.6.1 *Circumferential stressing.*

5.6.1.1 These paragraphs cover the application of high-tensile steel wire or strand, wound under tension by machines, around cylindrical concrete or shotcrete

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walls, or dome edge rings to place the concrete or shotcrete in compression. An essential feature of this stressing system is the proper application of tension to the prestressed reinforcement as it is placed on the wall.

5.6.1.2 Field handling and storage of prestressing wire and strand shall be such that they are fully protected from physical damage and corrosion before, during, and after placement. Such protection, particularly for nongalvanized steel wire, shall include enclosed, ventilated, temporary storage facilities where weather conditions warrant. In no event shall materials be stored on the ground or covered with polyethylene or other membrane cover that will permit condensation to form on the steel.

5.6.1.3 A stressing system shall be used that is capable of consistently producing a stress at any point around the wall, falling within ±7 percent tolerance of the specified initial stress. Understressed wire or strand shall be compensated for as specified in Sec. 5.6.1.8.

5.6.1.4 Each coil of prestressing wire or strand shall be temporarily anchored at sufficient intervals to minimize the loss of prestress in case a wire or strand breaks during wrapping. Anchor clamps on the outer prestressing wrap shall be removed after application of the wire coat and shall not be permanently buried in the shotcrete cover coats.

5.6.1.5 Ends of individual coils shall be joined by suitable steel-splicing devices capable of developing the full strength of the wire or strand.

5.6.1.6 Stress shall not be applied to either the concrete or shotcrete core wall or dome-roof edge ring by the prestressing operation until they attain a strength of at least 1.8 times the compressive stress being applied. The minimum curing period prior to stressing shall be subject to acceptance by the purchaser.

5.6.1.7 A calibrated stress-measuring device that can be easily recalibrated shall be used frequently to determine wire or strand stress levels during the wrapping process. At least one stress reading for every coil or a minimum of one per foot of wall height shall be taken immediately after application on the wall, and all such readings shall be on straight lengths of wire or strand. Readings should refer to the applicable height and layer of wire or strand for which stress is being recorded. A written record of stress readings shall be maintained until all stressing is completed and the cover coats have been applied. The record shall then be delivered to the purchaser. A stress-recording device, which continuously and accurately measures and records the stress as the wire or strand is placed, may be substituted for the above-described method. The recording device shall be calibrated by an independent laboratory prior to each project.

5.6.1.8 If measured wire or strand stress falls below design f_{si}, additional prestress wire or strand shall be applied. If the applied stress of the wire or strand exceeds 1.07 f_{si}, the wrapping operation shall be discontinued immediately on discovery of this condition and satisfactory adjustment made to the stressing equipment before proceeding. The total prestress force measured on the wall per vertical foot of height shall not be less than the specified force distributed as shown on the force diagram submitted for the structure, nor more than 5 percent greater.

5.6.1.9 The force diagram for the tank wall shall be prepared for minimum spacing of the horizontal prestressing elements of $\frac{3}{8}$ in. (9.5 mm). The minimum clear space between wires or strands on the wall shall be $\frac{5}{16}$ in. (8 mm) or 1.5 wire or strand diameters, whichever is greater. Any wires or strands not initially meeting the spacing requirements shall be respaced or removed. Wires or strands in areas adjacent to openings or inserts shall be uniformly spaced in accordance with the

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above. The band of prestressed reinforcement normally required over the height of an opening shall be displaced into circumferential bands immediately above and below the opening to maintain the required total circumferential prestressing force. Banded prestressed reinforcement causes vertical wall-bending effects that shall be taken into account in the design. Prestressing elements shall be placed no closer than 2 in. (50 mm) from the top of the wall or from edges of openings or inserts, nor closer than 3 in. (75 mm) from the base of wall, where radial movement may occur between wall base and floor or footing. Bundling of wires or strands shall be prohibited.

5.6.2 *Vertical wall stressing.*

5.6.2.1 These paragraphs provide recommendations for the application of high-tensile tendons as vertical prestressed reinforcement in cast-in-place tank walls, or linear prestressing tendons of precast panels through pretensioning or posttensioning techniques that are not covered by ACI 318.

5.6.2.2 All field handling of tendons and associated stressing and grouting equipment shall be under the direction of an individual with a technical knowledge of prestressing principles, i.e., one who has qualifying experience with the particular system or systems of posttensioning being used.

5.6.2.3 Field handling and storage of tendons and component parts on the jobsite shall be such that they are fully protected against physical damage and corrosion before, during, and after placement. Such protection shall include enclosed, dry, ventilated temporary storage when weather conditions warrant. In no event shall materials be stored on the ground or covered with polyethylene or other membrane cover that will permit condensation to form on the steel.

5.6.2.4 Tendons shall be handled and placed as follows:

5.6.2.4.1 Generally, tendons or tendon ducts shall be placed on the ground as near as possible to their final positions, then hoisted into final positions and secured. Neither tendons nor tendon ducts shall be dragged over supporting reinforcement, previously placed tendons, or ducts. A planned placing sequence considering supplemental reinforcements will preclude the need to thread tendons or ducts through previously placed reinforcing steel. Ducts shall be carefully inspected immediately prior to concreting to ensure against mortar leakage or indentations that would restrict the free movement of the tensioning steel during the stressing operation. No welding or burning shall be permitted in the vicinity of the prestressing steel, and the prestressed steel shall not be used as an electrical ground.

5.6.2.4.2 The duct sheathing for vertical tendons shall be tied to horizontal reinforcing steel or supported from the formwork to prevent displacement during concrete placement. Vertical tendons supported from the upper terminals require forms sufficiently strong to support their weight. Vertical tendon ducts shall be flushed with water immediately after concrete placement to ensure that the lower grout or epoxy injection ports remain unobstructed.

5.6.2.5 Tendons shall not be stressed until the concrete core wall attains a strength sufficient to sustain the concentration of bearing stresses under the anchorage plates without damage to the wall materials. The permissible compressive stress in the concrete shall be calculated as indicated in the PTI Post-Tensioning Manual, and shall not exceed 1.25 f'_{ci} at transfer load, nor 1.25 f'_c at service load. The minimum curing period prior to stressing shall be subject to acceptance by the purchaser.

5.6.2.6 Grout shall be injected under pressure in vertical tendon ducts from the lower duct terminal. Openings or voids in the anchorages shall be plugged to prevent grout leakage and the ensuing loss of pressure during the grouting operation.

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Grout riser tubes or suitable alternative containment shall be attached at the top of vertical tendon ducts to ensure that the duct remains full, thus permitting grout settlement to take place in the riser or other containment rather than in the duct. Grout shall be injected into the tendon duct immediately after the tendon has been stressed. When epoxy is used as encasement for the vertical tendons, the application will be similar and shall be as recommended by the manufacturer.

Sec. 5.7 Wall Tolerances

The maximum out-of-round tolerance for shotcrete, cast-in-place concrete, and precast-concrete panel walls shall be based on the ratio of ±½ in., –0. (+12.5 mm, –0) per 100-ft (30-m) diameter circle and the circumference shall be a smooth curve. Tolerance in wall thickness shall be + ½ in., –0 (+12.5 mm, –0). Wall thickness shall not be less than specified. All transitions shall be gradual and smooth. Walls shall be plumb within a tolerance not exceeding ⅜ in. (9.5 mm) per 10 ft (3 m) of vertical dimension.

Sec. 5.8 Seismic Cables

5.8.1 *General.* When the tank design requires seismic cables in separated floor–wall connections, the galvanized or epoxy-coated cables (strand) shall be installed between the base of the wall and the footing. Sleeves of sponge rubber or other suitable material shall surround the strands for the specified distance on each side of the joint to permit radial wall movements. Sleeves shall be positively sealed to prevent grout entry.

5.8.2 *Placing.* Cables shall be cut to uniform lengths and prebent, if necessary, for proper placement in the footing forms. Care shall be taken in placement to avoid compression of the bearing pad and restraint of radial wall movement. Cable units shall be securely tied to the nonprestressed wall reinforcement to prevent displacement as the concrete or shotcrete is placed.

Sec. 5.9 Waterstops

Waterstops shall be centered in the joints and secured by split forms or other acceptable means to ensure positive positioning. Horizontal waterstops that are accessible during concreting shall be secured in a manner that allows them to be bent up while concrete is placed and compacted underneath, after which the waterstop shall be allowed to return to position and concrete immediately placed over the waterstop. Waterstops that are not accessible during concreting shall be positively tied in such a manner that bending in either direction is prevented. Judicious use of nails or "hog-ties" driven through the edges of waterstops to facilitate placing and tying may be permitted. All waterstops shall be spliced by heat welding in a manner that ensures complete continuity as a water barrier.

Sec. 5.10 Elastomeric Bearing Pads

Bearing pads shall be positively positioned prior to wall placement and secured with an approved adhesive to prevent their being uplifted during concrete or shotcrete placement. Pads in cast-in-place concrete walls shall also be held in position by inserting small, dense concrete blocks or plastic shims under vertical reinforcing steel where possible. Nailing of pads shall not be permitted unless the pads are specifically designed for such anchorage and nailing does not restrict lateral deformation. Where bearing pads are used, the tank wall shall be free of all

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obstructions that would prevent free radial movement at the joint. The remaining voids between cast-in-place concrete or shotcrete wall and wall footing (or roof) shall be filled with a suitable closed-cell neoprene or rubber filler material and a caulking compound to positively prevent mortar from entering the joint.

Sec. 5.11 Sponge Fillers

Sponge fillers for cast-in-place concrete walls shall be 15 percent wider than required to fill the spaces between wall faces, bearing pads, and waterstops. The method of securing sponge-filler pads shall be the same as for elastomeric bearing pads. All voids shall be caulked with a suitable nontoxic sealant that bonds securely to all surfaces of pad, filler, and waterstop. Particular attention shall be paid to the filling and sealing of the joint between the bearing pad and waterstop.

Sec. 5.12 Disinfection

Disinfection of the completed tank shall follow the criteria found in ANSI/AWWA C652.

Sec. 5.13 Watertightness

On completion of the tank, and prior to any specified backfill placement at the footing or wall, the following test shall be applied to determine watertightness:

5.13.1 *Preparation.* Fill the tank with potable water to the maximum level and let it stand for at least 24 h.

5.13.2 *Measurement.* Measure the drop in liquid level over the next 72 h to determine the liquid volume loss for comparison with the allowable leakage. Evaporative losses shall be measured or calculated and deducted from the measured loss to determine the net liquid loss (leakage). The net liquid loss for a period of 24 h shall not exceed 0.05 of 1 percent of the tank capacity.

5.13.2.1 If the leakage exceeds the maximum allowable, the leakage test shall be extended to a total of five days. If at the end of five days the average daily leakage does not exceed the maximum allowable, the test shall be considered satisfactory. If the net liquid loss exceeds the maximum allowable, leakage shall be considered excessive and the tank shall be repaired, redisinfected, and retested until leakage falls within the appropriate limit.

5.13.2.2 Damp spots on the exterior wall surface or measurable leakage of water at the wall base shall not be permitted. Damp spots are defined as spots where moisture can be picked up on a dry hand. The source of water movement through the wall shall be located and permanently sealed in an acceptable manner. Leakage through the wall-base joint or footing shall likewise be corrected. Damp spots on the footing are generally to be expected, and are permissible.

Sec. 5.14 Repairs

The constructor shall make all necessary repairs if the tank fails the watertightness test or is otherwise defective. The method of repair shall be subject to acceptance by the purchaser.

5.14.1 *Concrete repair.* The most common repair method for small areas of honeycombed concrete (rock pockets) and other defective concrete is removal and replacement with nonshrink aggregate grout (which may include pea gravel aggregate) bonded to the concrete with an epoxy bonding agent. The minimum strength of material used in the repair shall equal or exceed that specified for the concrete.

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Defective tie hole patches shall be removed and the holes repacked or epoxy injected.

5.14.2 *Epoxy injection grouting.*

5.14.2.1 Wall repair. Damp or wet spots resulting from leakage through the wall shall be repaired with a high-pressure epoxy injection grouting system or other method acceptable to the purchaser. When epoxy grouting is to be performed, a low-viscosity, two-component, water-insensitive, nontoxic epoxy-resin system with an in-line metering and mixing system shall be used. The pumps shall be capable of producing a minimum injection pressure of 100 psi (680 kPa). Injection pressure shall be limited to 300 psi (2.1 MPa) to ensure complete penetration of the defect without damaging the structure. Epoxy shall reach a minimum compressive strength of 6,000 psi (40 MPa) in 24 h in accordance with the requirements of ASTM D695. An applicator with successful past experience in water-retaining structures shall be present on the job at all times while repairs are being made. Work shall be guaranteed against failure of the epoxy bond in the repair areas for a minimum period of one year.

Any exposed defect receiving epoxy repair shall first be cleaned of dirt, laitance, and other material that might prevent proper bonding. A suitable temporary seal shall then be applied to the surface of the defect to prevent the escape of the epoxy. Entry ports shall be spaced along the seal at intervals not greater than the thickness of the cracked element. The epoxy shall be injected into the crack at the lowest port first, with sufficient pressure to advance the epoxy to an adjacent port, using a small nozzle held tightly against the port. The operation shall continue until epoxy material begins to extrude from the adjacent port. The original port shall be sealed and the injection shall be repeated in one continuous operation until the crack has been injected with epoxy for its entire length. All ports, including adjacent locations where epoxy seepage occurs, shall be sealed as necessary to prevent drips and runouts. On completion of the injection of the crack, the grout shall be allowed to cure for sufficient time to allow the removal of the temporary seal without any draining or running out of the adhesive epoxy material from the crack. The surface of the crack shall then be finished flush with the adjacent surfaces and shall show no indentations or evidence of port filling.

5.14.2.2 Floor, piping, and valves. Generally the loss of water through the tank floor, piping, and valves is difficult to determine separately. The total loss shall not exceed the criteria set forth in Sec. 5.13.2. If the loss of water exceeds the criteria, the tank floor shall be inspected for point sources of leakage with the tank full or empty.

Water loss through floor joints or shrinkage cracks shall be located and the defective sections removed and replaced, or repaired by epoxy injection grouting as specified earlier or by other means acceptable to the purchaser. Any potential point sources of leakage found shall be repaired and the watertightness test repeated.

Sec. 5.15 Tank Backfill

When wall backfill is required, it shall be initiated only after the tank has been satisfactorily tested and filled, unless another procedure is acceptable to the purchaser. Backfill material shall be placed in uniform layers and compacted to the satisfaction of the purchaser for the material and site conditions prevailing. Avoid unbalanced backfill placement variation in elevation around the tank except as may be fully provided for in the design.

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Sec. 5.16 Clean Up

The premises shall be kept clean and orderly at all times during the work, and, on completion of construction, the constructor shall remove or otherwise dispose of all rubbish and other unsightly material caused by the construction operations. The constructor shall leave the premises in as good a condition as they were found.

Sec. 5.17 Electrical Grounding

Electrical grounding to the nonprestressed reinforcing steel or prestressed reinforcement for any equipment or electrical service shall be strictly prohibited.

SECTION 6: INSPECTION PROCEDURES

Sec. 6.1 Scope

This section provides procedures for field observation (inspection) of wire- or strand-wound, circular, prestressed concrete water tanks during construction, after construction, and during routine maintenance. ACI SP-2 and the appropriate requirements of ACI 318 shall be followed unless modified by this standard. The observer is to confirm that materials and construction techniques being used by the tank constructor are those approved by the purchaser. The presence of the purchaser's agent, and inspection and acceptance of the water tank, does not relieve the constructor from compliance with plans and specifications. Some suggestions for maintenance repairs are also included in this section.

Sec. 6.2 Field Observation During Construction

6.2.1 *General.* The purpose of field observation during construction is to assist the constructor in interpretating the plans and specifications and to verify that the constructor is complying with the plans and specifications. The goal is to ensure that the completed tank is structurally sound, has adequate protection for the nonprestressed steel reinforcement and prestressed steel elements, and is watertight. The construction procedures given in Sec. 5 are for the guidance of both the constructor and the observer. Section 6 provides additional guidance for field observation of those phases of construction requiring the greatest care to ensure creation of a well-constructed tank. Accurate and detailed records of all phases of construction should be kept and maintained for future reference of the purchaser and the constructor or design-constructor.

6.2.2 *Critical items.* Close observation of the following items is essential because of their importance to the corrosion resistance and structural integrity of the tank.

6.2.2.1 Confirm that the foundation for the tank has been prepared in accordance with the procedures of Sec. 5.2.2. Witness testing of all underfloor piping for watertightness in conformance with the specifications, and the placement and compaction of trench backfill and floor base material. Check all formwork for wall and column footings and the reinforcement for tank floor placement.

6.2.2.2 Review tests for all concrete, shotcrete, admixtures, and patching materials for conformance with the specifications and absence of water-soluble ions in excess of the limitations of Sec. 2.1. Verify tolerances on wall form construction and placement of reinforcement.

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Verify that all form ties and through bolts are of the type specified in Sec. 5.4.2.

Observe the placement of concrete and shotcrete of the approved mix proportions, slump, and air entrainment, and the steps taken to prevent segregation and achieve dense, impervious tank elements. Verify proper cleaning and patching of wall tie or bolt holes, initiated as soon as possible after removal of formwork and curing of the walls. Witness cleaning and patching procedures using approved materials in accordance with approved details and manufacturers' instructions.

6.2.2.3 Check all waterstop installations prior to concrete placement to verify that they are properly located in the joints, adequately secured, and fully fused together at the joints as specified. For horizontal waterstops accessible during concrete casting, verify that the free edge of the waterstop is lifted and the concrete is placed and compacted underneath the waterstop before any placement over the waterstop. The upper free edge of the waterstop in the floor-to-wall joint should be tied at approximately 12-in. (300-mm) maximum intervals to a securely fastened, horizontal reinforcing bar of size 4 or larger or otherwise secured to avoid displacement. It is extremely important that all waterstops are fully embedded in the concrete and that no voids remain.

6.2.2.4 If elastomeric pads are used between the tank wall and floor or footing ring, or between the tank roof and tank wall, see that the pads are properly positioned and secured before concrete is cast or precast concrete panels are placed. After placement, verify that the wall joint is free of any obstructions that would interfere with radial wall movement.

6.2.2.5 Prior to any wire or strand wrapping or shotcreting of the core wall, verify that all voids 1 in. (25 mm) or more in depth, honeycombed concrete, and other defects are completely cut out to solid concrete and dry-packed with mortar. Be sure that all dust, efflorescence, oil, and other foreign material is removed by sandblasting. Verify that the edges of precast panels are in alignment as specified in Sec. 5.2.7, and that all vertical slots between precast wall panels are filled with the specified cement–sand mortar, fine-aggregate concrete, or shotcrete in accordance with the approved details.

6.2.2.6 Make certain that vertical prestressing of the core wall is done prior to circumferential prestressing, but not until the core wall attains the strength specified in Sec. 5.6.2.5.

6.2.2.7 Verify that circumferential prestressing is not applied until the core wall and the shotcrete or grout in the vertical joints for precast wall sections reach a strength at least 1.8 times the compressive stress being applied. Ensure that wire anchors are not contacting the reinforcing bars by checking the anchor holes before the anchors are inserted. Prestressed wire or strand shall be electrically isolated from all other metallic structural elements. All anchors and clamps used with galvanized wire or strand should be galvanized steel. By direct measurement, verify that minimum wire spacing described in Sec. 5.6.1.9 is maintained. Measurement and recording of wire stress levels during the wrapping process are two of the most important tasks of field observation. Confirm that the measuring device is correctly calibrated as described in Sec. 5.6.1.7 and that stress levels are in compliance with the specifications as described in Sec. 5.6.1.8.

6.2.2.8 Confirm that the shotcrete mix complies with specifications, that the method of application and minimum thickness of the wire coats and cover coats are correct prior to removing of the shooting wires, and that there are no voids behind the wire or strand. See Sec. 5.3.3.

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6.2.2.8.1 As the shotcrete wire coat is being applied, visually observe the application of the coating to verify that proper encasement of the prestressed elements has been achieved in accordance with Sec. 5.3.3.3. Continuous monitoring of the application is recommended.

6.2.2.8.2 Checking for proper cover-coat thickness and bond are two of the most important tasks of field observation. Verify that vertical shooting wires are installed in the proper position to obtain the specified cover-coat thickness prior to applying the shotcrete. Verify the shooting wire spacing, tension, and distance from the final wire or strand wrap before shotcreting. After the coating has cured, check the surface of the shotcrete finish coat for hollow-sounding or "drummy" spots by tapping with a light hammer or similar tool. Such spots may indicate a lack of bond between coats and may need to be repaired prior to tank acceptance by the purchaser. If patching is extensive and an exterior coating is not specified, an additional shotcrete finish coat may be required to achieve an acceptable appearance.

6.2.2.8.3 If an exterior coating is specified to be applied over the shotcrete cover or finish coat, remove all laitance or other foreign material by sandblasting, water blasting, or other acceptable method prior to applying the coating.

6.2.2.9 The tank shall be disinfected, prior to checking for leakage, in accordance with Sec. 5.12, unless more rigid standards are mandated by state or local authorities, or by the purchaser.

Sec. 6.3 Inspection After Construction

Observe the leakage test to determine the watertightness of the tank, and conduct a visual inspection to verify that all work has been satisfactorily completed and all appurtenances installed in accordance with the plans and specifications.

6.3.1 *Watertightness.* Testing for watertightness shall be in accordance with Sec. 5.13. The weather must be dry in order to observe leakage. Particular attention shall be given to the ground surface around the tank and at the perimeter drains for evidence of leakage through the floor, the floor–wall connection, or around piping. To verify the source of the water from a suspected leak, it may be necessary to check for chlorine or to use a dye or nontoxic paint inside the tank. A knowledgeable scuba diver or hard-hat diver and use of underwater lights will often provide the most efficient way to locate leaks. Sometimes a diver can locate a leak by placing a waterproof membrane or sterile white cotton ball over a suspicious crack or floor joint. For tanks that are to remain in service, it may be desirable to employ a hard-hat or scuba diver with a wet or dry suit that can be sterilized before entry into the water in order to protect treated water from contamination due to body contact. It is recommended that this diver be equipped for underwater photography to detect and locate cracks that open only under hydrostatic loading. Personnel should never be permitted to enter a tank for underwater inspection without carefully observing safety procedures, such as guarding or valving off all outlets, providing suitable lighting, and other appropriate protective measures.

6.3.2 *Wall leaks.* Unless the purchaser approves another procedure, the wall shall be carefully inspected for any evidence of damp spots prior to placement of any backfill over the wall footing or against the wall, and under full head to the overflow level. The location and cause of all visible leakage and damp spots shall be carefully noted and made a matter of record prior to proceeding with repair.

6.3.3 *Repairs.* All repairs shall be made in accordance with Sec. 5.14. All repair work shall be inspected while in progress and on completion.

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Sec. 6.4 Inspection During Routine Maintenance

A wire- or strand-wound prestressed tank should be inspected after the first year of service, at any time that there are such visible problems as leaks or cracks, or routinely every 5 to 10 years following the initial inspection. Inspections should preferably take place during months when tank surfaces are dry and groundwater is at a minimum. The initial step should consist of valving off the tank, verifying the leakage rate by measuring a drop in the water surface, and comparing this with the initial test at the time of construction. The inspection should include the following items:

6.4.1 *Wall.* Physically examine the exterior surface to locate any signs of possible deterioration or corrosion, including rust stains, efflorescence, cracks, or leaks. Wide-angle binoculars are helpful in examining those portions of the wall not accessible by ladder or scaffolding. "Sound test" the shotcrete cover coat at areas or signs of deterioration for evidence of separation or "disbonding" from the core wall as specified in Sec. 6.2.2.8.2. Carefully record the location and severity of these signs of possible trouble. Color photographs and/or video tape are valuable additions to the written record. Repair all leaks, as described in Sec. 5.14.

6.4.2 *Floor.* For aboveground tanks, a visual inspection of the ground surface around the tank may reveal any leakage through the floor, at the floor–wall connection, or at piping. If a subdrain system has been installed under the floor, water flowing from this system can be checked for chlorine content and leakage rate. This is particularly important for buried tanks. Leaking from cracks or joints in the floor or from the floor–wall connection of a buried or partially backfilled tank may only be detected from inside the tank when the tank is full. Scuba divers can sometimes locate these cracks by evidence of silt buildup at small cracks, or by observation of clean lines at the larger cracks. The diver can release an indicator, such as a nontoxic dye or a sterile white cotton ball, at a suspected leak. The indicator verifies the leak if it moves toward the crack or if it appears outside the tank. All leaks should be promptly repaired.

6.4.3 *Roof.* The interior and exterior of the roof should be physically examined for any signs of rust, efflorescence, cracks, or spalling. Monitors, manholes, or other roof penetrations should be inspected for rust, cracks, or leakage. All spalled areas and cracks in the top surface over $\frac{1}{16}$ in. (1.5 mm) wide, where leakage through the roof may occur, should be repaired. If leakage is evident, cracks should be repaired with pumped epoxy as described in Sec. 5.14 or a suitable nontoxic roof sealant should be applied to protect the reinforcing steel and maintain water quality. Sealant at expansion joints in flat slab roofs should be carefully inspected. If joint leakage or disbonded sealant is observed, the sealant should be removed and replaced.

6.4.4 *Further inspection.* If the scheduled inspection shows rusting, cracking (other than surface crazing), or evidence of leakage on the exterior of the wall, small areas of shotcrete should be removed at selected locations and the prestressed wire or strand examined for corrosion damage. At least six areas should be selected for inspection of the prestressed reinforcement, based on the location of rust stains, wet areas, and evidence of disbonding of the shotcrete cover coat and cracks or spalling, as well as areas above or below any wall penetrations. Each exposure should be a minimum of 8 in. (200 mm) square. If no wire or strand damage is found at any of the six exposures, the shotcrete can be repaired with a dry-pack cement–sand mortar or epoxy grout and then the other routine maintenance work can proceed. If reinforcement damage is found at one or more exposures, then additional exposures should be made until enough information is obtained to determine if the tank has been structurally weakened.

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The inspection should be performed under the direction of a professional engineer thoroughly familiar with wire- or strand-wound prestressed tanks and their construction. After the engineer's review of this information, a decision should be made as to whether or not additional remedial work is needed.

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APPENDIX A
Bibliography for Seismic Design

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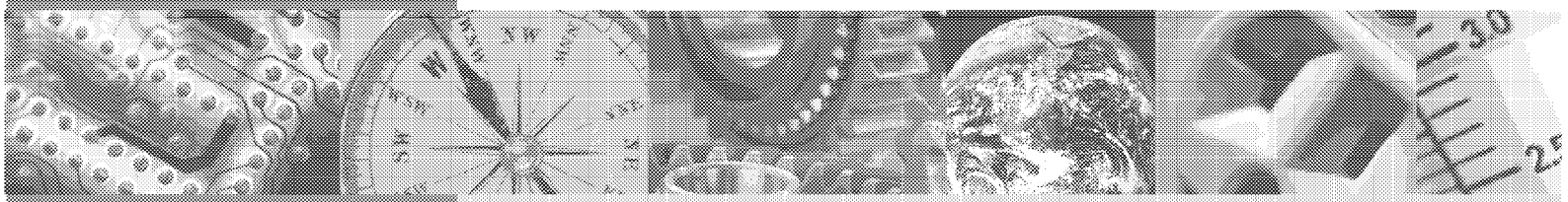

Flow Equations for Sizing Control Valves

Reaffirmed 18 October 1995

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1 Scope

This standard presents equations for predicting the flow of compressible and incompressible fluids through control valves. The equations are not intended for use when mixed-phase fluids, dense slurries, dry solids, or non-Newtonian liquids are encountered. In addition, the prediction of cavitation, noise, or other effects is not a part of this standard.

2 Introduction

The equations of this standard are based on the use of experimentally determined capacity factors obtained by testing control valve specimens according to the procedures of ANSI/ISA S75.02, "Control Valve Capacity Test Procedure" (see Annex J—References).

The equations are used to predict the flow rate of a fluid through a valve when all the factors, including those related to the fluid and its flowing condition, are known. When the equations are used to select a valve size, it is often necessary to use capacity factors associated with the fully open or rated condition to predict an approximate required valve flow coefficient (C_v). This procedure is further explained in Annex A.

2.1 Flow variable and fluid properties

The flow rate of a fluid through a control valve is a function of the following (where applicable):

a) Inlet and outlet conditions

   1) Pressure
   2) Temperature
   3) Piping geometry

b) Liquid properties

   1) Composition
   2) Density
   3) Vapor pressure
   4) Viscosity
   5) Surface tension
   6) Thermodynamic critical pressure

c) Gas and vapor properties

   1) Composition
   2) Density
   3) Ratio of specific heats

d) Control valve properties

   1) Size
   2) Valve travel
   3) Flow path geometry

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3 Nomenclature

Symbol	Description
C_v	Valve flow coefficient
d	Valve inlet diameter
D	Internal diameter of the pipe
F_d	Valve style modifier
F_F	Liquid critical pressure ratio factor, dimensionless
F_k	Ratio of specific heats factor, dimensionless
F_L	Liquid pressure recovery factor of a valve without attached fittings, dimensionless
F_{LP}	Product of the liquid pressure recovery factor of a valve with attached fittings (no symbol has been identified) and the piping geometry factor, dimensionless
F_P	Piping geometry factor, dimensionless
F_R	Reynolds number factor, dimensionless
F_s	Laminar, or streamline, flow factor, dimensionless
g	Local acceleration of gravity
G_f	Liquid specific gravity at upstream conditions [ratio of density of liquid at flowing temperature to density of water at 60°F (15.6°C)], dimensionless
G_g	Gas specific gravity (ratio of density of flowing gas to density of air with both at standard conditions, which is equal to the ratio of the molecular weight of gas to the molecular weight of air), dimensionless
k	Ratio of specific heats, dimensionless
K	Head loss coefficient of a device, dimensionless
K_B	Bernoulli coefficient, dimensionless
K_i	Velocity head factors for an inlet fitting, dimensionless
M	Molecular weight, atomic mass units
N_1, N_2, etc.	Numerical constants for units of measurement used
p_1	Upstream absolute static pressure, measured two nominal pipe diameters upstream of valve-fitting assembly
p_2	Downstream absolute static pressure, measured six nominal pipe diameters downstream of valve-fitting assembly
Δp	Pressure differential, $p_1 - p_2$
p_c	Absolute thermodynamic critical pressure
p_r	Reduced pressure, dimensionless
p_v	Absolute vapor pressure of liquid at inlet temperature
p_{vc}	Apparent absolute pressure at vena contracta
q	Volumetric flow rate
q_{max}	Maximum flow rate (choked flow conditions) at a given upstream condition

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Symbol	Description
Re_v	Valve Reynolds number, dimensionless
T_r	Reduced temperature, dimensionless
T_c	Absolute thermodynamic critical temperature
T_1	Absolute upstream temperature (in degrees K or R)
U_1	Velocity at valve inlet
w	Weight or mass flow rate
x	Ratio of pressure drop to absolute inlet pressure ($\Delta p/p_1$), dimensionless
x_T	Pressure drop ratio factor, dimensionless
x_{TP}	Value of x_T for valve-fitting assembly, dimensionless
Y	Expansion factor, ratio of flow coefficient for a gas to that for a liquid at the same Reynolds number, dimensionless
Z	Compressibility factor, dimensionless
γ_1 (gamma)	Specific weight, upstream conditions
μ (mu)	Viscosity, absolute
ν (nu)	Kinematic viscosity, centistokes
ρ (rho)	Density

Subscripts

1	Upstream conditions
2	Downstream conditions
s	Nonturbulent
t	Turbulent

4 Incompressible fluid — flow of nonvaporizing liquid

The flow rate of a liquid through a given control valve at a given travel is a function of the differential pressure ($p_1 - p_2$) when the liquid does not partially vaporize between the inlet and outlet of the valve. If vapor bubbles form either temporarily (cavitation) or permanently (flashing), this relationship may no longer hold. (Refer to Section 5 for choked flow equations that apply when extensive vaporization occurs.) In the transitional region between nonvaporizing liquid flow and fully choked flow, the actual flow rate is less than that predicted by either the equations in this section or those in Section 5. Cavitation that occurs in this transitional region can produce physical damage to the valve and/or to the downstream piping and equipment.

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4.1 Equations for turbulent flow

The equations for determining the flow rate of a liquid through a valve under turbulent, nonvaporizing flow conditions are:

$$q = N_1 F_p C_v \sqrt{\frac{p_1 - p_2}{G_f}}$$

or

$$C_v = \frac{q}{N_1 F_p \sqrt{\frac{G_f}{p_1 - p_2}}} \qquad \text{(Eq. 1)}$$

$$w = N_6 F_p C_v \sqrt{(p_1 - p_2)\gamma_1}$$

or

$$C_v = \frac{w}{N_6 F_p \sqrt{(p_1 - p_2)\gamma_1}} \qquad \text{(Eq. 2)}$$

4.2 Numerical constants *N*

The numerical constants *N* are chosen to suit the measurement units used in the equations. Values for *N* are listed in Table 1.

Table 1 — Numerical constants for liquid flow equations

Constant		Units Used in Equations					
N		*w*	*q*	*p*, Δ*p*	*d*, *D*	γ_1	ν
N_1	0.0865	—	m^3/h	kPa	—	—	—
	0.865	—	m^3/h	bar	—	—	—
	1.00	—	gpm	psia	—	—	—
N_2	0.00214	—	—	—	mm	—	—
	890	—	—	—	in	—	—
N_4	76 000	—	m^3/h	—	mm	—	centistokes*
	17 300	—	gpm	—	in	—	centistokes*
N_6	2.73	kg/h	—	kPa	—	kg/m^3	—
	27.3	kg/h	—	bar	—	kg/m^3	—
	63.3	lb/h	—	psia	—	lb/ft^3	—

*To convert m^2/s to centistokes, multiply m^2/s by 10^6. To convert centipoises to centistokes, divide centipoises by G_f.

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4.3 Piping geometry factor F_p

The piping geometry factor F_p accounts for fittings attached to either the valve inlet or the outlet that disturb the flow to the extent that valve capacity is affected. F_p is actually the ratio of the flow coefficient of a valve with attached fittings to the flow coefficient (C_v) of a valve installed in a straight pipe of the same size as the valve.

For maximum accuracy, F_p must be determined by the test procedures specified in ANSI/ISA S75.02 (see Annex J—References). Where estimated values are permissible (see Baumann reference, *Effect of Pipe Reducers on Control Valve Capacity*), F_p may be determined by using the following equation:

$$F_p = \left(\frac{\Sigma K C_v^2}{N_2 d^4} + 1 \right)^{-1/2} \qquad \text{(Eq. 3)}$$

(See Annex B for the mathematical derivation of F_p.)

In many instances, the nominal sizes for valve and pipe (d and D) may be used in Equations 3, 5, 6, and 7 without significant error.

The factor ΣK is the algebraic sum of the effective velocity head coefficients of all fittings attached to but not including the valve. For instance,

$$\Sigma K = K_1 + K_2 + K_{B1} - K_{B2} \qquad \text{(Eq. 4)}$$

where K_1 and K_2 are the resistance coefficients of the inlet and outlet fittings, respectively, and K_{B1} and K_{B2} are the Bernoulli coefficients for the inlet and outlet fittings, respectively. The Bernoulli coefficients compensate for the changes in pressure resulting from differences in stream area and velocity.

When the diameters of the inlet and outlet fittings are identical, $K_{B1} = K_{B2}$, both factors drop out of the equation. When the diameters of the inlet and outlet fittings are different, K_B is calculated as follows:

$$K_B = 1 - \left(\frac{d}{D} \right)^4 \qquad \text{(Eq. 5)}$$

The fittings most commonly encountered are standard, short-pattern concentric pipe reducers. These fittings have little taper, and their pressure loss will not exceed that of an abrupt contraction with a slightly rounded entrance. On that basis, if experimental values for the resistance coefficients K_1 and K_2 are unavailable, estimated values may be computed as follows:

Inlet reducer only:

$$K_1 = 0.5 \left(1 - \frac{d^2}{D_1^2} \right)^2 \qquad \text{(Eq. 6)}$$

Outlet increaser only:

$$K_2 = 1.0 \left(1 - \frac{d^2}{D_2^2} \right)^2 \qquad \text{(Eq. 7)}$$

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When the reducer and increaser are the same size:

$$K_1 + K_2 = 1.5\left(1 - \frac{d^2}{D^2}\right)^2 \qquad \text{(Eq. 8)}$$

(See Annex C for a graphic representation of system head changes around a valve with attached reducers.)

4.4 Equations for nonturbulent flow

Nonturbulent flow occurs at high fluid viscosities and/or low velocities. In these circumstances, the flow rate through a valve is less than for turbulent flow, and the Reynolds number factor F_R must be introduced. F_R is the ratio of nonturbulent flow rate to the turbulent flow rate predicted by Equations 1 or 2. The corresponding nonturbulent equations then become, respectively:

$$q = N_1 F_R C_v \sqrt{\frac{p_1 - p_2}{G_f}}$$

or

$$C_v = \frac{q}{N_1 F_R \sqrt{\frac{p_1 - p_2}{G_f}}} \qquad \text{(Eq. 9)}$$

$$w = N_6 F_R C_v \sqrt{(p_1 - p_2)\gamma_1}$$

or

$$C_v = \frac{w}{N_6 F_R \sqrt{(p_1 - p_2)\gamma_1}} \qquad \text{(Eq. 10)}$$

Note the absence of the piping geometry factor in the above equations. For nonturbulent flow, the effect of close-coupled reducers or other flow-disturbing fittings is unknown. Thus, Equation 3 applies to turbulent flow only.

Tests (see Stiles reference, *Liquid Viscosity Effects on Control Valve Sizing*, and McCutcheon reference, *A Reynolds Number for Control Valves*) show that F_R can be found by using the valve Reynolds number and Figure 1. The shading around the central curve indicates the scatter of test data and the range of uncertainty of flow rate prediction in the nonturbulent regimes.

The valve Reynolds number is defined as:

$$\mathrm{Re}_v = \frac{N_4 F_d q}{\nu F_L^{1/2} C_v^{1/2}}\left(\frac{F_L^2 C_v^2}{N_2 d^4} + 1\right)^{1/4} \qquad \text{(Eq. 11)}$$

The valve style modifier F_d in Equation 11 correlates data from tests of several valve styles with different hydraulic radii, so that a single curve represents all the styles tested. (See Annex D for representative values of F_d.) Caution must be used in applying the curve in Figure 1 to valve styles for which F_d has not been established.

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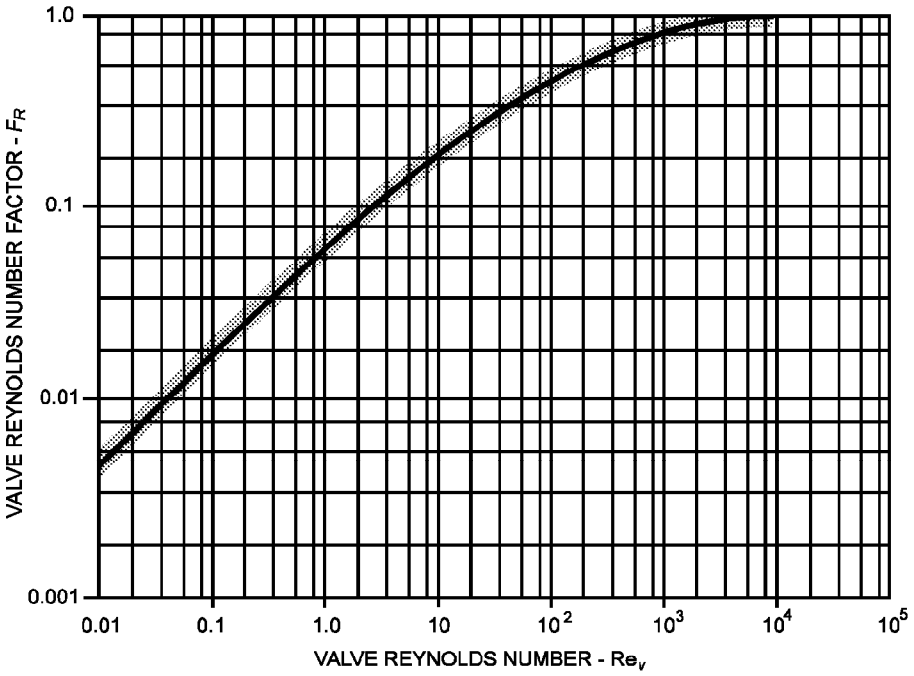

Figure 1 — Reynolds number factor

The bracketed term in Equation 11 accounts for the *velocity of approach**. Except for wide-open ball or butterfly valves, this term has only a slight effect on the Re_v calculation and can generally be omitted.

Most flow streams in process plant control valves are turbulent, with valve Reynolds numbers in excess of 10^4, where the Reynolds number factor is 1.0. When the flow regime is questionable, Equation 11 should be used to find Re_v. For additional information on nonturbulent flow, see Annexes E and F.

5 Incompressible fluid — choked flow of vaporizing liquid

Choked flow is a limiting, or maximum, flow rate. With fixed inlet (upstream) conditions, it is manifested by the failure of decreasing downstream pressure to increase the flow rate. With liquid streams, choking occurs as a result of vaporization of the liquid when the pressure within the valve falls below the vapor pressure of the liquid. Choked flow will be accompanied by either cavitation or flashing. If the downstream pressure is greater than the vapor pressure of the liquid, cavitation occurs. If the downstream pressure is equal to or less than the vapor pressure of the liquid, flashing occurs. This relationship between flow rate and pressure drop for a typical valve is shown in Figure 2.

*The flow rate through a valve is a function of the velocity of the jet stream at the vena contracta and the area of the jet at that location. This velocity is a function of the pressure drop across the valve orifice and also the valve inlet velocity, or *velocity of approach*. The velocity of approach factor is included in the valve flow coefficient C_v.

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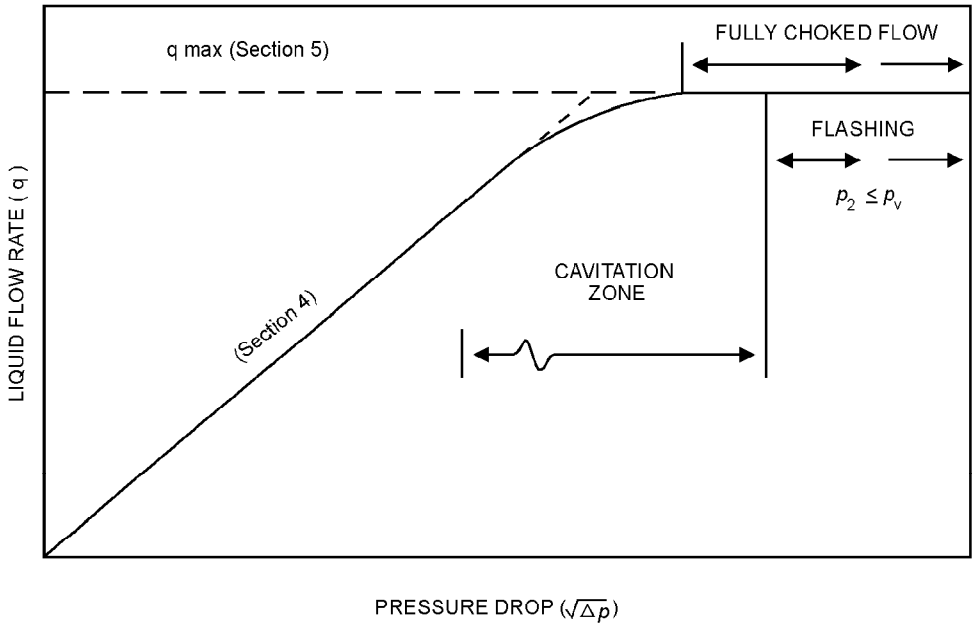

Figure 2 — Liquid flow rate versus pressure drop for a typical valve (constant upstream pressure and vapor pressure)

5.1 Liquid choked flow equations

The equations for determining the maximum flow rate of a liquid under choked conditions for valves in straight pipes of the same size are as follows:

$$q_{max} = N_1 F_L C_v \sqrt{\frac{p_1 - p_{vc}}{G_f}}$$

or

$$C_v = \frac{q_{max}}{N_1 F_L \sqrt{\frac{G_f}{p_1 - p_{vc}}}} \qquad \text{(Eq. 12a)}$$

where

$$p_{vc} = F_F p_v \qquad \text{(see Annex G for } F_F\text{)} \qquad \text{(Eq. 13a)}$$

giving

$$q_{max} = N_1 F_L C_v \sqrt{\frac{p_1 - F_F p_v}{G_f}}$$

or

$$C_v = \frac{q_{max}}{N_1 F_L \sqrt{\frac{G_f}{p_1 - F_F p_v}}} \qquad \text{(Eq. 14a)}$$

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The equations for determining the maximum flow rate of a liquid under choked conditions for valves with attached fittings are:

$$q_{max} = N_1 F_{LP} C_v \sqrt{\frac{p_1 - p_{vc}}{G_f}}$$

or

$$C_v = \frac{q_{max}}{N_1 F_{LP} \sqrt{\frac{p_1 - p_{vc}}{G_f}}}$$

(Eq. 12b)

where

$$p_{vc} = F_F p_v \qquad \text{(see Annex G for } F_F\text{)}$$

(Eq. 13b)

giving

$$q_{max} = N_1 F_{LP} C_v \sqrt{\frac{p_1 - F_F p_v}{G_f}}$$

or

$$C_v = \frac{q_{max}}{N_1 F_{LP} \sqrt{\frac{p_1 - F_F p_v}{G_f}}}$$

(Eq. 14b)

5.2 Liquid pressure recovery factor F_L

The liquid pressure recovery factor F_L applies to valves without attached fittings (see Baumann reference, *The Introduction of a Critical Flow Factor for Valve Sizing*). This factor accounts for the influence of the internal geometry of the valve on its capacity at choked flow. Under nonvaporizing flow conditions, it is defined by the equation:

$$F_L = \sqrt{\frac{p_1 - p_2}{p_1 - p_{vc}}} \qquad \text{(Eq. 15a)}$$

Representative F_L values for various valve styles are listed in Annex D.

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5.3 Combined liquid pressure recovery factor F_{LP}

When a valve is installed with reducers or other attached fittings, the liquid pressure recovery of the valve-fitting combination is not the same as that for the valve alone. For calculations involving choked flow, it is convenient to treat the piping geometry factor (F_p) and the F_L factor for the valve-fitting combination as a single factor, F_{LP}. The value of F_L for the combination is then F_{LP}/F_p, where

$$\frac{F_{LP}}{F_p} = \sqrt{\frac{p_1 - p_2}{p_1 - p_{vc}}} \qquad \text{(Eq. 15b)}$$

(Refer to Section 4.3 and Annex B.)

For maximum accuracy, F_{LP} must be determined by using the test procedures specified in ANSI/ISA S75.02 (see Annex J—References). When estimated values are permissible, reasonable accuracy may be obtained by using the following equation to determine F_{LP}:

$$F_{LP} = F_L\left(\frac{K_i F_L^2 C_v^2}{N_2 d^4} + 1\right)^{-1/2} \qquad \text{(Eq. 16)}$$

In this equation, K_i is the head loss coefficient ($K_1 + K_{B1}$) of any fitting between the upstream pressure tap and the inlet face of the valve only. (See Annex B for the mathematical derivation of F_{LP}.)

6 Compressible fluid — flow of gas and vapor

The flow rate of a compressible fluid varies as a function of the ratio of the pressure differential to the absolute inlet pressure ($\Delta p/p_1$), designated by the symbol x. At values of x near zero, the equations in this section can be traced to the basic Bernoulli equation for Newtonian incompressible fluids. However, increasing values of x result in expansion and compressibility effects that require the use of appropriate correction factors (see Buresh and Schuder reference, *The Development of a Universal Gas Sizing Equation for Control Valves*, and Driskell reference, *New Approach to Control Valve Sizing*).

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6.1 Equations for turbulent flow

The flow rate of a gas or vapor through a valve may be calculated by using any of the following equivalent forms of the equation:

$$w = N_6 F_p C_v Y \sqrt{x p_1 \gamma_1}$$

or

$$C_v = \frac{w}{N_6 F_p Y \sqrt{x p_1 \gamma_1}} \qquad \text{(Eq. 17)}$$

$$q = N_7 F_p C_v p_1 Y \sqrt{\frac{x}{G_g T_1 Z}}$$

or

$$C_v = \frac{q}{N_7 F_p p_1 Y} \sqrt{\frac{G_g T_1 Z}{x}} \qquad \text{(Eq. 18)}$$

$$w = N_8 F_p C_v p_1 Y \sqrt{\frac{xM}{T_1 Z}}$$

or

$$C_v = \frac{w}{N_8 F_p p_1 Y} \sqrt{\frac{T_1 Z}{xM}} \qquad \text{(Eq. 19)}$$

$$q = N_9 F_p C_v p_1 Y \sqrt{\frac{x}{M T_1 Z}}$$

or

$$C_v = \frac{q}{N_9 F_p p_1 Y} \sqrt{\frac{M T_1 Z}{x}} \qquad \text{(Eq. 20)}$$

Note that the numerical value of x used in these equations must not exceed the choking limit ($F_K x_{Tp}$), regardless of the actual value of x. (See Section 6.4.)

6.2 Numerical constants *N*

The numerical constants N are chosen to suit the measurement units used in the equations. Values for N are listed in Table 2.

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Table 2 — Numerical constants for gas and vapor flow equations

Constant		Units Used in Equations					
N		*w*	*q**	*p*,Δ*p*	γ_1	T_1	*d*, *D*
N_5	0.00241	—	—	—	—	—	mm
	1000	—	—	—	—	—	in
N_6	2.73	kg/h	—	kPa	kg/m^3	—	—
	27.3	kg/h	—	bar	kg/m^3	—	—
	63.3	lb/h	—	psia	lb/ft^3	—	—
N_7	4.17	—	m^3/h	kPa	—	K	—
	417	—	m^3/h	bar	—	K	—
	1360	—	scfh	psia	—	°R	—
N_8	0.948	kg/h	—	kPa	—	K	—
	94.8	kg/h	—	bar	—	K	—
	19.3	lb/h	—	psia	—	°R	—
N_9	22.5	—	m^3/h	kPa	—	K	—
	2250	—	m^3/h	bar	—	K	—
	7320	—	scfh	psia	—	°R	—

*q is in cubic feet per hour measured at 14.73 psia and 60°F, or cubic meters per hours measured at 101.3 kPa and 15.6°C.

6.3 Expansion factor *Y*

The expansion factor *Y* accounts for the change in density of a fluid as it passes from the valve inlet to the vena contracta and for the change in area of the vena contracta as the pressure drop is varied (contraction coefficient). Theoretically, *Y* is affected by all of the following:

1) Ratio of port area to body inlet area
2) Internal geometry of the valve
3) Pressure drop ratio, *x*
4) Reynolds number
5) Ratio of specific heats, *k*

The influence of items 1, 2, and 3 are defined by the factor x_T. Test data (see Driskell reference, *New Approach to Control Valve Sizing*) indicate that *Y* may be taken as a linear function of *x*, as shown in the following equation for a valve without attached fittings:

$$Y = 1 - \frac{x}{3F_k x_T} \qquad (\text{Limits } 1.0 \geq Y \geq 0.67) \qquad \text{(Eq. 21)}$$

For a valve with attached fittings, x_{TP} shall be substituted for x_T.

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For all practical purposes, Reynolds number effects may be disregarded in the case of compressible fluids. The effect of the ratio of specific heats is considered in Section 6.7.

6.4 Choked flow

If all inlet conditions are held constant and the differential pressure ratio (x) is increased by lowering the downstream pressure (p_2), the mass flow rate will increase to a maximum limit. Flow conditions where the value of x exceeds this limit are known as *choked flow*. Choking occurs when the jet stream at the vena contracta attains its maximum cross-sectional area at sonic velocity. This occurs at pressure ratios (p_1/p_{vc}) greater than about 2.0.

The value of x at the inception of choked flow conditions varies from valve to valve. It also varies with the piping geometry and with the thermodynamic properties of the flowing fluid. The factors involved are x_T (Section 6.5), x_{TP} (Section 6.6), and F_k (Section 6.7).

Choking affects the use of Equations 17 through 21 in the following manner: The value of x used in the equations must not exceed $F_k x_T$ or $F_k x_{TP}$, regardless of the actual value of x. The expansion factor Y at choked flow ($x \geq F_k x_{TP}$) is then at its minimum value of 2/3.

6.5 Pressure drop ratio factor x_T

For maximum accuracy, the pressure drop ratio factor x_T must be established by using the test procedures specified in ANSI/ISA S75.02 (see Annex J—References). Representative x_T values for valves are tabulated in Annex D. These representative values are not to be taken as actual. Actual values must be obtained from the valve manufacturer.

6.6 Pressure drop ratio factor with reducers or other fittings x_{TP}

When a valve is installed with reducers or other fittings, the pressure drop ratio factor of the assembly (x_{TP}) is different from that of the valve alone (x_T). For maximum accuracy, x_{TP} must be determined by test (see reference ANSI/ISA S75.02). When estimated values are permissible, the following equation may be used to determine x_{TP}:

$$x_{TP} = \frac{x_T}{F_p^2}\left(\frac{x_T K_i C_v^2}{N_5 d^4} + 1\right)^{-1} \qquad \text{(Eq. 22)}$$

In this equation, x_T is the pressure drop ratio factor for a given valve installed without reducers or other fittings, and K_i is the sum of the inlet velocity head coefficients ($K_1 + K_{B1}$) of the reducer or other fitting attached to the valve inlet. This correction to x_T is usually negligible if d/D is greater than 0.5 and C_v/d^2 is less than 20, where d is in inches.

See Annex H for the mathematical derivation of x_T.

6.7 Ratio of specific heats factor F_k

The ratio of specific heats of a compressible fluid affects the flow rate through a valve. The factor F_k accounts for this effect. F_k has a value of 1.0 for air at moderate temperatures and pressures, where its specific heat ratio is about 1.40. Both theoretical and experimental evidence indicate that for valve sizing purposes, F_k may be taken as having a linear relationship to k. Therefore:

$$F_k = \frac{k}{1.40} \qquad \text{(Eq. 23)}$$

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6.8 Compressibility factor *Z*

Equations 18, 19, and 20 do not contain a term for the actual specific weight of the fluid at upstream conditions. Instead, this term is inferred from the inlet pressure and temperature based on the laws of ideal gases. Under some conditions, real gas behavior can deviate markedly from the ideal. In these cases, the compressibility factor Z shall be introduced to compensate for the discrepancy. Z is a function of both reduced pressure and reduced temperature. For use in this section, reduced pressure p_r is defined as the ratio of the actual inlet absolute pressure to the absolute thermodynamic critical pressure for the fluid in question. The reduced temperature is defined similarly. That is:

$$p_r = \frac{p_1}{p_c} \qquad \text{(Eq. 24)}$$

$$T_r = \frac{T_1}{T_c} \qquad \text{(Eq. 25)}$$

Absolute thermodynamic critical pressures and temperatures for most fluids, and curves from which Z may be determined, can be found in many reference handbooks of physical data.

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Annex A — Use of flow rate equations for sizing valves

Laboratory tests are conducted on actual valves in a prescribed test setup (see reference ANSI/ISA S75.02). The test fluid is usually water or air. The flow coefficient C_v and the factors F_L, x_T, etc. are determined at the rated valve travel. These data, along with factors to account for the actual fluid and the pipe configuration (F_k, F_F, F_p, etc.), are used in the equations of this standard to predict the flow rate with the valve fully open.

The principal use of the flow equations is to aid in the selection of an appropriate valve size for a specific application. In this procedure, the numbers in the equations consist of known values for the fluid and flow conditions and known values for the selected valve type at its rated opening. With these factors in the equation, the unknown (or product of unknowns, e.g., F_pC_v) can be computed. Although these computed numbers are often suitable for selecting a valve from a series of discrete sizes, they do not represent a true operating condition, because the factors are mutually incompatible. Some of the factors used in the equation are for the wide-open valve while others relating to the operating conditions are for the partially open valve.

Once a valve size has been selected, the remaining unknowns, such as F_p, can be computed and a judgment can be made as to whether the valve size is adequate. It is not usually necessary to carry the calculations further to predict the exact valve opening. To do this, all the pertinent sizing factors must be known at fractional valve openings.

Additional information on the use of the flow equations, along with example problems, is available in *ISA Handbook of Control Valves* and Driskell reference, *Control Valve Selection and Sizing*.

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Annex B — Derivation of factors F_p and F_{LP}

If a valve is installed between reducers, the C_v of the entire assembly is different from that of the valve alone. If the inlet and outlet reducers are the same size, the only effect is the added resistance of the fittings, which creates an additional pressure drop. If there is only one reducer or if there are reducers of different sizes, there will be an additional effect on the pressure due to the difference in velocity between the inlet and outlet streams.

The velocity head expressed in feet of fluid equals $U_2/2g$, where U is the velocity of the stream and g is the acceleration of gravity. Expressed in U.S. customary units, psi, gpm, and inches, the velocity pressure becomes:

$$p = \frac{q^2 G_f}{890 d^4} \qquad \text{(Eq. B-1)}$$

For a resistance coefficient K, the pressure difference then becomes:

$$\Delta p = K\left(\frac{q^2 G_f}{890 d^4}\right) \qquad \text{(Eq. B-2)}$$

From Equations 1 and B-2, the resistance coefficient for a valve is:

$$K_{valve} = \frac{890 d^4}{C_v^2} \qquad \text{(Eq. B-3)}$$

The change in velocity pressure across a reducer with diameters d and D is

$$\frac{q^2 G_f}{890 d^4} - \frac{q^2 G_f}{890 D^4} = \frac{q^2 G_f}{890 d^4}\left(1 - \frac{d^4}{D^4}\right) \qquad \text{(Eq. B-4)}$$

From Equations B-2 and B-4, we have the factor K_B, which has been called the Bernoulli coefficient.

Here,

$$K_B = \left(1 - \frac{d^4}{D^4}\right) \qquad \text{(Eq. B-5)}$$

By definition:

$$(F_P C_v)^2 = \frac{q^2 G_f}{\Delta p} \qquad \text{(Eq. B-6)}$$

From Equations B-2 and B-6, adding all K factors:

$$(F_P C_v)^2 = \frac{890 d^4}{K_{\text{valve}} + K_1 + K_2 + K_{B1} - K_{B2}} \qquad \text{(Eq. B-7)}$$

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Substitute K_{valve} from Equation B-3:

$$(F_P C_v)^2 = \frac{890 d^4}{\frac{890 d^4}{C_v^2} + \Sigma K} \qquad \text{(Eq. B-8)}$$

where

$$\Sigma K = K_1 + K_2 + K_{B1} - K_{B2} \qquad \text{(Eq. B-9)}$$

Then, rearranging Equation B-8, we have:

$$F_p = \left(\frac{\Sigma K C_v^2}{890 d^4} + 1 \right)^{-1 \S 2} \qquad \text{(Eq. B-10)}$$

It should be noted in Equation B-9 that ΣK is the sum of all the effective velocity head coefficients. If the inlet and outlet reducers are the same size, $K_{B1} = K_{B2}$, and in Equation B-9 both drop out because of the difference in their sign. For K_1 and K_2, see Equations 6 and 7.

By definition, from Equation 15:

$$F_L^2 = \frac{p_1 - p_2}{p_1 - p_{vc}} = \frac{\Delta p_a}{\Delta p_{vc}} \qquad \text{(Eq. B-11)}$$

where Δp_a is the pressure drop across the valve, and Δp_{vc} is the drop to the vena contracta.

Also, from Equation 1:

$$q^2 = (F_P C_v)^2 \frac{\Delta p_b}{G_f} = C_v^2 \frac{\Delta p_a}{G_f} \qquad \text{(Eq. B-12)}$$

where Δp_b is the drop across the valve with reducers.

From Equation B-12:

$$\Delta p_a = F_P^2 \Delta p_b \qquad \text{(Eq. B-13)}$$

Substituting this expression into Equation B-11, we have:

$$F_L^2 = F_P^2 \frac{\Delta p_b}{\Delta p_{vc}} \qquad \text{(Eq. B-14)}$$

By definition:

$$(F_L)_p^2 = \frac{\Delta p_b}{\Delta p_{vc} + \Delta p_i} \qquad \text{(Eq. B-15)}$$

where $(F_L)_P$ is the pressure recovery factor for the valve with reducers, and Δp_i is the drop across the inlet reducer.

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From Equation B-2:

$$\Delta p_i = \frac{K_i q^2 G_f}{890 d^4} \qquad \text{(Eq. B-16)}$$

where $K_i = K_1 + K_{B1}$.

Substituting the expression for q^2 from Equation B-12 into Equation B-16, we have:

$$\Delta p_i = \frac{K_i F_p^2 C_v^2 \Delta p_b}{890 d^4} \qquad \text{(Eq. B-17)}$$

Substituting Equations B-14 and B-17 into B-15, we have the following development:

$$(F_L)_p^2 = \frac{\Delta p_b}{\frac{F_P^2 \Delta p_b}{F_L^2} + \frac{K_i F_p^2 C_v^2 \Delta p_b}{890 d^4}}$$

$$(F_L)_p = \frac{1}{F_p}\left(\frac{1}{F_L^2} + \frac{K_i C_v^2}{890 d^4}\right)^{-1/2}$$

$$F_{LP} = (F_L)_p F_P = \left[\frac{1}{F_L^2} + \frac{K_i}{890}\left(\frac{C_v}{d^2}\right)^2\right]^{-1/2}$$

$$F_{LP} = F_L\left[\frac{F_L^2 K_i}{N_2}\left(\frac{C_v}{d^2}\right)^2 + 1\right]^{1/2} \qquad \text{(Eq. B-18)}$$

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Annex C — Control valve-piping system head changes

An understanding of the various loss mechanisms involved in a control valve-piping system can be obtained by looking at the energy grade lines and the hydraulic grade lines for a liquid flow system containing abrupt contractions and expansions in the form of concentric reducers. These are shown schematically in Figure C-1. For ease of comprehension, the curves are displayed as straight line segments. The energy grade line includes only the available energy and excludes internal energy. Each point of pressure change associated with this figure is defined below. Some of the pressure drops are nonrecoverable and some are recoverable, as shown in the hydraulic grade line. The terms below also define the various coefficients associated with the system. The Bernoulli coefficients, K_{B1} and K_{B2}, account for the change in the velocity pressure of the stream and relate the total kinetic energy to that calculated with the valve inlet velocity U_1.

Table C-1 — Definitions of head terms (Refer to Figure C-1)

Reference Letter (See Fig. C-1)	Head Terms*	U.S. Units	SI Units
A	Inlet pressure head	p_1 / γ	$p_1 / \rho g$
B	Inlet velocity head	$(d/D_1)^4(U_1^2/2g)$	$(d/D_1)^4(U_1^2/2g)$
C	Reducer drop	$(K_1+K_{B1})(U_1^2/2g)$	$(K_1+K_{B1})(U_1^2/2g)$
D	Differential to vena contracta	$(E) / (1-F_L^2)$	$(E) / (1-F_L^2)$
E	Pressure recovery at valve	$(D) - (H)$	$(D) - (H)$
F	Increaser recovery	$(K_{B2} - K_2)(U_1^2 / 2g)$	$(K_{B2} - K_2)(U_1^2 / 2g)$
G	Reducer loss	$K_1(U_1^2/2g)$	$K_1(U_1^2/2g)$
H	Valve loss	$N_2(d^4/C_v^2)(U_1^2/2g)$	$N_2(d^4/C_v^2)(U_1^2/2g)$
I	Increaser loss	$K_2(U_1^2/2g)$	$K_2(U_1^2/2g)$
J	Outlet pressure head	p_2 / γ	$p_2 / \rho g$
K	Outlet velocity head	$(d/D_2)^4(U_1^2/2g)$	$(d/D_2)^4(U_1^2/2g)$
L	Total head loss	$(p_1 - p_2) / \gamma$	$(p_1 - p_2) / \rho g$

* All units are absolute and consistent: pound, foot, and second in U.S. customary units; SI for metric units.

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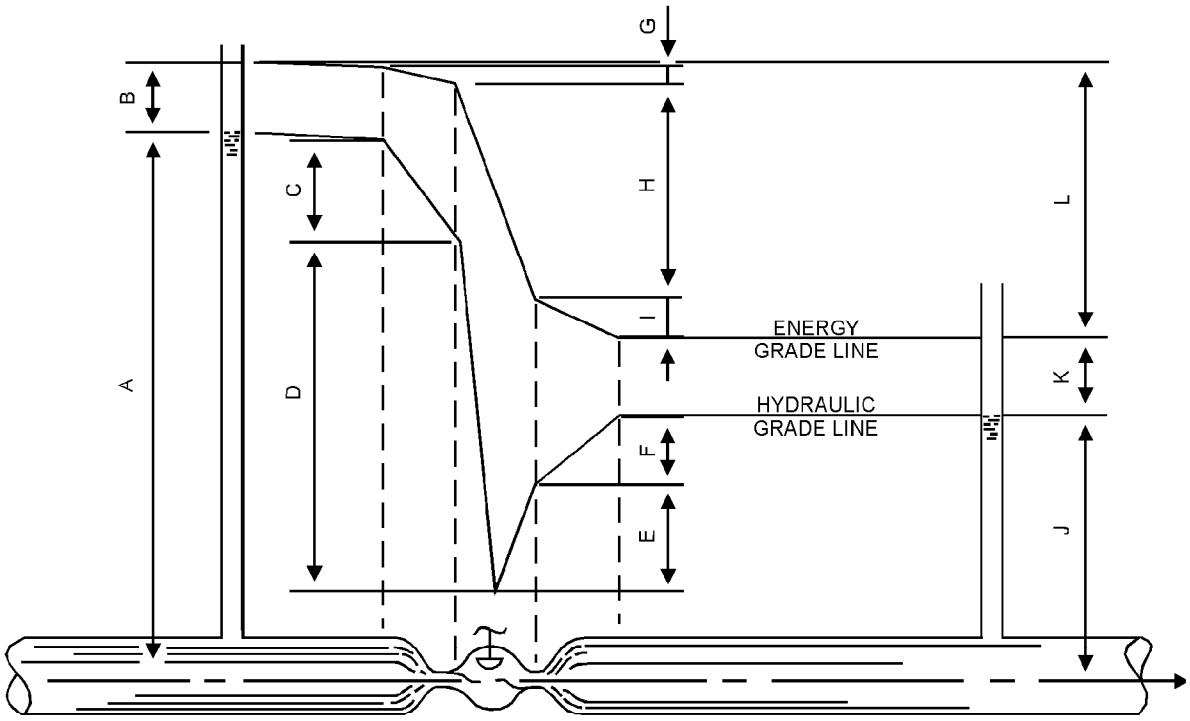

Figure C-1 — Head changes in a control valve-piping system

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Annex D — Representative values of valve capacity factors

The values in Table D-1 are typical only for the types of valves shown at their rated travel for full-size trim. Significant variations in value may occur because of any of the following reasons: reduced travel, trim type, reduced port size, and valve manufacturer.

Table D-1 — Representative values of valve capacity factors

Valve Type	Trim Type	Flow Direction*	x_T	F_L	F_s	F_d**	$C_v/d^{2\dagger}$
GLOBE							
Single port	Ported plug	Either	0.75	0.9	1.0	1.0	9.5
	Contoured plug	Open	0.72	0.9	1.1	1.0	11
		Close	0.55	0.8	1.1	1.0	11
	Characterized cage	Open	0.75	0.9	1.1	1.0	14
		Close	0.70	0.85	1.1	1.0	16
	Wing guided	Either	0.75	0.9	1.1	1.0	11
Double port	Ported plug	Either	0.75	0.9	0.84	0.7	12.5
	Contoured plug	Either	0.70	0.85	0.85	0.7	13
	Wing guided	Either	0.75	0.9	0.84	0.7	14
Rotary	Eccentric spherical plug	Open	0.61	0.85	1.1	1.0	12
		Close	0.40	0.68	1.2	1.0	13.5
ANGLE	Contoured plug	Open	0.72	0.9	1.1	1.0	17
		Close	0.65	0.8	1.1	1.0	20
	Characterized cage	Open	0.65	0.85	1.1	1.0	12
		Close	0.60	0.8	1.1	1.0	12
	Venturi	Close	0.20	0.5	1.3	1.0	22
BALL	Segmented	Open	0.25	0.6	1.2	1.0	25
	Standard port (diameter ≅ 0.8d)	Either	0.15	0.55	1.3	1.0	30
BUTTERFLY	60-Degree aligned	Either	0.38	0.68	0.95	0.7	17.5
	Fluted vane	Either	0.41	0.7	0.93	0.7	25
	90-Degree offset seat	Either	0.35	0.60	0.98	0.7	29

* Flow direction tends to *open* or *close* the valve, i.e., push the closure member away from or towards the seat.

** In general, an F_d value of 1.0 can be used for valves with a single flow passage. An F_d value of 0.7 can be used for valves with two flow passages, such as double-ported globe valves and butterfly valves.

† In this table, d may be taken as the nominal valve size, in inches.

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Annex E — Reynolds number factor F_R

The information contained in this annex is an elaboration of the discussion presented in Section 4.4. It presents a method used for resolving laminar and transitional flow problems.

Figure E-1 shows the relationships between F_R and the valve Reynolds number Re_v for the three types of problems that may be encountered with viscous flow. These are:

a) Determining the required flow coefficient when selecting a control valve size

b) Predicting the flow rate that a selected valve will pass

c) Predicting the pressure differential that a selected valve will exhibit

In Figure E-1, the straight diagonal lines extending downward at an F_R value of approximately 0.3 indicate conditions under which laminar flow exists. At a valve Reynolds number of 40 000, all three curves in Figure E-1 reach an F_R value of 1.0. At this number and at all higher Re_v values, fully turbulent flow conditions exist. Between the laminar region, indicated by the straight diagonal lines of Figure E-1, and the turbulent region, where F_R = 1.0, the flow regime is transitional (i.e., neither laminar nor turbulent).

Equation 11 for determining the valve Reynolds number Re_v is:

$$Re_v = \frac{N_4 F_d q}{\nu F_L^{1/2} C_v^{1/2}} \left(\frac{F_L^2 C_v^2}{N_2 d^4} + 1 \right)^{1/4} \qquad \text{(Eq. 11)}$$

F_R values and the solutions to the three classes of problems may be obtained by using the following procedures.

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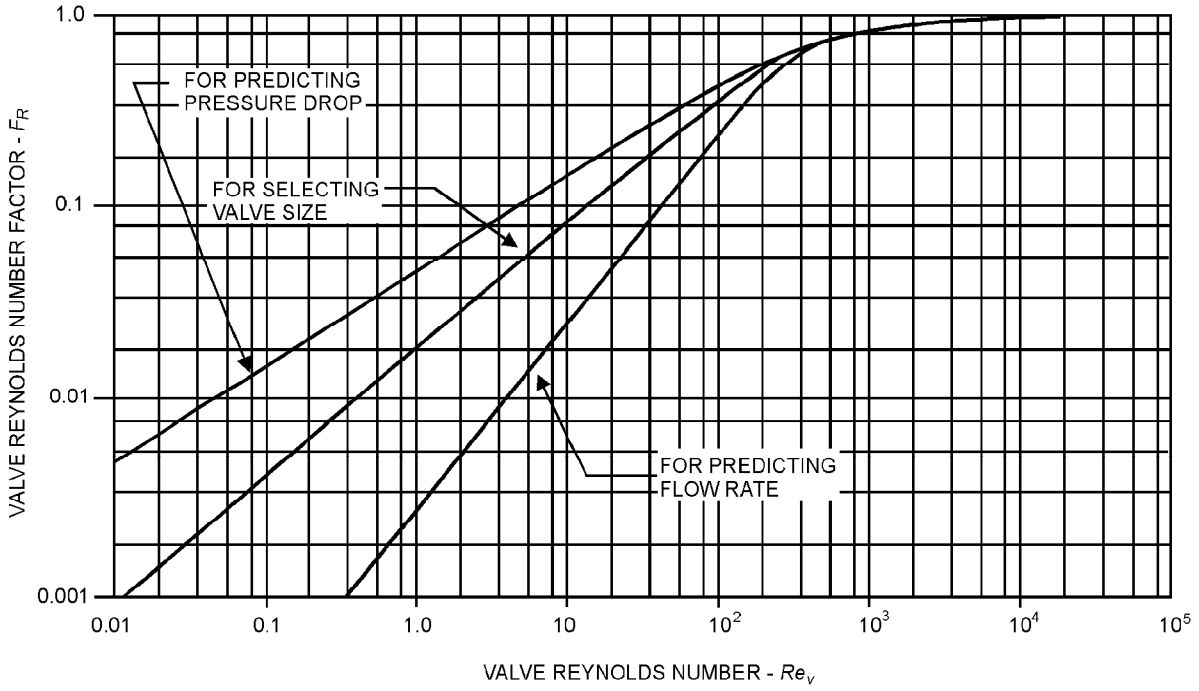

Figure E-1 — Reynolds number factor for valve sizing
(See Figure 1 for the range of uncertainty.)

Determining required flow coefficient (selecting valve size)

The following treatment is based on valves without attached fittings; therefore, F_p = 1.0.

a) Calculate a pseudo valve flow coefficient C_{vt}, assuming turbulent flow, using:

$$C_{vt} = \frac{q}{N_1 \sqrt{\frac{p_1 - p_2}{G_f}}} \qquad \text{(Eq. E-1)}$$

b) Calculate Re_v by using Equation 11, substituting C_{vt} from Step 1 for C_v. For F_L, select a representative value for the valve style desired.

c) Find F_R as follows:

1) If Re_v is less than 56, the flow is laminar, and F_R may be found by using either the curve in Figure E-1 labeled "For Selecting Valve Size" or by using the equation

$$F_R = 0.019\,(Re_v)^{0.67} \qquad \text{(Eq. E-2)}$$

2) If Re_v is greater than 40 000, the flow may be taken as turbulent, and F_R = 1.0.

3) If Re_v lies between 56 and 40 000, the flow is transitional, and F_R may be found by using either the curve in Figure E-1 or Table E-1 in the column headed "Valve Size Selection."

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d) Obtain the required C_v from:

$$C_v = \frac{C_{vt}}{F_R} \qquad \text{(Eq. E-3)}$$

e) After determining C_v, check the F_L value for the selected valve size and style. If this value is significantly different from the value selected in Step 2, use the new value and repeat Steps 1 through 4.

Predicting flow rate

a) Calculate q_t, assuming turbulent flow, using:

$$q_t = N_1 C_v \sqrt{\frac{p_1 - p_2}{G_f}} \qquad \text{(Eq. E-4)}$$

b) Calculate Re_v by using Equation 11, substituting q_t for q from Step 1.

c) Find F_R as follows:

1) If Re_v is less than 106, the flow is laminar, and F_R may be found by using the curve in Figure E-1 labeled "For Predicting Flow Rate" or by using the equation

$$F_R = 0.0027\ Re_v \qquad \text{(Eq. E-5)}$$

2) If Re_v is greater than 40 000, the flow may be taken as turbulent, and $F_R = 1.0$.

3) If Re_v lies between 106 and 40 000, the flow is transitional, and F_R may be found by using the curve in Figure E-1 or Table E-1 in the column headed "Flow Rate Prediction."

d) Obtain the predicted flow rate from:

$$q = F_R\, q_t \qquad \text{(Eq. E-6)}$$

Predicting pressure drop

a) Calculate Re_v according to Equation 11.

b) Find F_R as follows:

1) If Re_v is less than 30, the flow is laminar, and F_R may be found by using the curve in Figure E-1 labeled "For Predicting Pressure Drop" or by using the equation

$$F_R = 0.052\ (Re_v)^{0.5} \qquad \text{(Eq. E-7)}$$

2) If Re_v is greater than 40 000, the flow may be taken as turbulent, and $F_R = 1.0$.

3) If Re_v lies between 30 and 40 000, the flow is transitional, and F_R may be found by using the curve in Figure E-1 or Table E-1 in the column headed "Pressure Drop Prediction."

c) Obtain the predicted pressure drop from:

$$\Delta p = G_f \left(\frac{q}{N_1 F_R C_v} \right)^2 \qquad \text{(Eq. E-8)}$$

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Table E-1 — Reynolds number factor F_R for transitional flow

	Valve Reynolds Number, Re_v*		
F_R*	Valve Size Selection	Flow Rate Prediction	Pressure Drop Prediction
0.284	56	106	30
0.32	66	117	38
0.36	79	132	48
0.40	94	149	59
0.44	110	167	74
0.48	130	188	90
0.52	154	215	113
0.56	188	253	142
0.60	230	298	179
0.64	278	351	224
0.68	340	416	280
0.72	471	556	400
0.76	620	720	540
0.80	980	1100	870
0.84	1560	1690	1430
0.88	2470	2660	2300
0.92	4600	4800	4400
0.96	10 200	10 400	10 000
1.00	40 000	40 000	40 000

* Linear interpolation between listed values is satisfactory.

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Annex F — Equations for nonturbulent liquid flow

The following method for handling liquid nonturbulent flow permits a direct solution for the unknown — flow rate, C_v, or Δp — without using tables or curves and without first computing a Reynolds number. It is especially useful with programmable calculators or computers. The results are in conformance with Section 4.4.

Figure 1 in Section 4.4 has the following features:

a) A straight horizontal line at $F_R = 1.0$, representing the turbulent flow region. Here, the flow rate varies as the square root of differential pressure (Equation 1).

b) A straight diagonal line, representing the laminar flow region. Here, the flow rate varies directly with the differential pressure.

c) A curved portion, representing the transitional flow region.

d) A shaded envelope to indicate the scatter of the test data (see Stiles reference, *Liquid Viscosity Effects on Control Valve Sizing*, and McCutcheon reference, *A Reynolds Number for Control Valves*) and the uncertainty to be expected in the nonturbulent flow region.

From Equation 9:

$$q = N_1 F_R C_v \sqrt{\frac{p_1 - p_2}{G_f}} \qquad \text{(Eq. 9)}$$

and Equation 11:

$$\mathrm{Re}_v = \frac{N_4 F_d q}{v F_L^{1/2} C_v^{1/2}} \left(\frac{F_L^2 C_v^2}{N_2 d^4} + 1 \right)^{1/4} \qquad \text{(Eq. 11)}$$

For the laminar flow region, an equation can be written for the straight line found in Figure 1, such that:

$$F_R = \left(\frac{\mathrm{Re}_v}{370} \right)^{1/2} \qquad \text{(Eq. F-1)}$$

Combining these three equations, we obtain:

$$q = N_s (F_s C_v)^{3/2} \frac{\Delta p}{\mu}$$

or

$$C_v = \frac{1}{F_s} \left(\frac{q\mu}{N_s \Delta p} \right)^{2/3} \qquad \text{(Eq. F-2)}$$

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where,

$$F_s = \frac{F_d^{2/3}}{F_L^{1/3}}\left(\frac{F_L^2 C_v^2}{N_2 d^4} + 1\right)^{1/6} \qquad \text{(Eq. F-3)}$$

and

μ = absolute viscosity, centipoises

N_s = a constant that depends on the units used, i.e.,

N_s	q	Δp
47	gpm	psi
1.5	m^3/hr	kPa
15	m^3/hr	bar

F_s is generally a function of a specific manufacturer's valve style and varies little from size to size. This variation is usually no greater than the uncertainty in the value of the factor F_d that accounts for the hydraulic radius. Representative values of F_s are listed in Annex D. Once a particular valve has been selected, the actual values of F_d, F_L, and C_v/d^2 may be used to compute F_s.

Equation F-2 may be solved directly for the unknown if the flow is fully laminar. In the transitional region, to avoid using a curve or table, the following equations have been established for determining F_R:

$$F_R = 1.044 - 0.358\left(\frac{C_{vs}}{C_{vt}}\right)^{0.655} \qquad \text{(Eq. F-4)}$$

$$F_R = 1.084 - 0.375\left(\frac{\Delta p_s}{\Delta p_t}\right)^{0.336} \qquad \text{(Eq. F-5)}$$

$$F_R = 1.004 - 0.358\left(\frac{q_t}{q_s}\right)^{0.588} \qquad \text{(Eq. F-6)}$$

In these equations, the subscript s denotes a value computed from Equation F-2 assuming laminar flow conditions, and the subscript t denotes a value computed from Equation 9 assuming turbulent flow conditions (F_R = 1.0).

When the value F_R calculated by the above equations is less than 0.48, the flow may be taken as laminar, and Equation F-2 governs. When F_R is greater than 0.98, the flow may be taken as turbulent, and Equation 9 governs (F_R is $\cong$ 1.0). The piping geometry factor F_p should not be used in either Equation 9 or Equation F-2, because the effect that close-coupled fittings have on nonturbulent flow through control valves has not been established. Also, the equation used in this standard for F_p is based on turbulent flow only. For maximum accuracy, a valve must be installed with a straight inlet pipe the same size as the valve. The length of the straight pipe should be sufficient for the stream to attain its normal velocity profile, a condition upon which the research data are based.

The following examples demonstrate how problems may be solved.

PROBLEM 1. Find the valve size.

Given: q = 500 gpm, G_f = 0.9, Δp = 20 psi, μ = 20 000 cp

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Selected valve: Butterfly, $C_v / d^2 = 19$, $F_s = 0.93$ (from a manufacturer's catalog or Annex D)

Using Equation 9 for turbulent flow:

$$q = N_1 F_R C_{vt} \left(\frac{\Delta p}{G_f}\right)^{1/2}$$

$$500 = (1.0)(1.0) C_{vt} \left(\frac{20}{0.90}\right)^{1/2}$$

$C_{vt} = 106$

Using Equation F-2 for laminar flow:

$$C_{vs} = \frac{1}{F_s}\left(\frac{q\mu}{N_s \Delta p}\right)^{2/3}$$

$$C_{vs} = \frac{1}{0.93}\left(\frac{500(20\,000)}{47(20)}\right)^{2/3} = 520$$

Using Equation F-4 for transitional flow,

$$F_R = 1.044 - 0.358\left(\frac{520}{106}\right)^{0.655} = 0.03$$

This value for F_R is less than the 0.48 limit for transitional flow, so the flow is laminar. The C_v required is 520. To meet this requirement, a representative 6-inch valve has a $C_v = 19d^2 = 684$, or as listed in the manufacturer's catalog.

PROBLEM 2. Find the differential pressure.

Given: $q = 1070$ gpm, $G_f = 0.84$, $\mu = 5900$ cp, $C_v = 400$, $F_s = 1.25$

Using Equation 9 assuming turbulent flow:

$$q = N_1 (1.0) C_v \left(\frac{\Delta p_t}{G_f}\right)^{1/2}$$

$$1070 = (1.0)(1.0)400\left(\frac{\Delta p_t}{0.84}\right)^{1/2}$$

$\Delta p_t = 601$ psi

Using Equation F-2 assuming laminar flow:

$$q = N_s (F_s C_v)^{3/2} \frac{\Delta p_s}{\mu}$$

$$1070 = 47[1.25(400)]^{3/2} \frac{\Delta p_s}{5900}$$

$\Delta p_s = 12.0$ psi

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Using Equation F-5 for transitional flow:

$$F_R = 1.084 - 0.375\left(\frac{12.0}{6.01}\right)^{0.336} = 0.61$$

Because F_R is between 0.48 and 0.98, the flow is transitional.

Find the pressure drop using Equation 9:

$$q = N_1 F_R C_v \left(\frac{\Delta p}{G_f}\right)^{1/2}$$

$$1070 = 1.0(0.61)(400)\left(\frac{\Delta p}{0.84}\right)^{1/2}$$

Δp = 16 psi

Note that the pseudo values of Δp, assuming turbulent (6 psi) or laminar flow (12 psi), are not applicable, because the flow is actually transitional.

PROBLEM 3. Find the valve size.

Given: q = 17 m³/h, ρ = 1100 kg/m³, Δp = 69 kPa, μ = 1000 N·s/m² (or 10^6 cp)

Selected valve: Ball, C_v / d^2 = 30, F_s = 1.3

Using Equation 9 for turbulent flow:

$$q = N_1 F_R C_{vt} \left(\frac{\Delta p}{G_f}\right)^{1/2}$$

$$17 = 0.0865(1.0) C_{vt}\left(\frac{69}{1.1}\right)^{1/2}$$

C_{vt} = 24.8

Using Equation F-2 for laminar flow:

$$C_{vs} = \frac{1}{F_s}\left(\frac{q\mu}{N_s \Delta p}\right)^{2/3}$$

$$C_{vs} = \frac{1}{1.3}\left[\frac{17(10^6)}{1.5(69)}\right]^{2/3}$$

C_{vs} = 2310

For transitional flow:

$$F_R = 1.044 - 0.358\left(\frac{2310}{24.8}\right)^{0.655} = -5.9$$

A value less than 0.48 indicates laminar flow. Therefore, the required C_v is 2310. To meet this requirement, a 250-mm (10-in) valve has a $C_v = 30(10)^2 = 3000$.

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Annex G — Liquid critical pressure ratio factor F_F

Flow rate is a function of the pressure drop from the valve inlet to the vena contracta. Under nonvaporizing liquid flow conditions, the apparent vena contracta pressure (p_{vc}) can be predicted from the downstream pressure (p_2), because the pressure recovery is a consistent fraction of the pressure drop to the vena contracta. The effect of this pressure recovery is recognized in the valve flow coefficient (C_v).

Under choked flow conditions, there is no relationship between p_2 and p_{vc} because vaporization affects pressure recovery. The liquid critical pressure ratio factor is used to predict p_{vc}. It is the ratio of the apparent vena contracta pressure under choked flow conditions to the vapor pressure of the liquid at its inlet temperature.

An equation for predicting F_F has been published in previous standards. A theoretical equation based on the assumption (see Allen reference, *Flow of a Flashing Mixture of Water and Steam through Pipes and Valves*) that the fluid is always in thermodynamic equilibrium states that:

$$F_F = 0.96 - 0.28\left(\frac{p_v}{p_c}\right)^{1/2} \qquad \text{(Eq. G-1)}$$

Because a liquid does not remain in thermodynamic equilibrium as it flashes across a valve (see Bailey reference, *Metastable Flow of Saturated Water*), the actual flow rate will be greater than that predicted by the use of Equation G-1.

In experiments with nonvalve restrictions (see Burnell reference, *Flow of Boiling Water through Nozzles, Orifices and Pipes*), the following equation for F_F was derived:

$$F_F = 1 - \frac{\sigma}{F_o} \qquad \text{(Eq. G-2)}$$

where σ is the surface tension of the liquid in N/m and F_O is an experimentally determined orifice factor for the restriction or valve in the same units. This equation allows for the fact that liquids vaporizing across a restriction are not in thermodynamic equilibrium, but become metastable and choke at a critical vena contracta pressure. The equation has been tested only for deaerated water. Limited data indicate that values of F_O for values at rated travel range from around 0.2 N/m for a streamlined angle valve to nearly 1.0 for a more tortuous double-ported globe valve. The surface tension of water in N/m can be approximated based on the Othmer equation:

$$\sigma = \left[\frac{(374 - °C)}{4080}\right]^{1.05} \qquad \text{(Eq. G-3)}$$

or

$$\sigma = \left[\frac{(705 - °F)}{7340}\right]^{1.05} \qquad \text{(Eq. G-4)}$$

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Annex H — Derivation of factor x_{TP}

The slope of the Y versus x curve for any specific valve is determined using air or gas as the test fluid, and is designated by the value of x at $Y = 2/3$. This value, known as x_T, is the pressure drop ratio factor. For most valves, it is less than 1.0, but it may be greater for some valve styles.

If a valve is installed with a fitting at the inlet and/or outlet, the pressure drop ratio factor for the combination of the valve plus the fitting (x_{TP}) usually differs from that of the valve alone.

Let us consider a valve with reducers operating at choked flow

[$x = x_{TP}$, $Y = Y_T$ for an ideal gas ($Z = 1$)]

From Equation 18, the volumetric valve flow equation (in U.S. customary units) is:

$$q_T = 1360\ F_P C_v p_1 Y_T \sqrt{\frac{x_{TP}}{G_g T_1}} \qquad \text{(Eq. H-1)}$$

where the subscript T indicates the terminal or choked condition. For the valve alone at choked flow, the equation is:

$$q_T = 1360\ C_v p_i Y_T \sqrt{\frac{x_T}{G_g T_1}} \qquad \text{(Eq. H-2)}$$

where p_i is the valve inlet pressure. From Equations H-1 and H-2, we have:

$$p_i = F_p p_1 \sqrt{\frac{x_{TP}}{x_T}} \qquad \text{(Eq. H-3)}$$

From the gas laws, the mean specific weight across the inlet reducer is:

$$\gamma_1 = \left(\frac{p_1 - p_i}{2}\right)\frac{M}{RT_1} = \frac{144(p_1 + p_i)}{2}\left(\frac{28.97 G_g}{1545\ T_1}\right)$$

$$\gamma_1 = 1.350(p_1 + p_i)\frac{G_g}{T_1} \qquad \text{(Eq. H-4)}$$

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Since the pressure drop, expressed in feet of head, is $K(U^2/2g)$,

$$\frac{144(p_1 - p_i)}{\gamma} = \frac{K}{2g} U^2 \qquad \text{or} \qquad \frac{144(p_1 - p_i)}{1.350(p_1 + p_i)\frac{G_g}{T_1}}$$

$$= \frac{K}{2g}\left[\frac{q}{3600}\frac{14.73}{0.5(p_1 + p_i)}\frac{T_1}{519.69}\frac{4(144)}{\pi d^2}\right]^2$$

Simplifying:

$$p_1^2 - p_i^2 = 1.214(10^{-9})KG_gT_1q^2d^{-4} \qquad \text{(Eq. H-5)}$$

Substituting the expression for p_i from Equation H-3, we have:

$$p_1^2 - F_p^2 p_1^2\left(\frac{x_{TP}}{x_T}\right) = 1.214(10^{-9})KG_gT_1q^2d^{-4} \qquad \text{(Eq. H-6)}$$

From Equation H-1:

$$q_T^2 G_g \frac{T_1}{p_1^2} = (1360\ F_pC_vY_T)^2 x_{TP} \qquad \text{(Eq. H-7)}$$

Substituting this into Equation H-6, with $q = q_T$ and $K = K_i$, we have:

$$1.214(10^9)(1360\ F_pC_vY_T)^2 K_i \frac{x_{TP}}{d^4} = 1 - F_p^2 \frac{x_{TP}}{x_T} \qquad \text{(Eq. H-8)}$$

Solving for x_{TP}, with $Y_T = 2/3$, we have:

$$x_{TP} = \frac{x_T}{F_p^2}\left(\frac{K_i x_T}{1000}\frac{C_v^2}{d^4} + 1\right)^{-1} \qquad \text{(Eq. H-9)}$$

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Annex I — Control valve flow equations — SI Notation (International System of Units)

The valve flow coefficient that is compatible with SI units is A_v (see IEC reference, *Industrial Process Control Valves*). At the present time, A_v does not have wide acceptance by the technical community. This annex has been included for the benefit of those who wish to use pure, coherent SI units.

In the following equations, certain symbols commonly associated with SI practice differ from those listed in Section 3. These are:

A_v Valve flow coefficient, $m^2 [A_v = C_v \times 24(10^{-6})]$

ζ (Zeta) Head loss coefficient ($\zeta = K$), dimensionless

ρ (Rho) Density, kg/m^3

Liquid Equations

Turbulent flow:

$$q = F_p A_v \left(\frac{\Delta p}{\rho}\right)^{1/2} \quad \text{(Eq. I-1)}$$

$$w = F_p A_v (\Delta p \rho)^{1/2} \quad \text{(Eq. I-2)}$$

$$F_p = \left[\left(\frac{\Sigma \zeta A_v^2}{1.23 d^4}\right) + 1\right]^{-1/2} \quad \text{(Eq. I-3)}$$

Choked flow:

$$q = F_{LP} A_v \left[\frac{p_1 - p_{vc}}{\rho}\right]^{1/2} \quad \text{(Eq. I-4)}$$

$$w = F_{LP} A_v [\rho (p_1 - p_{vc})]^{1/2} \quad \text{(Eq. I-5)}$$

$$F_{LP} = F_L \left[\left(\frac{\zeta_1 F_L^2 A_v^2}{1.23 d^4}\right) + 1\right]^{-1/2} \quad \text{(Eq. I-6)}$$

where $\zeta_i = \zeta_1 + \zeta_{B1}$

$$p_{vc} = F_F p_v \text{ (See Annex G for } F_F) \quad \text{(Eq. I-7)}$$

Laminar flow (see Annex F):

$$q_s = (F_s A_v)^{3/2} \frac{\Delta p}{280 \mu} \quad \text{(Eq. I-8)}$$

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$$w_s = (F_s A_v)^{3/2} \frac{\Delta p \rho}{280 \mu} \quad \text{(Eq. I-9)}$$

$$F_s = \frac{F_d^{2/3}}{F_L^{1/3}} \left(\frac{F_L^2 A_v^2}{1.23 d^4} + 1 \right)^{1/6} \quad \text{(Eq. I-10)}$$

Transitional flow:

$$q = F_R A_v \left(\frac{\Delta p}{\rho} \right)^{1/2} \quad \text{(Eq. I-11)}$$

$$w = F_R A_v (\Delta p \rho)^{1/2} \quad \text{(Eq. I-12)}$$

$$F_R = 1.044 - 0.358 \left(\frac{A_{vs}}{A_{vt}} \right)^{0.655} \quad \text{(Eq. I-13)}$$

$$F_R = 1.084 - 0.375 \left(\frac{\Delta p_s}{\Delta p_t} \right)^{0.336} \quad \text{(Eq. I-14)}$$

$$F_R = 1.004 - 0.358 \left(\frac{q_t}{q_s} \right)^{0.588} \quad \text{(Eq. I-15)}$$

Limits for F_R = 0.48 to 1.0.

Gas and Vapor Equations

Turbulent flow:

$$w = F_p A_v Y (x p_1 \rho_1)^{1/2} \quad \text{(Eq. I-16)}$$

$$q = 0.246 F_p A_v p_1 Y \left(\frac{x}{M T_1 Z} \right)^{1/2} \quad \text{(Normal m}^3\text{ at 0°C and 101.3 kPa)} \quad \text{(Eq. I-17)}$$

Limit: $x \leq F_k x_{TP}$ (in equation only)

$$x_{TP} = \frac{x_T}{F_p^2} \left[\left(0.72 x_T \zeta_i \frac{A_v^2}{d^4} \right) + 1 \right]^{-1} \quad \text{(Eq. I-18)}$$

where

$$\zeta_i = \zeta_1 + \zeta_{B1} \quad \text{(Eq. I-19)}$$

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Annex J — References

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC/534-1 Part 1: General Considerations, 1976

IEC/534-2 Part 2: Flow Capacity. Section One — Sizing Equations for Incompressible Fluid Flow under Installed Conditions, 1978

IEC/534-2-2 Part 2: Flow Capacity. Section Two — Sizing Equations for Compressible Fluid Flow under Installed Conditions, 1980

IEC/534-2-3 Part 2: Flow Capacity. Section Three — Test Procedures, 1983

Available from: **ANSI**
11 West 42nd Street
New York, NY 10036 Tel: (212) 642-4900

or

IEC
Bureau Centrale de la Commission Electrotechnique International
1 rue de Varembe
Geneve, Suisse

ISA

ANSI/ISA-S75.02-1988 Control Valve Capacity Test Procedure

Baumann, H. D. "Effect of Pipe Reducers on Control Valve Capacity," *Instruments and Control Systems*, December 1968, pp. 92–102.

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Available from: **ISA**
67 Alexander Drive
P.O. Box 12277
Research Triangle Park, NC 27709 Tel: (919) 990-9200

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MSS SP-43-1991
Reaffirmed 2001

Wrought Stainless Steel Butt-Welding Fittings

Including Reference to Other Corrosion Resistant Materials

Standard Practice
Developed and Approved by the
Manufacturers Standardization Society of the
Valve and Fittings Industry, Inc.
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FOREWORD

ASME B16.9 is the American Standard for steel butt-welding fittings and although not so stated, it is implied that its scope deals primarily with the schedules of wall thicknesses which are common to carbon steel and the grades of alloy steel piping that are selected for pressure and temperature considerations.

The rapid expansion of the process industries in the field of chemicals, plastics, textiles, etc., has created a demand for a class of pipe referred to as stainless piping, using this word in its generic sense. This field employs the use of the austenitic stainless steels and also nickel and its related alloys. This stainless piping is used with resistance to corrosion, elimination of product contamination, or combination of the two as the principle reason for material selection. Pressure is seldom, if ever, a critical consideration.

When pressure is a consideration reference is made to ASME B16.9.

Mechanical strength, resistance to vacuum, and economy, are the most usual criteria in the selection of pipe thickness in this field, and for this reason the wall thicknesses employed in the field of corrosion resistant pipe are lighter than those in common usage with carbon steel piping.

In 1949 ANSI approved standard B36.19 Stainless Steel Pipe in which a schedule of wall thickness was established and designated as Schedule 10S. Numerous companies were also using a wall thickness lighter than Schedule 10S for services where contamination rather than corrosion was the prime consideration. These lighter wall thicknesses were designated Schedule 5S and the original 1950 edition of SP-43 established a series of Schedule 5S fittings. The 5S thicknesses were published in SP-43 and were developed in cooperation with representatives of the various principal chemical companies and processing industries. In 1952 the Stainless Steel Pipe Standard B36.19 was revised to recognize the Schedule 5S wall thickness pipe as American Standard.

The purpose of this standard is to provide industry with a set of dimensional standards for butt-welding fittings that can be used with these light wall pipes of corrosion resisting materials. The center-to-end dimensions of all fittings are identical with those in ASME B16.9 which give to industry the advantage of uniform design room practice and a maximum utilization of existing die equipment. The only departure from this is in the lap-joint stub end where for purposes of economy the face-to-end of the product has been reduced for use with thin wall piping.

The advantage of longer center-to-end dimensions of the size 3/4 elbows resulted in the change in the tables to permit a gradual changeover, providing the manufacturers ample time to deplete existing stocks, re-tool and replenish stocks.

The 1991 revision of the SP was required to delete the metric equivalents.

The 2001 Reaffirmation had no technical changes. There were minor editorial changes. The precedence of the longer dimensions for 3/4 elbows was made in accord with ASME B16.9. Referenced standards were brought up to date. The title of 180 degree returns was clarified.

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WROUGHT STAINLESS STEEL, BUTT-WELDING FITTINGS

1. SCOPE

1.1 This Standard covers overall dimensions, tolerances, and markings for wrought stainless steel butt-welding fittings. In this standard "wrought" is used to denote fittings made of pipe, tubing, plate, bar, sheet, strip or forgings.

1.2 This Standard covers only fittings made for use with Schedule 5S or 10S pipe as given in ASME B36.19M, except that short pattern stub ends suitable for use with Schedule 40S are also shown.

1.3 Annex A. Table A1 lists the dimensions of stainless steel pipe with which these fittings are intended to be used.

2. REFERENCES

2.1 Standards and specifications adopted by reference in this standard are shown in Annex B for convenience of identifying edition number, date, and source of supply.

3. PRESSURE RATINGS

3.1 Fittings produced under this standard shall carry the following ratings: [Schedule 5S piping is not recommended for use at temperatures above 400° F].

Temp	PSI	
F	10S	5S
100	275	225
150	255	215
200	240	200
250	225	190
300	210	175
350	195	165
400	180	150
450	165	—
500	150	—
550	140	—
600	130	—
650	120	—
700	110	—
750	100	—

3.2 Fabricated Tees employing intersection welds shall be considered in this standard and shall be rated at 70% of these ratings.

3.3 For fittings of same pressure rating of matching pipe, refer to ASME B16.9.

4. SIZE

4.1 The size of the fittings in Tables 1 through 6 and Annex A is identified by the corresponding nominal pipe size.

5. MARKING

5.1 Each fitting shall be marked to show the following:

a) Manufacturer's name or trademark
b) "CR" followed by the material identification symbol established for the respective grade in the appropriate ASTM or AISI specifications.
c) Schedule number or nominal wall thickness designation.
d) Size

5.2 Where the size of fittings does not permit complete marking, the identification marks may be omitted in the sequence specified in MSS SP-25.

5.3 Method of Marking – The manufacturer's name or trademark, thickness, the grade identification symbol, and size shall be marked by any suitable method not injurious to the fitting.

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6. MATERIALS

6.1 Fittings made from AISI Type 304, 304L, 347, 316, and 316L are considered standard under this specification. Fittings to other specifications are available and should be made from material complying with the requirements of one of the recognized AISI analyses of ASTM specifications.

7. METAL THICKNESS

7.1 As these fittings are to match pipe, the dimensions of the welding ends must conform with established pipe standards as to outside diameters and tolerances. The nominal wall thickness of the fittings shall be the same as the pipe to which it is welded, except that fittings with heavier walls may be butt welded to lighter wall pipe provided the heavier wall is tapered on the inside or outside to match the dimensions of the lighter pipe.

8. FITTINGS DIMENSIONS

8.1 Inch dimensions for the fittings covered by this standard are given in Tables 1 through 6.

8.2 One of the principals of this standard is the maintenance of a fixed position for welding ends with reference to center line of the fittings or the overall dimensions as the case may be.

9. TESTS

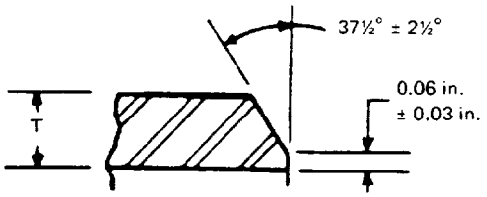
9.1 Hydrostatic testing of fittings is not required in this standard; however, fittings shall be capable of withstanding a hydrostatic test pressure one and one-half times the pressure ratings shown in Subsection 3.1 for 100°F.

10. TOLERANCES

10.1 Table 1 lists the tolerances for the fittings covered by this standard.

11. WELDING BEVEL

11.1 Fittings furnished to this standard may be finished with ends cut square for wall thickness 0.12 in. or less. For wall thicknesses in excess of 0.12 in., they shall be beveled at 37 1/2° plus or minus 2 1/2°; with root face (land) 0.06 in. plus or minus 0.03 in.



Welding Bevel for "T" in excess of 0.12 in.

12. FINISH AND HEAT TREATMENT

12.1 The fittings shall be satisfactorily heat treated by an accepted practice, and adequately cleaned to insure maximum corrosion resistance.

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TABLE 1 TOLERANCES

Dimensions in inches

Nominal Pipe Size	All Fittings		90° Elbows 45° Elbows Tees	Reducers Lap-Joint Stub Ends	180° Returns			Caps	Lap-Joint Stub Ends	
	Outside[a] Diameter at Welding End	Wall Thickness	Center-to-End Dimension A-B-C-M	Overall Length F-H	Center-to-Center Dimension O	Back-to-Face Dimension K	Alignment of Ends U	Overall Length E	Fillet[b] Radius of Lap A	Outside Diameter of Lap G
1/2 – 1-1/2	± 0.03	Not less than 87½% of nominal thickness	± 0.06	± 0.06	± 0.25	± 0.25	± 0.03	± 0.12	+0 −0.03	+0 −0.03
2 – 3-1/2	± 0.03		± 0.06	± 0.06	± 0.25	± 0.25	± 0.03	± 0.12	+0 −0.03	+0 −0.03
4	± 0.03		± 0.06	± 0.06	± 0.25	± 0.25	± 0.03	± 0.12	+0 −0.06	+0 −0.03
5 – 8	+0.06 −0.03		± 0.06	± 0.06	± 0.25	± 0.25	± 0.03	± 0.25	+0 −0.06	+0 −0.03
10 – 18	+0.09 −0.03		± 0.09	± 0.09	± 0.38	± 0.25	± 0.06	± 0.25	+0 −0.06	+0 −0.06
20 – 24	+0.12 −0.03		± 0.09	± 0.09	±0.38	± 0.25	± 0.06	± 0.25	+0 −0.06	+0 −0.06

NOTES:

[a] Out of roundness is the vector sum of plus and minus tolerance.

[b] Fillet B radius is maximum. (See Table 4).

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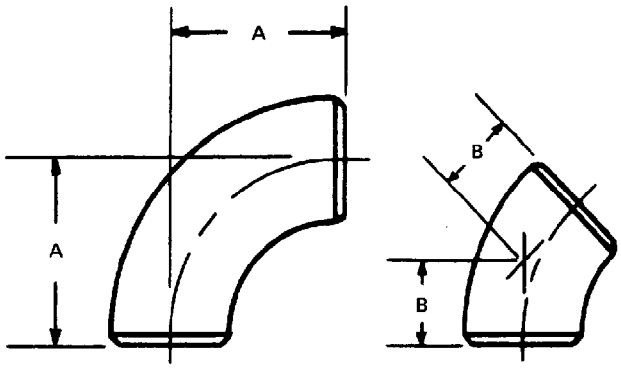

TABLE 2 DIMENSIONS OF LONG RADIUS ELBOWS

Nominal Pipe Size	Outside Diameter At Bevel	Center-to-End	
		90 -Deg Elbows A	45-Deg Elbows B
1/2	0.84	1.50	0.62
3/4	1.05	1.50	0.75
1	1.32	1.50	0.88
1-1/4	1.66	1.88	1.00
1-1/2	1.90	2.25	1.12
2	2.38	3.00	1.38
2-1/2	2.88	3.75	1.75
3	3.50	4.50	2.00
3-1/2	4.00	5.25	2.25
4	4.50	6.00	2.50
5	5.56	7.50	3.12
6	6.62	9.00	3.75
8	8.62	12.00	5.00
10	10.75	15.00	6.25
12	12.75	18.00	7.50
14	14.00	21.00	8.75
16	16.00	24.00	10.00
18	18.00	27.00	11.25
20	20.00	30.00	12.50
22	22.00	33.00	13.50
24	24.00	36.00	15.00

A and B Dimensions for size 3/4 may be as shown below at the manufacturers option.

Center-to-End	
90 Degree Elbows A	45 Degree Elbows B
1.12	0.44

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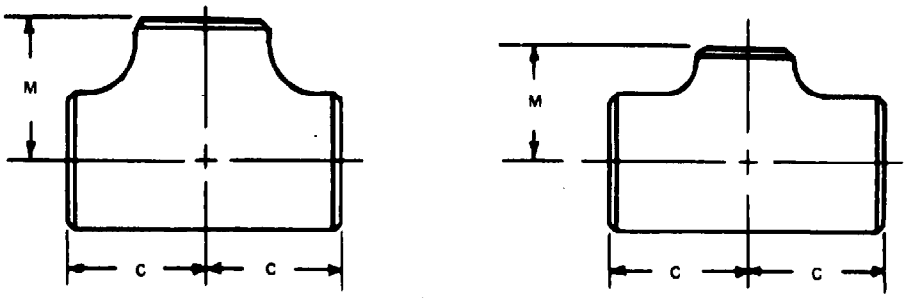

TABLE 3 DIMENSIONS OF STRAIGHT AND REDUCING-ON-THE-OUTLET TEES

Dimensions in inches

Nominal Pipe Size	Nominal Outside Diameter at Bevel		Center-to-End	
	Run	Outlet	Run C	Outlet M
1/2 Straight	0.84	0.84	1.00	1.00
3/4 Straight	1.05	1.05	1.12	1.12
3/4 x 3/4 x 1/2	1.05	0.84	1.12	1.12
1 Straight	1.32	1.32	1.50	1.50
1 x 1 x 3/4	1.32	1.05	1.50	1.50
1 x 1 x 1/2	1.32	0.84	1.50	1.50
1-1/4 Straight	1.66	1.66	1.88	1.88
1-1/4 x 1-1/4 x 1	1.66	1.32	1.88	1.88
1-1/4 x 1-1/4 x 3/4	1.66	1.05	1.88	1.88
1-1/4 x 1-1/4 x 1/2	1.66	0.84	1.88	1.88
1-1/2 Straight	1.90	1.90	2.25	2.25
1-1/2 x 1-1/2 x 1-1/4	1.90	1.66	2.25	2.25
1-1/2 x 1-1/2 x 1	1.90	1.32	2.25	2.25
1-1/2 x 1-1/2 x 3/4	1.90	1.05	2.25	2.25
2 Straight	2.38	2.38	2.50	2.50
2 x 2 x 1-1/2	2.38	1.90	2.50	2.38
2 x 2 x 1-1/4	2.38	1.66	2.50	2.25
2 x 2 x 1	2.38	1.32	2.50	2.00
2 x 2 x 3/4	2.38	1.05	2.50	1.75
2-1/2 Straight	2.88	2.88	3.00	3.00
2-1/2 x 2-1/2 x 2	2.88	2.38	3.00	2.75
2-1/2 x 2-1/2 x 1-1/2	2.88	1.90	3.00	2.62
2-1/2 x 2-1/2 x 1-1/4	2.88	1.66	3.00	2.50
2-1/2 x 2-1/2 x 1	2.88	1.32	3.00	2.25
3 Straight	3.50	3.50	3.38	3.38
3 x 3 x 2-1/2	3.50	2.88	3.38	3.25
3 x 3 x 2	3.50	2.38	3.38	3.00
3 x 3 x 1-1/2	3.50	1.90	3.38	2.88
3-1/2 Straight	4.00	4.00	3.75	3.75
3-1/2 x 3-1/2 x 3	4.00	3.50	3.75	3.62
3-1/2 x 3-1/2 x 2-1/2	4.00	2.88	3.75	3.50
3-1/2 x 3-1/2 x 2	4.00	2.38	3.75	3.25
3-1/2 x 3-1/2 x 1-1/2	4.00	1.90	3.75	3.12
4 Straight	4.50	4.50	4.12	4.12
4 x 4 x 3-1/2	4.50	4.00	4.12	4.00
4 x 4 x 3	4.50	3.50	4.12	3.88
4 x 4 x 2-1/2	4.50	2.88	4.12	3.75
4 x 4 x 2	4.50	2.38	4.12	3.50
4 x 4 x 1-1/2	4.50	1.90	4.12	3.38
5 Straight	5.56	5.56	4.88	4.88
5 x 5 x 4	5.56	4.50	4.88	4.62
5 x 5 x 3-1/2	5.56	4.00	4.88	4.50
5 x 5 x 3	5.56	3.50	4.88	4.38
5 x 5 x 2-1/2	5.56	2.88	4.88	4.25
5 x 5 x 2	5.56	2.38	4.88	4.12

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TABLE 3 DIMENSIONS OF STRAIGHT AND REDUCING-ON-THE-OUTLET TEES (Continued)

Dimensions in inches

Nominal Pipe Size	Nominal Outside Diameter at Bevel		Center-to-End	
	Run	Outlet	Run C	Outlet M
6 Straight	6.62	6.62	5.62	5.62
6 x 6 x 5	6.62	5.56	5.62	5.38
6 x 6 x 4	6.62	4.50	5.62	5.12
6 x 6 x 3-1/2	6.62	4.00	5.62	5.00
6 x 6 x 3	6.62	3.50	5.62	4.88
6 x 6 x 2-1/2	6.62	2.88	5.62	4.75
8 Straight	8.62	8.62	7.00	7.00
8 x 8 x 6	8.62	6.62	7.00	6.62
8 x 8 x 5	8.62	5.56	7.00	6.38
8 x 8 x 4	8.62	4.50	7.00	6.12
8 x 8 x 3-1/2	8.62	4.00	7.00	6.00
10 Straight	10.75	10.75	8.50	8.50
10 x 10 x 8	10.75	8.62	8.50	8.00
10 x 10 x 6	10.75	6.62	8.50	7.62
10 x 10 x 5	10.75	5.56	8.50	7.50
10 x 10 x 4	10.75	4.50	8.50	7.25
12 Straight	12.75	12.75	10.00	10.00
12 x 12 x 10	12.75	10.75	10.00	9.50
12 x 12 x 8	12.75	8.62	10.00	9.00
12 x 12 x 6	12.75	6.62	10.00	8.62
12 x 12 x 5	12.75	5.56	10.00	8.50
14 Straight	14.00	14.00	11.00	11.00
14 x 14 x 12	14.00	12.75	11.00	10.62
14 x 14 x 10	14.00	10.75	11.00	10.12
14 x 14 x 8	14.00	8.62	11.00	9.75
14 x 14 x 6	14.00	6.62	11.00	9.38
16 Straight	16.00	16.00	12.00	12.00
16 x 16 x 14	16.00	14.00	12.00	12.00
16 x 16 x 12	16.00	12.75	12.00	11.62
16 x 16 x 10	16.00	10.75	12.00	11.12
16 x 16 x 8	16.00	8.62	12.00	10.75
16 x 16 x 6	16.00	6.62	12.00	10.38
18 Straight	18.00	18.00	13.50	13.50
18 x 18 x 16	18.00	16.00	13.50	13.00
18 x 18 x 14	18.00	14.00	13.50	13.00
18 x 18 x 12	18.00	12.75	13.50	12.62
18 x 18 x 10	18.00	10.75	13.50	12.12
18 x 18 x 8	18.00	8.62	13.50	11.75
20 Straight	20.00	20.00	15.00	15.00
20 x 20 x 18	20.00	18.00	15.00	14.50
20 x 20 x 16	20.00	16.00	15.00	14.00
20 x 20 x 14	20.00	14.00	15.00	14.00
20 x 20 x 12	20.00	12.75	15.00	13.62
20 x 20 x 10	20.00	10.75	15.00	13.12
20 x 20 x 8	20.00	8.62	15.00	12.75
24 Straight	24.00	24.00	17.00	17.00
24 x 24 x 20	24.00	20.00	17.00	17.00
24 x 24 x 18	24.00	18.00	17.00	16.50
24 x 24 x 16	24.00	16.00	17.00	16.00
24 x 24 x 14	24.00	14.00	17.00	16.00
24 x 24 x 12	24.00	12.75	17.00	15.62
24 x 24 x 10	24.00	10.75	17.00	15.12

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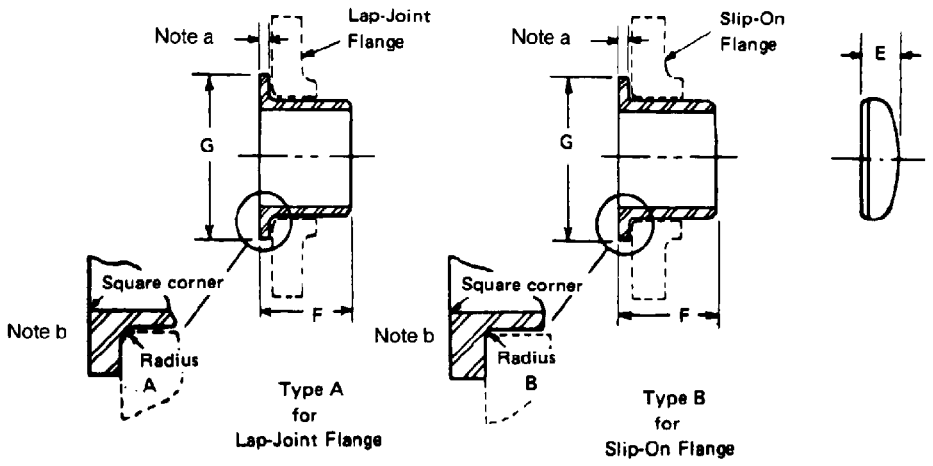

TABLE 4 DIMENSIONS OF LAP-JOINT STUB ENDS AND CAPS

Dimensions in inches

Nominal Pipe Size	Nominal O. D. at Bevel	Caps Length E	Lap-Joint Stub Ends[c]			
			Length F	Dia. of Lap-G Nominal & Maximum	Radius of Fillet	
					A Nominal & Max	B Max
1/2	0.84	1.00	2.00	1.38	0.12	0.03
3/4	1.05	1.00	2.00	1.69	0.12	0.03
1	1.32	1.50	2.00	2.00	0.12	0.03
1-1/4	1.66	1.50	2.00	2.50	0.19	0.03
1-1/2	1.90	1.50	2.00	2.88	0.25	0.03
2	2.38	1.50	2.50	3.62	0.31	0.03
2-1/2	2.88	1.50	2.50	4.12	0.31	0.03
3	3.50	2.00	2.50	5.00	0.38	0.03
3-1/2	4.00	2.50	3.00	5.50	0.38	0.03
4	4.50	2.50	3.00	6.19	0.44	0.03
5	5.56	3.00	3.00	7.31	0.44	0.06
6	6.62	3.50	3.50	8.50	0.50	0.06
8	8.62	4.00	4.00	10.62	0.50	0.06
10	10.75	5.00	5.00	12.75	0.50	0.06
12	12.75	6.00	6.00	15.00	0.50	0.06
14	14.00	6.50	6.00	16.25	0.50	0.06
16	16.00	7.00	6.00	18.50	0.50	0.06
18	18.00	8.00	6.00	21.00	0.50	0.06
20	20.00	9.00	6.00	23.00	0.50	0.06
24	24.00	10.50	6.00	27.25	0.50	0.06

NOTES:

[a] Minimum lap thickness shall not be less than nominal wall thickness.

[b] Contact faces of stub ends shall have a modified spiral or concentric serration.

[c] These lengths and radii for use with Schedule 40S or thinner pipe.

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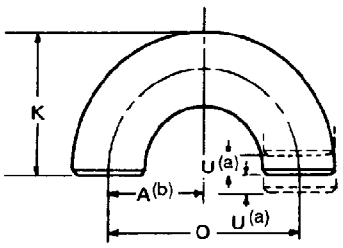

TABLE 5 DIMENSIONS OF LONG RADIUS 180 DEGREE RETURNS

Dimensions in inches

Nominal Pipe Size	Outside Diameter At Bevel	Center-to-Center O	Back-to-Face(c) K
1/2	0.84	3.00	1.88
3/4	1.05	2.25	1.69
1	1.32	3.00	2.19
1-1/4	1.66	3.75	2.75
1-1/2	1.90	4.50	3.25
2	2.38	6.00	4.19
2-1/2	2.88	7.50	5.19
3	3.50	9.00	6.25
3-1/2	4.00	10.50	7.25
4	4.50	12.00	8.25
5	5.56	15.00	10.31
6	6.62	18.00	12.31
8	8.62	24.00	16.31
10	10.75	30.00	20.38
12	12.75	36.00	24.38
14	14.00	42.00	28.00
16	16.00	48.00	32.00
18	18.00	54.00	36.00
20	20.00	60.00	40.00
24	24.00	72.00	48.00

NOTES:

(a) Alignment of ends - U - for nom pipe size 8 and smaller ±0.03 in. and for size 10 and larger ±0.06 in.

(b) "A" dimension is equal to 1/2 "O" dimension.

(c) O and K dimensions for size 3/4 may be as shown below at the manufacturer's option.

Center-to-Center O	Back-to-Face K
3.00	2.00

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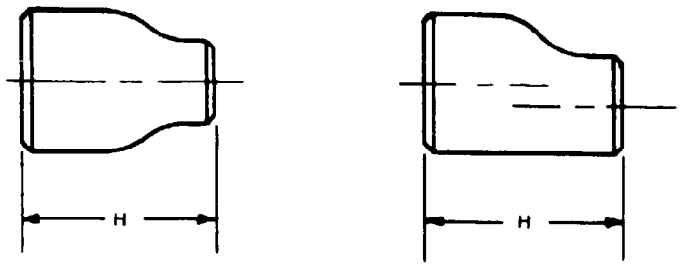

TABLE 6 DIMENSIONS OF CONCENTRIC AND ECCENTRIC REDUCERS

Dimensions in inches

Nominal Pipe Size	Outside Diameter at Bevel		Length H
	Large End	Small End	
3/4 x 1/2	1.05	0.84	1.50
1 x 3/4	1.32	1.05	2.00
1 x 1/2	1.32	0.84	2.00
1 x 3/8	1.32	0.68	2.00
1-1/4 x 1	1.66	1.32	2.00
1-1/4 x 3/4	1.66	1.05	2.00
1-1/4 x 1/2	1.66	0.84	2.00
1-1/2 x 1-1/4	1.90	1.66	2.50
1-1/2 x 1	1.90	1.32	2.50
1-1/2 x 3/4	1.90	1.05	2.50
1-1/2 x 1/2	1.90	0.84	2.50
2 x 1-1/2	2.38	1.90	3.00
2 x 1-1/4	2.38	1.66	3.00
2 x 1	2.38	1.32	3.00
2 x 3/4	2.38	1.05	3.00
2-1/2 x 2	2.88	2.38	3.50
2-1/2 x 1-1/2	2.88	1.90	3.50
2-1/2 x 1-1/4	2.88	1.66	3.50
2-1/2 x 1	2.88	1.32	3.50
3 x 2-1/2	3.50	2.88	3.50
3 x 2	3.50	2.38	3.50
3 x 1-1/2	3.50	1.90	3.50
3 x 1-1/4	3.50	1.66	3.50
3-1/2 x 3	4.00	3.50	4.00
3-1/2 x 2-1/2	4.00	2.88	4.00
3-1/2 x 2	4.00	2.38	4.00
3-1/2 x 1-1/2	4.00	1.90	4.00
3-1/2 x 1-1/4	4.00	1.66	4.00
4 x 3-1/2	4.50	4.00	4.00
4 x 3	4.50	3.50	4.00
4 x 2-1/2	4.50	2.88	4.00
4 x 2	4.50	2.38	4.00
4 x 1-1/2	4.50	1.90	4.00
5 x 4	5.56	4.50	5.00
5 x 3-1/2	5.56	4.00	5.00
5 x 3	5.56	3.50	5.00
5 x 2-1/2	5.56	2.88	5.00
5 x 2	5.56	2.38	5.00

Dimensions in inches

Nominal Pipe Size	Outside Diameter at Bevel		Length H
	Large End	Small End	
6 x 5	6.62	5.56	5.50
6 x 4	6.62	4.50	5.50
6 x 3-1/2	6.62	4.00	5.50
6 x 3	6.62	3.50	5.50
6 x 2-1/2	6.62	2.88	5.50
8 x 6	8.62	6.62	6.00
8 x 5	8.62	5.56	6.00
8 x 4	8.62	4.50	6.00
8 x 3-1/2	8.62	4.00	6.00
10 x 8	10.75	8.62	7.00
10 x 6	10.75	6.62	7.00
10 x 5	10.75	5.56	7.00
10 x 4	10.75	4.50	7.00
12 x 10	12.75	10.75	8.00
12 x 8	12.75	8.62	8.00
12 x 6	12.75	6.62	8.00
12 x 5	12.75	5.56	8.00
14 x 12	14.00	12.75	13.00
14 x 10	14.00	10.75	13.00
14 x 8	14.00	8.62	13.00
14 x 6	14.00	6.62	13.00
16 x 14	16.00	14.00	14.00
16 x 12	16.00	12.75	14.00
16 x 10	16.00	10.75	14.00
16 x 8	16.00	8.62	14.00
18 x 16	18.00	16.00	15.00
18 x 14	18.00	14.00	15.00
18 x 12	18.00	12.75	15.00
18 x 10	18.00	10.75	15.00
20 x 18	20.00	18.00	20.00
20 x 16	20.00	16.00	20.00
20 x 14	20.00	14.00	20.00
20 x 12	20.00	12.75	20.00
24 x 20	24.00	20.00	20.00
24 x 18	24.00	18.00	20.00
24 x 16	24.00	16.00	20.00

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ANNEX A

TABLE A1 DIMENSIONS OF WELDED AND SEAMLESS STAINLESS STEEL PIPE

Dimensions in inches

Nominal Pipe Size	Outside Diameter	Nominal Wall Thickness		
		Schedule 5S [a]	Schedule 10S [a]	Schedule 40S [a]
1/2	0.84	0.065	0.083	0.109
3/4	1.05	0.065	0.083	0.113
1	1.32	0.065	0.109	0.133
1-1/4	1.66	0.065	0.109	0.140
1-1/2	1.90	0.065	0.109	0.145
2	2.38	0.065	0.109	0.154
2-1/2	2.88	0.083	0.120	0.203
3	3.50	0.083	0.120	0.216
3-1/2	4.00	0.083	0.120	0.226
4	4.50	0.083	0.120	0.237
5	5.56	0.109	0.134	0.258
6	6.62	0.109	0.134	0.280
8	8.62	0.109	0.148	0.322
10	10.75	0.134	0.165	0.365
12	12.75	0.156	0.180	0.375 [b]
14	14.00	0.156	0.188 [b]	0.375 [b]
16	16.00	0.165	0.188 [b]	0.375 [b]
18	18.00	0.165	0.188 [b]	0.375 [b]
20	20.00	0.188	0.218 [b]	0.375 [b]
22	22.00	0.188	0.218 [b]	0.375 [b]
24	24.00	0.218	0.250	0.375 [b]
30	30.00	0.250	0.312	0.375 [b]

NOTES:

[a] ASME B36.19M

[b] These do not conform to ASME B36.10M for carbon steel schedules 10 and 40. The carbon steel schedules are heavier than the stainless. Fittings ordered to SP-43 will be furnished to the "S" schedules only.

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ANNEX B Referenced Standards and Applicable Dates

This Annex is an integral part of this standard practice and is placed after the main text for convenience.

Standard Name or Description

ASME, ANSI/ASME, ANSI, ASME/ANSI

ASME B16.9 – 1993 Factory-Made Wrought Steel Buttwelding Fittings
ASME B36.10M – 1996 Welded and Seamless Wrought Steel Pipe
ASME B36.19M – 1994 Stainless Steel Pipe

MSS

SP-25-1998 – Standard Marking System for Valves, Fittings, Flanges and Unions

Publications of the following organizations appear in the above list:

AISI	American Iron and Steel Institute 1101 17th Street, N.W., Washington, D.C. 20036-4700
ANSI	American National Standards Institute 11 West 42nd Street, New York, NY 10036-8002
ASME	American Society of Mechanical Engineers Three Park Avenue, New York, NY 10016-5990
ASTM	American Society for Testing and Materials 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959
MSS	Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. 127 Park Street, N.E., Vienna, VA 22180-4602

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List of MSS Standard Practices
(Price List Available Upon Request)

Number	
SP-6-2001	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP-9-2001	Spot Facing for Bronze, Iron and Steel Flanges
SP-25-1998	Standard Marking System For Valves, Fittings, Flanges and Unions
SP-42-1999	Class 150 Corrosion Resistant Gate, Globe, Angle and Check Valves with Flanged and Butt Weld Ends
SP-43-1991	(R 01) Wrought Stainless Steel Butt-Welding Fittings
SP-44-1996	Steel Pipeline Flanges
SP-45-1998	Bypass and Drain Connections
SP-51-2000	Class 150LW Corrosion Resistant Cast Flanges and Flanged Fittings
SP-53-1999	Quality Standard for Steel Castings and Forgings for Valves. Flanges and Fittings and Other Piping Componets - Magnetic Particle Examination Method
SP-54-1999	Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components - Radiographic Examination Method
SP-55-1996	Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components - Visual Method for Evaluation of Surface Irregularities
SP-58-1993	Pipe Hangers and Supports - Materials, Design and Manufacture
SP-60-1999	Connecting Flange Joint Between Tapping Sleeves and Tapping Valves
SP-61-1999	Pressure Testing of Steel Valves
SP-65-1999	High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets
SP-67-1995	Butterfly Valves
SP-68-1997	High Pressure Butterfly Valves with Offset Design
SP-69-1996	Pipe Hangers and Supports - Selection and Application
SP-70-1998	Cast Iron Gate Valves, Flanged and Threaded Ends
SP-71-1997	Gray Iron Swing Check Valves, Flanged and Threaded Ends
SP-72-1999	Ball Valves with Flanged or Butt Welding Ends for General Service
SP-73-1991	(R 96) Brazing Joints for Wrought and Cast Copper Alloy Solder Joint Pressure Fittings
SP-75-1998	Specification for High Test Wrought Butt Welding Fittings
SP-77-1995	(R 00) Guidelines for Pipe Support Contractual Relationships
SP-78-1998	Cast Iron Plug Valves, Flanged and Threaded Ends
SP-79-1999a	Socket-Welding Reducer Inserts
SP-80-1997	Bronze Gate, Globe, Angle and Check Valves
SP-81-2000	Stainless Steel, Bonnetless, Flanged, Knife Gate Valves
SP-82-1992	Valve Pressure Testing Methods
SP-83-1995	Class 3000 Steel Pipe Unions, Socket-Welding and Threaded
SP-85-1994	Cast Iron Globe & Angle Valves, Flanged and Threaded Ends
SP-86-1997	Guidelines for Metric Data in Standards for Valves, Flanges, Fittings and Actuators
SP-87-1991	(R 96) Factory-Made Butt-Welding Fittings for Class 1 Nuclear Piping Applications
SP-88-1993	Diaphragm Type Valves
SP-89-1998	Pipe Hangars and Supports - Fabrication and Installation Practices
SP-90-2000	Guidelines on Terminology for Pipe Hangers and Supports
SP-91-1992	(R 96) Guidelines for Manual Operations of Valves
SP-92-1999	MSS Valve User Guide
SP-93-1999	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components-Liquid Penetrant Examination Method
SP-94-1999	Quality Std for Ferritic and Martensitic Steel Castings for Valves, Flanges, and Fittings and Other Piping Components-Ultrasonic Examination Method
SP-95-2000	Swage(d) Nipples and Bull Plugs
SP-96-1996	Guidelines on Terminology for Valves and Fittings
SP-97-1995	Integrally Reinforced Forged Branch Outlet Fittings-Socket Welding, Threaded and Buttwelding Ends
SP-98-1996	Protective Coatings for the Interior of Valves, Hydrants, and Fittings
SP-99-1994	Instrument Valves
SP-100-1997	Qualification Requirements for Elastomer Diaphragms for Nuclear Diaphragm Type Valves
SP-101-1989	Part-Turn Valve Actuator Attachment-Flange and Driving Component Dimensions and Performance Characteristics
SP-102-1989	Multi-Turn Valve Actuator Attachment - Flange and Driving Component Dimensions and Performance Characteristics
SP-103-1995	(R 00) Wrought Copper and Copper Alloy Insert Fittings for Polybutylene Systems
SP-104-1995	Wrought Copper Solder Joint Pressure Fittings
SP-105-1996	Instrument Valves for Code Applications
SP-106-1990	(R 96) Cast Copper Alloy Flanges and Flanged Fittings, Class 125, 150 and 300
SP-107-1991	(R 00) Transition Union Fittings for Joining Metal and Plastic Products
SP-108-1996	Resilient-Seated Cast Iron-Eccentric Plug Valves
SP-109-1997	Welded Fabricated Copper Solder Joint Pressure Fittings
SP-110-1996	Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
SP-111-1996	Gray-Iron and Ductile-Iron Tapping Sleeves
SP-112-1999	Quality Standard for Evaluation of Cast Surface Finishes - Visual and Tactile Method. This SP must be sold with a 10-surface, three dimensional Cast Surface Comparator, which is a necessary part of the Standard. Additional Comparators may be sold separately at $25.00 each. Same quantity discounts apply on total order.
SP-113-2001	Connecting Joint between Tapping Machines and Tapping Valves
SP-114-1995	Corrosion Resistant Pipe Fittings Threaded and Socket Welding, Class 150 and 1000
SP-115-1999	Excess Flow Valves for Natural Gas Service
SP-116-1996	Service Line Valves and Fittings for Drinking Water Systems
SP-117-1996	Bellows Seals for Globe and Gate Valves
SP-118-1996	Compact Steel Globe & Check Valves - Flanged, Flangeless, Threaded & Welding Ends (Chemical & Petroleum Refinery Service)
SP-119-1996	Belled End Socket Welding Fittings, Stainless Steel and Copper Nickel
SP-120-1997	Flexible Graphite Packing System for Rising Stem Steel Valves (Design Requirements)
SP-121-1997	Qualification Testing Methods for Stem Packing for Rising Stem Steel Valves
SP-122-1997	Plastic Industrial Ball Valves
SP-123-1998	Non-Ferrous Threaded and Solder-Joint Unions for Use With Copper Water Tube
SP-124-2001	Fabricated Tapping Sleeves
SP-125-2000	Gray Iron and Ductile Iron In-Line, Spring-Loaded, Center-Guided Check Valves
SP-126-2000	Steel In-Line Spring-Assisted Center Guided Check Valves

(R YEAR) Indicates year standard reaffirmed without substantive changes

A large number of former MSS Practices have been approved by the ANSI or ANSI Standards, published by others. In order to maintain a single source of authoritative information, the MSS withdraws its Standard Practice in such cases.

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Steel Pipeline Flanges

Standard Practice
Developed and Approved by the
Manufacturers Standardization Society of the
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Substantive changes in this 1996 edition are "flagged" by parallel bars as shown on the margins of this paragraph. The specific detail of the change may be determined by comparing the material flagged with that in the previous edition.

Non-toleranced dimensions in this Standard Practice are nominal, and unless otherwise specified, shall be considered "for reference only".

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FOREWORD

The Manufacturers Standardization Society originally developed the Standard Practice in response to the continued requests for steel pipe flanges for pipeline use, particularly in sizes larger than those covered by ANSI Standard B16.5 on Steel Pipe Flanges and Flanged Fittings. The line pipe is uniquely characterized by high-strength, cold worked, thin-wall of the carbon steel grade, which necessitates special considerations for the welding end of the flanges.

The size and pressure class range was originally NPS 26 through NPS 36 in pressure classes customarily designated in ANSI Standard B16.5 as 300, 400, 600, and 900 lb. The 1970 edition deleted the slip-on flanges for lack of demand, and added a 150 lb. class and coverage for sizes NPS 12 through NPS 24. Additional coverage was also necessitated by the advent of the use of line pipe of grades having minimum specified yield strength higher than the 52,000 psi maximum contemplated at the time of initial development, and therefore still thinner walls.

In some instances, this advent widened the differential between the tensile properties of the flange steel versus that of the mating pipe steel. This, in turn necessitated greater flexibility in the selection of hub dimensions, so that various combinations of material-strength and flange-dimensions could be utilized to supply the flanges. Section 5 on Flange Design was introduced at this point, and is one of the key features of this standard. The 1972 edition included the coverage of blind flanges in all pressure classes and clarification of text requirements for better understanding and usage under the more diverse conditions.

The 1975 edition expanded the size range above size NPS 36. The drilling templates for the Class 150 flanges of the NPS 38 and larger sizes continued the previous philosophy of adopting the drilling template of the Class 125 of ANSI Standard B16.1. However, the drilling templates of the Class 300 flanges of the NPS 38 and larger sizes did not continue the adoption of the Class 250 of ANSI Standard B16.1 drilling templates, nor did the NPS 38 and larger sizes of Classes 400, 600, and 900 continue the extrapolation of ANSI B16.5 drilling templates; instead, these drilling templates were necessarily designed more compactly because of the increased loads. While these flanges are designated by the customary ANSI Standard Class 150, 300, 400, 600, and 900, their use is almost entirely confined to cross country transmission pipelines at atmospheric temperatures. The flanges have been designed primarily for use at their cold ratings which conform to the ANSI Standard B16.5 ratings of 100F, and are intended primarily for attachment to relatively thin-wall, high-strength cold worked pipe, and high-strength butt-welding fittings in pipeline service at temperatures of 450F and lower. However, flanges forged of other materials are capable of pressure temperature ratings as specified in Paragraph 2.2.

The 1980 edition was created to bring the document into closer editorial alignment with ANSI B16.5. However, out of recognition of the successful experience of the pipeline industry, room temperature ratings were extended to 250F. De-rating above 250F was accelerated such that the 450F ratings are the same as B16.5. Users are cautioned that when these flanges are bolted to valves and used at temperatures between 100F and 450F, the rating of the valve will not be as high as the flange.

The 1990 revision of this SP was required to update the reference standards list and delete the metric equivalents.

The 1991 revision of this SP was required to add blind flange machining guidance, flat face requirements and precautionary notes as well as update of referenced standards.

The 1996 revision adds a table with permissible imperfections in flange facing finish and clarifies annex A design criteria. There were several errata, or corrections made to references to other standards. Dimensional tolerances have been changed where necessary to conform with ASME B16.5 and B16.47.

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1. SCOPE

1.1 General — This standard covers pressure-temperature ratings, materials, dimensions, tolerances (by reference to ASME/ANSI B16.5), marking and testing. The welding neck type flanges shall be forged steel, and the blind flanges may be made of either forged steel or from steel plates.

1.1.1 Dimensional requirements for sizes NPS 10 and smaller are provided by reference to ASME/ANSI B16.5. When such flanges meet all other stipulations of this standard, they shall be considered as complying therewith.

1.2 References

1.2.1 Referenced Standards — Standards and specifications adopted by reference in this standard are shown in Annex C, for convenience of identifying edition number, date and source of supply.

A flange made in conformance with a prior edition of referenced standards and in all other respects conforming to this standard will be considered to be in conformance even though the edition reference may be changed in a subsequent revision of this Standard Practice.

1.2.2 Codes and Regulations — A flange used under the jurisdiction of the ASME Boiler and Pressure Vessel Code, the ANSI Code for Pressure Piping, or Governmental Regulations, is subject to any limitation of that code or regulation. This includes any maximum temperature limitation for a material, or rule governing the use of a material at a low temperature.

2. PRESSURE-TEMPERATURE RATINGS

2.1 General Flanges covered by this standard shall be designated as one of the following: Class 150, 300, 400, 600 and 900. Ratings in Table 3 are in U.S. customary units.

2.2 Rating for Other Materials and Temperatures above 450 F — NPS 26 and larger flanges forged of steels covered in ASME/ANSI B16.5 whose bores are no larger than those which may be calculated for pipe complying with parallel ASTM pipe specifications, and which comply with all requirements (except dimensions) of American National Standard B16.5 are capable of being utilized at the pressure-temperature ratings given in that standard.

3. MATERIALS

3.1 The steel used in the manufacture of these flanges shall be selected by the manufacturer to meet the following requirements.

3.1.1 All materials used for flanges shall be killed steel.

3.1.2 The steel used shall be suitable for field welding to other flanges, fittings, or pipe manufactured under ASTM specifications A 105, A 53, A 106, A 350, A 381, A 694, A 707, or API Standard 5L.

3.1.3 The steel used shall have a maximum carbon content of 0.35 and a carbon equivalent computed by the following equation:

$$\text{C.E.} = \text{C} + \frac{\text{Mn}}{6} + \frac{\text{Cr} + \text{Mo} + \text{V}}{5} + \frac{\text{Ni} + \text{Cu}}{15}$$

that should not exceed 0.48%, based on ladle analysis. If the carbon equivalent factor exceeds 0.48%, the acceptance of the flanges shall be based on agreement between purchaser and manufacturer.

3.1.3.1 The choice and use of alloying elements, combined with the elements within the limits prescribed in paragraph 3.1.3 to give the required tensile properties prescribed in paragraphs 3.1.4 shall be made by the flange manufacturer and included and reported in the ladle analysis to identify the type of steel.

3.1.4 The steel used shall have tensile properties conforming to the requirements prescribed in Table 1 and capable of meeting the requirements of section 4 and the flange manufacturer's design conditions as given in Annex A.

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3.1.4.1 The test specimens may be taken from the forgings or, at the manufacturers' option, from the billets or forging bar entering into the finished product, provided such test blank has undergone relatively the same forming and the equivalent heat treatment as the finished flange. The dimensions of the test blank must be such as to adequately reflect the heat treatment properties of the hub of the flange. Specimens shall be obtained from the midwall of the thinnest section of the hub of the flange or ¾ in. from the surface of the test blank. The orientation of specimens taken from a flange shall be longitudinal.

3.2 Bolting — Bolting listed in Table 2 shall be used in flanged joints covered by this standard. Bolting of other material may be used if permitted by the applicable code or governmental regulation. All bolting materials are subject to the following limitations.

3.2.1 High Strength Bolting — Bolting materials having allowable stresses not less than those for ASTM A193 Gr B7 are listed as high strength in Table 2. These and other materials of comparable strength may be used in any flanged joint.

3.2.2 Intermediate Strength Bolting — Bolting materials listed as intermediate strength in Table 2, and other bolting of comparable strength, may be used in any flanged joint, provided the user verifies their ability to seat the selected gasket and maintain a sealed joint under expected operating conditions.

3.2.3 Low Strength Bolting — Bolting materials having not more than 30 ksi specified minimum yield strength are listed as low strength in Table 2. These materials and others of comparable strength shall be used only in Class 150 and Class 300 joints, and only with gaskets described in 3.3.2.

TABLE 1. TENSILE REQUIREMENTS

GRADE	YIELD POINT MIN. ksi	TENSILE STRENGTH MIN. ksi	ELONGATION IN 2 IN. MIN. PERCENT
F36	36[(a)]	60	20
F42	42	60	20
F46	46	60	20
F48	48	62	20
F50	50	64	20
F52	52	66	20
F56	56	68	20
F60	60	75	20
F65	65	77	18
F70	70	80	18

[(a)] Note: except as required in para. 4.2.

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TABLE 2. LIST OF BOLTING SPECIFICATIONS

ASTM BOLTING MATERIALS							
HIGH STRENGTH [a]		INTERMEDIATE STRENGTH [b]			LOW STRENGTH [c]		
SPEC-GR.	NOTES	SPEC-GR.		NOTES	SPEC-GR.		NOTES
A193-B7		A193-B5			A193-B8	CL1	(g)
A193-B16		A193-B6			A193-B8C	CL1	(g)
A320-L7	(d)	A193-B6X			A193-B8M	CL1	(g)
A320-L7A	(d)	A193-B7M			A193-B8T	CL1	(g)
A320-L7B	(d)	A193-B8	CL2	(f)	A193-B8A		(g)
A320-L7C	(d)	A193-B8C	CL2	(f)	A193-B8CA		(g)
A320-L43	(d)	A193-B8M	CL2	(f)	A193-B8MA		(g)
A354-BC		A193-B8T	CL2	(f)	A193-B8TA		(g)
A354-BD		A320-B8	CL2	(f)	A307-B		(h)
A540-B21		A320-B8C	CL2	(f)	A320-B8	CL1	(g)
A540-B22		A320-B8F	CL2	(f)	A320-B8C	CL1	(g)
A540-B23		A320-B8M	CL2	(f)	A320-B8M	CL1	(g)
A540-B24							
		A320-B8T	CL2	(f)	A320-B8T	CL1	(g)
		A449		(i)			
		A453-651		(e)			
		A453-660		(e)			

General Note:

Bolting materials shall not be used beyond temperature limits specified in the governing Code.

NOTES:

(a) These bolting materials may be used with all listed materials and gaskets.

(b) These bolting materials may be used with all listed materials and gaskets; provided it has been verified that a sealed joint can be maintained under rated pressure and temperature.

(c) These bolting materials may be used with all listed materials but are limited to Class 150 and Class 300 joints. See 3.3 for recommended gasket practices.

(d) This ferritic material is intended for low temperature service, use A194 Gr. 4 or Gr. 7 nuts.

(e) This special alloy is intended for high temperature service with austenitic stainless steel.

(f) This austenitic stainless steel has been carbide solution treated and strain hardened. Use A194 nuts of corresponding material.

(g) This austenitic stainless material has been carbide solution treated but not strain hardened. Use A194 nuts of corresponding material.

(h) This carbon steel fastener shall not be used above 400 F or below -20 F, see also Note (c). Bolts with drilled or undersized heads shall not be used.

(i) Acceptable nuts for use with quenched and tempered bolts are A194 Gr. 2 and Gr. 2H. Mechanical property requirements for studs shall be the same as those for bolts.

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TABLE 3. PRESSURE-TEMPERATURE RATINGS
MAXIMUM ALLOWABLE NON-SHOCK WORKING PRESSURES
IN POUNDS PER SQUARE INCH (GAGE)

TEMP. F	CLASS 150	CLASS 300	CLASS 400	CLASS 600	CLASS 900
-20 to 250	285	740	990	1480	2220
300	275	715	955	1430	2145
350	265	690	925	1380	2070
400	255	665	890	1330	2000
450	245	640	860	1285	1925

3.3 Gasket Material

3.3.1 The user is responsible for selection of gasket materials which will withstand the expected bolt loading without injurious crushing, and which are suitable for the service conditions. Particular attention should be given to gasket selection if a system hydrostatic test will exceed the test pressure specified in 8.2. Such a test involves the risk of excessive flange distortion.

3.3.2 Gasket dimensions for 1/16 inch sheet asbestos in Table 4 are based on a contact area equal to approximately twice the bolt root area. Class 150 flanged joints should use these exclusively.

3.3.3 Ring joint gasket materials shall conform to ANSI B16.20 with dimensions as given in Table 5.

3.3.4 Sheet and ring joint gaskets for sizes NPS 10 and smaller shall conform to ASME/ANSI B16.5 dimensions and recommendations.

4. HEAT TREATMENT

4.1 The F42 and higher grades of flanges of all pressure classes and the class 400 and higher classes of Grade F36 flanges shall be normalized or quenched and tempered.

4.2 It is recognized that the cooling rate in a quenching operation may be slower in the thicker ring section of the flange than in the thinner hub section. Hence, the increase in yield strength due to the quenching operation may be less in the ring section than in the hub section. This factor is accounted for in the Section on Design in Paragraph 5.3. NPS 38 and larger sizes of the 300 and higher classes of welding neck flanges shall have 42 ksi minimum yield strength in the ring section.

5. FLANGE DESIGN

5.1 Drilling Templates — Drilling templates are derived as follows:

5.1.1 Class 150 flange drilling templates are the same as ASME/ANSI B16.5 and Class 125 of ANSI/ASME B16.1.

5.1.2 Sizes 24 and smaller class 300 flanges have drilling templates which are the same as ASME/ANSI B16.5 and Class 250 of ANSI/ASME B16.1. Sizes 24 through 36 inclusive have drilling templates which are interpolations of Class 250 of ANSI/ASME B16.1 except the diameter of the bolt holes are only one-eighth inch larger than bolt diameters. Larger sizes are designed in accordance with Appendix 2 of Division 1 of Section VIII of ASME Boiler and Pressure Vessel Code.

5.1.3 Size 36 and smaller of Classes 400, 600, and 900 flanges have drilling templates which are extrapolations from ASME/ANSI B16.5. Larger sizes are designed in accordance with Appendix 2 of Division I of Section VIII of ASME Boiler and Pressure Vessel Code.

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5.2 Flange Ring Design — The outside diameter and flange thickness of sizes NPS 24 and smaller flanges are in accordance with ASME/ANSI B16.5. Larger sizes are designed in accordance with Appendix 2 of Division 1 of Section VIII of ASME Boiler and Pressure Vessel Code and the flange ring shall have sufficient pressure capacity for the service based on its strength in the normalized condition. This capacity shall be substantiated by the Rules for Bolted Flange Connections, Appendix 2 of Division 1 of the ASME Unfired Pressure Code Section VIII, with allowable design stresses as given in Annex A of this standard.

5.3 Hub Design

5.3.1 Sizes NPS 24 and smaller. When the mechanical (minimum yield strength) properties of all sections of the flanges are equal to or higher than those of the pipe to be matched, the hub dimensions may be the same as those of ASME/ANSI B16.5. Larger sizes are designed in accordance with Appendix 2 of Section VIII of ASME Boiler and Pressure Vessel Code.

5.3.2 In addition, when the minimum yield strength of the hub portion of any flange or its representative test specimen is less than that specified for the pipe to be matched, the minimum thickness of the hub at the welding end shall be such that the product of its thickness times its yield strength (at welding end) shall at least equal the product of the specified nominal wall thickness and minimum specified yield strength of the pipe to be matched. Under these conditions, Sizes NPS 24 and smaller flanges may also have a single taper hub and the outside diameter of the hub at the base may be modified in accordance with ASME Section VIII Division 1 Appendix 2 calculations.

5.3.3 When the manufacturer employs this option, the flange identification should be a combination of the class of material of the flange and of the pipe for which the flange has been designed. See 6.1.

5.3.4 When the hub thickness at the welding end must be greater than the adjoining pipe, the joint design shall be as shown in any of the three sketches in Figure 1.

5.4 Welding End — The welding end shall be in accordance with Figure 2 for wall thickness (of intended mating pipe) of 0.88 in. and less. For thicker walls, refer to Figure 3.

5.5 Blind Flange

5.5.1 a) The outside diameter and thickness of blind flanges shall be as listed in Tables 6, 7, 8, 9 and 10. Thicknesses listed are based on material having mechanical properties for Grade F36 of Table 1. Drilling templates are per Paragraph 5.1. Thinner flanges of higher strength material may be furnished in accordance with Annex B rules.

5.5.2 b) Blind flanges need not be faced in the center if, when this center is raised, its diameter is at least 5 in. smaller than the nominal pipe size. When the center part is depressed, its diameter shall not be greater than the gasket ID specified in Table 4 less 2 inches (I.D. - 2 = max. depression O.D.).

5.6 Dimensional requirements for NPS 10 and smaller shall be in accordance with ASME/ANSI B16.5.

5.7 Flat Face Flanges — This standard permits flat face flanges in all classes, by providing flanges having either the full thickness or the thickness with the raised face removed, without reduction of the pressure-temperature ratings subject to the following provisions.

5.7.1 The thickness of a Class 150 or 300 flange from which the raised face has been removed shall be no less than the applicable dimension C of Tables 6 & 7 minus 0.06 in.

5.7.2 The thickness of a flange of Class 400 or higher from which the raised face has been removed shall be no less than the applicable C dimension of Tables 8, 9 and 10.

5.7.3 The flange facing shall conform with section 7.2 for the full width of seating of the gasket.

5.8 Spot Facing — All flanges shall have bearing surfaces for bolting which shall be parallel to the flange face within 1 deg. Any back facing or spot

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facing required to accomplish parallelism shall not reduce the flange thickness C below the dimensions given in Tables 6, 7, 8, 9 and 10. Any spot facing or back facing shall be in accordance with MSS SP-9.

6. MARKING

6.1 Flanges shall be marked in accordance with the rules established in MSS Standard Practice SP-25, Standard Marking System for Valves, Fittings, Flanges, and Unions. In addition, the letters, "PL" shall precede the grade symbol marking. The grade symbol marked on the Welding Neck Flange shall designate the grade of material in the welding end of the hub. When flanges are produced under the option of Paragraph 5.3.1, the marking will also include the grade of the material of the pipe which the flange will match. For example, a flange having a grade F42 hub designed to be used with grade X60 pipe would contain the marking PL F42/X60 in addition to the marking specified in MSS SP-25.

6.2 Flanges in sizes NPS 10 and smaller produced to B16.5 dimensions and complying with all other requirements of this Standard Practice shall be marked in accordance with 6.1.

7. FACINGS

7.1 Flange Facing Finish — The finish of contact faces of pipe flanges shall be judged by visual comparison with Ra Standards (see ANSI B46.1) and not by instruments having stylus tracers and electronic amplification. The finishes required are given below. Other finishes may be furnished by agreement between user and manufacturer.

7.2 Raised Face — Either a serrated-concentric or serrated-spiral finish having from 125 μ in. to 250 μ in. average shall be furnished. The cutting tool employed should have an approximate 0.06 in. or larger radius, and there should be from 44 to 55 grooves per in.

7.3 Ring Joint — The side wall surface of gasket groove shall not exceed 63 microinch roughness.

7.4 Flange Facing Finish Imperfections in the flange facing finish shall not exceed the dimensions shown in Table 11. Adjacent imperfections shall be separated by a distance of at least four times the permissable radial projection. Protrusions above the separations are not allowed.

8. CODE LIMITATIONS

8.1 A product used under the jurisdiction of the ASME Boiler and Pressure Vessel Code or of the ANSI Code for Pressure Piping, is subject to any limitation of that code. This includes any maximum temperature limitation for a material, or a code rule governing the use of a material at a low temperature.

8.2 Flange Testing — Flanges are not required to be hydrostatically tested. Flanged joints may be subjected to system hydrostatic tests at pressures not exceeding 1.5 times the 100 F rating.

9. FLANGE BOLTING DIMENSIONS

9.1 Alloy-steel stud-bolts threaded at both ends or full length, or bolts with hexagonal heads conforming to American National Standard heavy dimensions (ANSI B18.2.1) may be used and shall have nuts conforming to American National Standard heavy dimensions (ANSI B18.2.2).

9.2 Carbon Steel bolts smaller than ¾ in. shall have square heads or heavy hex heads (ANSI B18.2.1), and shall have heavy hex nuts (ANSI B18.2.2). Bolts ¾ in. and larger shall have square heads or hex heads (ANSI B18.2.1), and shall have hex nuts or heavy hex nuts (ANSI B18.2.2).

9.3 Threads of carbon steel bolts and stud bolts shall be coarse series, Class 2A (ANSI B1.1), and nuts shall be coarse series, Class 2B.

9.4 All alloy steel bolting shall be threaded in accordance with ANSI B1.1. Nominal diameters 1 in. and smaller shall be of the coarse thread series; nominal diameters 1⅛ in. and larger shall be of the 8 thread series. Bolts, studs and stud-bolts shall have a Class 2A thread, and nuts shall have a class 2B thread.

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9.5 Bolting to Cast Iron Flanges — Where Class 150 steel flanges are bolted to Class 125 cast iron flanges or Class 300 steel flanges are bolted to Class 250 cast iron flanges, it is recommended that low strength bolting be used. If intermediate or high-strength bolting is used, it is recommended that the mating flanges be flat faced and that full faced gaskets extending to the O.D. of the flange be used.

10. TOLERANCES

10.1 Facings

Outside Diameter, 0.06 in. raised face:
Sizes NPS 12 to NPS 24 inclusive: ±0.03 in.
Sizes NPS 26 and Larger: ±0.08 in.

Outside Diameter, 0.25 in. raised face:
Sizes NPS 12 to NPS 24 inclusive: ±0.02 in.
Sizes NPS 26 and Larger: ±0.04 in.

10.2 Flange Thickness

Sizes NPS 18 and Smaller	+0.12 in. −zero
Sizes NPS 20 and larger	+0.19 in. −zero

10.3 Hub Dimensions (including welding ends)

10.3.1 Nominal Outside Diameter of Welding End of welding neck flanges (Dimension H, in Tables 6, 7, 8, 9 and 10.

Sizes NPS 12 to NPS 24 in.	+0.16 in. −0.03 in.
Sizes NPS 26 and larger	+0.21 in. −0.06 in.

10.3.2 Nominal Inside Diameter of Welding Ends of welding neck flanges (Dimension B in the referenced Figures).

Sizes NPS 12 to 18 inclusive	±0.06 in.
Sizes NPS 20 and larger	+0.12 in. −0.06 in.

10.3.3 Thickness of Hub — Regardless of tolerances specified for dimensions A and B, the thickness of hub at the welding end shall never be less than 87½ percent of the nominal thickness of the pipe to which the flange is to be attached.

10.4 Overall Length through Hub on Welding Neck Flanges

Sizes NPS 12 to NPS 24 incl.	+0.12 in. - 0.18 in.
Sizes NPS 26 and larger	±0.19 in.

10.5 Drilling and Facing

10.5.1 Bolt Circle Diameter, ±0.06 in.

10.5.2 Center-to-Center of adjacent bolt holes, ±0.03 in.

10.5.3 Eccentricity between bolt circle diameter and machined facing diameters.

Sizes NPS 12 to NPS 24, incl.	0.06 in.
Sizes NPS 26 and larger	0.09 in.

10.6 Sizes NPS 10 and Smaller Tolerances for these sizes shall be as specified in ASME/ANSI B16.5.

The listing of decimal tolerances does not imply method of measurement.

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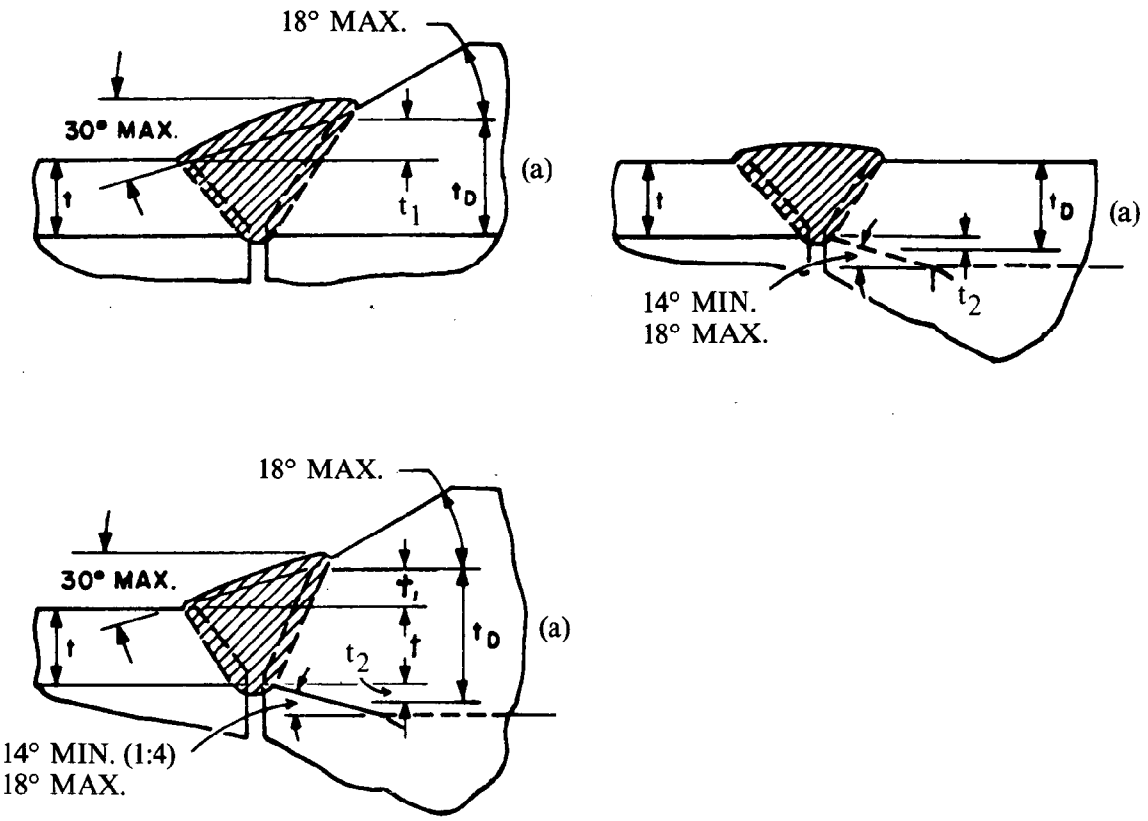

NOTES:

GENERAL:

When the minimum specified yield strengths of the sections to be joined are unequal, the deposited weld metal shall have mechanical properties at least equal to those of the section having the higher strength, and the minimum thickness, t_D, shall at least equal t times the ratio of minimum specified yield strength of pipe and flange, but not to exceed 1.5t.

(a) Neither t_1, t_2, nor $t_1 + t_2$ shall exceed 0.5t.

FIGURE 1 — ACCEPTABLE DESIGNS FOR UNEQUAL WALL THICKNESS(1)
(See Paragraph 5.3)

(1) SUPPLEMENTARY FOOTNOTE: See ASME B31 Piping Codes for additional fabrication details.

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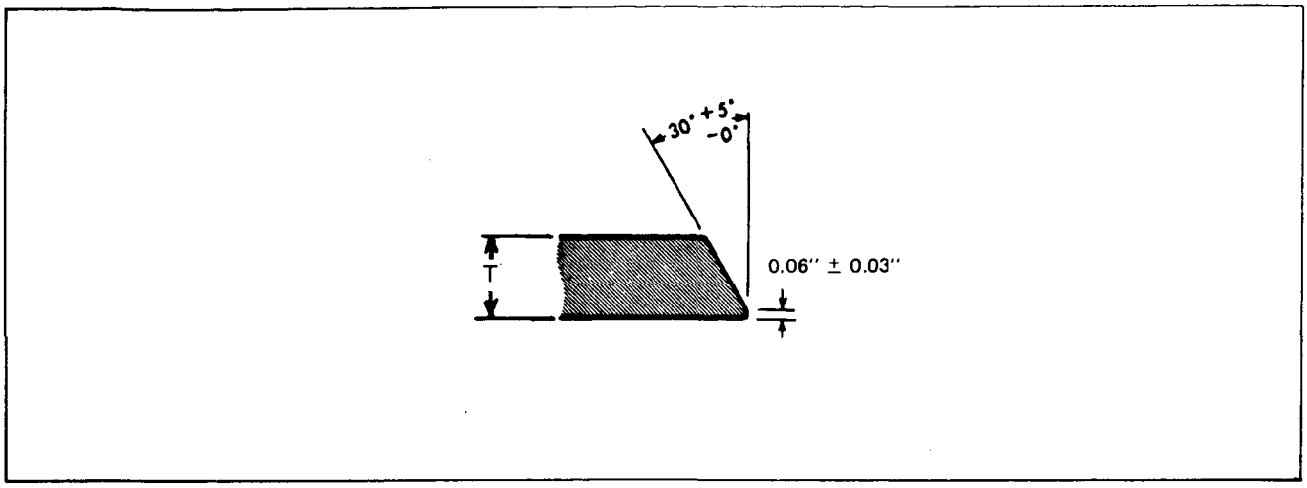

FIGURE 2 — BEVEL DETAIL FOR WALL THICKNESS (T) 0.88[a] OR LESS

NOTE: [a] Flange sizes 24 and smaller may be furnished with 37-½° bevel at option of manufacturer.

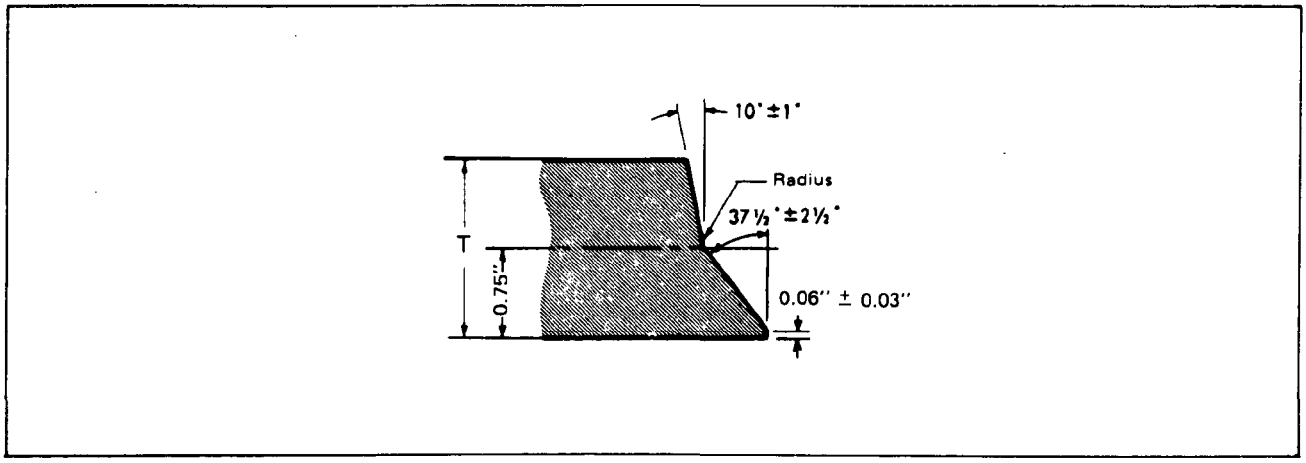

FIGURE 3 — BEVEL DETAIL FOR WALL THICKNESS (T) GREATER THAN 0.88

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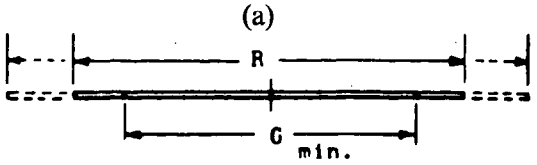

TABLE 4 — SHEET GASKET DIMENSIONS Dimensions in inches

NOM. PIPE SIZE	O.D. GASKET R[(a)]	I. D. GASKET G MIN.				
		150	300	400	600	900
12	15.00	12.75	12.75	12.75	12.75	12.75
14	16.25	14.00	14.00	14.00	14.00	14.00
16	18.50	16.00	16.00	16.00	16.00	16.00
18	21.00	18.00	18.00	18.00	18.00	18.00
20	23.00	20.00	20.00	20.00	20.00	20.00
22	25.25	22.00	22.00	22.00	22.00	–
24	27.25	24.00	24.00	24.00	24.00	24.00
26	29.50	26.00	27.62	27.00	26.62	26.38
28	31.50	28.00	29.50	28.88	28.38	28.38
30	33.75	30.00	31.62	30.88	30.38	30.38
32	36.00	32.00	33.75	33.00	32.50	32.38
34	38.00	34.00	35.62	34.88	34.25	34.38
36	40.25	36.00	37.62	36.88	36.25	36.38
38	Same as O.D. of Raised Face, R, in Tables 6, 7, 8, 9 & 10	38.00	38.00	37.75	37.50	37.00
40		40.00	40.00	39.75	39.50	39.00
42		42.00	42.00	41.75	41.50	41.00
44		44.00	44.00	43.75	43.50	43.00
46		46.00	46.00	45.75	45.50	45.00
48		48.00	48.00	47.75	47.50	47.00
50		50.00	50.00	49.62	49.25	–
52		52.00	52.00	51.62	51.25	–
54		54.00	54.00	53.62	53.25	–
56		56.00	56.00	55.62	55.25	–
58		58.00	58.00	57.62	57.25	–
60		60.00	60.00	59.62	59.25	–

NOTE: [(a)] Outside Diameter R may be made to fit the inside diameter of the bolts to act as a locating device when making a joint in the field, however, in no case should the contact area of the gasket be increased by changing the diameter of the raised face on the flange.

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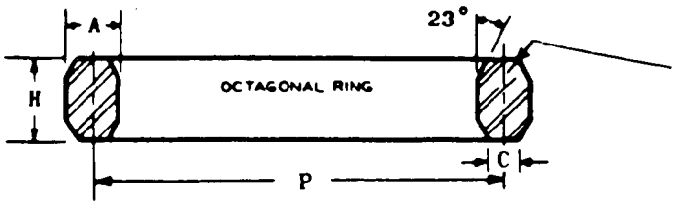

Radius
0.06 in. for ring widths 0.88 in. and smaller;
0.09 in. for ring widths 1 in. and larger.

TABLE 5 — RING-JOINT GASKET DIMENSIONS [1]

Dimensions in inches

CLASS 300,400, AND 600						CLASS 900				
Nominal Pipe Size	Pitch Dia. of Ring P	Width of Ring A	Height of Octagonal Ring H	Oct. Ring Flat C	Ring No.	Pitch Dia. of Ring P	Width of Ring A	Height of Octagonal Ring H	Oct. Ring Flat C	Ring No.
12	15.000	0.438	0.625	0.305	R57	15.000	0.438	0.625	0.305	R57
14	16.500	0.438	0.625	0.305	R61	16.500	0.625	0.812	0.413	R62
16	18.500	0.438	0.625	0.305	R65	18.500	0.625	0.812	0.413	R66
18	21.000	0.438	0.625	0.305	R69	21.000	0.750	0.938	0.485	R70
20	23.000	0.500	0.688	0.341	R73	23.000	0.750	0.938	0.485	R74
22	25.000	0.562	0.750	0.377	R81	———	———	———	———	———
24	27.250	0.625	0.812	0.413	R77	27.250	1.000	1.250	0.681	R78
26	29.500	0.750	0.938	0.485	R93	29.500	1.125	1.375	0.780	R100
28	31.500	0.750	0.938	0.485	R94	31.500	1.250	1.500	0.879	R101
30	33.750	0.750	0.938	0.485	R95	33.750	1.250	1.500	0.879	R102
32	36.000	0.875	1.062	0.583	R96	36.000	1.250	1.500	0.879	R103
34	38.000	0.875	1.062	0.583	R97	38.000	1.375	1.625	0.977	R104
36	40.250	0.875	1.062	0.583	R98	40.250	1.375	1.625	0.977	R105

SUPPLEMENTAL INFORMATION

NOTE: [1] For matching tolerances of ring-joint gasket dimensions, see ASME B16.20.
Ring-Joint Gaskets are not contemplated for size 38, and larger flanges.

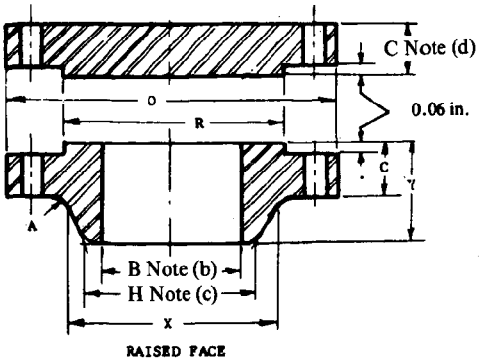

TABLE 6 — CLASS 150, 285 PSI AT ATMOSPHERIC TEMPERATURE RAISED FACE[a]

Dimensions in inches

PIPE SIZE	FLANGE DIMENSIONS			HUB DIMENSIONS	DRILLING			Raised Face Dia.	
	OD of Flange O	Thick. of Flange C (MIN)	Length Thru Hub Y	OD Large End Hub X	No. of Bolt Holes	Dia. of Bolt Holes	Dia. of Bolt Circle	R	Fillet Radius (MIN) A
12	19.00	1.25	4.50	14.38	12	1.00	17.00	15.00	0.38
14	21.00	1.38	5.00	15.75	12	1.12	18.75	16.25	0.38
16	23.50	1.44	5.00	18.00	16	1.12	21.25	18.50	0.38
18	25.00	1.56	5.50	19.88	16	1.25	22.75	21.00	0.38
20	27.50	1.69	5.69	22.00	20	1.25	25.00	23.00	0.38
22	29.50	1.81	5.88	24.00	20	1.38	27.25	25.25	0.38
24	32.00	1.88	6.00	26.12	20	1.38	29.50	27.25	0.38
26	34.25	2.69	4.75	26.62	24	1.38	31.75	29.50	0.38
28	36.50	2.81	4.94	28.62	28	1.38	34.00	31.50	0.44
30	38.75	2.94	5.38	30.75	28	1.38	36.00	33.75	0.44
32	41.75	3.18	5.69	32.75	28	1.62	38.50	36.00	0.44
34	43.75	3.25	5.88	34.75	32	1.62	40.50	38.00	0.50
36	46.00	3.56	6.19	36.75	32	1.62	42.75	40.25	0.50
38	48.75	3.44	6.19	39.00	32	1.62	45.25	42.25	0.50
40	50.75	3.56	6.44	41.00	36	1.62	47.25	44.25	0.50
42	53.00	3.81	6.75	43.00	36	1.62	49.50	47.00	0.50
44	55.25	4.00	7.00	45.00	40	1.62	51.75	49.00	0.50
46	57.25	4.06	7.31	47.12	40	1.62	53.75	51.00	0.50
48	59.50	4.25	7.56	49.12	44	1.62	56.00	53.50	0.50
50	61.75	4.38	8.00	51.25	44	1.88	58.25	55.50	0.50
52	64.00	4.56	8.25	53.25	44	1.88	60.50	57.50	0.50
54	66.25	4.75	8.50	55.25	44	1.88	62.75	59.50	0.50
56	68.75	4.88	9.00	57.38	48	1.88	65.00	62.00	0.50
58	71.00	5.06	9.25	59.38	48	1.88	67.25	64.00	0.50
60	73.00	5.19	9.44	61.38	52	1.88	69.25	66.00	0.50

General Notes:

For matching tolerances see Section 10.

For matching end detail see Figures 1, 2 and 3.

(a) Rating for raised face flanges is predicated on the use of sheet gaskets shown in Table 2.

(b) Dimensions to be specified by customer.

(c) See Section 5.

(d) Where calculated blind thickness is less than the mating welding neck, the thicknesses were made equal. See paragraph 5.5 for material requirements.

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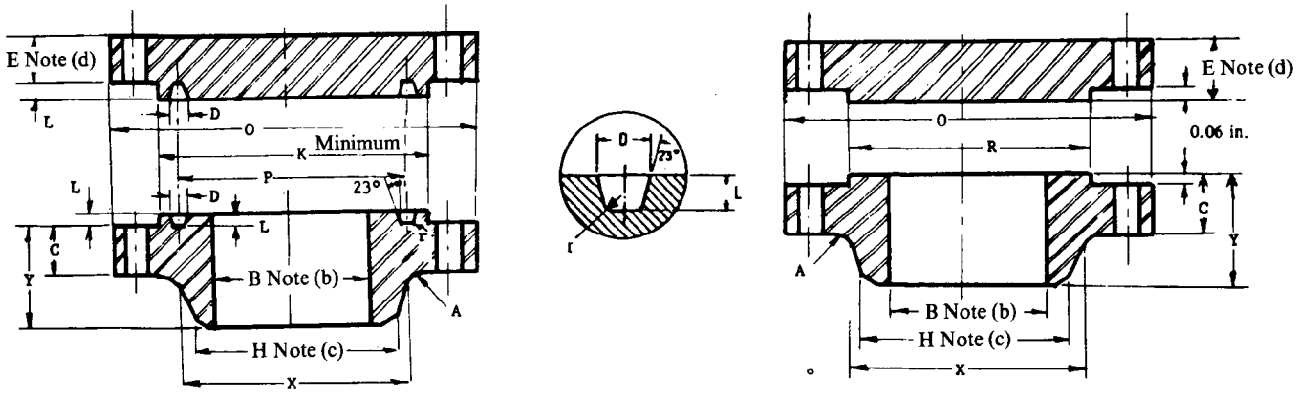

RING-TYPE JOINT RAISED FACE

TABLE 7 — CLASS 300, 740 PSI AT ATMOSPHERIC TEMPERATURE RAISED FACE[a] AND RING-TYPE JOINTS

Dimensions in inches

Pipe Size	FLANGE DIMENSIONS				HUB DIM.	DRILLING			FACING DIMENSIONS						Fillet Radius (min)	Groove Fillet Radius
	OD of Flange	Thick of Flange: Weld-Neck	Thick of Flange: (d) Bld. Flg.	Length Thru Hub	OD[e] Large End Hub	No. of Bolt Holes	Dia. of Bolt Holes	Dia. of Bolt Circle	Raised Face Dia.	Ring-Type Joint: Facing Dia.	Ring-Type Joint: Depth of Groove	Ring-Type Joint: Ptich Dia.	Ring-Type Joint: Width of Groove	Ring-Type Joint: Ring No.		
	O	C	E	Y	X				R	K	L	P	D		A	r
12	20.50	2.00	2.00	5.12	14.75	16	1.25	17.75	15.00	16.25	0.312	15.000	0.469	R57	0.38	0.03
14	23.00	2.12	2.12	5.62	16.75	20	1.25	20.25	16.25	18.00	0.312	16.500	0.469	R61	0.38	0.03
16	25.50	2.25	2.25	5.75	19.00	20	1.38	22.50	18.50	20.00	0.312	18.500	0.469	R65	0.38	0.03
18	28.00	2.38	2.38	6.25	21.00	24	1.38	24.75	21.00	22.62	0.312	21.000	0.469	R69	0.38	0.03
20	30.50	2.50	2.50	6.38	23.12	24	1.38	27.00	23.00	25.00	0.375	23.000	0.531	R73	0.38	0.06
22	33.00	2.62	2.62	6.50	25.25	24	1.62	29.25	25.25	27.00	0.438	25.000	0.594	R81	0.38	0.06
24	36.00	2.75	2.75	6.62	27.62	24	1.62	32.00	27.25	29.50	0.438	27.250	0.656	R77	0.38	0.06
26	38.25	3.12	3.31	7.25	28.38	28	1.75	34.50	29.50	31.88	0.500	29.500	0.781	R93	0.38	0.06
28	40.75	3.38	3.56	7.75	30.50	28	1.75	37.00	31.50	33.88	0.500	31.500	0.781	R94	0.44	0.06
30	43.00	3.62	3.75	8.25	32.56	28	1.88	39.25	33.75	36.12	0.500	33.750	0.781	R95	0.44	0.06
32	45.25	3.88	3.94	8.75	34.69	28	2.00	41.50	36.00	38.75	0.562	36.000	0.906	R96	0.44	0.06
34	47.50	4.00	4.12	9.12	36.88	28	2.00	43.50	38.00	40.75	0.562	38.000	0.906	R97	0.50	0.06
36	50.00	4.12	4.38	9.50	39.00	32	2.12	46.00	40.25	43.00	0.562	40.250	0.906	R98	0.50	0.06
38	46.00	4.25	4.25	7.12	39.12	32	1.62	43.00	40.50	—	—	—	—	—	0.50	—
40	48.75	4.50	4.50	7.62	41.25	32	1.75	45.50	42.75	—	—	—	—	—	0.50	—
42	50.75	4.69	4.69	7.88	43.25	32	1.75	47.50	44.75	—	—	—	—	—	0.50	—
44	53.25	4.88	4.88	8.12	45.25	32	1.88	49.75	47.00	—	—	—	—	—	0.50	—
46	55.75	5.06	5.06	8.50	47.38	28	2.00	52.00	49.00	—	—	—	—	—	0.50	—
48	57.75	5.25	5.25	8.81	49.38	32	2.00	54.00	51.25	—	—	—	—	—	0.50	—
50	60.25	5.50	5.50	9.12	51.38	32	2.12	56.25	53.50	—	—	—	—	—	0.50	—
52	62.25	5.69	5.69	9.38	53.38	32	2.12	58.25	55.50	—	—	—	—	—	0.50	—
54	65.25	6.00	6.00	9.94	55.50	28	2.38	61.00	57.75	—	—	—	—	—	0.50	—
56	67.25	6.06	6.06	10.25	57.62	28	2.38	63.00	59.75	—	—	—	—	—	0.50	—
58	69.25	6.25	6.25	10.50	59.62	32	2.38	65.00	62.00	—	—	—	—	—	0.50	—
60	71.25	6.44	6.44	10.75	61.62	32	2.38	67.00	64.00	—	—	—	—	—	0.50	—

General Notes:

For matching tolerances see Section 10.

For welding end detail see Figures 1, 2 and 3.

Notes: (a) Rating for raised face flanges is predicated on the use of sheet gaskets shown in Table 2.

(b) Dimensions to be specified by customer.

(c) See Section 5.

(d) Where calculated blind thickness is less than the mating welding neck, the thicknesses were made equal. See paragraph 5.5 for material requirements.

(e) Hub dimension for Size 24 and smaller flanges may vary as explained in paragraph 5.3.2.

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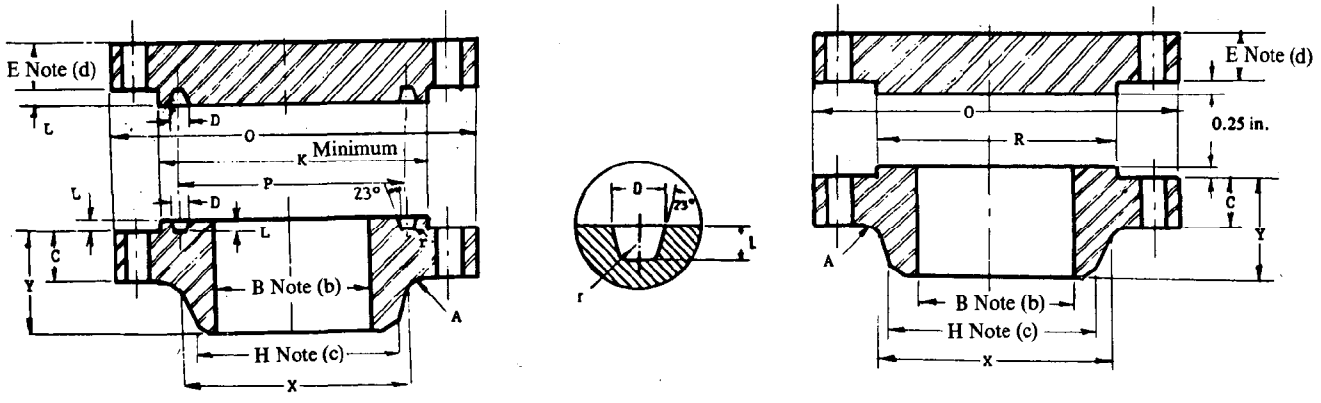

RING-TYPE JOINT

RAISED FACE

TABLE 8 — CLASS 400, 990 PSI AT ATMOSPHERIC TEMPERATURE RAISED FACE[a] AND RING-TYPE JOINTS

Dimensions in inches

Pipe Size	FLANGE DIMENSIONS				HUB DIM.	DRILLING			FACING DIMENSIONS								
	OD of Flange	THICK OF FLANGE		Length Thru Hub	OD Large[e] End Hub	No. of Bolt Holes	Dia. of Bolt Holes	Dia. of Bolt Circle	Raised Face Dia.	RING-TYPE JOINT					Fillet Radius (min.)	Groove Fillet Radius
		Weld-Neck	Bld. Flg.[d]							Facing Dia.	Depth of Groove	Pitch Dia.	Width of Groove	Ring No.		
	O	C	E	Y	X				R	K	L	P	D		A	r
12	20.50	2.25	2.25	5.38	14.75	16	1.38	17.75	15.00	16.25	0.312	15.000	0.469	R57	0.44	0.03
14	23.00	2.38	2.38	5.88	16.75	20	1.38	20.25	16.25	18.00	0.312	16.500	0.469	R61	0.44	0.03
16	25.50	2.50	2.50	6.00	19.00	20	1.50	22.50	18.50	20.00	0.312	18.500	0.469	R65	0.44	0.03
18	28.00	2.62	2.62	6.50	21.00	24	1.50	24.75	21.00	22.62	0.312	21.000	0.469	R69	0.44	0.03
20	30.50	2.75	2.75	6.62	23.12	24	1.62	27.00	23.00	25.00	0.375	23.000	0.531	R73	0.44	0.06
22	33.00	2.88	2.88	6.75	25.25	24	1.75	29.25	25.25	27.00	0.438	25.000	0.594	R81	0.44	0.06
24	36.00	3.00	3.00	6.88	27.62	24	1.88	32.00	27.25	29.50	0.438	27.250	0.656	R77	0.44	0.06
26	38.25	3.50	3.88	7.62	28.62	28	1.88	34.50	29.50	31.88	0.500	29.500	0.781	R93	0.44	0.06
28	40.75	3.75	4.12	8.12	30.81	28	2.00	37.00	31.50	33.88	0.500	31.500	0.781	R94	0.50	0.06
30	43.00	4.00	4.38	8.62	32.94	28	2.12	39.25	33.75	36.12	0.500	33.750	0.781	R95	0.50	0.06
32	45.25	4.25	4.56	9.12	35.00	28	2.12	41.50	36.00	38.75	0.562	36.000	0.906	R96	0.50	0.06
34	47.50	4.38	4.81	9.50	37.19	28	2.12	43.50	38.00	40.75	0.562	38.000	0.906	R97	0.56	0.06
36	50.00	4.50	5.06	9.88	39.38	32	2.12	46.00	40.25	43.00	0.562	40.250	0.906	R98	0.56	0.06
38	47.50	4.88	4.88	8.12	39.50	32	1.88	44.00	40.75	———	———	———	———	———	0.56	———
40	50.00	5.12	5.12	8.50	41.50	32	2.00	46.25	43.00	———	———	———	———	———	0.56	———
42	52.00	5.25	5.25	8.81	43.62	32	2.00	48.25	45.00	———	———	———	———	———	0.56	———
44	54.50	5.50	5.50	9.19	45.62	32	2.12	50.50	47.25	———	———	———	———	———	0.56	———
46	56.75	5.75	5.75	9.62	47.75	36	2.12	52.75	49.50	———	———	———	———	———	0.56	———
48	59.50	6.00	6.00	10.12	49.88	28	2.38	55.25	51.50	———	———	———	———	———	0.56	———
50	61.75	6.19	6.25	10.56	52.00	32	2.38	57.50	53.62	———	———	———	———	———	0.56	———
52	63.75	6.38	6.44	10.88	54.00	32	2.38	59.50	55.62	———	———	———	———	———	0.56	———
54	67.00	6.69	6.75	11.38	56.12	28	2.62	62.25	57.88	———	———	———	———	———	0.56	———
56	69.00	6.88	6.94	11.75	58.25	32	2.62	64.25	60.12	———	———	———	———	———	0.56	———
58	71.00	7.00	7.12	12.06	60.25	32	2.62	66.25	62.12	———	———	———	———	———	0.56	———
60	74.25	7.31	7.44	12.56	62.38	32	2.88	69.00	64.38	———	———	———	———	———	0.56	———

General Notes:

For matching tolerances see Section 10.

For welding end detail see Figures 1, 2 and 3.

Notes: (a) Rating for raised face flanges is predicated on the use of sheet gaskets shown in Table 2.

(b) Dimensions to be specified by customer.

(c) See Section 5.

(d) Where calculated blind thickness is less than the mating welding neck, the thicknesses were made equal. See paragraph 5.5 for material requirements.

(e) Hub dimension for Size 24 and smaller flanges may vary as explained in paragraph 5.3.2.

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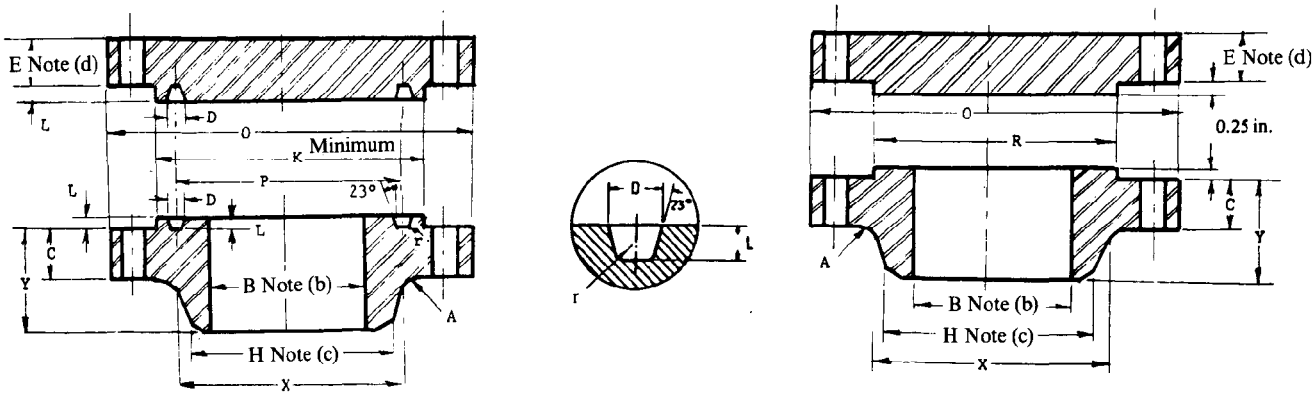

RING-TYPE JOINT RAISED FACE

TABLE 9 — CLASS 600, 1480 PSI AT ATMOSPHERIC TEMPERATURE RAISED FACE[a] AND RING-TYPE JOINTS

Dimensions in inches

Pipe Size	FLANGE DIMENSIONS				HUB DIM.	DRILLING			FACING DIMENSIONS						Fillet Radius (min)	Groove Fillet Radius
	OD of Flange	THICK. OF FLAN. Weld-Neck	THICK. OF FLAN. Bld. Flg.(d)	Length Thru Hub	(e) OD Large End Hub	No. of Bolt Holes	Dia. of Bolt Holes	Dia. of Bolt Circle	Raised Face Dia.	RING-TYPE JOINT Facing Dia.	Depth of Groove	Pitch Dia.	Width of Groove	Ring No.		
	O	C	E	Y	X				R	K	L	P	D		A	r
12	22.00	2.62	2.62	6.12	15.75	20	1.38	19.25	15.00	16.25	0.312	15.000	0.469	R57	0.44	0.03
14	23.75	2.75	2.75	6.50	17.00	20	1.50	20.75	16.25	18.00	0.312	16.500	0.469	R61	0.44	0.03
16	27.00	3.00	3.00	7.00	19.50	20	1.62	23.75	18.50	20.00	0.312	18.500	0.469	R65	0.44	0.03
18	29.25	3.25	3.25	7.25	21.50	20	1.75	25.75	21.00	22.62	0.312	21.000	0.469	R69	0.44	0.03
20	32.00	3.50	3.50	7.50	24.00	24	1.75	28.50	23.00	25.00	0.375	23.000	0.531	R73	0.44	0.06
22	34.25	3.75	3.75	7.75	26.25	24	1.88	30.62	25.25	27.00	0.438	25.000	0.594	R81	0.44	0.06
24	37.00	4.00	4.00	8.00	28.25	24	2.00	33.00	27.25	29.50	0.438	27.250	0.656	R77	0.44	0.06
26	40.00	4.25	4.94	8.75	29.44	28	2.00	36.00	29.50	31.88	0.500	29.500	0.781	R93	0.50	0.06
28	42.25	4.38	5.19	9.25	31.62	28	2.12	38.00	31.50	33.88	0.500	31.500	0.781	R94	0.50	0.06
30	44.50	4.50	5.50	9.75	33.94	28	2.12	40.25	33.75	36.12	0.500	33.750	0.781	R95	0.50	0.06
32	47.00	4.62	5.81	10.25	36.12	28	2.38	42.50	36.00	38.75	0.562	36.000	0.906	R96	0.50	0.06
34	49.00	4.75	6.06	10.62	38.31	28	2.38	44.50	38.00	40.75	0.562	38.000	0.906	R97	0.56	0.06
36	51.75	4.88	6.38	11.12	40.62	28	2.62	47.00	40.25	43.00	0.562	40.250	0.906	R98	0.56	0.06
38	50.00	6.00	6.12	10.00	40.25	28	2.38	45.75	41.50	----	----	----	----	----	0.56	----
40	52.00	6.25	6.38	10.38	42.25	32	2.38	47.75	43.75	----	----	----	----	----	0.56	----
42	55.25	6.62	6.75	11.00	44.38	28	2.62	50.50	46.00	----	----	----	----	----	0.56	----
44	57.25	6.81	7.00	11.38	46.50	32	2.62	52.50	48.25	----	----	----	----	----	0.56	----
46	59.50	7.06	7.31	11.81	48.62	32	2.62	54.75	50.25	----	----	----	----	----	0.56	----
48	62.75	7.44	7.69	12.44	50.75	32	2.88	57.50	52.50	----	----	----	----	----	0.56	----
50	65.75	7.75	8.00	12.94	52.88	28	3.12	60.00	54.50	----	----	----	----	----	0.56	----
52	67.75	8.00	8.25	13.25	54.88	32	3.12	62.00	56.50	----	----	----	----	----	0.56	----
54	70.00	8.25	8.56	13.75	57.00	32	3.12	64.25	58.75	----	----	----	----	----	0.56	----
56	73.00	8.56	8.88	14.25	59.12	32	3.38	66.75	60.75	----	----	----	----	----	0.62	----
58	75.00	8.75	9.12	14.56	61.12	32	3.38	68.75	63.00	----	----	----	----	----	0.62	----
60	78.50	9.19	9.56	15.31	63.38	28	3.62	71.75	65.25	----	----	----	----	----	0.69	----

General Notes:

For matching tolerances see Section 10.

For welding end detail see Figures 1, 2 and 3.

Notes: (a) Rating for raised face flanges is predicated on the use of sheet gaskets shown in Table 2.

(b) Dimensions to be specified by customer.

(c) See Section 5.

(d) Where calculated blind thickness is less than the mating welding neck, the thicknesses were made equal. See paragraph 5.5 for material requirements.

(e) Hub dimension for Size 24 and smaller flanges may vary as explained in paragraph 5.3.2.

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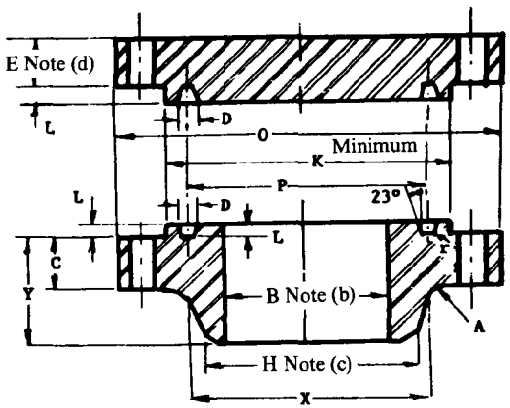
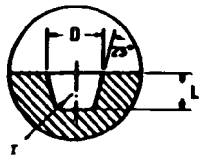
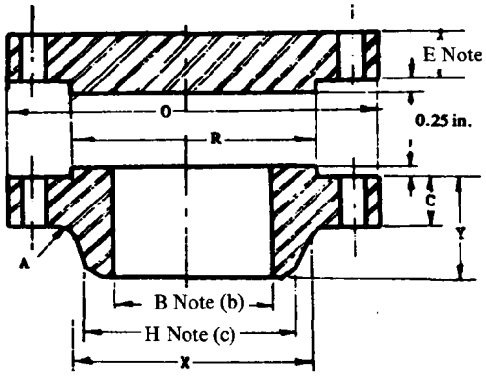


RING-TYPE JOINT





RAISED FACE

TABLE 10 — CLASS 900, 2220 PSI AT ATMOSPHERIC TEMPERATURE RAISED FACE[a] AND RING-TYPE JOINTS Dimensions in inches

Pipe Size	FLANGE DIMENSIONS				HUB DIM.	DRILLING			FACING DIMENSIONS							
	OD of Flange	THICK OF FLANGE		Length Thru Hub	OD Large [e] End Hub	No. of Bolt Holes	Dia. of Bolt Holes	Dia. of Bolt Circle	Raised Face Dia.	RING-TYPE JOINT					Fillet Radius (min)	Groove Fillet Radius
		Weld-Neck	Bld. Flg. [d]							Facing Dia.	Depth of Groove	Pitch Dia.	Width of Groove	Ring No.		
	O	C	E	Y	X				R	K	L	P	D		A	r
12	24.00	3.12	3.12	7.88	16.50	20	1.50	21.00	15.00	16.50	0.312	15.000	0.469	R57	0.44	0.03
14	25.25	3.38	3.38	8.38	17.75	20	1.62	22.00	16.25	18.38	0.438	16.500	0.656	R62	0.44	0.06
16	27.75	3.50	3.50	8.50	20.00	20	1.75	24.25	18.50	20.62	0.438	18.500	0.656	R66	0.44	0.06
18	31.00	4.00	4.00	9.00	22.25	20	2.00	27.00	21.00	23.38	0.500	21.000	0.781	R70	0.44	0.06
20	33.75	4.25	4.25	9.75	24.50	20	2.12	29.50	23.00	25.50	0.500	23.000	0.781	R74	0.44	0.06
24	41.00	5.50	5.50	11.50	29.50	20	2.62	35.50	27.25	30.38	0.625	27.250	1.062	R78	0.44	0.09
26	42.75	5.50	6.31	11.25	30.50	20	2.88	37.50	29.50	32.75	0.688	29.500	1.188	R100	0.44	0.09
28	46.00	5.62	6.75	11.75	32.75	20	3.12	40.25	31.50	35.00	0.688	31.500	1.312	R101	0.50	0.09
30	48.50	5.88	7.18	12.25	35.00	20	3.12	42.75	33.75	37.25	0.688	33.750	1.312	R102	0.50	0.09
32	51.75	6.25	7.62	13.00	37.25	20	3.38	45.50	36.00	39.50	0.688	36.000	1.312	R103	0.50	0.09
34	55.00	6.50	8.06	13.75	39.62	20	3.62	48.25	38.00	42.00	0.812	38.000	1.438	R104	0.56	0.09
36	57.50	6.75	8.44	14.25	41.88	20	3.62	50.75	40.25	44.25	0.812	40.250	1.438	R105	0.56	0.09
38	57.50	7.50	8.50	13.88	42.25	20	3.62	50.75	43.25	—	—	—	—	—	0.75	—
40	59.50	7.75	8.81	14.31	44.38	24	3.62	52.75	45.75	—	—	—	—	—	0.81	—
42	61.50	8.12	9.12	14.62	46.31	24	3.62	54.75	47.75	—	—	—	—	—	0.81	—
44	64.88	8.44	9.56	15.38	48.62	24	3.88	57.62	50.00	—	—	—	—	—	0.88	—
46	68.25	8.88	10.06	16.18	50.88	24	4.12	60.50	52.50	—	—	—	—	—	0.88	—
48	70.25	9.19	10.38	16.50	52.88	24	4.12	62.50	54.50	—	—	—	—	—	0.94	—

General Notes:

For matching tolerances see Section 10.

For welding end detail see Figures 1, 2 and 3.

Notes: [a] Rating for raised face flanges is predicated on the use of sheet gaskets shown in Table 2.

[b] Dimensions to be specified by customer.

[c] See Section 5.

[d] Where calculated blind thickness is less than the mating welding neck, the thicknesses were made equal. See paragraph 5.5 for material requirements.

[e] Hub dimension for Size 24 and smaller flanges may vary as explained in paragraph 5.3.2.

TABLE 11 — PERMISSABLE IMPERFECTIONS IN FLANGE FACING FINISH[a]

NPS	MAXIMUM RADIAL[b] PROJECTION OF IMPERFECTIONS WHICH ARE NO DEEPER THAN THE BOTTOM OF THE SERRATIONS, IN.	MAXIMUM DEPTH AND RADIAL PROJECTION OF IMPERFECTIONS WHICH ARE DEEPER THAN THE BOTTOM OF THE SERRATIONS, IN.
12 - 14	0.31	0.18
16	0.38	0.18
18 - 24	0.50	0.25
26 - 36	0.50	0.25
38 - 48	0.56	0.28
50 - 60	0.62	0.31

NOTES: [a] Imperfections less than half the depth of the serrations shall not be cause for rejection. See paragraph 7.4.

[b] A radial projection shall be measured by the difference between an inner radius and an outer radius encompassing the imperfection where the radius is struck from the center line of the bore.

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ANNEX A

DESIGN CRITERIA

This Annex is an integral part of this Standard Practice which is placed after the main text for convenience.

These flanges were designed in accordance with the formula of paragraphs UA 45 - UA 59 (inclusive) of Section VIII Unfired Pressure Vessel, Division 1. (1950ed.) Currently, the equivalent paragraphs are found in Appendix 2 of ASME Section VIII Division 1. This Annex is presented as a description of the basis for this Standard. Any deviations from the dimensions, material, or provisions of this standard are the responsibility of the User/ Designer. The maximum allowable stresses were established as follows.

	SIZES 12-36 incl. ksi	SIZES 38-60 incl. ksi
Longitudinal Hub Stress	30	30
Radial Flange Stress	20	25
Tangential Flange Stress	20	25
Average Stress	20	25
Bolt Stress (2½" and Smaller)	20	25
Bolt Stress (Larger than 2½")		23

1. The suggested ASME Section VIII, Division 1 values of 3700 and 2.75 for Y and M factors of 0.06 in. thick, flat, asbestos ring gaskets were assumed.

2. The widths of the gaskets were established as those whose surface areas would be at least twice the new bolt area.

3. For the Class 300, 400, 600 and 900 flanges, the slope and the O.D. of the hub at the base are designed for welding ends having equivalent yield strength and thickness as those of the mating pipe. The wall thickness of the intended mating pipe was based upon API 5LX-52 with a 0.68 design factor for the NPS 26-36 sizes, and API 5LX-65 with 0.72 design factor for the NPS 38 and larger sizes. When the manufacturer of the NPS 26-36 sizes elects to utilize the alternative permitted in paragraph 5.3.1, or when the mating pipe has a minimum specified yield strength exceeding 65,000 psi, it will be necessary for him to recalculate the design in accordance with the requirements of paragraph 5.3.1.

4. The design of the 38 NPS and larger sizes of the 300 and higher classes of welding neck flanges is predicated upon the flange material having a minimum specified yield strength of at least 42,000 psi in the ring section of the flange and a minimum yield at the welding end at least equal to that specified for the mating pipe. When the yield strength of the welding end of the flange is less than specified, compensation in accordance with paragraph 5.3.1.b may be made, but the hub slope and diameter at larger end must be preserved.

5. The design of all sizes is predicated on the use of heat treated carbon steel bolt studs for Class 150 flanges and alloy steel bolt studs for Class 300, 400, 600, and 900 flanges. Bolt diameters shall be ⅛ in. less than the bolt hole sizes shown in the tables.

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ANNEX B
BLIND FLANGE DESIGN CRITERIA

This Annex is an integral part of this Standard Practice which is placed after the main text for convenience.

Blind flanges were designed in accordance with the formula of Paragraph UG34 of Section VIII (Pressure Vessels, Division 1) of the ASME Boiler and Pressure Vessel Code. The thicknesses listed in Tables 6, 7, 8, 9 and 10 were based on material having mechanical properties for Grade F36 of Table 1 with allowable stresses as listed below:

	SIZES 26-60
	KSI
Blind Flange Stress	26
	(1.5x17.5)

Where the calculated blind flange thickness is less than the mating welding neck, the thicknesses were made equal to the welding neck thicknesses.

Blind flanges may be produced using any of the higher strength grades of materials listed in Table 1. The thicknesses may then be reduced in accordance with the following formula, but in no case shall they be thinner than the corresponding welding neck flange:

$$E' = E \sqrt{\frac{60000}{UTS_F}}$$

where E' = Reduced blind flange thicknesses based on higher grade material.

$E^{(a)}$ = Present blind thickness based on F36 grade material (See Tables 6-10).

UTS_F = Tensile strength of higher grade material from Table 1.

Blinds produced to a thinner thickness from higher strength material should be identified in the marking with the higher grade material designation. All other marking required by Section 6 shall be included.

NOTE: [a] E' shall not be less than the corresponding welding neck flange thickness "C".

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ANNEX C
Referenced Standards and Applicable Dates

This Annex is an integral part of this Standard Practice which is placed after the main text for convenience.

ANSI, ANSI/ASME, ASME/ANSI, ASME

B1.1-1989	Unified Inch Screw Threads
B16.1-1989	Cast Iron Pipe Flanges and Flanged Fittings
B16.5-1988-92 add	Pipe Flanges and Flanged Fittings
B16.20-1993	Ring-Joint Gaskets and Grooves for Steel Pipe Flanges
B16.47-1990-92 add	Large Diameter Steel Flanges
B18.2.1-1981 (R 1992)	Square and Hex Bolts and Screws (Inch Series)
B18.2.2-1987 (R 1993)	Square and Hex Nuts (Inch Series)
B31.1-B31.8-1994	Code for Pressure Piping
B46.1-1985	Surface Texture, Surface Roughness, Waviness, and Lay

Boiler and Pressure Vessel Code 1992 Edition (including addendum)

ASTM

A 53-93a	Pipe, Steel, Black and Hot-Dipped, Zinc Coated, Welded and Seamless
A 105-92	Forgings, Carbon Steel, for Piping Components
A 106-93	Seamless Carbon Steel Pipe for High-Temperature Service
A 193-93a	Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
A 194-94a	Carbon and Alloy Steel Nuts for Bolts for High-Pressure
A 307-92a	Carbon Steel Bolts and Studs, 60,000 PSI Tensile
A 320-94a	Alloy Steel Bolting Materials for Low Temperature Service
A 350-93	Forgings, Carbon and Low Alloy Steel, Requiring Notch Toughness Testing for Piping Components
A 354-92a	Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
A 381-93	Metal-Arc-Welded Steel Pipe for Use with High-Pressure Transmission Systems
A 449-92	Quenched and Tempered Steel Bolts and Studs
A 453-92	Bolting Materials, High-Temperature, 50 to 120 ksi Yield Strength, With Expansion Coefficients. Comparable to Austenetic Steels.
A 540-92	Alloy-Steel Bolting Materials for Special Applications
A 694-93	Forgings, Carbon and Alloy Steel, for Pipe Flanges, Fittings, Valves, and Parts for High-Pressure Transmission Service
A 707-92	Flanges, Forged, Carbon and Alloy Steel for Low-Temperature Service

API

5L	Line Pipe, Thirty-Ninth Edition, May 1991

MSS

SP-9-1992	Spot Facing for Bronze, Iron and Steel Flanges
SP-25-1993	Standard Marking System for Valves, Fittings, Flanges and Unions

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ANNEX C
Referenced Standards (con't.)

Publications of the following organizations appear on the previous page:

ANSI	American National Standards Institute, Inc. 11 West 42nd Street, 13th floor, New York, NY 10036
API	American Petroleum Institute 1220 L Street, N.W., Washington, D.C. 20005-8029
ASME	The American Society of Mechanical Engineers 345 East 47th Street, New York, NY 10017-2392
ASTM	American Society for Testing and Materials 100 Barr Harbor Drive, West Conshohoken, PA 19428-2959
MSS	Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. 127 Park Street, N.E., Vienna, VA 22180-4602

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List of MSS Standard Practices
(Price List Available Upon Request)

Number	
SP-6-2001	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP-9-2001	Spot Facing for Bronze, Iron and Steel Flanges
SP-25-1998	Standard Marking System For Valves, Fittings, Flanges and Unions
SP-42-1999	Class 150 Corrosion Resistant Gate, Globe, Angle and Check Valves with Flanged and Butt Weld Ends
SP-43-1991	(R 01) Wrought Stainless Steel Butt-Welding Fittings
SP-44-1996	(R 01) Steel Pipeline Flanges
SP-45-1998	Bypass and Drain Connections
SP-51-2000	Class 150LW Corrosion Resistant Cast Flanges and Flanged Fittings
SP-53-1999	Quality Standard for Steel Castings and Forgings for Valves. Flanges and Fittings and Other Piping Componets - Magnetic Particle Examination Method
SP-54-1999	Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components - Radiographic Examination Method
SP-55-2001	Quality Standard for Steel Castings for Valves, Flanges, Fittings, and Other Piping Components - Visual Method for Evaluation of Surface Irregularities
SP-58-1993	Pipe Hangers and Supports - Materials, Design and Manufacture
SP-60-1999	Connecting Flange Joint Between Tapping Sleeves and Tapping Valves
SP-61-1999	Pressure Testing of Steel Valves
SP-65-1999	High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets
SP-67-1995	Butterfly Valves
SP-68-1997	High Pressure Butterfly Valves with Offset Design
SP-69-1996	Pipe Hangers and Supports - Selection and Application
SP-70-1998	Cast Iron Gate Valves, Flanged and Threaded Ends
SP-71-1997	Gray Iron Swing Check Valves, Flanged and Threaded Ends
SP-72-1999	Ball Valves with Flanged or Butt Welding Ends for General Service
SP-73-1991	(R 96) Brazing Joints for Wrought and Cast Copper Alloy Solder Joint Pressure Fittings
SP-75-1998	Specification for High Test Wrought Butt Welding Fittings
SP-77- 1995	(R 00) Guidelines for Pipe Support Contractual Relationships
SP-78-1998	Cast Iron Plug Valves, Flanged and Threaded Ends
SP-79-1999a	Socket-Welding Reducer Inserts
SP-80-1997	Bronze Gate, Globe, Angle and Check Valves
SP-81-2000	Stainless Steel, Bonnetless, Flanged, Knife Gate Valves
SP-82-1992	Valve Pressure Testing Methods
SP-83-1995	Class 3000 Steel Pipe Unions, Socket-Welding and Threaded
SP-85-1994	Cast Iron Globe & Angle Valves, Flanged and Threaded Ends
SP-86-1997	Guidelines for Metric Data in Standards for Valves, Flanges, Fittings and Actuators
SP-87-1991	(R 96) Factory-Made Butt-Welding Fittings for Class 1 Nuclear Piping Applications
SP-88-1993	(R 01) Diaphragm Valves
SP-89-1998	Pipe Hangars and Supports - Fabrication and Installation Practices
SP-90-2000	Guidelines on Terminology for Pipe Hangers and Supports
SP-91-1992	(R 96) Guidelines for Manual Operations of Valves
SP-92-1999	MSS Valve User Guide
SP-93-1999	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components-Liquid Penetrant Examination Method
SP-94-1999	Quality Std for Ferritic and Martensitic Steel Castings for Valves, Flanges, and Fittings and Other Piping Components-Ultrasonic Examination Method
SP-95-2000	Swage(d) Nipples and Bull Plugs
SP-96-1996	Guidelines on Terminology for Valves and Fittings
SP-97-1995	Integrally Reinforced Forged Branch Outlet Fittings-Socket Welding, Threaded and Buttwelding Ends
SP-98-2001	Protective Coatings for the Interior of Valves, Hydrants, and Fittings
SP-99-1994	(R 01) Instrument Valves
SP-100-1997	Qualification Requirements for Elastomer Diaphragms for Nuclear Diaphragm Type Valves
SP-101-1989	Part-Turn Valve Actuator Attachment-Flange and Driving Component Dimensions and Performance Characteristics
SP-102-1989	Multi-Turn Valve Actuator Attachment - Flange and Driving Component Dimensions and Performance Characteristics
SP-103-1995	(R 00) Wrought Copper and Copper Alloy Insert Fittings for Polybutylene Systems
SP-104-1995	Wrought Copper Solder Joint Pressure Fittings
SP-105-1996	(R 01) Instrument Valves for Code Applications
SP-106-1990	(R 96) Cast Copper Alloy Flanges and Flanged Fittings, Class 125, 150 and 300
SP-107-1991	(R 00) Transition Union Fittings for Joining Metal and Plastic Products
SP-108-1996	Resilient-Seated Cast Iron-Eccentric Plug Valves
SP-109-1997	Welded Fabricated Copper Solder Joint Pressure Fittings
SP-110-1996	Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
SP-111-2001	Gray-Iron and Ductile-Iron Tapping Sleeves
SP-112-1999	Quality Standard for Evaluation of Cast Surface Finishes - Visual and Tactile Method. This SP must be sold with a 10-surface, three dimensional Cast Surface Comparator, which is a necessary part of the Standard. Additional Comparators may be sold separately at $25.00 each. Same quantity discounts apply on total order.
SP-113-2001	Connecting Joint between Tapping Machines and Tapping Valves
SP-114-2001	Corrosion Resistant Pipe Fittings Threaded and Socket Welding, Class 150 and 1000
SP-115-1999	Excess Flow Valves for Natural Gas Service
SP-116-1996	Service Line Valves and Fittings for Drinking Water Systems
SP-117-1996	Bellows Seals for Globe and Gate Valves
SP-118-1996	Compact Steel Globe & Check Valves - Flanged, Flangeless, Threaded & Welding Ends (Chemical & Petroleum Refinery Service)
SP-119-1996	Belled End Socket Welding Fittings, Stainless Steel and Copper Nickel
SP-120-1997	Flexible Graphite Packing System for Rising Stem Steel Valves (Design Requirements)
SP-121-1997	Qualification Testing Methods for Stem Packing for Rising Stem Steel Valves
SP-122-1997	Plastic Industrial Ball Valves
SP-123-1998	Non-Ferrous Threaded and Solder-Joint Unions for Use With Copper Water Tube
SP-124-2001	Fabricated Tapping Sleeves
SP-125-2000	Gray Iron and Ductile Iron In-Line, Spring-Loaded, Center-Guided Check Valves
SP-126-2000	Steel In-Line Spring-Assisted Center Guided Check Valves
SP-127-2001	Bracing for Piping Systems Seismic-Wind-Dynamic Design, Selection, Application

(R YEAR) Indicates year standard reaffirmed without substantive changes

A large number of former MSS Practices have been approved by the ANSI or ANSI Standards, published by others. In order to maintain a single source of authoritative information, the MSS withdraws its Standard Practice in such cases.

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MSS SP-51-2000

Class 150LW Corrosion Resistant Flanges and Cast Flanged Fittings

Standard Practice
Developed and Approved by the
Manufacturers Standardization Society of the
Valve and Fittings Industry, Inc.
127 Park Street, N.E.
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This document has been substantively revised from the previous edition. It is suggested that if the user is interested in knowing what changes have been made, that direct page by page comparision should be made of this document with the 1995 edition.

Metric and U.S. Customary units are to be regarded separately as standard in this SP.

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FOREWORD

The subject matter of this Standard Practice was formerly a part of MSS SP-42, Corrosion Resistant Cast Flanged Valves, Flanges and Flanged Fittings. MSS SP-42 now covers valves only.

The 1978 revision of this Standard Practice was delayed beyond the normal review interval in consideration of extensive revisions being developed for SP-42. Following publication of the rewritten SP-42 1978, in which the flange thickness for most sizes were made the same as those in ANSI B16.5 Class 150, it was determined that a commercial need remained for flanges and flanged fittings of reduced weight, and that this standard should continue to serve that need. The committee decided, however, that pressure-temperature ratings should be reduced to limit pressure stresses to levels consistent with those applied in ANSI B16.5 Class 150 flanges. While pressure stresses are generally less significant than bolting and piping stresses in these flanges, the new ratings, in combination with the gasket selection recommended herein, serve to limit the assembly bolting loads required. It is intended that the reduction in ratings should substantially reduce the likelihood of misapplication of these flanges and fittings.

The 1982 and 1986 revisions of this SP were required to update the referenced standards list in Section 2.

The 1991 revision of this SP was required to update the reference standards list and delete the metric equivalents.

The 1995 reaffirmed edition of this Standard Practic was required to update the reference standards list and reaffirm the document.

The 2000 revision of this SP was required to incorporate standard metric dimensions, include forged and plate materials for flanges, and update reference standards.

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CLASS 150LW, CORROSION RESISTANT CAST FLANGES AND FLANGED FITTINGS

1. SCOPE

This Standard Practice covers a series of cast austenitic type stainless steel flanged fittings and cast and forged type austenitic stainless steel flanges of reduced weight with mating dimensions for assembly with ISO 7005-1, PN20 or ASME B16.5, Class 150 flanges, but identified as Class 150LW (Light Weight) and limited to use at reduced pressure-temperature ratings.

2. STANDARD UNITS

The values stated in either metric units or customary units are to be regarded separately as standard. Within the text, the inch units are shown in parentheses. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the standard. Class 150 and NPS are the standard descriptors for Pressure Class and Nominal Size for both metric and customary products covered under this standard practice. PN an DN are shown only for reference purposes.

Table 2 and 3 show fittings dimensional requirements in millimeters. Tables 4 and 5 show the dimensional requirements for inch dimensioned fittings.

3. PRESSURE TEMPERATURE RATINGS

Ratings for flanges and flanged fittings conforming to this standard are shown in Table 1.

TABLE 1
PRESSURE TEMPERATURE RATINGS

Temperature °C	Pressure Rating (Bar)
-29 to 38	6.9
50	6.8
100	6.1
150	5.5
200	4.9
260	4.1
Temperature °F	**Pressure Rating (psig)**
-20 to 100	100
200	90
300	80
400	70
500	60

4. MATERIALS

4.1 Cast Flanges and fittings may be made using materials conforming to the following specifications.

a) ASTM A351/A351M	Gr. CF8
b) ASTM A351/A351M	Gr. CF8M
c) ASTM A351/A351M	Gr. CF8C
d) ASTM A351/A351M	Gr. CF3
e) ASTM A351/A351M	Gr. CF3M
f) ASTM A351/A351M	Gr. CN7M

4.2 Flanges may also be made from forgings or plates (blind flanges only) conforming to the following specifications:

a) ASTM A182/A182M	Gr. F304
b) ASTM A182/A182M	Gr. F316
c) ASTM A182/A182M	Gr. F347
d) ASTM A240/A240M	Gr. F304
e) ASTM A240/A240M	Gr. F316
f) ASTM A240/A240M	Gr. F347
g) ASTM B 462	Gr. N08020
h) ASTM B 463	Gr. N08020

5. DESIGN

5.1 Flanges shall be flat faced with serrated finish in accordance with MSS SP-6.

5.2 Flange assembly with flange having raised face is not recommended. Raised face of mating flange should be removed.

5.3 Flanges should be spot faced in conformance with MSS SP-9 or back faced if necessary to meet maximum tolerance on thickness through bolt holes.

5.3.1 Spot facing or back facing shall not reduce the thickness of flange below minimum specified in Table 2 or Table 4.

5.4 Threads of threaded flanges shall conform to ANSI/ASME B1.20.1 Pipe Threads. Threads shall be concentric with the axis of the flange and variations in alignment shall not exceed 1 mm in 200 mm (1/16" per ft.)

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5.4.1 Threads shall be countersunk a distance not less than one-half the pitch of the thread at an angle approximately 45 deg. with the axis of the thread, to provide easy entrance in assembly and for protection of the thread. The chamfer shall be concentric with the thread, and shall be included in measurements of thread length.

5.4.2 Variations in threading shall be limited to one turn large or one turn small from the gaging notch when using working gages. The reference point for gaging is the starting end of the fitting or flange, providing the chamfer does not exceed the major diameter of the internal thread. When a chamfer on the internal thread exceeds this limit, the reference point becomes the last thread scratch on the chamfer cone.

5.5 Flanged fitting dimensions shall be in conformance with Table 3 or Table 5.

5.5 .1 Reducing fittings shall be designated as shown in Figure 1.

6. FITTING TOLERANCES

6.1 Inspection tolerances shall be as follows:

NPS	DN	Center to Face		Face to Face	
		mm	Inches	mm	Inches
1/4 to 10	8≤DN≤250	±1	±1/32	±2	±1/16
12	DN300	±2	±1/16	±3	±1/8

7. GASKETS

Full face gaskets are recommended.

Caution: Since flanges conforming to this Standard Practice are reduced in thickness as compared with standard ISO 7005-1, PN 20 and B16.5 Class 150 flanges, proper flange joint assembly is critically important for satisfactory performance. Gaskets should be selected from Group Number IA in Figure E1 of ASME B16.5.

8. MARKING

8.1 Products conforming with this Standard Practice shall be marked as shown:

a) Manufacturer's name or trademark	A B Co
b) Class designation	150LW
c) Material designation	CF8
d) Melt identification	12345
e) Size (NPS)	6

8.2 At the option of the manufacturer, products may be marked PN20LW or 150LW/PN20LW.

8.3 At the option of the manufacturer, products may be marked with size in DN or NPS/DN.

9. TESTS

Flanged fittings shall be hydrostatic shell tested at 10.3 Bar (150psi).

Flanges are not tested.

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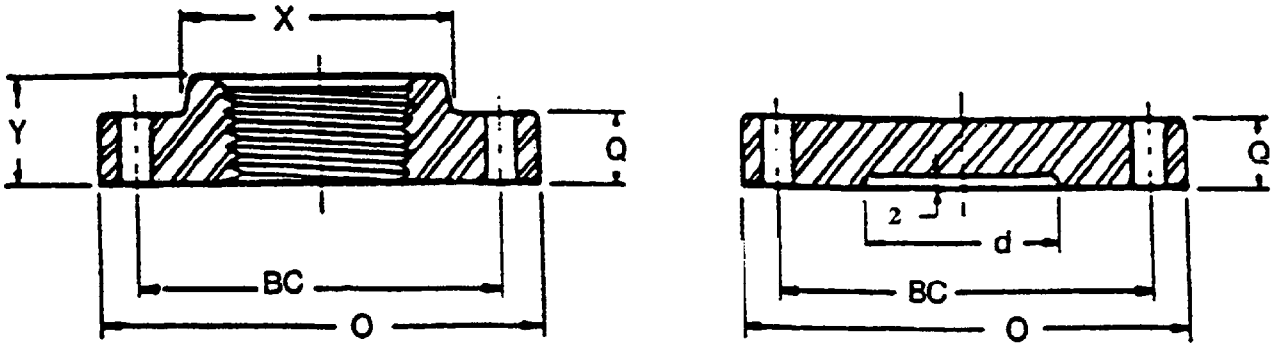

TABLE 2. CLASS 150LW (PN20LW) CORROSION RESISTANT FLANGES

NPS	DN	d Dia. Min. (b)	O Flange Diameter	Q Flange Thickness (Min) (a)	BC Bolt Circle (d)	No. of Bolts	Bolt Diameter (e)	Bolt Hole Diameter (c)	X Diameter of Hub (Min)	Y Length Overall
1/4	8	6	65	7.5	43	4	M10	11	22	10
3/8	10	9	65	7.5	43	4	M10	11	22	10
1/2	15	12	90	8	60.5	4	M14	16	30	16
3/4	20	19	100	9	70	4	M14	16	38	16
1	25	25	110	10	79.5	4	M14	16	49	17
1-1/4	32	31	120	10.5	89	4	M14	16	59	21
1-1/2	40	38	130	11.5	98.5	4	M14	16	65	22
2	50	50	150	13	120.5	4	M16	18	78	25
2-1/2	65	63	180	14.5	139.5	4	M16	18	90	29
3	80	76	190	16	152.5	4	M16	18	108	30
4	100	101	230	17.5	190.5	8	M16	18	135	33
6	150	152	280	21	241.5	8	M20	22	192	40
8	200	203	345	24	298.5	8	M20	22	246	44
10	250	254	405	25.5	362	12	M24	26	305	49
12	300	304	485	27	432	12	M24	26	365	56

GENERAL NOTE: Dimensions in mm.

(a) The "Flange Thickness (Min)" as shown in the table is the dimension from the back of flange to gasket contact face. Tolerance on thickness is + 2 for flanges NPS 1/4 through 1-1/4, + 3 for flanges NPS 1-1/2 through 12.

(b) Blind flanges are recessed 2 mm with a diameter equal to the inside diameter of the flanged fitting.

(c) When flanges are integral with fittings, holes for bolts shall be drilled to straddle the center line.

(d) Flange diameters and drilling templates, NPS 1/2 and larger, correspond to those specified in ISO7005-1, PN20 and ASME B16.5, Class 150.

(e) Inch bolts shown in Table 4 fit into the bolt holes shown for these flanges.

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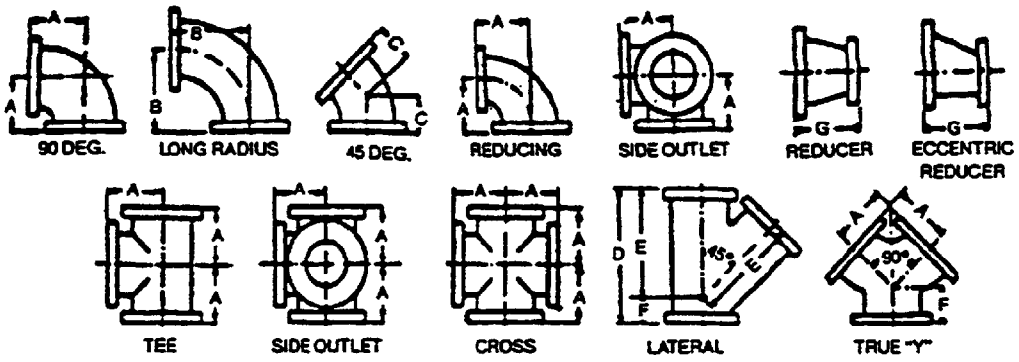

TABLE 3 . CLASS 150LW (PN20LW) CORROSION RESISTANT CAST FLANGED FITTINGS

NPS	DN	d Fitting ID (min.)	A Center to Face	AA Face to Face	B Center to Face	C Center to Face	D Face to Face	E Center to Face	F Center to Face	G Face to Face	T Min. Wall Thickness of Fitting
1/4	8	6	65	127	—	32	—	—	—	—	3.97
3/8	10	9	65	127	—	32	—	—	—	—	3.97
1/2	15	12	76	152	—	41	—	—	—	—	3.97
3/4	20	19	83	165	—	44	—	—	—	—	3.97
1	25	25	89	178	127	44	191	146	44	—	4.76
1-1/4	32	31	95	191	140	51	203	159	44	—	4.26
1-1/2	40	38	102	203	152	57	229	178	51	—	5.56
2	50	50	114	229	165	64	267	203	64	127	5.56
2-1/2	65	63	127	254	173	76	305	241	64	140	6.35
3	80	76	140	279	197	76	330	254	76	152	6.35
4	100	101	165	330	229	102	381	305	76	178	6.35
6	150	152	203	406	292	127	457	368	89	229	7.14
8	200	203	229	457	356	140	559	444	114	279	7.94
10	250	254	279	559	419	165	648	521	127	305	8.73
12	300	304	305	610	483	191	762	622	140	356	9.52

GENERAL NOTES

(a) Dimensions in mm.
(b) Side outlet elbows have all openings on intersecting center lines.
(c) Reducing fittings have same center-to-face and face-to-face dimensions as straight size fittings corresponding to the size of the largest opening.
(d) Reducers and eccentric reducers for all reductions have same face-to-face dimensions as listed in the table for the larger opening.
(e) Class 150LW corrosion resistant fittings in NPS 1 and larger have center-to-face dimesnsions and flange diameters corresponding to those specified in ASME B16.5, Class 150. Flange diameters and drilling templates, NPS 1/2 and larger, correspond to those specified in ISO7005-1, PN 20 and ASME B16.5, Class 150.
(f) See Table 2 for bolt hole requirements.
(g) Flange dimensions to be in accordance with Table 2.

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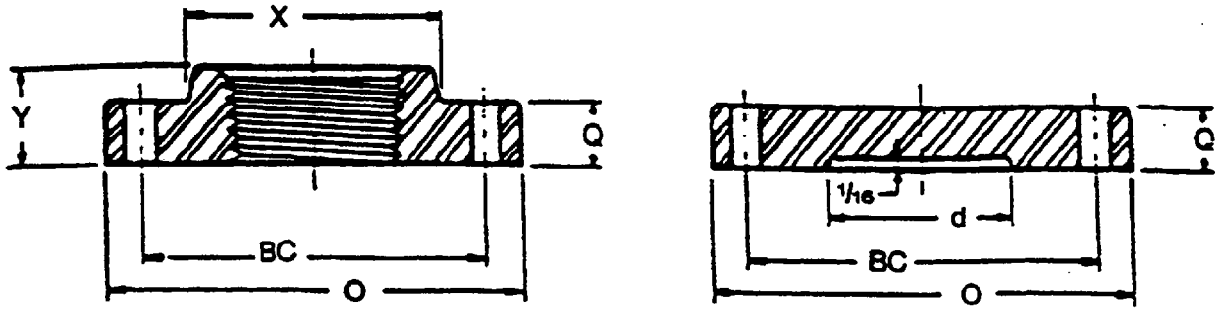

TABLE 4. CLASS 150LW CORROSION RESISTANT FLANGES

NPS	d Dia Min. (b)	O Flange Diameter	Q Flange Thickness (Min) (a)	BC Bolt Circle (d)	No. of Bolts	Bolt Diameter (e)	Bolt Hole Diameter (c)	X Diameter of Hub (Min)	Y Length Overall
1/4	0.25	2.50	0.28	1.69	4	3/8	0.44	0.88	0.38
3/8	0.38	2.50	0.28	1.69	4	3/8	0.44	0.88	0.38
1/2	0.50	3.50	0.31	2.38	4	1/2	0.62	1.19	0.59
3/4	0.75	3.88	0.34	2.75	4	1/2	0.62	1.50	0.62
1	1.00	4.25	0.38	3.12	4	1/2	0.62	1.94	0.69
1-1/4	1.25	4.62	0.41	3.50	4	1/2	0.62	2.31	0.81
1-1/2	1.50	5.00	0.44	3.88	4	1/2	0.62	2.56	0.88
2	2.00	6.00	0.50	4.75	4	5/8	0.75	3.06	1.00
2-1/2	2.50	7.00	0.56	5.50	4	5/8	0.75	3.56	1.12
3	3.00	7.50	0.62	6.00	4	5/8	0.75	4.25	1.19
4	4.00	9.00	0.69	7.50	8	5/8	0.75	5.31	1.31
6	6.00	11.00	0.81	9.50	8	3/4	0.88	7.56	1.56
8	8.00	13.50	0.94	11.75	8	3/4	0.88	9.69	1.75
10	10.00	16.00	1.00	14.25	12	7/8	1.00	12.00	1.94
12	12.00	19.00	1.06	17.00	12	7/8	1.00	14.38	2.19

GENERAL NOTE: Dimensions in mm.

(a) The "Flange Thickness (Min)" as shown in the table is the dimension from the back of flange to gasket contact face. Tolerance on thickness is + 1/16 for flanges NPS 1/4 through 1-1/4, + 1/8 for flanges NPS 1-1/2 through 12.

(b) Blind flanges are recessed 1/16 inch with a diameter equal to the inside diameter of the flanged fitting.

(c) When flanges are integral with fittings, holes for bolts shall be drilled to straddle the center line.

(d) Flange diameters and drilling templates, NPS 1/2 and larger, correspond to those specified in ASME B16.5, Class 150.

(e) Metric Bolts shown in Table 2 fit into the bolt holes shown for these flanges.

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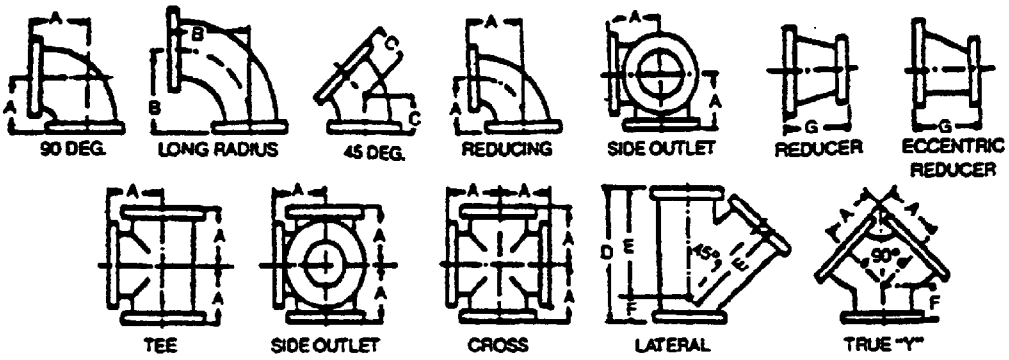

TABLE 5. CLASS 150LW (PN20LW) CORROSION RESISTANT CAST FLANGED FITTINGS

NPS	dDia. Fitting ID (Min)	A Center to Face	AA Face to Face	B Center to Face	C Center to Face	D Face to Face	E Center to Face	F Center to Face	G Face to Face	T Min. Wall Thickness of Fitting
1/4	0.25	2.50	5.00	—	1.25	—	—	—	—	.16
3/8	0.38	2.50	5.00	—	1.25	—	—	—	—	.16
1/2	0.50	3.00	6.00	—	1.62	—	—	—	—	.16
3/4	0.75	3.25	6.50	—	1.75	—	—	—	—	.16
1	1.00	3.50	7.00	5.00	1.75	7.50	5.75	1.75	—	.19
1-1/4	1.25	3.75	7.50	5.50	2.00	8.00	6.25	1.75	—	.19
1-1/2	1.50	4.00	8.00	6.00	2.25	9.00	7.00	2.00	—	.22
2	2.00	4.50	9.00	6.50	2.50	10.50	8.00	2.50	5.00	.22
2-1/2	2.50	5.00	10.00	7.00	3.00	12.00	9.50	2.50	5.50	.25
3	3.00	5.50	11.00	7.75	3.00	13.00	10.00	3.00	6.00	.25
4	4.00	6.50	13.00	9.00	4.00	15.00	12.00	3.00	7.00	.25
6	6.00	8.00	16.00	11.50	5.00	18.00	14.50	3.50	9.00	.28
8	8.00	9.00	18.00	14.00	5.50	22.00	17.50	4.50	11.00	.31
10	10.00	11.00	22.00	16.50	6.50	25.50	20.50	5.00	12.00	.34
12	12.00	12.00	24.00	19.00	7.50	30.00	24.50	5.50	14.00	.38

GENERAL NOTES

(a) Dimensions in inches.
(b) Side outlet elbows have all openings on intersecting center lines.
(c) Reducing fittings have same center-to-face and face-to-face dimensions as straight size fittings corresponding to the size of the largest opening.
(d) Reducers and eccentric reducers for all reductions have same face-to-face dimensions as listed in the table for the larger opening.
(e) Class 150LW corrosion resistant fittings in NPS 1 and larger have center-to-face dimesnsions, flange diameters and drilling templates corresponding to those specified in ASME B16.5, Class 150.
(f) See Table 4 for bolt hole requirements.
(g) Flange dimensions to be in accordance with Table 4.

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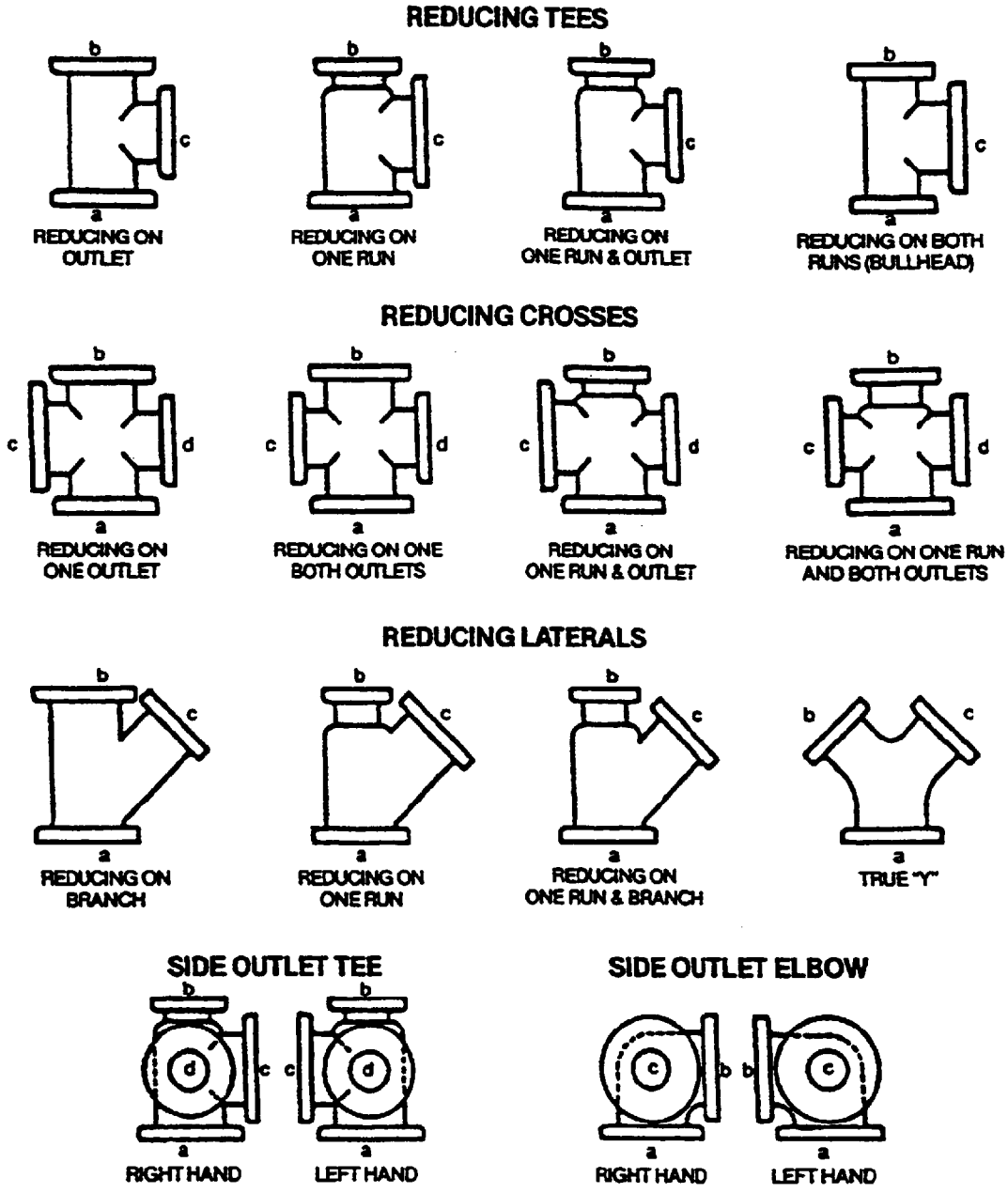

Method of Designating Outlets of Reducing Fittings
FIGURE 1

In designating the outlets of reducing fittings the openings should be read in the order indicated by the sequence of the letters, a, b, c, and d. In designating the outlets of side outlet reducing fittings, the side outlet is named last, and in the case of the side outlet cross (which is not shown), the side outlet is designated by the letter "o."

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ANNEX A
REFERENCED STANDARDS AND APPLICABLE DATES

This Annex is an integral part of this Standard Practice which is placed after the main text for convenience.

Standard Name or Designation

ASME, ANSI/ASME, ANSI, ASME/ANSI

B1.20.1-1983 (R 1992)	Pipe Threads, General Purpose (Inch)
B16.5-1996	Pipe Flanges and Flanged Fittings (NPS 1/2 through NPS 24)

ASTM

A182/182M-97c	Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service.
A240/A240M-97a	Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels.
A351/351M-94a	Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts
B462-96	Forged or Rolled UNS N08020, UNS N08024, AND UNS N08026, UNS N08367, and UNS R20033 Alloy Pipe Flanges, Forged Fittings, and Valve and Parts for Corrosive High-Temperature Service
B463-93	UNS N08020, UNS N08026, AND UNS N08024 Alloy Plate, Sheet and Strip.

ISO

7005-1:1992	Metallic flanges-Part1: Steel flanges

MSS

SP-6-1996	Standard Finishes for Contact Faces of Pipe Flanges and Connecting End Flanges of Valves and Fittings.
SP-9-1997	Spot Facing for Bronze, Iron and Steel Flanges.

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Publications of the following organizations appear in the above list.

ANSI	American National Standards Insitute, Inc. 11 West 42nd Street, 13th Floor, New York, NY 10036
ASME	ASME International Three Park Ave., New York, NY 10016-5990
ASTM	American Society for Testing and Materials 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959
ISO	International Organization for Standardization 1 rue de Varembe', Case postale 56, CH-1121 Geneve' 20, Switzerland/Suisse
MSS	Manufacturers Standardization of the Valve and Fittings Industry 127 Park Street, NE, Vienna, VA 22180-4602

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List of MSS Standard Practices
(Price List Available Upon Request)

Number	
SP-6-1996	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP-9-1997	Spot Facing for Bronze, Iron and Steel Flanges
SP-25-1998	Standard Marking System For Valves, Fittings, Flanges and Unions
SP-42-1999	(R 95) Class 150 Corrosion Resistant Gate, Glove, Angle and Check Valves with Flanged and Butt Weld Ends
SP-43-1991	(R 96) Wrought Stainless Steel Butt-Welding Fittings
SP-44-1996	Steel Pipeline Flanges
SP-45-1998	Bypass and Drain Connections
SP-51-2000	(R 95) Class 150LW Corrosion Resistant Cast Flanges and Flanged Fittings
SP-53-1999	Quality Standard for Steel Castings and Forgings for Valves, Flanges and Fittings and Other Piping Components - Magnetic Particle Examination Method
SP-54-1999	Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components - Radiographic Examination Method
SP-55-1996	Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components - Visual Method for Eval. of Surface Irregularities
SP-58-1993	Pipe Hangers and Supports - Materials, Design and Manufacture
SP-60-1999	Connecting Flange Joint Between Tapping Sleeves and Tapping Valves
SP-61-1999	Pressure Testing of Steel Valves
SP-65-1999	High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets
SP-67-1995	Butterfly Valves
SP-68-1997	High Pressure Butterfly Valves with Offset Design
SP-69-1996	Pipe Hangers and Supports - Selection and Application
SP-70-1998	Cast Iron Gate Valves, Flanged and Threaded Ends
SP-71-1997	Gray Iron Swing Check Valves, Flanged and Threaded Ends
SP-72-1999	Ball Valves with Flanged or Butt-Welding Ends for General Service
SP-73-1991	(R 96) Brazing Joints for Wrought and Cast Copper Alloy Solder Joint Pressure Fittings
SP-75-1998	Specification for High Test Wrought Butt Welding Fittings
SP-77-1995	Guidelines for Pipe Support Contractual Relationships
SP-78-1998	(R 92) Cast Iron Plug Valves, Flanged and Threaded Ends
SP-79-1999a	Socket-Welding Reducer Inserts
SP-80-1997	Bronze Gate, Globe, Angle and Check Valves
SP-81-1995	Stainless Steel, Bonnetless, Flanged, Knife Gate Valves
SP-82-1992	Valve Pressure Testing Methods
SP-83-1995	Class 3000 Steel Pipe Unions, Socket-Welding and Threaded
SP-85-1994	Cast Iron Globe & Angle Valves, Flanged and Threaded Ends
SP-86-1997	Guidelines for Metric Data in Standards for Valves, Flanges, Fittings and Actuators
SP-87-1991	(R 96) Factory-Made Butt-Welding Fittings for Class 1 Nuclear Piping Applications
SP-88-1993	Diaphragm Type Valves
SP-89-1998	Pipe Hangers and Supports - Fabrication and Installation Practices
SP-90-1986	(R 91) Guidelines on Terminology for Pipe Hangers and Supports
SP-91-1999	(R 96) Guidelines for Manual Operation of Valves
SP-92-1999	(R 92) MSS Valve User Guide
SP-93-1999	(R 92) Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components - Liquid Penetrant Examination Method
SP-94-1999	Quality Std for Ferritic and Martensitic Steel Castings for Valves, Flanges, and Fittings and Other Piping Components - Ultrasonic Examination Method
SP-95-1999	(R 91) Swage (d) Nipples and Bull Plugs
SP-96-1996	Guidelines on Terminology for Valves and Fittings
SP-97-1995	Integrally Reinforced Forged Branch Outlet Fittings - Socket Welding, Threaded and Buttwelding Ends
SP-98-1996	Protective Coatings for the Interior of Valves, Hydrants, and Fittings
SP-99-1994	Instrument Valves
SP-100-1997	Qualification Requirements for Elastomer Diaphragms for Nuclear Service Diaphragm Type Valves
SP-101-1989	Part-Turn Valve Actuator Attachment - Flange and Driving Component Dimensions and Performance Characteristics
SP-102-1989	Multi-Turn Valve Actuator Attachment - Flange and Driving Component Dimensions and Performance Characteristics
SP-103-1995	Wrought Copper and Copper Alloy Insert Fittings for Polybutylene Systems
SP-104-1995	Wrought Copper Solder Joint Pressure Fittings
SP-105-1996	Instrument Valves for Code Applications
SP-106-1990	(R 96) Cast Copper Alloy Flanges and Flanged Fittings, Class 125, 150 and 300
SP-107-1999	Transition Union Fittings for Joining Metal and Plastic Products
SP-108-1996	Resilient-Seated Cast Iron-Eccentric Plug Valves
SP-109-1996	Welded Fabricated Copper Solder Joint Pressure Fittings
SP-110-1996	Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
SP-111-1996	Gray-Iron and Ductile-Iron Tapping Sleeves
SP-112-1999	Quality Standard for Evaluation of Cast Surface Finishes - Visual and Tactile Method. This SP must be sold with a 10-surface, three-dimensional Cast Surface Comparator, which is a necessary part of the Standard. Additional Comparators may be sold separately at $19.00 each. Same quantity discounts apply on total order.
SP-113-1999	Connecting Joint between Tapping Machines and Tapping Valves
SP-114-1995	Corrosion Resistant Pipe Fittings Threaded and Socket Welding, Class 150 and 1000
SP-115-1999	Excess Flow Valves for Natural Gas Service
SP-116-1996	Service Line Valves and Fittings for Drinking Water Systems
SP-117-1996	Bellows Seals for Globe and Gate Valves
SP-118-1996	Compact Steel Globe & Check Valves - Flanged, Flangeless, Threaded & Welding Ends (Chemical & Petroleum Refinery Service)
SP-119-1996	Belled End Socket Welding Fittings, Stainless Steel and Copper Nickel
SP-120-1997	Flexible Graphite Packing System for Rising Stem Steel Valves (Design Requirements)
SP-121-1997	Qualification Testing Methods for Stem Packing for Rising Stem Steel Valves
SP-122-1997	Plastic Industrial Ball Valves
SP-123-1998	Non-Ferrous Threaded and Solder-Joint Unions for Use With Copper Water Tube

(R-YEAR) Indicates year standard reaffirmed without substantive changes

A large number of former MSS Practices have been approved by the ANSI or ANSI Standards, published by others. In order to maintain a single source of authoritative information, the MSS withdraws its Standard Practices in such cases.

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STANDARD PRACTICE **SP-58**

1993
Edition

PIPE HANGERS AND SUPPORTS — MATERIALS, DESIGN AND MANUFACTURE

Developed and Approved
by the
Manufacturers Standardization Society
of the
Valve and Fittings Industry, Inc.
127 Park Street, N.E.
Vienna, Virginia 22180
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MSS SP-58, "Pipe Hangers and Supports - Materials, Design and Manufacture," was adopted on 11 April 1994, and is approved for use by the Department of Defense (DoD). Proposed changes by DoD activities must be submitted to the DoD Adopting Activity: Naval Construction Battalion Center, 1000 23rd Avenue, Code 156, Port Hueneme, CA 93043-4301. DoD activities may obtain copies of this standard from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094. The private sector and other Government agencies may purchase copies from Manufacturers Standardization Society of the Valve and Fittings Industry, Inc., 127 Park Street, N.E, Vienna, VA 22180.

Custodians:
Navy - YD1

Review Activities:
Army - ME, CE
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FOREWORD

This standard was developed by a cooperative effort of representatives of the pipe hanger manufacturers. It is based on the best practice current at this time and on the collective experience of the industry. There are two companion standards, SP-69 and SP-89 relating to hanger selection, application, fabrication and installation as stated in subsections 2.4 and 2.5. In addition, the MSS Hanger Committee has developed guidelines for pipe supports contractural relationships and on hanger terminology as covered in SP-77 and SP-90 respectively.

U.S. customary units in this SP are the standard; the metric units are for reference only.

This document has been substantively revised from the previous edition. It is suggested that if the user is interested in knowing what changes have been made, that direct page by page comparison should be made of this document.

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Reference to Specifications and Standards of the following organizations appear in this publication:

ANSI American National Standards Institute
11 West 42nd Street, New York, NY 10036
Phone: (212) 642-4900

ASME The American Society of Mechanical Engineers
345 East 47th Street, New York, NY 10017
Phone: (212) 705-7500

ASTM American Society for Testing and Material
1916 Race Street, Philadelphia, PA 19103
Phone: (215) 299-5450

MSS Manufacturers Standarization Society of the Valve and Fittings Industry, Inc.
127 Park Street, N.E., Vienna, VA 22180
Phone: (703) 281-6613

NIST National Institute of Standards and Technology, U.S. Department of Commerce, Standards Services
Route 270, Building 101, Gaithersburg, MD 20899
Phone: (301) 975-4000

SMI Spring Manufacturers Institute, Inc.
380 West Palatine Road, Wheeling, IL 60090
Phone: (312) 520-3290

FM Factory Mutual Research
1151 Boston-Providence Turnpike, Norwood, MA 02062
Phone: (617) 762-4300

UL Underwriters Laboratories
333 Pfingsten Road, Northbrook, IL 60062
Phone: (312) 272-8800

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PIPE HANGERS AND SUPPORTS—MATERIALS, DESIGN AND MANUFACTURE

1. SCOPE

1.1 This standard establishes the material, design, fabrication and inspection criteria to be used in the manufacture of standard types of pipe hanger components.

1.2 This standard also establishes minimum design load ratings for rigid pipe hanger assemblies (see Table 1).

1.3 This standard includes design criteria for springs and design characteristics for spring hangers.

1.4 Where applicable, design and manufacture of these products must also conform to Codes and Standards, such as:

ANSI/ASME B31 Codes for Pressure Piping,
ASME Boiler and Pressure Vessel Codes,
UL203 Standard for Pipe Hanger Equipment for Fire Protection Service,
Factory Mutual FM 1951 Approval Standard for Pipe Hanger Components for Automatic Sprinkler Systems,
Local Building Codes.

2. OBJECTIVES

2.1 To serve as a guide for pipe hanger material selection, design and manufacturing.

2.2 To enable the user to specify a minimum level of acceptance for pipe hanger design and performance.

2.3 To define types of hangers and supports which are illustrated in the Type Chart, Figure 1. Hangers and supports shown on the Type Chart indicate general types only and manufacturers' other standard products shall be accepteable under this standard if they meet dimensional and load rating limitations set forth in this standard.

2.4 To serve as a companion document to MSS SP-69 which provides recommendations for the selection and application of the types illustrated in the Type Chart, Figure 1.

2.5 To serve as a companion document to MSS SP-89 which provides recommendations for fabrication and installation of pipe hangers and supports.

3. MATERIAL STANDARDS

3.1 Materials commonly used in manufacturing pipe hangers and supports are listed in Tables 2 and A1.

3.2 Other materials may be used provided they comply with the allowable stress requirements of Subsection 4.4 or 4.6.

4. ALLOWABLE STRESSES, LOAD RATINGS, AND TEMPERATURES

4.1 The allowable Tensile Stress for materials commonly used in the design of pipe hangers and supports are listed in Tables 2 and A1. Allowable values for the types of stress stated in 4.1.1 thru 4.1.5, shall be computed by multiplying the allowable tensile stress by the applicable factor. Materials may not be used above the highest temperature for which a stress value appears.

		Factor
4.1.1	Tension:	
a)	On the Gross Area	1.0
b)	On the net section at pin holes	0.9
4.1.2	Bending	1.0
4.1.3	Shear	0.8
4.1.4	Bearing	1.5
4.1.5	Compression	1.0 (max)

Allowable Compressive stress must be reduced on the basis of structural stability and buckling (column action).

4.1.6 Combined Stress Check.

$$\frac{\text{Stress in Tension or Compression}}{\text{Allowable Tension or Compression}} + \frac{\text{Stress in Bending}}{\text{Allowable Bending}} \leq 1.0$$

4.2 Welds

4.2.1 Weld allowable shear stress shall be limited to 80% of the allowable tensile stress of the weaker of the base metals being joined. Weld tension and bending stress allowables shall be limited to the allowable tensile stress of the weaker of the base metals being joined.

4.3 Higher allowable stresses under well defined short-term loading conditions shall be as designated by the applicable codes.

4.4 Allowable tensile stresses for materials not listed in Tables 2 and A1, produced in accordance with a recognized specification and with known physical properties shall be determined as the lower of the following values:

a) 1/4 of minimum tensile strength at service temperature.
b) 5/8 of minimum yield strength at service temperature.

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TABLE 1. MINIMUM DESIGN LOAD RATINGS FOR RIGID PIPE HANGER ASSEMBLIES

Applicable to all components of complete assembly; including pipe attachment, rod, fixtures and building attachment.			
Nominal Pipe or Tube Size		Ratings at Normal Temperature Range[2]	
Inch	mm	Pounds	Kilograms
3/8	10	150	65
1/2	15	150	65
3/4	20	150	65
1	25	150	65
1 1/4	32	150	65
1 1/2	40	150	65
2	50	150	65
2 1/2	65	170	75
3	80	210	95
3 1/2	90	250	110
4	100	300	135
5	125	400	180
6	150	530	240
8	200	760	345
10	250	1120	505
12	300	1480	670
14	350	1710	775
16	400	2030	920
18	450	2580	1170
20	500	2920	1325
24	600	4180	1895

Notes:

1. See Section 4 for allowable stresses and temperatures.
2. Normal temperature range is −20°F to 650°F (−29°C to 343°C) for carbon steel and −20°F to 450°F (−29°C to 231°C) for cast and malleable iron.
3. See Subsection 7.3 for minimum rod diameter restrictions.
4. For loads greater than those tabluated, hanger component load ratings shall be established by the manufacturer. Design shall be in accordance with all criteria as outlined in this document.
5. Pipe attachment ratings for temperature ranges between 650°F to 750°F (343°C to 398°C) shall be reduced by the ratio of allowable stress at service temperature to the allowable stresses at 650°F (343°C).
6. For services over 750°F (398°C), attachments in direct contact with the pipe shall be designed to allowable stresses listed in Tables 2 and A1.

Such materials shall not be used where temperatures exceed 650° F (345° C) and shall not be welded to the piping or piping component.

4.5 Allowable stresses for cast materials calculated in accordance with subsection 4.4 shall be reduced by a casting quality factor of 20%.

4.6 For steel materials not listed in Tables 2 and A1 of unknown specification, a stress value of 30% of yield strength (0.2% offset) at room temperature may be used. The yield strength shall be established by tensile testing a sample of material in accordance with ASTM A370. The value corresponding to a 0.2% permanent strain (offset) is the material yield strength. The stress value so established shall not exceed 9500 psi (65.5 MPA).

4.7 Load ratings for threaded hanger rods made from A36, A575 GR 1020 or A576 GR 1020 are shown in Table 3. Hanger rods made from all other materials shall also have a 25% reduction of the allowable stress. Load ratings shall be based on the thread root area. (The 25% reduction is to allow for normal installation and service conditions.)

4.8 Forged eye rods, and formed and welded eye rods shall have load capacities equal to those determined in accordance with Subsection 4.7 for the same nominal diameter. Formed but not welded eye rods shall have load capacities not greater than 35% of those determined in accordance with Subsection 4.7 for the same nominal diameter.

4.9 Capacities for U-bolts, loaded in tension, shall be limited to twice the capacity of hanger rods of the same material and diameter.

4.10 All threaded items, both external and internal, not covered by Subsections 4.7, 4.8 or 4.9 need not be subjected to the 25% stress reduction.

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4.11 Design temperature of hanger components in direct contact with the pipe shall be the temperature of the contained fluid. For conventional high temperature piping installations, a reduction in temperature of 100°F/in. as measured from the outer pipe surfaces may be applied for strength calculations and material requirements. Alloy bolting within insulation may be furnished with ASTM A194 Grade 2H nuts for line temperatures to 1050°F (566°C).

TABLE 2. MATERIALS AND ALLOWABLE STRESSES

ASTM Spec	Grade	Material Composition	Condition	Minimum Tensile KSI	Minimum Yield KSI	Maximum Allowable Stresses in Tension in KSI for Metal Temperatures Not Exceeding Degrees F											
						-20 to 450	650	700	750	800	850	900	950	1000	1050	1100	1150	1200
STRUCTURAL STEEL																		
A36	—	Carbon Steel	HR	58.0	36.0	14.5	14.5	13.9	12.6									
(1) A500	B	Carbon Steel	CF	58.0	42.0	14.5	14.5	13.9	12.6									
(1) A500	C	Carbon Steel	CF	62.0	46.0	15.0	15.0	14.4	13.0									
(1) A501	—	Carbon Steel	HR	58.0	36.0	14.5	14.5	13.9	12.6									
A514	t≤ 2½	Alloy Steel	QT	110.0	100.0	27.5	27.4	26.9										
A514	t> 2½	Alloy Steel	QT	100.0	90.0	25.0	24.9	24.5										
A517	t≤ 2½	Alloy Steel	QT	115.0	100.0	28.8	28.7	—										
A517	t> 2½	Alloy Steel	QT	105.0	90.0	26.3	26.3	26.2										
RODS & BARS																		
A36	—	Carbon Steel	HR	58.0	36.0	14.5	14.5	13.9	12.6									
(1)(14) A108	1018	Carbon Steel	CF	60.0	50.0	13.5	13.5											
(1)(15) A108	1018	Carbon Steel	CF	55.0	45.0	12.4	12.4											
(1) A108	1141	Carbon Steel	CF	90.0	80.0	20.3	20.3											
(1) A108	12L14	Carbon Steel	CF	78.0	60.0	17.5	17.5											
(1)(2) A575	1010	Carbon Steel	HR	47.0	26.0	10.6	10.6											
(1)(2) A575	1015	Carbon Steel	HR	50.0	27.5	11.3	11.3											
(1)(2) A575	1020	Carbon Steel	HR	55.0	30.0	12.4	12.4											
(1)(2) A575	1025	Carbon Steel	HR	58.0	32.0	13.0	13.0											
(1) A576	1010	Carbon Steel	HR	47.0	26.0	11.3	11.3	11.0	10.3									
(1) A576	1015	Carbon Steel	HR	50.0	27.5	12.5	12.5	12.1	11.2									
(1) A576	1020	Carbon Steel	HR	55.0	30.0	13.8	13.8	13.3	12.1									
(1) A576	1025	Carbon Steel	HR	58.0	32.0	13.8	13.8	13.3	12.1									
A322	4130	1 CR - 1/5 Mo	A	81.0	52.0	18.2	18.2	18.2										
A322	4140	1 CR - 1/5 Mo	A	95.0	70.0	21.4	21.4	21.4										
A331	41L40	1 CR - 1/5 Mo	A	95.0	70.0	21.4	21.4	21.4										
(3)(4) A276	304	18 CR - 8 Ni	—	75.0	30.0	12.5	11.2	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.0
(3)(4) A276	316	16CR-12Ni-2Mo	—	75.0	30.0	12.9	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4
(3)(4) A276	321	18CR-10Ni-Ti	—	75.0	30.0	12.4	11.2	11.0	10.8	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6
(3)(4) A276	347	18CR-10Ni-Cb	—	75.0	30.0	14.5	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4
(3)(4) A479	304	18 CR - 8 Ni	—	75.0	30.0	12.5	11.2	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.0
(3)(4) A479	316	16CR-12Ni-2Mo	—	75.0	30.0	12.9	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4
(3)(4) A479	321	18CR-10Ni-Ti	—	75.0	30.0	12.4	11.2	11.0	10.8	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6
(3)(4) A479	347	18CR-10Ni-Cb	—	75.0	30.0	14.5	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4
(6) A564	630	17CR-4Ni-4Cu	AH	145.0	125.0	34.8	33.7	—	—									
A675	60	Carbon Steel	HR	60.0	30.0	15.0	15.0	14.4	13.0									
A675	65	Carbon Steel	HR	65.0	32.5	16.3	16.3	15.5	13.9									
A675	70	Carbon Steel	HR	70.0	35.0	17.5	17.5	16.6	14.8									
PLATE																		
A36	—	Carbon Steel	HR	58.0	36.0	14.5	14.5	13.9	12.6									
A285	A	Carbon Steel	HR	45.0	24.0	11.3	11.3	10.9	9.7									
A285	B	Carbon Steel	HR	50.0	27.0	12.5	12.5	12.1	11.0									
A285	C	Carbon Steel	HR	55.0	30.0	13.8	13.8	13.3	12.1									
A515	60	Carbon Steel	HR	60.0	32.0	15.0	15.0	14.4	12.9									
A515	65	Carbon Steel	HR	65.0	35.0	16.3	16.3	15.5	13.8									
A515	70	Carbon Steel	HR	70.0	38.0	17.5	17.5	16.6	14.7									
A516	60	Carbon Steel	HR	60.0	32.0	15.0	15.0	14.4	12.9									
A516	65	Carbon Steel	HR	65.0	35.0	16.3	16.3	15.5	13.8									
A516	70	Carbon Steel	HR	70.0	38.0	17.5	17.5	16.6	14.7									
A514	t≤ 2½	Alloy Steel	QT	110.0	100.0	27.5	27.4	26.9										
A514	t> 2½	Alloy Steel	QT	100.0	90.0	25.0	24.9	24.9										
A517	t≤ 2½	Alloy Steel	QT	115.0	100.0	28.8	28.7											
A517	t> 2½	Alloy Steel	QT	105.0	90.0	26.3	26.3	26.2										
A387	22	2¼CR-1Mo	—	60.0	30.0	15.0	15.0	15.0	15.0	15.0	14.4	13.1	11.0	7.8	5.8	4.2		
(3)(4) A240	304	18CR-8Ni	—	75.0	30.0	12.5	11.2	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.0
(3)(4) A240	316	16CR-12Ni-2Mo	—	75.0	30.0	12.9	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4
(3)(4) A240	321	18CR-10Ni-Ti	—	75.0	30.0	12.4	11.2	11.0	10.8	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6
(3)(4) A240	347	18CR-10Ni-Cb	—	75.0	30.0	14.5	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4

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TABLE 2. MATERIALS AND ALLOWABLE STRESSES (Continued)

ASTM Spec	Grade	Material Composition	Condition	Minimum Tensile KSI	Minimum Yield KSI	Maximum Allowable Stresses in Tension in KSI for Metal Temperatures Not Exceeding Degrees F											
						-20 to 450	650	700	750	800	850	900	950	1000	1050	1100	1150	1200
SHEET & STRIP																		
A109	#4	Carbon Steel	CF	42.0	—	9.5	9.5											
(1) A366	—	Carbon Steel	CF	48.0	41.0	9.5	9.5											
(1) A446	A	Carbon Steel	HR	45.0	24.0	11.3	11.3											
(1) A526	—	Carbon Steel	HR	45.0	24.0	11.3	11.3											
(1) A569	—	Carbon Steel	HR	45.0	24.0	11.3	11.3											
(1) A570	33	Carbon Steel	HR	52.0	33.0	11.5	11.5											
(1) A570	40	Carbon Steel	HR	55.0	40.0	12.7	12.7											
(1) A635	1010	Carbon Steel	HR	47.0	26.0	10.6	10.6											
(1) A659	1020	Carbon Steel	HR	50.0	27.0	11.5	11.5											
(3)(4) A240	304	18CR-8Ni	—	75.0	30.0	12.5	11.2	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.0
(3)(4) A240	316	16CR-12Ni-2Mo	—	75.0	30.0	12.9	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4
(3)(4) A240	321	18CR-10Ni-Ti	—	75.0	30.0	12.4	11.2	11.0	10.8	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6
(3)(4) A240	347	18CR-10Ni-Cb	—	75.0	30.0	14.5	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4
(6) A693	630	17CR-4Ni-4Cu	AH	145.0	125.0	34.8	33.7											
PIPE & TUBING																		
A53	A	Carbon Steel	HR	48.0	30.0	12.0	12.0	11.7	10.7									
A53	B	Carbon Steel	HR	60.0	35.0	15.0	15.0	14.4	13.0									
A106	A	Carbon Steel	HR	48.0	30.0	12.0	12.0	11.7	10.7									
A106	B	Carbon Steel	HR	60.0	35.0	15.0	15.0	14.4	13.0									
A106	C	Carbon Steel	HR	70.0	40.0	17.5	17.5	16.6	14.8									
A513	1015	Carbon Steel	HR	48.0	35.0	12.0	12.0	—	—									
A513	1020	Carbon Steel	HR	52.0	38.0	13.0	13.0	—	—									
A513	1025	Carbon Steel	HR	56.0	40.0	14.0	14.0	—	—									
A519	1018	Carbon Steel	HR	50.0	32.0	12.5	12.5	—	—									
A335	P11	1¼CR-½Mo	HR	60.0	30.0	15.0	15.0	15.0	15.0	15.0	14.4	12.8	11.0	6.6	4.1	3.0		
A335	P22	2¼CR-1Mo	HR	60.0	30.0	15.0	15.0	15.0	15.0	15.0	14.4	12.8	11.0	7.8	5.8	4.2		
(3)(4) A312	304	18CR-8Ni	—	75.0	30.0	12.5	11.2	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.0
(3)(4) A312	316	16CR-12Ni-2Mo	—	75.0	30.0	12.9	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4
(3)(4) A312	321	18Cr-10Ni-Ti	—	75.0	30.0	12.4	11.2	11.0	10.8	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6
(3)(4) A312	347	18CR-10Ni-Cb	—	75.0	30.0	14.5	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4
CASTINGS																		
A48	20	Gray Iron	—	20.0	—	2.0												
A48	25	Gray Iron	—	25.0	—	2.5												
A48	30	Gray Iron	—	30.0	—	3.0												
A126	A	Gray Iron	—	21.0	—	2.0												
A126	B	Gray Iron	—	31.0	—	3.0												
A126	C	Gray Iron	—	41.0	—	4.0												
A47	32510	Malleable Iron	A	50.0	32.5	10.0												
A47	35018	Malleable Iron	A	53.0	35.0	10.6												
A197	—	Malleable Iron	A	40.0	30.0	8.0												
A216	WCA	Carbon Steel	N	60.0	30.0	12.0	12.0	11.5	10.4									
A216	WCB	Carbon Steel	N	70.0	36.0	14.0	14.0	13.3	11.8									
A217	WC6	1¼CR-½Mo	NT	70.0	40.0	14.0	14.0	14.0	14.0	14.0	13.7	12.7	8.8	5.5	3.6	2.2		
A217	WC9	2¼CR-1Mo	NT	70.0	40.0	13.4	13.3	13.2	12.9	12.6	12.0	11.4	8.8	6.1	4.6	3.5		
A351	CF8	18CR-8Ni	—	70.0	30.0	10.0	8.8	8.8	8.6	8.5	8.2	8.1	7.9	7.6	7.2	6.0	4.6	3.6
A351	CF8C	18CR-10Ni-Cb	—	70.0	30.0	11.3	10.5	10.3	10.2	10.2	10.1	10.1	10.0	9.5	9.0	8.4	6.4	4.0
A351	CF8M	18CR-10Ni-2Mo	—	70.0	30.0	10.2	9.2	9.0	8.9	8.8	8.7	8.6	8.6	8.5	8.1	7.5	6.4	4.8
A395	—	Ductile Iron	—	60.0	40.0	12.0	12.0											
A536	65-45-12	Ductile Iron	—	65.0	45.0	13.0	13.0											
FORGINGS																		
A668	A	Carbon Steel	—	47.0	—	11.7	11.7											
A668	B	Carbon Steel	A	60.0	30.0	15.0	15.0											
A668	C	Carbon Steel	A	66.0	33.0	16.5	16.5											
A668	D	Carbon Steel	N	75.0	37.5	18.3	18.3											
A668	E	Carbon Steel	DNT	85.0	44.0	21.2	21.2											
A668	F	Carbon Steel	QT	90.0	55.0	22.5	22.5											
A105	—	Carbon Steel	HT	70.0	36.0	17.5	17.5	16.6	14.8									
A181	70	Carbon Steel	—	70.0	36.0	17.5	17.5	16.6	14.8									
A182	F11	1¼CR-½Mo-Si	A	70.0	40.0	17.5	17.5	17.5	17.5	17.5	17.1	15.9	11.0	6.9	4.6	2.8		
A182	F22	2¼CR-1Mo	A	75.0	45.0	17.9	17.7	17.5	17.2	16.9	16.4	15.8	11.0	7.6	5.8	4.4		
(3)(4) A182	F304	18CR-8Ni	HT	75.0	30.0	12.5	11.2	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.0
(3)(4) A182	F316	16CR-12Ni-2Mo	HT	75.0	30.0	12.9	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4
(3)(4) A182	F321	18CR-10Ni-Ti	HT	75.0	30.0	12.4	11.2	11.0	10.8	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6
(3)(4) A182	F347	18CR-10Ni-Cb	HT	75.0	30.0	14.5	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4

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TABLE 2. MATERIALS AND ALLOWABLE STRESSES (Continued)

ASTM Spec	Grade	Material Composition	Condition	Minimum Tensile KSI	Minimum Yield KSI	Maximum Allowable Stresses in Tension in KSI for Metal Temperatures Not Exceeding Degrees F												
						-20 to 450	650	700	750	800	850	900	950	1000	1050	1100	1150	1200
BOLTING																		
A307	A	Carbon Steel	—	60.0	—	15.0	15.0											
A307	B	Carbon Steel	—	60.0	—	15.0	15.0											
(8) A325	Type 2	Carbon Steel	HT	120.0	92.0	23.0	23.0											
(9) A325	Type 2	Carbon Steel	HT	105.0	81.0	20.2	20.2											
(10) A193	B7	1 CR - 1/5 Mo	HT	125.0	105.0	25.0	25.0	25.0	23.6	21.0	17.0	12.5	8.5	4.5				
(11) A193	B7	1 CR - 1/5 Mo	HT	115.0	95.0	23.0	23.0	23.0	22.2	20.0	16.3	12.5	8.5	4.5				
(12) A193	B7	1 CR - 1/5 Mo	HT	100.0	75.0	18.8	18.8	18.8	18.8	18.0	16.3	12.5	8.5	4.5				
(3)(4)(5) A193	B8	18CR-8Ni	—	75.0	30.0	12.5	11.2	11.0	10.8	10.5	10.3	10.1	9.9	9.7	9.5	8.8	7.7	6.0
(3)(4)(5) A193	B8M	18CR-10Ni-2Mo	—	75.0	30.0	12.9	11.5	11.3	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4
(3)(4)(5) A193	B8C	18CR-10Ni-Cb	—	75.0	30.0	14.5	13.1	12.9	12.8	12.7	12.6	12.6	12.5	12.5	11.9	9.1	6.1	4.4
(3)(4)(5) A193	B8T	18CR-10Ni-Ti	—	75.0	30.0	12.0	11.1	10.9	10.8	10.7	10.6	10.6	10.5	10.4	9.2	6.9	5.0	3.6
(8) A449	—	Carbon Steel	QT	120.0	92.0	23.0	23.0	23.0										
(9) A449	—	Carbon Steel	QT	105.0	81.0	20.2	20.2	20.2										
(13) A449	—	Carbon Steel	QT	90.0	58.0	14.5	14.5	14.5										
A490	—	Alloy Steel	QT	150.0	130.0	37.5	37.5											
RIVETS & NUTS																		
A563	ALL	Carbon Steel	—	Product Specification														
A194	ALL	—	—	Product Specification														
A502	—	Carbon Steel	—	52.0	28.0	12.0	12.0											
SPRINGS	See Figures 2 and 3 for Materials and Stresses																	

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GENERAL NOTES

1) Allowable stresses for these materials are based upon those of comparable materials of similar chemical properties.
2) "M" grade steels are acceptable for A575 listings in lieu of non "M" grade steels.
3) For temperatures above 1000° F, these stress values may be used only if the material is heat treated by heating it to a minimum temperature of 1900° F and quenching in water or rapidly cooling by other means.
4) At temperatures above 1000° F, these stress values apply only when the carbon is 0.04% or higher on heat analysis.
5) Class 1 only.
6) Age hardened at 1075° F.
7) For temperatures above 800° F, these stress values apply only when the carbon is 0.04% or higher.
8) For bolt diameters less than or equal to 1 inch.
9) For bolt diameters greater than 1 inch and less than or equal to 1-1/2 inch.
10) For diameters less than or equal to 2-1/2 inch.
11) For diameters greater than 2-1/2 inch and less than or equal to 4 inch.
12) For diameters greater than 4 inch.
13) For bolt diameters greater than 1-1/2 inch and less than or equal to 3 inch.
14) For material thickness less than 2 inch.
15) For material thickness 2 to 3 inch.

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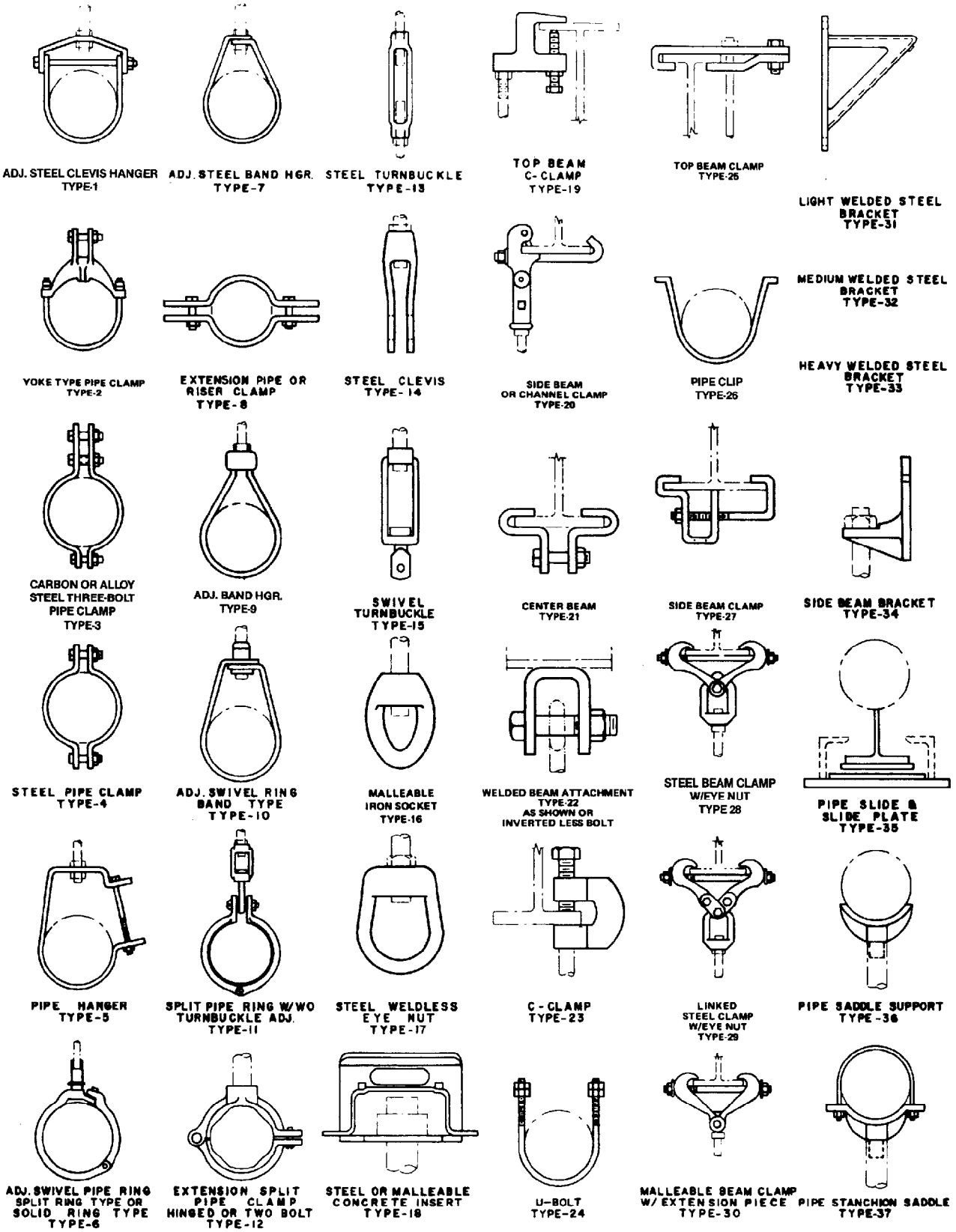

FIGURE 1. TYPE CHART

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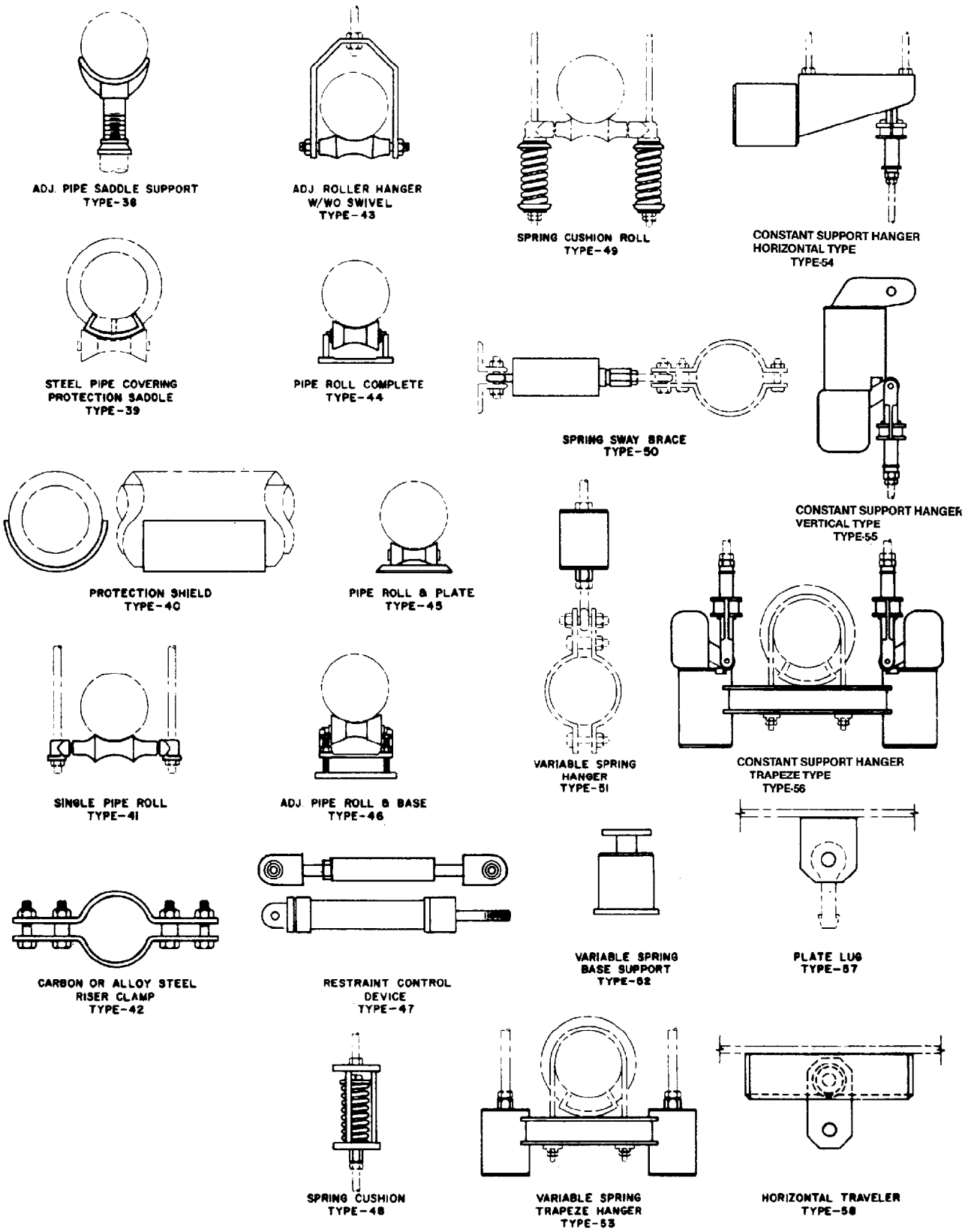

FIGURE 1. TYPE CHART (Continued)

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TABLE 3. LOAD RATINGS OF THREADED HANGER RODS MATERIALS—ASTM 36, A575 Gr 1020 or A576 Gr 1020

Nominal Rod Diameter		Root Area of Thread		Max. Safe Load At Rod Temp Of 650°F (343°C)	
Inch	mm	Sq. Inch	Sq. mm	Pounds	Kg
3/8	9.6	0.068	43.8	610	275
1/2	12.7	0.126	81.3	1130	515
5/8	15.8	0.202	130.3	1810	820
3/4	19.0	0.302	194.8	2710	1230
7/8	22.2	0.419	270.3	3770	1710
1	25.4	0.552	356.1	4960	2250
1 1/4	31.8	0.889	573.5	8000	3630
1 1/2	38.1	1.293	834.2	11630	5280
1 3/4	44.4	1.744	1125	15690	7120
2	50.8	2.292	1479	20690	9390
2 1/4	57.2	3.021	1949	27200	12350
2 1/2	63.5	3.716	2397	33500	15200
2 3/4	69.8	4.619	2980	41600	18890
3	76.2	5.621	3626	50600	22970
3 1/4	82.6	6.720	4435	60500	27460
3 1/2	88.9	7.918	5108	71260	32350
3 3/4	95.2	9.214	5945	82900	37640
4	101.6	10.608	6844	95500	43360
4 1/4	108.0	12.100	7806	108900	49440
4 1/2	114.3	13.690	8832	123200	55930
4 3/4	120.6	15.379	9922	138400	62830
5	127.0	17.165	11074	154500	70140

Notes:

1. Rods 3 inch (76.2mm) and larger shall be ASTM A36 or A576 gr 1020.
2. For load rating of threaded materials, other than ASTM A36, A575 Gr 1020, or A576 Gr 1020, see requirements of Subsection 4.5 and Tables 2 and A1.
3. Tabulated loads are based on an allowable tensile stress of 12,000 psi (82.7 MPa) reduced by 25% resulting in 9,000 psi (62 MPa). (12,000 psi allows for the interchangeability of the referenced rod materials.) (The 25% reduction is to allow for normal installation and service conditions.)

5. FABRICATION REQUIREMENTS FOR STEEL HANGERS

5.1 Cold Forming

5.1.1 Cold forming of plate and flat bars may be performed on materials 0.5 inch (12.7mm) thick or less to a minimum inside radius of one times the stock thickness. Cold forming may be performed on material over 0.5 inch (12.7mm) thick to a minimum inside radius of 2.5 times the stock thickness. Material over 0.5 inch (12.7mm) thick may be cold formed to an inside radius less than 2.5 times but not less than one times the stock thickness provided heat treatment is performed as prescribed in Subsection 5.3 and a case history is established showing that forming or a subsequent process does not have a damaging effect detrimental to the strength or function of the product.

5.1.2 Round bars 0.75 inch (19mm) diameter and smaller may be cold formed to a minimum inside radius of 1/2 times the bar diameter. Round bars greater than 0.75 inch (19mm) diameter may be cold formed to a minimum inside radius of 2-1/2 times bar diameter. Forming is not permitted on threaded areas.

5.1.3 Heating material to less than minimum temperature shown in 5.2.1, to facilitate the forming operation, shall be considered cold forming.

5.2 Hot Forming

5.2.1 Hot forming of plate and flat bars may be performed on materials of any thickness to an inside radius not less than one times the stock thickness within the following surface temperature ranges (no holding time required):

Carbon Steel	1400°F Min. (760°C)	2000°F Max. (1093°C)

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Chrome-Moly Alloy Steel	1550°F Min. (843°C)	2000°F Max. (1093°C)
Austenitic Stainless Steel	1400°F Min. (760°C)	2100°F Max. (1148°C)

Material shall not be heated in bundles or closed stacks in other than induction type furnaces but shall be separated to allow good circulation within the furnaces. Materials should not be heated above the maximum temperature shown. No hot forming operation shall be performed below the minimum temperature shown. Carbon steel and chrome-moly alloy steel shall be cooled in still air. Water quenching is not permitted. Cooling of stainless steel other than still air cooling, may be accomplished as per ASTM A403, Paragraph 6.

5.2.2 Round bars of any diameter may be hot formed to a minimum inside radius of 1/2 times the bar diameter within the temperature ranges given in Subsection 5.2.1. Forming is not permitted on threaded areas.

5.3 Heat Treatment After Forming

5.3.1 Stress relieving, when required of carbon steel and chrome-moly steel, shall be done within the temperature ranges shown below. The material is to be held at temperature for one hour per inch of thickness, but not less than one hour, followed by slow cooling in furnace. Carbon steel may be cooled in still air.

Carbon Steel	1100°F Min. (593°C)	1250°F Max. (676°C)
Chrome-Moly Alloy Steel	1300°F Min. (704°C)	1400°F Max. (760°C)

5.3.2 A carbide solution heat treatment of austenitic stainless steel, when required by design specification, shall be performed as prescribed by ASTM A403, Paragraph 6.

5.4 Incremental bending by braking is an acceptable method of forming.

5.5 Formed components may be furnished in "as formed" condition without any further mechanical work.

5.6 Welding

5.6.1 Unless otherwise specified by the job specification, welders and welding procedures shall be qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX. When qualifying a welding procedure for materials listed in Table 2, which do not have a P-number, use of the S-number and Group Number from ASME Section III, Code Case N-71-11 qualifies that material to corresponding P-Number and Group Number in Section IX. Welder's performance test results and Welding Procedure Qualification Records shall be available, upon request, to authorized inspection personnel.

5.6.2 When tack welds are to become a part of the finished weld, they shall be visually examined and ground or feathered, if necessary. Defective tack welds and tack welds made by unqualified welders shall be removed.

5.6.3 Attachments welded directly to the pipe shall be of appropriate chemical composition, compatible for welding and able to withstand the anticipated loads at the piping temperature. The method of attachment to the pipe shall meet all the preheating, welding and post weld heat treating requirements of the applicable piping code.

5.6.4 Prehating and post weld heat treating (PWHT) requirements for pipe hangers shall be as outlined in Tables 4 and A4.

5.6.5 Unacceptable welds shall be removed by flame or arc gouging, grinding, chipping, or machining. Welds requiring repair shall be welded in accordance with the requirements of the original weld. Base metal irregularities requiring repair by welding shall be repaired in accordance with the material specification or ASTM A6, as applicable. Welders and welding procedures used in making repair welds shall be qualified in accordance with Subsection 5.6.1.

5.7 Surface Discontinuities

5.7.1 Only those surface discontinuities that are detrimental to the strength or function of a product shall be cause for rejection.

5.7.2 Surface discontinuities of welds shall be evaluated in accordance with the applicable code or job specification requirements.

6. PROTECTIVE COATINGS FOR CORROSION, ABRASION AND ELECTROLYTIC RESISTANCE

6.1 Metallic Coatings

6.1.1 Metallic coatings for corrosion resistance may be applied by electroplating, pre-galvanizing, hot dip galvanizing, or mechanical plating.

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TABLE 4. PREHEAT AND POST WELD HEAT TREATMENT (PWHT) REQUIREMENTS FOR PIPE HANGERS AND SUPPORTS

Material Designation	Base Material Size	Thickness of Weld (Equal Leg Fillet Weld)*	Other Requirements	Minimum Preheat Temperature	Post Weld Heat Treatment (See Note 4)
P-1 Carbon Steel	3/4″ & Less	All Weld Sizes	None	50°F	Not Required
	Over 3/4″ to 1″	1/16″ to 3/4″ (1/8″ to 1″ Fillet)	None	50°F	Not Required
		Over 3/4″ (Over 1″ Fillet)			1100°F - 1200°F (See Note 6)
	Over 1″	3/4″ & Less (1″ & Less Fillet)	.30% Carbon or Less	50°F	1100°F to 1200°F (See Note 6)
			Greater than .30% Carbon	175°F	
			Or as an Option None	200°F	Not Required
		Over 3/4″ (Over 1″ Fillet)	.30% Carbon or Less	50°F	1100°F to 1200°F (See Note 6)
			Greater than .30% Carbon	175°F	
P-4 Chrome/Moly Alloy Steel	1/2″ & Less	All Weld Sizes	60 KSI & Less	50°F	1300°F to 1375°F (See Note 6)
			Greater than 60 KSI	250°F	
	Over 1/2″	All Weld Sizes	None	250°F	
P-5 Chrome/Moly Alloy Steel	1/2″ & Less	All Weld Sizes	60 KSI & Less	300°F	1300°F - 1400°F (See Note 6)
			Greater than 60 KSI	400°F	
	Over 1/2″	All Weld Sizes	6% Cr. & Less and 60 KSI & Less	300°F	
	All	All Weld Sizes	Greater than 6% Cr.	400°F	
			Greater than 60 KSI All Percentages of Cr.	400°F	
P-8 Stainless Steel	All	All Weld Sizes	None	50°F	(See Note 7)

*Size of equivalent equal leg fillet weld shown for convenience. The weld thickness of all other types of welds need to be determined by an acceptable conventional method.

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TABLE A4. PREHEAT AND POST WELD HEAT TREATMENT (PWHT) REQUIREMENTS FOR PIPE HANGERS AND SUPPORTS — METRIC UNITS

Material Designation	Base Material Size	Thickness of Weld (Equal Leg Fillet Weld)*	Other Requirements	Minimum Preheat Temperature	Post Weld Heat Treatment (See Note 4)
P-1 Carbon Steel	20mm & Less	All Weld Sizes	None	10°C	Not Required
	Over 20mm to 25mm	2mm to 20mm (3mm to 25mm Fillet)	None	10°C	Not Required
		Over 20mm (25mm Fillet)			593°C - 649°C (See Note 6)
	Over 25mm	20mm & Less (25mm & Less Fillet)	.30% Carbon or Less	10°C	593°C - 649°C (See Note 6)
			Greater than .30% Carbon	79°C	
			Or as an Option None	93°C	Not Required
		Over 20mm (Over 25mm Fillet)	.30% Carbon or Less	10°C	593°C - 649°C (See Note 6)
			Greater than .30% Carbon	79°C	
P-4 Chrome/Moly Alloy Steel	13mm & Less	All Weld Sizes	414 MPA & Less	10°C	704°C - 746°C (See Note 6)
			Greater than 414 MPA	121°C	
	Over 13mm	All Weld Sizes	None	121°C	
P-5 Chrome/Moly Alloy Steel	13mm & Less	All Weld Sizes	414 MPA & Less	149°C	704°C - 760°C (See Note 6)
			Greater than 414 MPA	204°C	
	Over 13mm	All Weld Sizes	6% Cr. & Less and 414 MPA & Less	149°C	
	All	All Weld Sizes	Greater than 6% Cr.	204°C	
			Greater than 414 MPA All Percentages of Cr.	204°C	
P-8 Stainless Steel	All	All Weld Sizes	None	10°C	(See Note 7)

*Size of equivalent equal leg fillet weld shown for convenience. The weld thickness of all other types of welds need to be determined by an acceptable conventional method.

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TABLE 4 and TABLE A4 (Continued)

NOTES:

1. When joining carbon steel and alloy steel by welding, the higher preheat and PWHT temperatures of the two materials shall apply.

2. When joining stainless steel to either carbon steel or alloy steel, caution shall be exercised as the stainless steel material may not be suited for the preheat or PWHT temperatures required by the other materials.

3. When carbide solution heat treatment of stainless steel is required by the design specification, heat treatment shall be in accordance with ASTM A403, Paragraph 6.

4. PWHT Requirements:

   a) PWHT may be by full furnace heat treatment or by local heating. When local heating is used, the width of the heated band shall be at least three (3) times the thickness of the thickest section at the joint.

   b) For Table 4 — Above 600° F the rate of heating and cooling shall not exceed 600° F per hour divided by one-half (1/2) the maximum thickness of material in inches at the weld, but in no case shall the rate exceed 600° F per hour.

   c) For Table A4 — Above 315° C the approximate rate of heating and cooling shall not exceed 315° C per hour divided by .021 times the maximum thickness of material in mm at the weld, but in no case shall the rate exceed 315° C per hour.

5. Base material size refers to the thickness at the weld of the thicker part being joined.

6. Hold Time Requirements:

   a) For Table 4 — Hold time shall be one (1) hr./in. up to 2″ thick with fifteen (15) minutes maximum. For 2″ and over; two (2) hours plus fifteen (15) minutes for each inch over 2″.

   b) For Table A4 — Hold time shall be one (1) hour/25.4mm up to 50.8mm thick with fifteen (15) minutes minimum. For 50.8mm and over; two (2) hours plus fifteen (15) minutes for each 25.4mm over 50.8mm.

7. Post weld heat treatment of stainless steel is neither required nor prohibited (Notes 2 and 3).

8. Information contained in this table, which covers materials commonly used in the manufacture of pipe hangers and supports, has been consolidated from ANSI/ASME B31.1-1986 edition.

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6.1.2 Electroplating shall be in accordance with ASTM B633 or B766 for the specific coating used. To avoid difficulty in assembling threaded parts that are plated, female machine threads may be tapped oversize. It is not permissible to rethread male parts after plating. It is acceptable for female threads to be uncoated.

6.1.3 Pre-galvanized sheet shall meet the requirements of ASTM A525.

6.1.4 Hot dip galvanizing shall be done in accordance with ASTM A153 or A123. To avoid difficulty in assembling threaded parts, it is recommended that male parts be shaken, spun, or hand brushed to remove spelter lumps from the threads. It is recommended that female machine threads be tapped oversize to accommodate the male thread. It is acceptable for female threads to be uncoated.

6.1.5 Mechanical plating shall be done in accordance with ASTM B695 and B696.

6.1.6 Repair of metallic protective coatings may be performed in accordance with coating manufacturer's recommendations.

6.2 Non-Metallic Coatings

6.2.1 Non-metallic coatings shall be the types selected for specific purposes. Application of coatings shall be in accordance with the coating manufacturer's recommendations. In general, only such coatings with good adhesive quality that will withstand reasonably rough handling should be used.

6.2.2 Non-metallic coatings that are suitable for threaded products may be applied before assembly.

6.2.3 Non-metallic coatings, jackets and liners to prevent abrasion of glass or plastic pipe, etc., shall be applied in accordance with manufacturer's recommendations.

6.2.4 Non-metallic coatings, jackets and liners for electrolytic resistance shall have dielectric strength suitable for the intended use.

6.3 Superficial copper plating or other superficial coatings are not intended to provide corrosion protection and are applied for identification purposes only.

7. DIMENSIONS

7.1 Unprotected flat steel bands shall have a minimum thickness of 0.12 inch (3.2mm) and a minimum width of 1 inch (25.4mm). As an exception for pipe NPS 1 (DN25) and smaller, the minimum cross section shall be 0.06 inch (1.6mm) x 0.75 inch (19.1mm). Equivalent cross sections may be substituted provided the minimum thickness is not decreased.

7.2 Hanger Types 5, 7, 9 and 10 that meet with tabulated load requirements of Table 1 and that have protective coatings in accordance with Section 6 need not conform to minimum dimensional requirements of Subsection 7.1.

7.3 Hanger rods shall be a minimum of 0.37 inch (9.6mm) diameter and shall be limited to pipe or tubing NPS 2 (DN50) and less. For pipe and tubing NPS 2.5 (DN65) and greater, the rod diameter shall be not less than 0.5 inch (12.7mm). In addition, the minimum rod diameter for rigid hangers must be sized for the loads shown in Table 1.

7.4 Hanger rods utilizing rolled threads must be threaded full length.

7.5 Eye rods shall have a minimum inside diameter of eye 0.12 inch (3.2mm) larger than the rod size.

7.5.1 Forged eye rods shall have a metal area across the eye equal to or greater than 1.25 times the area of the rod.

7.5.2 Formed and welded eye rods shall have a circumferential length of weld not less than twice the rod diameter.

8. THREADS

8.1 Screw threads shall be in conformance with ANSI B1.1 or National Institute of Standards Technology Handbook H-28, UNC 2A/2B for the coarse thread series and 8UN 2A/2B for the eight thread series.

8.2 Pipe threaded for adjustment means, shall be in accordance with ANSI/ASME B1.20-1 NPSM and NPSL for Standard Straight Pipe Threads.

8.3 Special thread forms and fits other than specified by Subsection 8.1 and 8.2 shall be used only when both male and female members are furnished as part of a permanent assembly or in cases listed in Section 6.

9. PROTECTION SADDLES AND SHIELDS

9.1 Pipe covering protection saddles (Type 39) shall be made of material as follows: For pipe NPS 5

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(DN125) and smaller, the minimum metal thickness shall be 0.12 inch (3.2mm); for pipe NPS 6 (DN150) and larger, the minimum metal thickness shall be 0.19 inch (4.8mm). Saddles shall have sufficient depth for the insulation thickness required and the ribs shall be notched so that rib contact with pipe is between 25% and 50% of each rib length. All standard saddles shall be 12 inch (305mm) in axial length and shall span an arc of approximately 60°. Saddles for pipe NPS 12 (DN300) and larger shall have a center rib. Standard saddles shall accommodate nominal insulation thicknesses 1″, 1-1/2″, 2″, 2-1/2″, 3″, 4″ and 5-1/2″ (25mm, 38mm, 51mm, 64mm, 76mm, 102mm and 140mm).

9.2 Pipe coverings protection shields (Type 40) can be used with or without high compressive strength inserts.

9.2.1 When used without high compressive strength inserts, pipe covering protection shields shall be in accordance with Table 5, and shall span an arc of 180°.

9.2.2 When pipe covering protection shields are used with high compressive strength inserts, the shield length and thickness shall be appropriate for the compressive strength of the insert material. The insert shall be at least as long as the shield and where a vapor barrier is required, the vapor barrier shall extend 2 inches (51mm) beyond the shield and overlap the outside circumference by 2 inches (51mm).

9.2.3 It is recommended that provision be made to hold shields in place.

TABLE 5. DIMENSIONS FOR PIPE COVERING PROTECTION SHIELDS—TYPE 40

Nom. Pipe or Tub. Size		Length		Thickness	
Inches	mm	Inches	Millimeters	Gage	Inches
¼-3½	7-90	12	305	18	.048
4	100	12	305	16	.060
5 & 6	125 & 150	18	457	16	.060
8-14	200-350	24	610	14	.075
16-24	400-600	24	610	12	.105

Table 5 is based on 15 psi (103 kPa) compressive strength insulation. For compressive strengths other than 15 psi (103 kPa) dimensions may be adjusted accordingly.

10. SPRING SUPPORTS AND SWAY BRACES

10.1 Spring supports are divided into three classes; Spring Cushion, Variable Support, and Constant Support.

10.1.1 Spring Cushion Supports (Types 48 and 49). This class is limited to those using springs having a 2 inch (51mm) or less total deflection and which are not provided with load or travel indicators. Springs shall be confined so that accidental release of load is impossible. Travel limit stops need not be provided.

10.1.2 Variable Supports (Types 51, 52 and 53). This class applies to all variable effort type spring supports. Supports in this class shall have load and travel scales with provisions for marking "hot" and "cold" settings. Limit stops shall be provided to prevent excessive travel from overstressing the spring or release of load. A properly designed confined compression spring will serve as such a stop. Where stops for hydrostatic test purposes are provided, the unit shall be capable of supporting up to 2 times the normal operating load. Spring supports for this class shall have characteristics so that use at the maximum recommended pipe travel results in a variability factor of not more than 25%. (See Equation 1.)

Equation 1:

$$\text{Variability Factor} = \frac{\text{Pipe travel in (mm) x spring rate lbs/in (Kg/mm)}}{\text{Operating load lbs (Kg)}}$$

10.1.3 Constant Supports (Types 54, 55 and 56). This class applies to all constant effort type spring supports where the variable spring force is compensated either mechanically or by auxiliary springs to result in a mean variability (deviation from specified load)[1], including friction, of not more than 6% throughout total travel range. These supports shall be provided with a travel scale, a load adjustment scale, provisions for field load adjustment of at least ± 10%, provisions for "hot" and "cold" settings, limit stops to prevent over travel or release of load, and

(1) Deviation from specified load is the sum of kinematic friction and manufacturing tolerance factor. Determination of deviation is by load test machine and is calculated as in Equation 2.

Equation 2:

$$\text{Deviation from Specified Load} = \frac{\text{Max. reading moving down - Min. reading moving up}}{\text{Max. reading moving down + Min. reading moving up}}$$

Maximum reading moving down and minimum reading moving up shall be within 6% of specified load.

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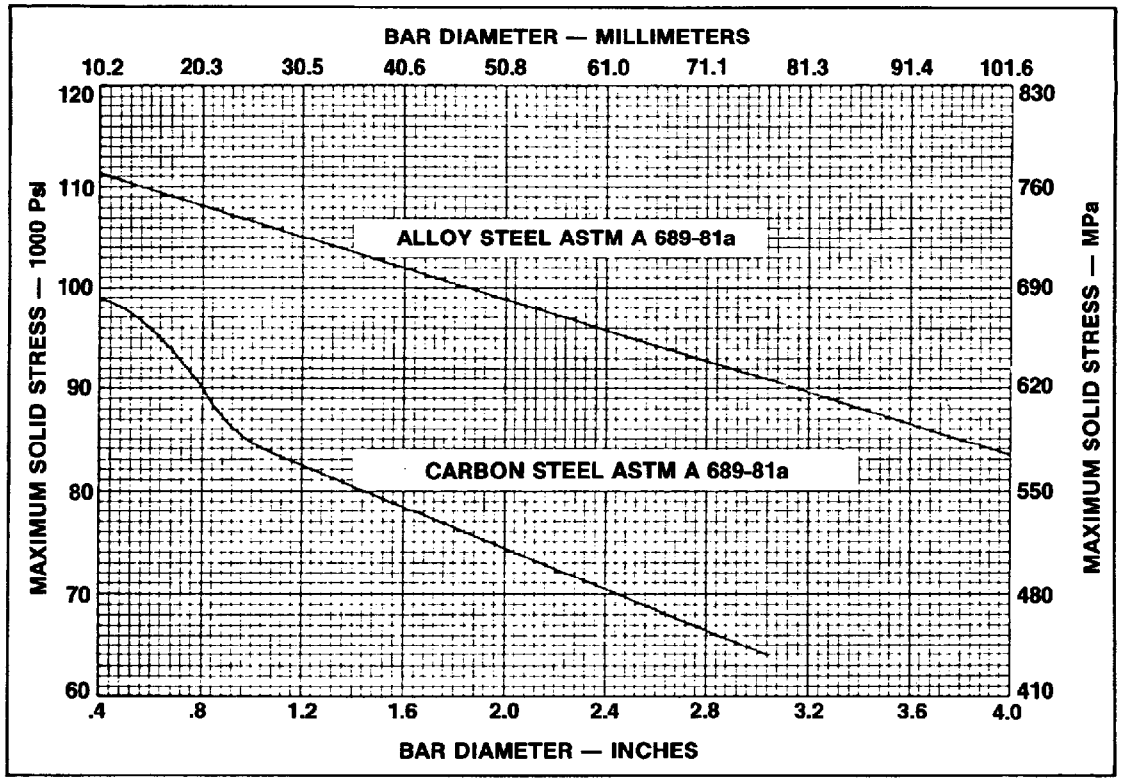

FIGURE 2. SOLID DESIGN STRESS (UNCORRECTED) FOR HOT WOUND COMPRESSION SPRINGS

auxiliary stops (where required) for erection and hydrostatic test purposes. The unit shall be capable of supporting up to 2 times the normal operating load. All constant supports shall be calibrated by the manufacturer. Special consideration shall be given to the possible effects of calibrating the unit in other than the intended installed position. The user is advised to specify a unit with sufficient total travel to provide adequate travel reserve.

10.2 Spring Sway Brace (Type 50). This class includes spring devices designed to control undesirable pipe movement and also provide forces to restore pipe to normal operating position. They shall consist of one or more springs, suitably confined, and may be either single or double acting.

11. SPRING DESIGN

11.1 Structural components of all classes of spring supports and sway braces noted in Section 10 shall be designed as specified elsewhere in this standard except that springs shall be designed as stated in 11.2 through 11.5.

11.2 Springs for pipe supports are generally of the helical coil type. Compression springs, unless suitably guided, shall have a free length to coil diameter (O.D.) ratio not greater than 4:1. Special forms of springs such as leaf, disc, volute, involute, torsion, and the like may be used. Such forms, when used, are to be designed and manufactured in accordance with acceptable commercial practices.

11.3 Helical Hot Wound Springs

11.3.1 Springs shall be designed so that maximum uncorrected solid stress[1] for compression springs shall not exceed those shown on the chart, Figure 2, by more than 10%. Working stresses (uncorrected) for compression springs shall be limited to 80% of the chart values. For extension springs the solid stress (uncorrected) shall be limited to 90% of chart values and working stress (uncorrected) shall be limited to 70% of the chart values.

11.3.2 Springs shall be manufactured in accordance with ASTM A125.

11.3.3 Alloy Springs of 1.5 inch (38.1mm) and larger bar diameter shall be inspected after heat

[1] Maximum uncorrected solid stress is a calculated stress without correction for curvature.

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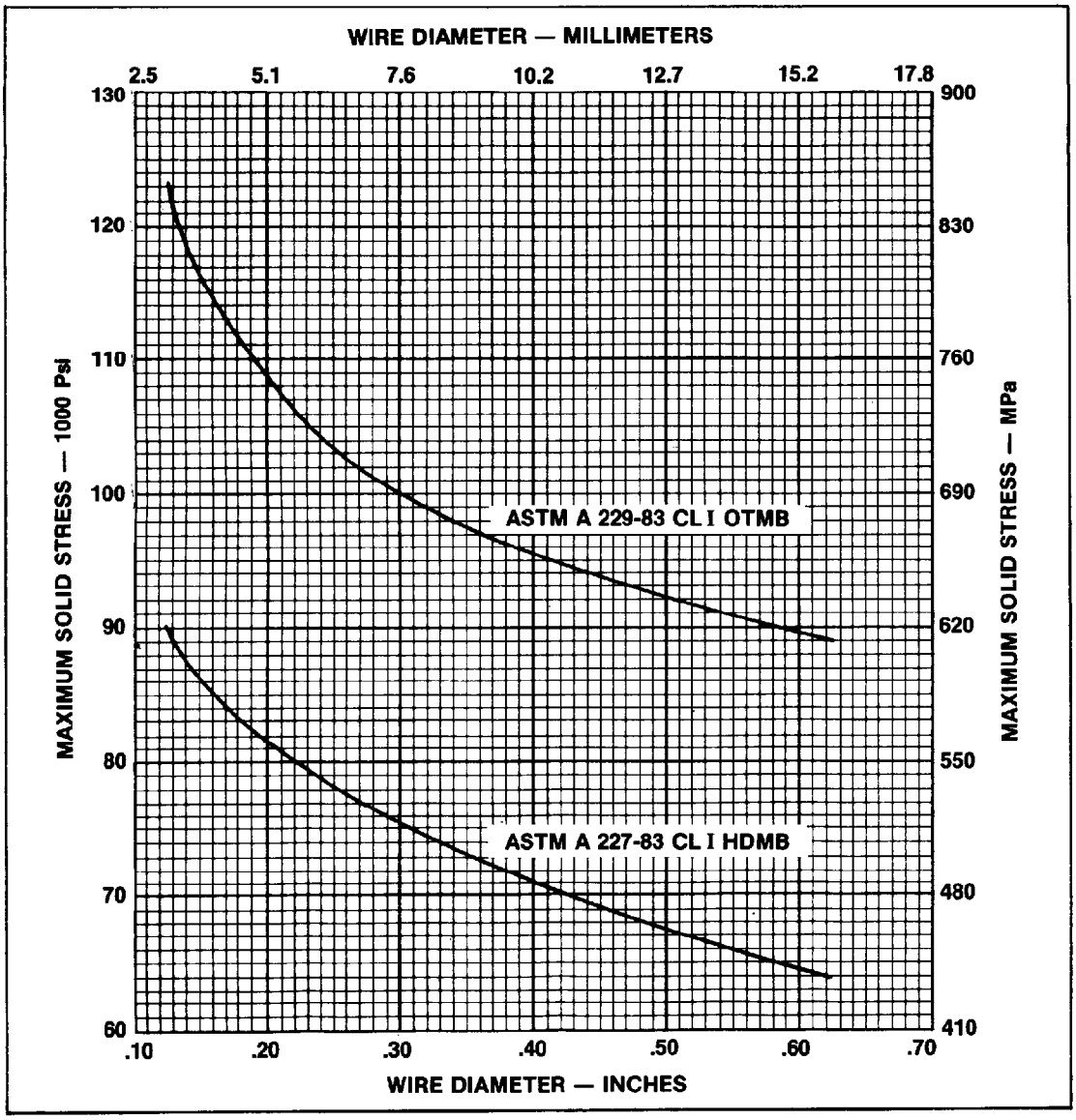

FIGURE 3. SOLID DESIGN STRESS (UNCORRECTED) FOR COLD WOUND COMPRESSION SPRINGS

treatment by the magnetic particle or equivalent method. Springs with seams, slits, or quench cracks deeper than 3% of bar diameter shall be rejected. The depth of discontinuity may be determined by grinding and blending, and measuring the minimum diameter of the remaining bar.

11.4 Helical Cold Wound Springs

11.4.1 Compression springs shall be designed so that the maximum uncorrected solid stress shall not exceed those shown on the chart, Figure 3. Working stresses (uncorrected) for compression springs shall be limited to 80% of chart values. For extension springs both solid stress and working stress shall be reduced 10% from that allowed for compression springs.

11.4.2 Springs shall be manufactured in accordance with Spring Manufacturers Institute, Inc., Standard for Compression, Extension, Torsion and Flat Springs.

11.5 Springs may be electroplated for corrosion protection provided proper procedures to avoid embrittlement are observed in accordance with ASTM B242. Maximum allowable working stress shall be reduced 15% for electroplated springs. Non-

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metallic coatings shall be applied for corrosion protection wherever possible to avoid inherent electroplating difficulties.

12. RESTRAINT CONTROL DEVICES (TYPE 47)

12.1 Hydraulic devices for the control of vibration or shock may be piston or rotating vane type and shall be designed in accordance with proven commercial practice. It is recommended that a non-flammable fluid be used. These devices can accommodate thermal movement.

12.2 Mechanical devices for the control of vibration and shock shall be designed in accordance with the requirements of Section 4. Materials shall be suitable for the intended service and ambient conditions. These devices can accommodate thermal movement.

12.3 Rigid struts or sway braces used for the control of vibration and shock shall be designed in accordance with the requirements of Section 4. Materials shall be suitable for the intended service and ambient conditions. These devices cannot accommodate thermal movement in the primary direction (Tension or compression).

13. MARKING

13.1 On cast hangers or supports, the name, initial or other identifying mark may be legibly cast on each piece. On fabricated hangers and supports, the name or mark may be die stamped on a main member. This marking may be omitted if it cannot be incorporated into the regular production process without additional operational steps, and should be omitted where it may impair the strength.

13.2 Hanger components specifically sized for use on copper tubing or copper pipe are normally identified by the manufacturer by a color system; this may not be intended to provide corrosion protection. The user should consult with the manufacturer when corrosion protection is required. (See Subsection 6.3)

14. INSPECTION

Units shall be inspected in accordance with the established quality control procedures of the manufacturer.

15. TESTING

Any physical or non-destructive testing of units or parts thereof, beyond that required for normal production control, shall be the responsibility of the purchaser.

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TABLE A1. MATERIALS AND ALLOWABLE STRESSES — METRIC UNITS

ASTM Spec	Grade or Class	Material Composition	Condition	Minimum Tensile MPa	Minimum Yield MPa	Maximum Allowable Stresses in Tension in MPa for Metal Temperatures Not Exceeding Degrees C													
						-29 to 231	325	350	375	400	425	450	475	500	525	550	575	600	625	650
STRUCTURAL STEEL																				
A36	—	Carbon Steel	HR	400	248	100	100	99	95	87										
(1) A500	B	Carbon Steel	CF	400	290	100	100	99	95	87										
(1) A500	C	Carbon Steel	CF	427	317	103	103	102	98	90										
(1) A501	—	Carbon Steel	HR	400	248	100	100	99	95	87										
A514	t≤ 2½	Alloy Steel	QT	758	690	190	190	188	184											
A514	t> 2½	Alloy Steel	QT	690	621	172	172	171	168											
A517	t≤ 2½	Alloy Steel	QT	793	690	199	199	197												
A517	t> 2½	Alloy Steel	QT	724	621	181	181	181	180											
RODS & BARS																				
A36	—	Carbon Steel	HR	400	248	100	100	99	94	87										
(1)(14) A108	1018	Carbon Steel	CF	414	345	93	93	92												
(1)(15) A108	1018	Carbon Steel	CF	379	310	85	85	84												
(1) A108	1141	Carbon Steel	CF	621	552	140	140	138												
(1) A108	12L14	Carbon Steel	CF	538	414	121	121	119												
(1)(2) A575	1010	Carbon Steel	HR	324	179	73	73	72												
(1)(2) A575	1015	Carbon Steel	HR	345	190	78	78	77												
(1)(2) A575	1020	Carbon Steel	HR	379	207	85	85	84												
(1)(2) A575	1025	Carbon Steel	HR	400	221	90	90	89												
(1) A576	1010	Carbon Steel	HR	324	179	78	78	77	75	71										
(1) A576	1015	Carbon Steel	HR	345	190	86	86	85	82	77										
(1) A576	1020	Carbon Steel	HR	379	207	95	95	94	90	83										
(1) A576	1025	Carbon Steel	HR	400	221	95	95	94	90	83										
A322	4130	1 CR - 1/5 Mo	A	558	359	125	125	125	123											
A322	4140	1 CR - 1/5 Mo	A	655	483	148	148	148	146											
A331	41L40	1 CR - 1/5 Mo	A	655	483	148	148	148	146											
(3)(4) A276	304	18 CR - 8 Ni	—	517	207	86	78	77	76	74	73	72	70	69	68	67	64	59	51	41
(3)(4) A276	316	16CR-12Ni-2Mo	—	517	207	89	81	79	77	77	76	75	74	74	73	72	71	69	62	51
(3)(4) A276	321	18CR-10Ni-Ti	—	517	207	85	78	76	75	74	74	74	73	73	72	68	58	44	32	25
(3)(4) A276	347	18CR-10Ni-Cb	—	517	207	100	92	90	88	88	88	88	87	87	86	84	75	57	40	30
(3)(4) A479	304	18 CR - 8 Ni	—	517	207	86	78	77	76	74	73	72	70	69	68	67	64	59	51	41
(3)(4) A479	316	16CR-12Ni-2Mo	—	517	207	89	81	79	77	77	76	75	74	74	73	72	71	69	62	51
(3)(4) A479	321	18CR-10Ni-Ti	—	517	207	85	78	76	75	74	74	74	73	73	72	68	58	44	32	25
(3)(4) A479	347	18CR-10Ni-Cb	—	517	207	100	92	90	88	88	88	88	87	87	86	84	75	57	40	30
(6) A564	630	17CR-4Ni-4Cu	AH	1000	862	240	233	230												
A675	60	Carbon Steel	HR	414	207	103	103	102	97	90										
A675	65	Carbon Steel	HR	448	224	112	112	111	105	96										
A675	70	Carbon Steel	HR	483	241	121	121	119	112	102										
PLATE																				
A36	—	Carbon Steel	HR	400	248	100	100	99	94	87										
A285	A	Carbon Steel	HR	310	165	78	78	77	73	67										
A285	B	Carbon Steel	HR	345	186	86	86	85	82	76										
A285	C	Carbon Steel	HR	379	207	95	95	94	90	83										
A515	60	Carbon Steel	HR	414	221	103	103	102	97	89										
A515	65	Carbon Steel	HR	448	241	112	112	110	105	95										
A515	70	Carbon Steel	HR	483	262	121	121	119	112	101										
A516	60	Carbon Steel	HR	414	221	103	103	102	97	89										
A516	65	Carbon Steel	HR	448	241	112	112	110	105	95										
A516	70	Carbon Steel	HR	483	262	121	121	119	112	101										
A514	t≤ 2½	Alloy Steel	QT	758	690	190	189	188	183											
A514	t> 2½	Alloy Steel	QT	690	621	172	172	171	167											
A517	t≤ 2½	Alloy Steel	QT	793	690	199	198	196												
A517	t> 2½	Alloy Steel	QT	724	621	181	181	181	179											
A387	22	2¼CR-1Mo	—	414	207	103	103	103	103	103	103	99	92	81	64	48	36	25		
(3)(4) A240	304	18CR-8Ni	—	517	207	86	78	77	76	74	73	72	70	69	68	67	64	59	51	41
(3)(4) A240	316	16CR-12Ni-2Mo	—	517	207	89	81	79	77	77	76	75	74	74	73	72	71	69	62	51
(3)(4) A240	321	18CR-10Ni-Ti	—	517	207	85	78	76	75	74	74	74	73	73	72	68	58	44	32	25
(3)(4) A240	347	18CR-10Ni-Cb	—	517	207	100	92	90	88	88	88	88	87	87	86	84	75	57	40	30

HR - Hot Rolled
CF - Cold Finished
DNT - Double Normalized & Tempered
A - Annealed
N - Normalized
NT - Normalized & Tempered
QT - Quenched & Tempered
HT - Heat Treated
AH - Age Hardened

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TABLE A1. MATERIALS AND ALLOWABLE STRESSES (Continued) — METRIC UNITS

ASTM Spec	Grade or Class	Material Composition	Condition	Minimum Tensile MPa	Minimum Yield MPa	Maximum Allowable Stresses in Tension in MPa for Metal Temperatures Not Exceeding Degrees C													
						-29 to 231	325	350	375	400	425	450	475	500	525	550	575	600	625	650
SHEET & STRIP																				
A109	#4	Carbon Steel	CF	290	—	66	66	64												
(1) A366	—	Carbon Steel	CF	331	283	66	66	64												
(1) A446	A	Carbon Steel	HR	310	165	78	78	76												
(1) A526	—	Carbon Steel	HR	310	165	78	78	76												
(1) A569	—	Carbon Steel	HR	310	165	78	78	76												
(1) A570	33	Carbon Steel	HR	359	228	79	79	77												
(1) A570	40	Carbon Steel	HR	379	276	88	88	86												
(1) A635	1010	Carbon Steel	HR	324	179	73	73	71												
(1) A659	1020	Carbon Steel	HR	345	186	79	79	77												
(3)(4) A240	304	18CR-8Ni	—	517	207	86	78	77	76	74	73	72	70	69	68	67	64	59	51	41
(3)(4) A240	316	16CR-12Ni-2Mo	—	517	207	89	81	79	77	77	76	75	74	74	73	72	71	69	62	51
(3)(4) A240	321	18CR-10Ni-Ti	—	517	207	85	78	76	75	74	74	74	73	73	72	68	58	44	32	25
(3)(4) A240	347	18CR-10Ni-Cb	—	517	207	100	92	90	88	88	88	88	87	87	86	84	75	57	40	30
(6) A693	630	17CR-4Ni-4Cu	AH	1000	862	240	232	230												
PIPE & TUBING																				
A53	A	Carbon Steel	HR	331	207	83	83	82	81	81										
A53	B	Carbon Steel	HR	414	241	103	103	102	97	90										
A106	A	Carbon Steel	HR	331	207	83	83	82	80	74										
A106	B	Carbon Steel	HR	414	241	103	103	102	97	90										
A106	C	Carbon Steel	HR	483	276	121	121	119	112	102										
A513	1015	Carbon Steel	HR	331	241	83	83	81												
A513	1020	Carbon Steel	HR	359	262	90	90	88												
A513	1025	Carbon Steel	HR	386	276	97	97	95												
A519	1018	Carbon Steel	HR	345	221	86	86	84												
A335	P11	1¼CR-½Mo	HR	414	207	103	103	103	103	103	103	102	91	80	59	38	25	20		
A335	P22	2¼CR-1Mo	HR	414	207	103	103	103	103	103	103	102	91	80	64	48	36	27		
(3)(4) A312	304	18 CR - 8 Ni	—	517	207	86	78	77	76	74	73	72	70	69	68	67	64	59	51	41
(3)(4) A312	316	16CR-12Ni-2Mo	—	517	207	89	81	79	77	77	76	75	74	74	73	72	71	69	62	51
(3)(4) A312	321	18CR-10Ni-Ti	—	517	207	85	78	76	75	74	74	74	73	73	72	68	58	44	32	25
(3)(4) A312	347	18CR-10Ni-Cb	—	517	207	100	92	90	88	88	88	88	87	87	86	84	75	57	40	30
CASTINGS																				
A48	20	Gray Iron	—	138	—	14 (Limited to 200° C)														
A48	25	Gray Iron	—	172	—	17 (Limited to 200° C)														
A48	30	Gray Iron	—	207	—	21 (Limited to 200° C)														
A126	A	Gray Iron	—	145	—	14 (Limited to 200° C)														
A126	B	Gray Iron	—	214	—	21 (Limited to 200° C)														
A126	C	Gray Iron	—	283	—	28 (Limited to 200° C)														
A47	32510	Malleable Iron	A	345	224	69														
A47	35018	Malleable Iron	A	365	241	73														
A197	—	Malleable Iron	A	276	207	55														
A216	WCA	Carbon Steel	N	414	207	83	83	82	78	72										
A216	WCB	Carbon Steel	N	483	248	97	97	95	90	81										
A217	WC6	1¼CR-½Mo	NT	483	276	97	97	97	97	97	97	94	89	70	48	32	21			
A217	WC9	2¼CR-1Mo	NT	483	276	92	92	91	90	89	87	83	80	67	50	37	29			
A351	CF8	18CR-8Ni	—	483	207	69	62	61	59	59	59	57	56	54	53	51	47	38	31	25
A351	CF8C	18CR-10Ni-Cb	—	483	207	78	73	71	70	70	70	70	70	69	67	64	60	54	41	28
A351	CF8M	16CR-12Ni-2Mo	—	483	207	70	64	62	61	61	61	60	59	59	59	57	54	50	42	33
A395	—	Ductile Iron	—	414	276	83	83	81												
A536	-45-12	Ductile Iron	—	448	310	90	90	88												
FORGINGS																				
A668	A	Carbon Steel	—	324	—	81	81	79												
A668	B	Carbon Steel	A	414	207	103	103	101												
A668	C	Carbon Steel	A	455	228	114	114	112												
A668	D	Carbon Steel	N	517	259	126	126	124												
A668	E	Carbon Steel	DNT	586	303	146	146	144												
A668	F	Carbon Steel	QT	621	379	155	155	153												
A105	—	Carbon Steel	HT	483	248	121	121	119	112	102										
A181	70	Carbon Steel	—	483	248	121	121	119	112	102										
A182	F11	1¼CR-½Mo-Si	A	483	276	121	121	121	121	121	121	118	112	88	61	41	27	15		
A182	F22	2¼CR-1Mo	A	517	310	123	122	121	120	119	117	113	112	88	63	46	36	25		
(3)(4) A182	F308	18CR-8Ni	HT	517	207	86	78	77	76	74	73	72	70	69	68	67	64	59	51	41
(3)(4) A182	F320	16CR-12Ni-2Mo	HT	517	207	89	81	79	77	77	76	75	74	74	73	72	71	69	62	51
(3)(4) A182	F325	18CR-10Ni-Ti	HT	517	207	85	78	76	75	74	74	74	73	73	72	68	58	44	32	25
(3)(4) A182	F351	18CR-10Ni-Cb	HT	517	207	100	92	90	88	88	88	88	87	87	86	84	75	57	40	30

HR - Hot Rolled
CF - Cold Finished
DNT - Double Normalized & Tempered
A - Annealed
N - Normalized
NT - Normalized & Tempered
QT - Quenched & Tempered
HT - Heat Treated
AH - Age Hardened

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TABLE A1. MATERIALS AND ALLOWABLE STRESSES (Continued) — METRIC UNITS

ASTM Spec	Grade or Class	Material Composition	Condition	Minimum Tensile MPa	Minimum Yield MPa	Maximum Allowable Stresses in Tension in MPa for Metal Temperatures Not Exceeding Degrees C														
						-29 to 231	325	350	375	400	425	450	475	500	525	550	575	600	625	650
BOLTING																				
A307	A	Carbon Steel	—	414	—	103	103	101												
A307	B	Carbon Steel	—	414	—	103	103	101												
(8) A325	Type 2	Carbon Steel	HT	827	634	159	159	157												
(9) A325	Type 2	Carbon Steel	HT	724	558	139	139	137												
(10) A193	B7	1 CR - 1/5 Mo	HT	862	724	172	172	172	170	163	145	117	93	68	44					
(11) A193	B7	1 CR - 1/5 Mo	HT	793	655	159	159	159	158	153	138	112	92	68	44					
(12) A193	B7	1 CR - 1/5 Mo	HT	690	517	130	130	130	130	130	124	112	92	68	44					
(3)(4)(5) A193	B8	18 CR - 8 Ni	—	517	207	86	78	76	75	74	72	71	69	68	67	66	64	59	51	41
(3)(4)(5) A193	B8M	16CR-12Ni-2Mo	—	517	207	89	80	78	77	77	76	75	74	74	73	72	71	71	62	51
(3)(4)(5) A193	B8C	18 CR-10Ni-Cb	—	517	207	100	91	89	88	88	88	87	87	86	86	84	75	57	40	30
(3)(4)(5) A193	B8T	18CR-10Ni-Ti	—	517	207	83	78	76	74	74	74	73	73	72	72	68	58	44	32	25
(8) A449	—	Carbon Steel	QT	827	634	159	159	159	157											
(9) A449	—	Carbon Steel	QT	724	558	139	139	139	137											
(13) A449	—	Carbon Steel	QT	621	400	100	100	100	98											
A490	—	Alloy Steel	QT	1034	896	259	259	255												
RIVETS & NUTS																				
A563	All	Carbon Steel	—	Product Specification																
A194	All	—	—	Product Specification																
A502	—	Carbon Steel	—	359	193	83	83	80												
SPRINGS	See Figures 2 and 3 for Materials and Stresses																			

HR - Hot Rolled
CF - Cold Finished
DNT - Double Normalized & Tempered
A - Annealed
N - Normalized
NT - Normalized & Tempered
QT - Quenched & Tempered
HT - Heat Treated
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GENERAL NOTES

1) Allowable stresses for these materials are based upon those of comparable materials of similar chemical properties.
2) "M" grade steels are acceptable for A575 listings in lieu of non "M" grade steels.
3) For temperatures above 538°C, these stress values may be used only if the material is heat treated by heating it to a minimum temperature of 1038°C and quenching in water or rapidly cooling by other means.
4) At temperatures above 538°C, these stress values apply only when the carbon is 0.04% or higher on heat analysis.
5) Class 1 only.
6) Age hardened at 579°C.
7) For temperatures above 427°C, these stress values apply only when the carbon is 0.04% or higher.
8) For bolt diameters less than or equal to 25.4mm.
9) For bolt diameters greater than 25.4mm and less than or equal to 38.1mm.
10) For diameters less than or equal to 63.5mm.
11) For diameters greater than 63.5mm and less than or equal to 101.6mm.
12) For diameters greater than 101.6mm.
13) For bolt diameters greater than 38.1mm and less than or equal to 76.2mm.
14) For material thicknesses less than 50.8mm.
15) For material thicknesses 50.8 to 76.2mm.

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LIST OF MSS STANDARD PRACTICES

NUMBER	
SP- 6-1990	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP- 9-1992	Spot Facing for Bronze, Iron and Steel Flanges
SP-25-1993	Standard Marking System for Valves, Fittings, Flanges and Unions
SP-42-1990	Class 150 Corrosion Resistant Gate, Globe, Angle and Check Valves with Flanged and Butt Weld Ends
SP-43-1991	Wrought Stainless Steel Butt-Welding Fittings
SP-44-1991	Steel Pipe Line Flanges
SP-45-1992	Bypass and Drain Connections
SP-51-1991	Class 150 LW Corrosion Resistant Cast Flanges and Flanged Fittings
SP-53-1985 (R 1990)	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Magnetic Particle Examination Method
SP-54-1985 (R 1990)	Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components — Radiographic Examination Method
SP-55-1985 (R 1990)	Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components — Visual Method
SP-58-1993	Pipe Hangers and Supports — Materials, Design and Manufacture
SP-60-1991	Connecting Flange Joint Between Tapping Sleeves and Tapping Valves
SP-61-1992	Pressure Testing of Steel Valves
SP-65-1990	High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets
SP-67-1990	Butterfly Valves
SP-68-1988	High Pressure-Offset Seat Butterfly Valves
SP-69-1991	Pipe Hangers and Supports — Selection and Application
SP-70-1990	Cast Iron Gate Valves, Flanged and Threaded Ends
SP-71-1990	Cast Iron Swing Check Valves, Flanged and Threaded Ends
SP-72-1992	Ball Valves with Flanged or Butt-Welding Ends for General Service
SP-73-1991	Brazing Joints for Wrought and Cast Copper Alloy Solder Joint Pressure Fittings
SP-75-1993	Specifications for High Test Wrought Butt Welding Fittings
SP-77-1984 (R 1990)	Guidelines for Pipe Support Contractual Relationships
SP-78-1987 (R 1992)	Cast Iron Plug Valves, Flanged and Threaded Ends
SP-79-1992	Socket-Welding Reducer Inserts
SP-80-1987	Bronze Gate, Globe, Angle and Check Valves
SP-81-1981 (R 1986, 91)	Stainless Steel, Bonnetless, Flanged Knife Gate Valves
SP-82-1992	Valve Pressure Testing Methods
SP-83-1987	Steel Pipe Unions, Socket-Welding and Threaded
SP-84-1990	Valves — Socket-Welding and Threaded Ends
SP-85-1985	Cast Iron Globe & Angle Valves, Flanged and Threaded Ends
SP-86-1987 (R 1992)	Guidelines for Metric Data in Standards for Valves, Flanges, Fittings and Actuators
SP-87-1991	Factory-Made Butt-Welding Fittings for Class I Nuclear Piping Applications
SP-88-1993	Diaphragm Type Valves
SP-89-1991	Pipe Hangers and Supports — Fabrication and Installation Practices
SP-90-1986 (R 1991)	Guidelines on Terminology for Pipe Hangers and Supports
SP-91-1992	Guidelines for Manual Operation of Valves
SP-92-1987 (R 1992)	MSS Valve User Guide
SP-93-1987 (R 1992)	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Liquid Penetrant Examination Method
SP-94-1992	Quality Standard for Ferritic and Martensitic Steel Castings for Valves, Flanges, and Fittings and Other Piping Components — Ultrasonic Examination Method
SP-95-1986 (R 1991)	Swage(d) Nipples and Bull Plugs
SP-96-1991	Guidelines on Terminology for Valves and Fittings
SP-97-1987	Forged Carbon Steel Branch Outlet Fittings — Socket Welding, Threaded and Buttwelding Ends
SP-98-1992	Protective Epoxy Coatings for the Interior of Valves and Hydrants
SP-99-1989	Instrument Valves
SP-100-1988	Qualification Requirements for Elastomer Diaphragms for Nuclear Service Diaphragm Type Valves
SP-101-1989	Part-Turn Valve Actuator Attachment — Flange and Driving Component Dimensions and Performance Characteristics
SP-102-1989	Multi-Turn Valve Actuator Attachment — Flange and Driving Component Dimensions and Performance Characteristics
SP-103-1990	Wrought Copper and Copper Alloy Insert Fittings for Polybutylene Systems
SP-104-1990	Wrought Copper LW Solder Joint Pressure Fittings
SP-105-1990	Instrument Valves for Code Applications
SP-106-1990	Cast Copper Alloy Flanges and Flanged Fittings, Class 125, 150 and 300
SP-107-1991	Transition Union Fittings for Joining Metal and Plastic Products
SP-108-1991	Resilient Seated-Eccentric Cast Iron Plug Valves
SP-109-1991	Welded Fabricated Copper Sodder Joint Pressure Fittings
SP-110-1992	Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
SP-111-1992	Gray-Iron and Ductile-Iron Tapping Sleeves
SP-112-1993	Quality Standard for Evaluation of Cast Surface Finishes — Visual and Tactile Method. This SP must be sold with a 10-surface, three-dimensional Cast Surface Comparator, which is a necessary part of the Standard. Additional comparators may be sold separately.

R-Year — Indicates year standard reaffirmed without substantive change.

Prices available upon request.

A large number of former MSS Practices have been approved by the ANSI as ANSI Standards, published by others. In order to maintain a single source of authoritative information, the MSS withdraws its Standard Practices in such cases.

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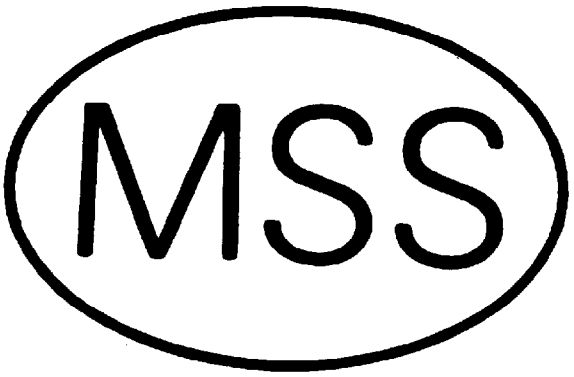

STANDARD PRACTICE **SP-69**

1996
Edition

PIPE HANGERS AND SUPPORTS — SELECTION AND APPLICATION

Developed and Approved
by the
Manufacturers Standardization Society
of the
Valve and Fittings Industry, Inc.
127 Park Street, N.E.
Vienna, Virginia 22180
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Originally Approved July 1966

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A Standard Practice is intended as a basis for common practice by the manufacturer, the user, and the general public. The existence of an MSS Standard Practice does not in itself preclude the manufacturer, sale, or use of products not conforming to the Standard Practice. Mandatory conformance is established only by reference in a code, specification, sales contract, or public law, as applicable.

FOREWORD

This standard was developed by a cooperative effort of representatives of the pipe hanger manufacturers. It is based on the best practice current at this time and on the collective experience of the industry. There are two companion standards, MSS SP-58 and MSS SP-89, relating to hanger materials, design, manufacture, fabrication and installation. In addition, the MSS Hanger Committee has developed guidelines for pipe supports contractural relationships and on hanger terminology as covered in MSS SP-77 and MSS-90 respectively.

U.S. customary units in this SP are the standard; the metric units are for reference only.

This document has been substantively revised from the previous 1991 edition. It is suggested that if the user is interested in knowing what changes have been made, that direct page by page comparison should be made of this document.

Other standards documents referred to herein are identified by the date of issue that was applicable to this standard at the date of issue of this standard. See Annex A. This standard shall remain silent on the applicability of those other standards of prior or subsequent dates of issue even though provisions of concern may not have changed.

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FIGURE 1. — TYPE CHART 5

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PIPE HANGERS AND SUPPORTS — SELECTION AND APPLICATION

1. SCOPE

1.1 This standard presents the recommended practice for the selection and application of pipe hangers and supports for all service temperatures.

2. OBJECTIVE

2.1 To serve as a pipe hanger and support specification for selection and application, by being referenced in whole or in part.

2.2 To serve as a guide to proven industry practice during engineering design and writing of job specifications covering the hanging, supporting and controlling the movement of piping systems.

2.3 To provide the erector with information on types of hanger and support components to be used for specific application and installations, where such information is not otherwise provided.

2.4 To serve as a companion document to MSS SP-58 which provides recommendations for material, design and manufacture of standard types of pipe hanger components.

2.5 To serve as a companion document to MSS SP-89 which provides recommendations for fabrication and installation of pipe hangers and supports.

3. CLASSIFICATION OF PIPING SYSTEMS

For the purpose of pipe hanger and support selection, this document establishes an identification of piping systems according to the operating (service) temperatures of the piping contents as follows:

3.1 Hot Systems

A-1. 120°F (49°C) to 450°F (232°C)
A-2. 451°F (233°C) to 750°F (399°C)
A-3. Over 750°F (399°C)

3.2 Ambient Systems

B. 60°F (16°C) to 119°F (48°C)

3.3 Cold Systems

C-1. 33°F (1°C) to 59°F (15°C)
C-2. -19°F (-28°C) to 32°F (0°C)
C-3. -39°F (-39°C) to -20°F (-29°C)
C-4. -40°F (-40°C) and below (Cryogenic Range)

4. GENERAL REQUIREMENTS

4.1 Where applicable, selection and application of pipe hangers and supports may be required to conform to Codes and Standards, such as:

a) ANSI/ASME B31 Codes for Pressure Piping
b) ASME Boiler and Pressure Vessel Codes
c) UL 203 Standard for Pipe Hanger Equipment for Fire Protection Service
d) Factory Mutual FM1951 Approval Standard for Pipe Hanger Components for Automatic Sprinkler Systems
e) NFPA 13
f) National and Local Building Codes
g) All Other Applicable Codes

4.2 The selection of pipe hangers and supports shall be based upon the overall design concept of the piping systems and any special requirements which may be called for in the specifications. The supporting systems shall provide for, and control, the free or intended movement of the piping including its movement in relation to that of connected equipment.

4.3 A careful study shall be made of the piping layout in relation to the surrounding structure and adjacent piping and equipment before selecting the type of support to be used at each hanger point.

4.4 Hangers, supports, anchors and restraints shall be selected to withstand all static and specified dynamic conditions of loading to which the piping and associated equipment may be subjected.

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4.5 When pipe hanger load and movement calculations are required by the design specification, the following must be considered:

a) Deadweight Loads
b) Hydrostatic Loads
c) Thermal Loads
d) Loading Due to Expansion Joint Reaction Forces

4.6 When occasional pipe hanger load calculations are required, they must be clearly defined in the design specification. Types of occasional loads are:

a) Safety Valve Thrust Loads
b) Seismic Loads
c) Wind, Snow or Ice Loads
d) Turbine Trip-out Loads
e) Water Hammer Loads

4.7 Allowable stress levels listed in MSS SP-58 shall be used in the design of hanger assemblies with the following exceptions:

a) The load capacities for threaded hanger rods shall conform to Table 3 of MSS SP-58.

b) A 20% increase in allowable stress may be permitted for short time overloading conditions during operation.

c) For steels of known physical properties, an increase to 80% of minimum yield strength, at room temperature, during hydrostatic testing, is permissible. For steels of unknown physical properties, an increase to 80% of yield strength, as determined by physical test, is permissible, provided that the maximum allowable stress does not exceed 16,000 PSI (110MPa).

d) Loading combination considerations and allowable stress levels to be applied shall be established by the architect-engineer.

4.8 Hanger and support components shall be selected from Table 1 within the system classification.

4.9 Where additional structural framing members are required, they shall be designed for the specific loads they are to support in accordance with the AISC Specification for the Design, Fabrication and Erection of Structural Steel for Buildings. No increase in allowable stress is permitted for hydrostatic test periods.

4.10 Hangers for the suspension of size 2½ and larger pipe and tubing shall be capable of vertical hanger component adjustment under load.

4.11 Building structure shall be adequate for supporting pipe hanger loads as generated in 4.5 and 4.6, including hydrostatic test loads.

4.12 Installed hangers or hanger components shall be used only for their purpose. They shall not be used for rigging and erection purposes.

5. MATERIAL REQUIREMENTS

5.1 The materials of all pipe hanging and supporting elements shall be in accordance with MSS SP-58.

5.2 The material in contact with the pipe shall be compatible with the piping material so that neither shall have a deteriorating action on the other.

5.3 Materials subject to corrosion or electrolysis shall be protected as specified by the engineering design and such protection shall be applied in accordance with the requirements of MSS SP-58.

6. DIMENSIONAL REQUIREMENTS

6.1 Hangers and supports shall be sized to fit the outside diameter of pipe, tubing, or, if specified, the outside diameter of insulation. Manufacturers' catalog hangers provide a nominal clearance over standard tolerance piping and tubing. Consideration for fit should be given by the user for large diameter and/or out of tolerance piping and tubing.

6.2 Dimensional tolerances shall be in accordance with Section 4 of MSS SP-89.

7. SELECTION OF HANGERS AND SUPPORTS FOR PIPE MOVEMENT

7.1 The selection of hangers and supports shall be made to provide the piping system with the degree of control that its operating characteristics require.

7.2 Where negligible movement of pipe occurs at hanger locations, and no harmful loading on connecting equipment, piping, or structure would result, rod hangers may be used for suspended lines. For piping supported from below, bases, brackets or structural cross members may be used.

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TABLE 1. HANGER & SUPPORT SELECTIONS

(For Spring Hangers, See Table 2)

To find recommended hanger or support components,

1. Locate the system temperature and insulation condition in the two columns at left.
2. Read across the column headings for the type of component to be used.
3. Numbers in boxes refer to those types shown in Figure 1, which corresponds to figure 1 of MSS-SP58.

SYSTEM TEMP. RANGE DEG. F(C)	INSULATION	HORIZONTAL PIPE ATTACHMENTS									
		STEEL CLIPS A	MALLEABLE IRON RINGS B	STEEL BANDS C	STEEL CLAMPS D	CAST IRON HANGING ROLLS E	CAST IRON SUPPORTING ROLLS F	STEEL TRAPEZES G	STEEL PROTECTION SADDLES & SHIELDS H	STEEL OR CAST IRON STANCHIONS I	STEEL WELDED ATTACHMENTS J
HOT A-1 120 (49) to 450 (232)	COVERED NOTE 1	24 W/ 39	NONE	1, 5, 7, 9, 10 W/ 39 OR 40	2, 3	41, 43 W/ 39 OR 40	44, 45, 46 W/ 39 OR 40	59 W/ 39 OR 40	39, 40	36, 37, 38 W/ 39 OR 40	35 NOTE 3
	BARE	24, 26	6, 11, 12	1, 5, 7, 9, 10	3, 4	41, 43	44, 45, 46	59	NONE	36, 37, 38	
HOT A-2 451 (233) to 750 (399)	COVERED NOTE 1	24 W/ 39	NONE	1 W/ 39 OR 40	3	41 W/ 39 OR 40	44, 45, 46 W/ 39 OR 40	59 W/ 39 OR 40	39, 40	36, 37, 38 W/ 39 OR 40	35 NOTE 3
	BARE	NONE	NONE	NONE	3, 4	NONE	NONE	NOTE 3	NONE	NONE	
HOT A-3 OVER 750 (399)	COVERED NOTE 1	NONE	NONE	1 W/ 40	ALLOY 2, 3	41, 43 W/ 40 OR ALLOY 39	44, 45, 46 W/ 40 OR ALLOY 39	59 W/ 40 OR ALLOY 39	40 ALLOY 39	36, 37, 38 W/ 40 OR ALLOY 39	ALLOY 35 NOTE 3
	BARE	NONE	NONE	NONE	ALLOY 2, 3, 4	NONE	NONE	NOTE 3	NONE	NONE	
AMBIENT B 60 (16) to 119 (48)	COVERED NOTE 1	24, 26	NONE	1, 5, 7, 9, 10 W/ 39 OR 40	3, 4	41, 43 W/ 39 OR 40	44, 45, 46 W/ 39 OR 40	59 W/ 39 OR 40	39, 40	36, 37, 38 W/ 39 OR 40	35 NOTE 3
	BARE	24, 26	6, 11, 12	1, 5, 7, 9, 10	3, 4	41, 43	44, 45, 46	59	NONE	36, 37, 38	
COLD C-1 33 (1) to 59 (15)	COVERED NOTE 1	26 W/ 40	NONE	1, 5, 7, 9, 10 W/ 40	3, 4 W/ 40	41, 43 W/ 40 NOTE 4	44, 45, 46 W/ 40 NOTE 4	59 W/ 40	40	36, 37, 38 W/ 40	NOTE 3
	BARE	24, 26	6, 11, 12	1, 5, 7, 9, 10	3, 4	41, 43	44, 45, 46	NOTE 3	NONE	36, 37, 38	
COLD C-2 -19 (-28) to 32 (0)	COVERED NOTE 1	NONE	NONE	1, 5, 7, 9, 10 W/ 40	NONE	41, 43 W/ 40 NOTE 4	44, 45, 46 W/ 40 NOTE 4	NOTES 3 & 4 W/ 40	40	36, 37, 38 W/ 40	NOTE 3
	BARE	NONE	NONE	1, 5, 7, 9, 10	3, 4	41, 43	44, 45, 46	NOTE 3	NONE	36, 37, 38	
COLD C-3 & C4 BELOW -19 (-28)	COVERED NOTE 1	NONE	NONE	1, 5, 7, 9, 10 W/ 40	NONE	41, 43 W/ 40 NOTE 4	44, 45, 46 W/ 40 NOTE 4	NOTES 2, 3, 4 W/ 40	40	36, 37, 38 W/ 40	NOTES 2 & 3
	BARE	NONE	NONE	NOTES 2 & 3	NOTES 2 & 3	NONE	NONE	NOTES 2 & 3	NONE	NOTES 2 & 3	

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TABLE 1. HANGER & SUPPORT SELECTIONS (Continued)

(For Spring Hangers, See Table 2)

SYSTEM	VERTICAL PIPE ATTACHMENTS			HANGER ROD FIXTURES			BUILDING STRUCTURE ATTACHMENTS				
TEMP. RANGE DEG. F(C)	STEEL RISER CLAMPS 2 BOLT	STEEL RISER CLAMPS 4 BOLT	WELDED ATTACHMENTS STEEL	STEEL OR MALLEABLE IRON			STEEL AND/OR MALLEABLE IRON				
				TURN BUCKLES	SWING EYES	CLEVISES	INSERTS	C-CLAMPS	BEAM CLAMPS	WELDED ATTACHMENTS	BRACKETS
	K	L	M	N	O	P	Q	R	S	T	U
HOT A-1 120 (49) to 450 (232	8	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	19, 23	20, 21, 25, 27 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
HOT A-2 451 (233) to 750 (399)	NONE	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	NONE	20, 21, 25, 27 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
HOT A-2 451 (233) to 750 (399)	NONE	ALLOY 42 NOTE 3	ALLOY NOTE 3	13	17	14	NOTES 3 & 5	NONE	20, 21, 25, 27 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
AMBIENT B 60 (16) to 119 (48)	8	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	19, 23	20, 21, 25, 27 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
COLD C-1 33 (1) to 59 (15)	8	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	19, 23	20, 21, 25, 27 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
COLD C2 -19 (-28) to 32 (0)	8	42 NOTE 3	NOTE 3	13, 15	16, 17	14	18 NOTE 5	19, 23	20, 21, 25, 27 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34
COLD C3 & C4 Below -19 (-28)	NOTES 2 & 3	NOTES 2 & 3	NOTES 2 & 3	13, 15	16, 17	14	18 NOTE 5	19, 23	20, 21, 25, 27 28, 29, 30	22, 57, 58 NOTE 3	31, 32, 33, 34

NOTES:

1. Hangers on insulated systems shall incorporate protection saddles or shields or shall be clamped or welded to the pipe and project through the insulation to provide external attachment. (See section 10)
2. The selection of type and material shall be made by the Design Engineer.
3. The design shall be in accordance with MSS SP-58 or as specified by the Design Engineer.
4. For shields used with rollers or subject to point loading, see Table 5.
5. Continuous inserts, embedded plates, anchor bolts and concrete fasteners may be used as specified by the Design Engineer.

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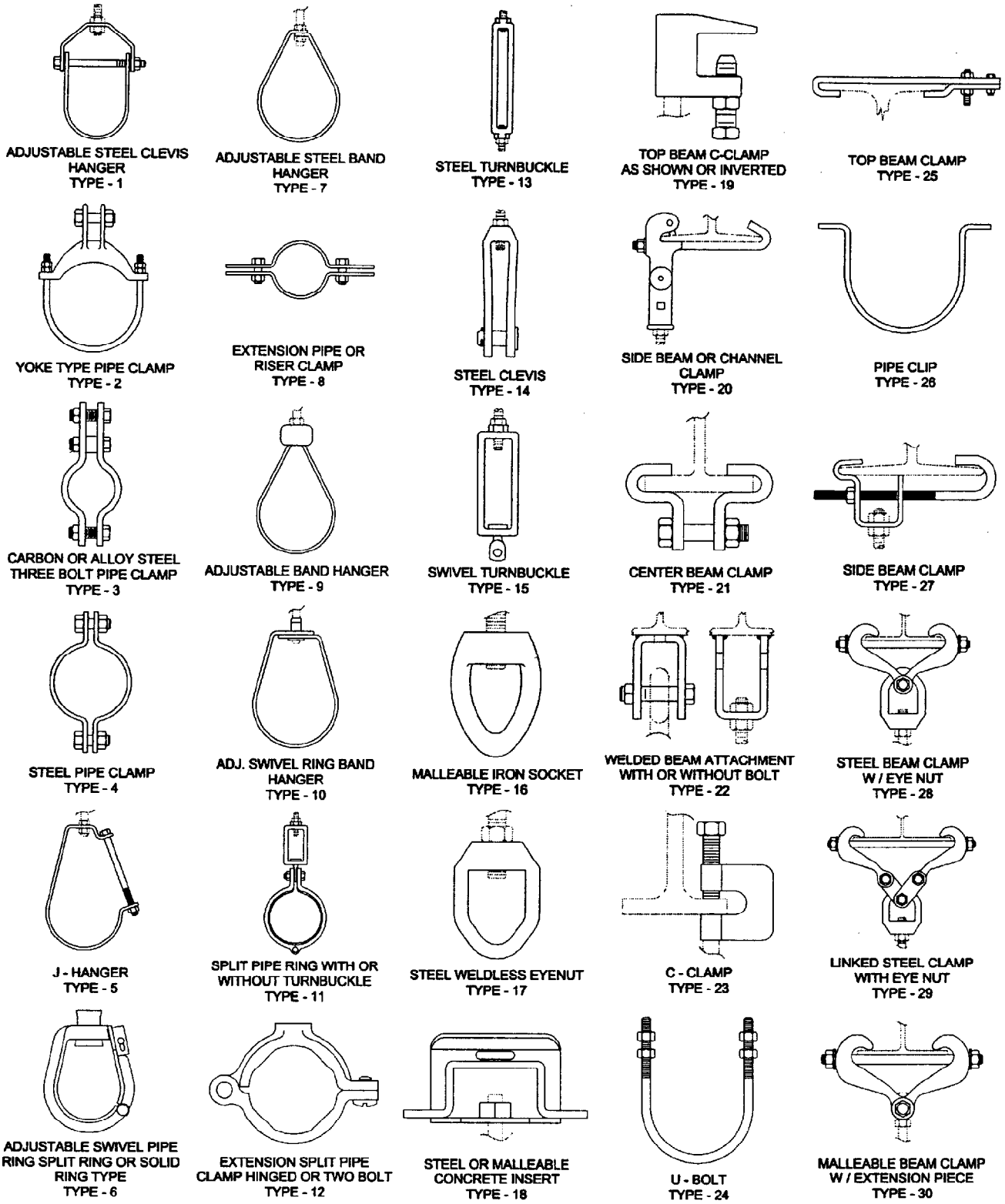

FIGURE 1. TYPE CHART

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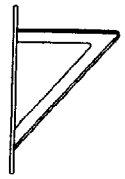
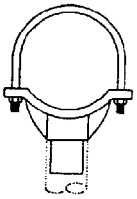
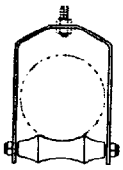
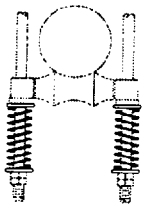
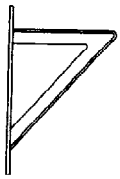

LIGHT WELDED STEEL BRACKET TYPE - 31

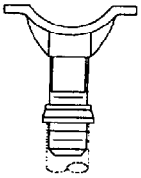

PIPE STANCHION SADDLE TYPE - 37

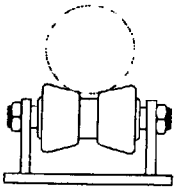

ADJUSTABLE ROLLER HANGER WITH OR WITHOUT SWIVEL TYPE - 43

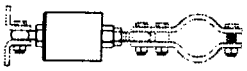

SPRING CUSHION ROLL TYPE - 49

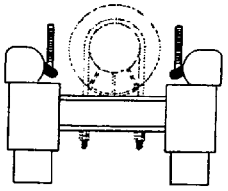
VERTICAL CONSTANT SUPPORT HANGER TYPE - 55

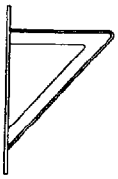

MEDIUM WELDED STEEL BRACKET TYPE - 32

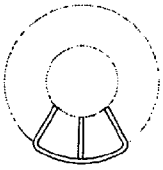

ADJUSTABLE PIPE SADDLE SUPPORT TYPE - 38

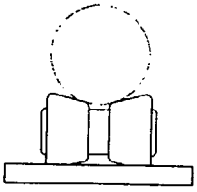

PIPE ROLL COMPLETE TYPE - 44


SPRING SWAY BRACE TYPE - 50


TRAPEZE CONSTANT SUPPORT HANGER TYPE - 56


HEAVY WELDED STEEL BRACKET TYPE - 33


STEEL PIPE COVERING PROTECTIVE SADDLE TYPE - 39


PIPE ROLL AND PLATE TYPE - 45

VARIABLE SPRING HANGER TYPE - 51

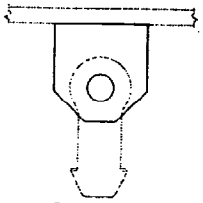
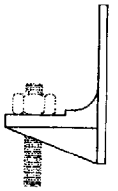
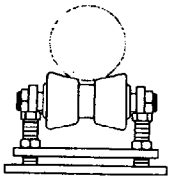
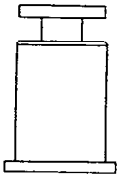


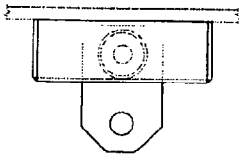
PLATE LUG TYPE - 57

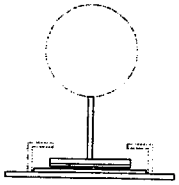

SIDE BEAM BRACKET TYPE - 34

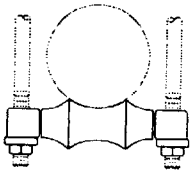
PROTECTION SHIELD TYPE - 40

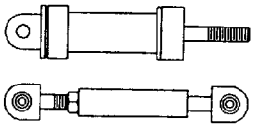

ADJUSTABLE PIPE ROLL AND BASE TYPE - 46

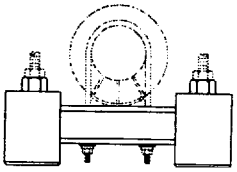

VARIABLE SPRING BASE SUPPORT TYPE - 52

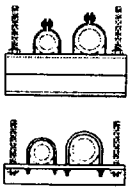

HORIZONTAL TRAVELER TYPE - 58

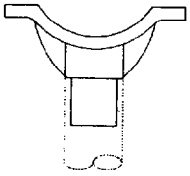

PIPE SLIDE & SLIDE PLATE TYPE - 35

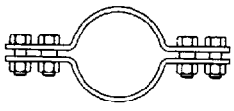

SINGLE PIPE ROLL TYPE - 41

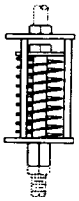

RESTRAINT CONTROL DEVICE TYPE - 47


VARIABLE SPRING TRAPEZE HANGER TYPE - 53


TRAPEZE HANGER TYPE - 59


PIPE SADDLE SUPPORT TYPE - 36


CARBON OR ALLOY STEEL RISER CLAMP TYPE - 42


SPRING CUSHION TYPE - 48

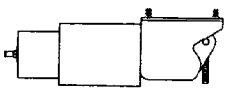

HORIZONTAL CONSTANT SUPPORT HANGER TYPE - 54

FIGURE 1. TYPE CHART

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7.3 Where there is horizontal movement at a suspended type hanger location, hanger components shall be selected to allow for swing. Where horizontal piping displacement exceeds 1 inch, it is common practice to offset the pipe attachment or structural attachment by the amount of anticipated displacement or a percentage thereof. If the vertical angle of the hanger rod is greater than 4 degrees, a traveling device should be provided for horizontal movement. In special cases, vertical angles greater than 4 degrees may be used provided the resulting horizontal force and vertical deflection are considered in the piping and support design. For piping supported from below, slides, rollers, or roller carriages should be used.

7.4 Where significant vertical movement of the pipe occurs at the hanger location, a resilient support must be used. Selection of resilient supports shall be based on permissible load variation and effects on adjacent equipment. Support selection for typical load variations are shown in Table 2. Load and movement calculations shall be made for the proper selection of spring hangers. Vertical movement and load transfer from riser expansion to horizontal runs shall be given consideration when applying spring hangers.

TABLE 2. SPRING SUPPORT SELECTION

VERTICAL EXPANSION	ALLOWABLE VARIABILITY OR DEVIATION	SINGLE ROD HANGER	DOUBLE ROD HANGER	BASE SUPPORT
	NOTE (1)	NOTE (2) AND NOTE (3)		
MAX. 1/4 INCH (6.3mm)	25% 6%	48,51SS 51SS	48,49,51SS,53SS 51S, 53S	52SS 52S
MAX. 1 INCH (25.4mm)	25% 6%	51S 54,55	51S, 53S 54,55,56	52S 54,55
MAX. 3 INCH (76.2mm)	25% 6%	51LS 54,55	51LS,53LS 54,55,56	52LS 54,55
OVER 3 INCH (76.2mm)	25% 6%	54,55 54,55	54,55,56 54,55,56	54,55 54,55

NOTE (1) VARIABLE SPRING HANGERS

$$\text{VARIABILITY FACTOR} = \frac{\text{Pipe Travel in. (mm) X Spring Rate lbs/in. (Kg/mm)}}{\text{Operating Load LBS (Kg)}}$$

CONSTANT SUPPORT HANGERS

$$\text{DEVIATION FROM SPECIFIED LOAD} = \frac{\text{Max Reading Moving Down - Min Reading Moving Up}}{\text{Max Reading Moving Down + Min Reading Moving Up}}$$

Max. Reading Moving Down and Min. Reading Moving Up shall be within 6% of specified load.

(2) – NUMBERS IN COLUMNS ARE TYPE NUMBERS FROM FIGURE 1.

(3) – VARIABLE SPRING TYPES 51, 52, AND 53, i.e., STANDARD SPRING, SHORT SPRING AND LONG SPRING MODELS ARE IDENTIFIED AS S, SS, AND LS, RESPECTIVELY.

7.4.1 Spring Cushion Hangers may be used where vertical movement does not exceed ¼ inch (6.3 mm), and where formal load and movement calculations are not required.

7.4.2 Variable Spring Hangers shall be used for all other resilient support requirements except as noted in Subsection 7.4.3.

7.4.3 Constant Support Hangers shall be used on piping systems where the deviation in supporting force must be limited to 6 percent and which cannot be accommodated by a Variable Spring Hanger.

8. ATTACHMENTS MADE BY WELDING OR BOLTING

8.1 All attachments welded to the pipe shall be in accordance with MSS SP-58 and Pipe Fabrication Institute, Standard ES-26.

8.2 Welding or bolting or attachments to the building structural steel shall be in accordance with the AISC Specification for the Design, Fabrication and Erection of Structural Steel for Buildings. There shall be no drilling, punching or burning of holes in the building structural steel without prior approval by the design engineers.

8.3 For attachment to concrete structure, poured in place anchor bolts or inserts are preferred whenever possible. When necessary, approved concrete fasteners may be used.

8.4 Recommended applied torque for set screws in C-clamps (Types 19 and 23) is listed below:

Thread size Inch	(mm)	Torque Inch Pound	(Nm)
1/4	6.4	40	4.5
3/8	9.6	60	6.8
1/2	12.7	125	14.1
5/8	15.8	250	28.2
3/4	19.0	400	45.2
7/8	22.2	665	75.1

Note: Caution should be taken not to overtighten the set screw.

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TABLE 3. MAXIMUM HORIZONTAL PIPE HANGER AND SUPPORT SPACING

NOMINAL PIPE OR TUBE SIZE	1 STD WT STEEL PIPE WATER SERVICE ft	1 STD WT STEEL PIPE WATER SERVICE m	2 STD WT STEEL PIPE VAPOR SERVICE ft	2 STD WT STEEL PIPE VAPOR SERVICE m	3 COPPER TUBE WATER SERVICE ft	3 COPPER TUBE WATER SERVICE m	4 COPPER TUBE VAPOR SERVICE ft	4 COPPER TUBE VAPOR SERVICE m
1/4	7	2.1	8	2.4	5	1.5	5	1.5
3/8	7	2.1	8	2.4	5	1.5	6	1.8
1/2	7	2.1	8	2.4	5	1.5	6	1.8
3/4	7	2.1	9	2.7	5	1.5	7	2.1
1	7	2.1	9	2.7	6	1.8	8	2.4
1 1/4	7	2.1	9	2.7	7	2.1	9	2.7
1 1/2	9	2.7	12	3.7	8	2.4	10	3.0
2	10	3.0	13	4.0	8	2.4	11	3.4
2 1/2	11	3.4	14	4.3	9	2.7	13	4.0
3	12	3.7	15	4.6	10	3.0	14	4.3
3 1/2	13	4.0	16	4.9	11	3.4	15	4.6
4	14	4.3	17	5.2	12	3.7	16	4.9
5	16	4.9	19	5.8	13	4.0	18	5.5
6	17	5.2	21	6.4	14	4.3	20	6.1
8	19	5.8	24	7.3	16	4.9	23	7.0
10	22	6.1	26	7.9	18	5.5	25	7.6
12	23	7.0	30	9.1	19	5.8	28	8.5
14	25	7.6	32	9.8				
16	27	8.2	35	10.7				
18	28	8.5	37	11.3				
20	30	9.1	39	11.9				
24	32	9.8	42	12.8				
30	33	10.1	44	13.4				

5 FIRE PROTECTION	6 DUCTILE IRON PIPE	7 CAST IRON SOIL	8 GLASS	9 PLASTIC	10 FIBERGLASS REINFORCED
FOLLOW REQUIREMENTS OF THE NATIONAL FIRE PROTECTION ASSOCIATION. SEE SECTION 14.	20 ft (6.1m) MAX SPACING; MIN OF ONE (1) HANGER PER PIPE SECTION CLOSE TO THE JOINT BEHIND THE BELL AND AT CHANGE OF DIRECTION AND BRANCH CONNECTIONS. FOR PIPE SIZES SIX (6) INCHES (150mm) AND UNDER, INSTALLED ON ANSI B31 PROJECTS, THAT ARE SUBJECTED TO LOADINGS OTHER THAN WEIGHT OF PIPE AND CONTENTS, THE SPAN SHOULD BE LIMITED TO THE MAXIMUM SPACING FOR WATER SERVICE STEEL PIPE.	10 ft (3.0m) MAX SPACING; MIN OF ONE (1) HANGER PER PIPE SECTION CLOSE TO JOINT ON THE BARREL. ALSO AT CHANGE OF DIRECTION AND BRANCH CONNECTIONS.	8 ft (2.4m) MAX SPACING, FOLLOW MANUFACTURER'S RECOMMENDATIONS. SEE SECTION 17.	FOLLOW PIPE MANUFACTURER'S RECOMMENDATIONS FOR MATERIAL AND SERVICE CONDITION. SEE SECTION 18.	FOLLOW PIPE MANUFACTURER'S RECOMMENDATIONS FOR MATERIAL AND SERVICE CONDITION. SEE SECTION 19.

NOTE: (1) FOR SPACING SUPPORTS INCORPORATING TYPE 40 SHIELDS, SEE TABLE 5.
(2) DOES NOT APPLY WHERE SPAN CALCULATIONS ARE MADE OR WHERE THERE ARE CONCENTRATED LOADS BETWEEN SUPPORTS SUCH AS FLANGES, VALVES, SPECIALTIES, ETC., OR CHANGES IN DIRECTION REQUIRING ADDITIONAL SUPPORTS.
(3) UNBALANCED FORCES OF HYDROSTATIC OR HYDRODYNAMIC ORIGIN (THRUST FORCES) UNLESS RESTRAINED EXTERNALLY CAN RESULT IN PIPE MOVEMENT AND SEPARATION OF JOINTS IF THE JOINTS OF THE SYSTEM ARE NOT OF A RESTRAINED JOINT DESIGN. SEE SECTION 13.3.

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9. HANGER AND SUPPORT SPACING

9.1 The maximum spacing of hangers and supports shall be as shown in Table 3.

9.2 Spacings less than shown in Table 3 may be required to conform with building structure loading limitations and standard product load ratings.

9.3 Minimum rod diameters for rigid rod hangers are listed in Table 4.

9.4 When periodic dismantling of a piping system for cleaning, etc. is anticipated, the design engineer shall specify any required additional supports.

9.5 For piping systems using type 40 protection shields for insulated piping, see Table 5 for spacing.

10. PIPE ATTACHMENTS FOR INSULATED LINES

10.1 The connections to pipe attachments shall be outside the insulation so that movement of the line shall not cause damage to the insulation.

10.2 Insulation protection shields shall be provided to protect the vapor barrier of insulation on cold lines. Under no circumstances shall hangers, supports or guides be applied directly to horizontal pipe or tubing on vapor barriered lines. (See Table 5.)

TABLE 4. MIN ROD DIAMETER FOR SINGLE RIGID ROD HANGERS(1)(2)

	COLUMNS(3) 1, 2, 6, 7		COLUMNS(3) 3, 4, 8, 9, 10	
NOMINAL PIPE OR TUBING SIZE	NOMINAL ROD DIA.		NOMINAL ROD DIA.	
	in	mm	in	mm
1/4	3/8	9.6	3/8	9.6
3/8	3/8	9.6	3/8	9.6
1/2	3/8	9.6	3/8	9.6
3/4	3/8	9.6	3/8	9.6
1	3/8	9.6	3/8	9.6
1 1/4	3/8	9.6	3/8	9.8
1 1/2	3/8	9.6	3/8	9.6
2	3/8	9.6	3/8	9.6
2 1/2	1/2	12.7	1/2	12.7
3	1/2	12.7	1/2	12.7
3 1/2	1/2	12.7	1/2	12.7
4	5/8	15.8	1/2	12.7
5	5/8	15.8	1/2	12.7
6	3/4	19.0	5/8	15.8
8	3/4	22.2	3/4	19.0
10	7/8	22.2	3/4	19.0
12	7/8	22.2	3/4	19.0
14	1	25.4		
16	1	25.4		
18	1	25.4		
20	1 1/4	31.8		
24	1 1/4	31.8		

NOTE:
(1) For calculated loads, rod diameters may be sized in accordance with MSS SP-58, Table 3 provided Table 1 and paragraph 7.3 of MSS SP-58 are satisfied.
(2) Rods may be reduced one size for double rod hangers. Minimum rod diameter shall be 3/8 in. (9.6 mm).
(3) Columns noted refer to MSS SP-69, Table 3.

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TABLE 5. TYPE 40 PROTECTION SHIELDS FOR INSULATED PIPE AND TUBING

NOM. PIPE SIZE	SHIELD LENGTH		SHIELD THICKNESS		SPACING	
	in	mm	gage	in	ft	m
1/2 - 1 1/4	12	305	18	.048	7*	2.1
1 1/2	12	305	18	.048	9*	2.7
2 - 3 1/2	12	305	18	.048	10	3.0
4	12	305	16	.060	10	3.0
5 - 6	18	457	16	.060	10	3.0
8 - 14	24	610	14	.075	10	3.0
16 - 24	24	610	12	.105	10	3.0
NOM. TUBING SIZE	**SHIELD LENGTH**		**SHIELD THICKNESS**		**SPACING**	
	in	mm	gage	in	ft	m
1/4 - 3/4	12	305	18	.048	5*	1.5
1	12	305	18	.048	6*	1.8
1 1/4	12	305	18	.048	7*	2.1
1 1/2 - 2	12	305	18	.048	8*	2.4
2 1/2	12	305	18	.048	9*	2.7
3 - 3 1/2	12	305	18	.048	10	3.0
4	12	305	16	.060	10	3.0
5 - 6	18	457	16	.060	10	3.0
8	24	610	14	.075	10	3.0

NOTES: The listed spans and shield lengths are based on insulation with a compressive strength of 15 psi (103kPa). For insulation with compressive strengths greater than 15 psi (103kPa), span may be increased proportionately up to the maximum allowable as listed in Table 3. Spans marked * are the maximum allowable.

Protection shield gages listed are for use with band type hangers only. For point loading, increase shield thickness and length. When shields are used with rollers, shield thickness shall be adjusted accordingly and shield lengths shall be increased to keep rolling point of contact within the middle one-third of the shield length. For compressive strengths other than 15 psi (103kPa), shield dimensions may be adjusted accordingly.

10.3 For cryogenic piping systems, shields incorporating rigid, high density polyurethane foam inserts or other load bearing insulation should be used. The support should include means for maintaining vapor barrier integrity. Because of the temperature/compressive strength relationship of polyurethane foam, the recommended shield designs shown in Table 5 do not apply. Shields must be designed to accommodate loading conditions at both the installation and operating temperature.

11. MULTIPLE SUPPORTS

11.1 Horizontal banks of piping may be supported on a common base member without regard to the pipe centerline elevation. The particular method of support to be used shall be as required by the engineering design.

11.2 In the supporting of multiple pipe runs, provisions shall be made to keep the lines in their relative lateral positions, using clamps or clips as required. Lines subject to thermal expansion shall be free to roll axially or slide.

12. RISER SUPPORTS

12.1 The selection and location of riser supports shall take into consideration the entire weight of the riser, and adjacent piping, hydrostatic test load conditions, line temperature and available supporting structure. On a riser subject to expansion, only one support of the rigid type shall be used.

12.2 Riser clamps (Type 42) shall have a positive means of engagement between the pipe and the clamp.

12.3 Rigid riser clamps (Type 42), when used for deadweight purposes, shall be designed for two times the calculated load.

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13. ANCHORS, GUIDES AND RESTRAINTS

13.1 Anchors, guides and restraints shall be located by the specifications and/or drawings. Should the need or the desirability of relocating, eliminating or adding anchors, guides or restraints arise, such changes shall be brought to the attention of the design engineer for consideration and approval.

13.2 Anchors, guides and restraints shall be designed for imposed loadings as determined by the design engineer. For guided systems in the absence of specific lateral loads, the guide shall be designed for 20% of the dead weight load as a minimum.

13.3 For pressure piping with joints not having a restraining design, other positive restraining means such as clamps, rods and/or thrust blocking shall be used to maintain the integrity of the joints.

13.4 The necessity for, and the location of, shock suppressors and seismic control devices shall be as determined by the design engineer.

13.5 The location, type and number of corrective devices which may be necessary to control any unforeseen vibrations, as determined after the piping is in service, are not a part of this standard.

14. FIRE PROTECTION SYSTEMS

14.1 Hangers and supports for fire protection systems shall conform to the following standards published by the National Fire Protection Association in the National Fire Codes for fixed extinguishing equipment:

NFPA-11—Foam Extinguishing Systems
NFPA-12—Carbon Dioxide Systems
NFPA-13—Installation of Sprinkler Systems
NFPA-14—Standpipe and Hose Systems
NFPA-15—Water Spray Systems
NFPA-16—Foam Water Systems
NFPA-17—Dry Chemical Extinguishing Systems

14.2 Hangers, in general, are covered in NFPA-13. If the system is other than a standard water sprinkler system, the applicable NFPA Standard shall also be consulted.

15. DUCTILE IRON PIPING

15.1 The size of hanger components shall be suitable for the O.D. of the pipe to be supported.

15.2 For buried lines, supporting means that may be required due to soil conditions or settlement of terminal points, shall be specified by the design engineer.

16. CAST IRON SOIL PIPING

Requirements shall be as set forth in Section 15 except for spacing as noted in Table 3.

17. GLASS PIPING

17.1 Hangers shall be provided with pads or cushions on the bearing surfaces to prevent scratching the pipe. The hangers shall fit loosely around the pipe yet contact it through the pads or cushions in a manner to distribute the load over the largest possible area. Point loading shall be avoided. The system of hangers shall be designed with the least practical number of rigid anchor points. Supports for vertical piping and all anchors shall be as recommended by the pipe manufacturer.

17.2 Hangers shall be placed approximately one foot (305mm) from each side of fittings or couplings. At least two hangers shall be used for each 10-foot (3.0m) section.

18. PLASTIC PIPING

18.1 Rigid plastic piping shall normally be supported by the same type of hangers used with steel pipe.

18.2 In pressure applications, hangers shall be provided with pads or cushions on the bearing surfaces to prevent scratching the pipe. The hangers shall fit loosely around the pipe yet contact it through the pads or cushions in a manner to distribute the load over the largest possible area. Point loading shall be avoided. The system of hangers shall be designed with the least practical number of rigid anchor points. Supports for

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vertical piping and all anchors shall be as recommended by the pipe manufacturer.

18.3 Support spacing shall be based on the manufacturer's recommendations for the service conditions.

18.4 Flexible plastic tubing or rigid plastic pipe operating at temperatures high enough to materially lower its strength, shall be supported continuously.

19. FIBERGLASS REINFORCED PIPE (FRP)

19.1 The size of hanger shall be suitable for the O.D. of the pipe to be supported.

19.2 Support spacing shall be based on the manufacturer's recommendations for the service condition.

19.3 FRP should not be point loaded and all shields and hangers in contact with the pipe shall be free of burrs.

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ANNEX A
Referenced Standards and Applicable Dates

This Annex is an integral part of this standard practice which is placed after the main text for convenience.

AISC

AISC-1991	Manual of Steel Construction, 9th Edition

ANSI, ANSI/ASME, ASME, ASME/ANSI

B31.1-1992	Power Piping
B31.3-1993	Chemical Plant and Petroleum Refinery Piping
B31.4-1992	Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols
B31.5-1992	Refrigeration Piping
B31.8-1992	Gas Transmission and Distribution Piping Systems
B31.9-1988	Building Services Piping Code
ASME-1992	Boiler and Pressure Vessel Code

FM

FM1951-1975	Approval Standard for Pipe Hanger Components for Automatic Sprinkler Systems

MSS

SP-58-1993	Pipe Hangers and Supports - Materials, Design and Manufacture
SP-89-1991	Pipe Hangers and Supports - Fabrication and Installation Practices

NFPA

NFPA 11-1994	Low Expansion Foam
NFPA 12-1993	Carbon Dioxide Extinguishing Systems
NFPA 13-1994	Installation of Sprinkler Systems
NFPA 14-1993	Installation of Standpipe and Hose Systems
NFPA 15-1990	Water Spray Fixed Systems for Fire Protection
NFPA 16-1995	Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems
NFPA 17-1994	Dry Chamical Extinguishing Systems

PFI

ES-26-1993	Welded Load-Bearing Attachments to Pressure Retaining Piping Materials

UL

UL203-1992	Pipe Hanger Equipment for Fire Protection Service

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Publications of the following organizations appear in the above list:

AISC	American Institute of Steel Construction, Inc. 400 N. Michigan Avenue, Chicago, IL 60611, Phone: (708) 670-2400
ANSI	American National Standards Institute 11 West 42nd Street, New York, NY 10036, Phone: (212) 354-3300
ASME	The American Society of Mechanical Engineers 345 East 47th Street, New York, NY 10017, Phone: (212) 705-7500
FM	Factory Mutual Research 1151 Boston-Providence Turnpike, Norwood, MA 02062, Phone: (617) 762-4300
MSS	Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. 127 Park Street, N.E., Vienna, VA 22180, Phone: (703) 281-6613
NFPA	National Fire Protection Association Battery March Park, Quincy, MA 02269, Phone: (617) 770-3000
PFI	Pipe Fabrication Institute 1326 Freeport Road, Pittsburgh, PA 15238, Phone: (412) 274-4722
UL	Underwriters Laboratories 333 Pfingsten Road, Northbrook, IL 60062, Phone: (708) 272-8800

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LIST OF MSS STANDARD PRACTICES

NUMBER	
SP- 6-1996	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP- 9-1992	Spot Facing for Bronze, Iron and Steel Flanges
SP-25-1993	Standard Marking System for Valves, Fittings, Flanges and Unions
SP-42-1990 (R 1995)	Class 150 Corrosion Resistant Gate, Globe, Angle and Check Valves with Flanged and Butt Weld Ends
SP-43-1991 (R 1996)	Wrought Stainless Steel Butt-Welding Fittings
SP-44-1996	Steel Pipeline Flanges
SP-45-1992	Bypass and Drain Connections
SP-51-1991 (R 1995)	Class 150 LW Corrosion Resistant Cast Flanges and Flanged Fittings
SP-53-1995	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Magnetic Particle Examination Method
SP-54-1995	Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components — Radiographic Examination Method
SP-55-1996	Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components — Visual Method for Evaluation of Surface Irregularities
SP-58-1993	Pipe Hangers and Supports — Materials, Design and Manufacture
SP-60-1991	Connecting Flange Joint Between Tapping Sleeves and Tapping Valves
SP-61-1992	Pressure Testing of Steel Valves
SP-65-1994	High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets
SP-67-1995	Butterfly Valves
SP-68-1988	High Pressure-Offset Seat Butterfly Valves
SP-69-1996	Pipe Hangers and Supports — Selection and Application
SP-70-1990	Cast Iron Gate Valves, Flanged and Threaded Ends
SP-71-1990	Cast Iron Swing Check Valves, Flanged and Threaded Ends
SP-72-1992	Ball Valves with Flanged or Butt-Welding Ends for General Service
SP-73-1991	Brazing Joints for Wrought and Cast Copper Alloy Solder Joint Pressure Fittings
SP-75-1993	Specifications for High Test Wrought Butt Welding Fittings
SP-77-1995	Guidelines for Pipe Support Contractual Relationships
SP-78-1987 (R 1992)	Cast Iron Plug Valves, Flanged and Threaded Ends
SP-79-1992	Socket-Welding Reducer Inserts
SP-80-1987	Bronze Gate, Globe, Angle and Check Valves
SP-81-1995	Stainless Steel, Bonnetless, Flanged Knife Gate Valves
SP-82-1992	Valve Pressure Testing Methods
SP-83-1995	Class 3000 Steel Pipe Unions, Socket-Welding and Threaded
SP-85-1994	Cast Iron Globe & Angle Valves, Flanged and Threaded Ends
SP-86-1987 (R 1992)	Guidelines for Metric Data in Standards for Valves, Flanges, Fittings and Actuators
SP-87-1991 (R 1996)	Factory-Made Butt-Welding Fittings for Class I Nuclear Piping Applications
SP-88-1993	Diaphragm Type Valves
SP-89-1991	Pipe Hangers and Supports — Fabrication and Installation Practices
SP-90-1986 (R 1991)	Guidelines on Terminology for Pipe Hangers and Supports
SP-91-1992 (R 1996)	Guidelines for Manual Operation of Valves
SP-92-1987 (R 1992)	MSS Valve User Guide
SP-93-1987 (R 1992)	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Liquid Penetrant Examination Method
SP-94-1992	Quality Standard for Ferritic and Martensitic Steel Castings for Valves, Flanges, and Fittings and Other Piping Components — Ultrasonic Examination Method
SP-95-1986 (R 1991)	Swage(d) Nipples and Bull Plugs
SP-96-1996	Guidelines on Terminology for Valves and Fittings
SP-97-1995	Integrally Reinforced Forged Branch Outlet Fittings — Socket Welding, Threaded and Buttwelding Ends
SP-98-1996	Protective Coatings for the Interior of Valves, Hydrants, and Fittings
SP-99-1994	Instrument Valves
SP-100-1988	Qualification Requirements for Elastomer Diaphragms for Nuclear Service Diaphragm Type Valves
SP-101-1989	Part-Turn Valve Actuator Attachment — Flange and Driving Component Dimensions and Performance Characteristics
SP-102-1989	Multi-Turn Valve Actuator Attachment — Flange and Driving Component Dimensions and Performance Characteristic:
SP-103-1995	Wrought Copper and Copper Alloy Insert Fittings for Polybutylene Systems
SP-104-1995	Wrought Copper Solder Joint Pressure Fittings
SP-105-1996	Instrument Valves for Code Applications
SP-106-1990 (R 1996)	Cast Copper Alloy Flanges and Flanged Fittings, Class 125, 150 and 300
SP-107-1991	Transition Union Fittings for Joining Metal and Plastic Products
SP-108-1996	Resilient-Seated Cast Iron-Eccentric Plug Valves
SP-109-1991	Welded Fabricated Copper Solder Joint Pressure Fittings
SP-110-1996	Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
SP-111-1996	Gray-Iron and Ductile-Iron Tapping Sleeves
SP-112-1993	Quality Standard for Evaluation of Cast Surface Finishes — Visual and Tactile Method. This SP must be sold with a 10-surface, three-dimensional Cast Surface Comparator, which is a necessary part of the Standard. Additional comparators may be sold separately.
SP-113-1994	Connecting Joint between Tapping Machines and Tapping Valves
SP-114-1995	Corrosion Resistant Pipe Fittings, Threaded and Socket Welding, Class 150 and 1000
SP-115-1995	Excess Flow Valves for Natural Gas Service
SP-116-1996	Service Line Valves and Fittings for Drinking Water Systems
SP-117-1996	Bellows Seals for Globe and Gate Valves
SP-118-1996	Compact Steel Globe & Check Valves — Flanged, Flangeless, Threaded & Welding Ends (Chemical & Petroleum Refinery Service)

R-Year — Indicates year standard reaffirmed without substantive change. **Prices available upon request.**

A large number of former MSS Practices have been approved by the ANSI or ANSI Standards, published by others. In order to maintain a single source of authoritative information, the MSS withdraws its Standard Practices in such cases.

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STD.MSS SP-73-ENGL 1991 ■ 5770640 0500845 403 ■

STANDARD PRACTICE **SP-73**

1991
Edition

Reaffirmed
1996

BRAZING JOINTS for COPPER and COPPER ALLOY PRESSURE FITTINGS

Developed and Approved
by the
Manufacturers Standardization Society
of the
Valve and Fittings Industry, Inc.
127 Park Street, N.E.
Vienna, Virginia 22180
(703) 281-6613

Originally Approved February 1970

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Non-toleranced dimensions in this Standard Practice are nominal, and, unless otherwise specified, shall be considered "for reference only".

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STD.MSS SP-73-ENGL 1991 ■ 5770640 0500847 286 ■

BRAZING JOINTS for COPPER and COPPER ALLOY PRESSURE FITTINGS

1. SCOPE

This standard covers joints for installations assembled by brazing into a piping system with BAg or BCuP materials. This standard is allied to American National Standards ASME B16.18-1984 (R94), Cast Copper Alloy Solder Joint Pressure Fittings, and ASME B16.22-1995, Wrought Copper and Copper Alloy Solder Joint Pressure Fittings. It was developed for the purpose of providing dimensional information in regard to recommended minimum fitting ends suitable for brazing for the Pressure-Temperature Ratings of Table 1.

2. DESCRIPTION

Fittings shall be the same types and kinds and shall meet all requirements of ASME Standards B16.18 and ASME B16.22 with the following exceptions:

a) Pressure-temperature ratings (See Table 1).

b) Dimensions of ends (See Table 2).

c) Center-to-end and end-to-end dimensions prescribed by ASME B16.18 may be reduced in accordance with the variations of the solder joint end dimensions of the standard.

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TABLE 1. PRESSURE-TEMPERATURE RATINGS, BRAZED JOINTS FOR USE WITH TYPE L COPPER TUBING

Degree F and psi

Nominal Size	150°F psi	250°F psi	350°F psi	400°F psi
1/4	760	720	600	450
3/8	630	600	500	370
1/2	590	550	460	350
3/4	480	450	380	280
1	420	390	330	250
1¼	370	350	290	220
1½	350	330	270	200
2	300	290	240	180
2½	290	270	230	170
3	270	260	220	160
3½	260	250	210	150
4	250	240	200	150
5	230	220	180	140
6	220	200	170	130
8	230	220	180	140

(a) The table uses the computed allowable stress for annealed copper tubing at the indicated temperatures. Reference ASME B31.5-1992, Refrigeration Piping.

TABLE 2. DIMENSIONS OF ENDS FOR BRAZING

Dimensions in Inches

Nominal Size	Male End Length K (Minimum)	Female End Depth G (Minimum)
1/4	0.23	0.17
3/8	0.26	0.20
1/2	0.28	0.22
3/4	0.31	0.25
1	0.34	0.28
1-1/4	0.37	0.31
1-1/2	0.40	0.34
2	0.47	0.40
2-1/2	0.53	0.47
3	0.59	0.53
3-1/2	0.65	0.59
4	0.72	0.64
5	0.81	0.73
6	0.94	0.83
8	1.28	1.17

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SP-43-1991 (R 1996)	Wrought Stainless Steel Butt-Welding Fittings
SP-44-1996	Steel Pipeline Flanges
SP-45-1992	Bypass and Drain Connections
SP-51-1991 (R 1995)	Class 150 LW Corrosion Resistant Cast Flanges and Flanged Fittings
SP-53-1995	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Magnetic Particle Examination Method
SP-54-1995	Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components — Radiographic Examination Method
SP-55-1996	Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components — Visual Method for Evaluation of Surface Irregularities
SP-58-1993	Pipe Hangers and Supports — Materials, Design and Manufacture
SP-60-1991	Connecting Flange Joint Between Tapping Sleeves and Tapping Valves
SP-61-1992	Pressure Testing of Steel Valves
SP-65-1994	High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets
SP-67-1995	Butterfly Valves
SP-68-1988	High Pressure-Offset Seat Butterfly Valves
SP-69-1996	Pipe Hangers and Supports — Selection and Application
SP-70-1990	Cast Iron Gate Valves, Flanged and Threaded Ends
SP-71-1990	Cast Iron Swing Check Valves, Flanged and Threaded Ends
SP-72-1992	Ball Valves with Flanged or Butt-Welding Ends for General Service
SP-73-1991 (R 1996)	Brazing Joints for Wrought and Cast Copper Alloy Solder Joint Pressure Fittings
SP-75-1993	Specifications for High Test Wrought Butt Welding Fittings
SP-77-1995	Guidelines for Pipe Support Contractual Relationships
SP-78-1987 (R 1992)	Cast Iron Plug Valves, Flanged and Threaded Ends
SP-79-1992	Socket-Welding Reducer Inserts
SP-80-1987	Bronze Gate, Globe, Angle and Check Valves
SP-81-1995	Stainless Steel, Bonnetless, Flanged Knife Gate Valves
SP-82-1992	Valve Pressure Testing Methods
SP-83-1995	Class 3000 Steel Pipe Unions, Socket-Welding and Threaded
SP-85-1994	Cast Iron Globe & Angle Valves, Flanged and Threaded Ends
SP-86-1987 (R 1992)	Guidelines for Metric Data in Standards for Valves, Flanges, Fittings and Actuators
SP-87-1991 (R 1996)	Factory-Made Butt-Welding Fittings for Class I Nuclear Piping Applications
SP-88-1993	Diaphragm Type Valves
SP-89-1991	Pipe Hangers and Supports — Fabrication and Installation Practices
SP-90-1986 (R 1991)	Guidelines on Terminology for Pipe Hangers and Supports
SP-91-1992 (R 1996)	Guidelines for Manual Operation of Valves
SP-92-1987 (R 1992)	MSS Valve User Guide
SP-93-1[illegible]97 (R 1992)	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Liquid Penetrant Examination Method
SP-94-1992	Quality Standard for Ferritic and Martensitic Steel Castings for Valves, Flanges, and Fittings and Other Piping Components — Ultrasonic Examination Method
SP-95-1986 (R 1991)	Swage(d) Nipples and Bull Plugs
SP-96-1996	Guidelines on Terminology for Valves and Fittings
SP-97-1995	Integrally Reinforced Forged Branch Outlet Fittings — Socket Welding, Threaded and Buttwelding Ends
SP-98-1996	Protective Coatings for the Interior of Valves, Hydrants, and Fittings
SP-99-1994	Instrument Valves
SP-100-1988	Qualification Requirements for Elastomer Diaphragms for Nuclear Service Diaphragm Type Valves
SP-101-1989	Part-Turn Valve Actuator Attachment — Flange and Driving Component Dimensions and Performance Characteristics
SP-102-1989	Multi-Turn Valve Actuator Attachment — Flange and Driving Component Dimensions and Performance Characteristics
SP-103-1995	Wrought Copper and Copper Alloy Insert Fittings for Polybutylene Systems
SP-104-1995	Wrought Copper Solder Joint Pressure Fittings
SP-105-1996	Instrument Valves for Code Applications
SP-106-1990 (R 1996)	Cast Copper Alloy Flanges and Flanged Fittings, Class 125, 150 and 300
SP-107-1991	Transition Union Fittings for Joining Metal and Plastic Products
SP-108-1996	Resilient-Seated Cast Iron-Eccentric Plug Valves
SP-109-1991	Welded Fabricated Copper Solder Joint Pressure Fittings
SP-110-1996	Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
SP-111-1996	Gray-Iron and Ductile-Iron Tapping Sleeves
SP-112-1993	Quality Standard for Evaluation of Cast Surface Finishes — Visual and Tactile Method. This SP must be sold with a 10-surface, three-dimensional Cast Surface Comparator, which is a necessary part of the Standard. Additional comparators may be sold separately.
SP-113-1994	Connecting Joint between Tapping Machines and Tapping Valves
SP-114-1995	Corrosion Resistant Pipe Fittings, Threaded and Socket Welding, Class 150 and 1000
SP-115-1995	Excess Flow Valves for Natural Gas Service
SP-116-1996	Service Line Valves and Fittings for Drinking Water Systems
SP-117-1996	Bellows Seals for Globe and Gate Valves
SP-118-1996	Compact Steel Globe & Check Valves — Flanged, Flangeless, Threaded & Welding Ends (Chemical & Petroleum Refinery Service)
SP-119-1996	Belled End Socket Welding Fittings, Stainless Steel and Copper Nickel

R-Year — Indicates year standard reaffirmed without substantive change.

Prices available upon request

A large number of former MSS Practices have been approved by the ANSI or ANSI Standards, published by others. In order to maintain a single source of authoritative information, the MSS withdraws its Standard Practices in such cases.

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MSS SP-89-1998

Pipe Hangers and Supports Fabrication and Installation Practices

Standard Practice
Developed and Approved by the
Manufacturers Standardization Society of the
Valve and Fittings Industry, Inc.
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Unless otherwise specifically noted in this MSS SP, any standard referred to herein is identified by the date of issue that was applicable to the referenced standard(s) at the date of issue of this MSS SP. (See Annex A.)

U.S. customary units in this SP are the standard; the metric units are for reference only.

This document has been substantively revised from the previous edition. It is suggested that if the user is interested in knowing what changes have been made, that direct page by page comparison should be made of this document.

FOREWORD

This standard was developed by a cooperative effort of representatives of the pipe hanger manufacturers. It is based on the best practice current at this time and on the collective experience of the industry. There are two companion standards, MSS SP-58, and MSS SP-69, relating to hanger materials, design, manufacture, fabrication, selection and application. In addition, The MSS Pipe Hanger Committee has developed guidelines for pipe supports contractual relationships and on hanger terminology as covered in MSS SP-77 and MSS SP-90 respectively.

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PIPE HANGERS AND SUPPORTS - FABRICATION AND INSTALLATION PRACTICES

1. OBJECTIVE

1.1 To serve as a guide to the fabricator and erector of pipe supports, so they may understand their mutual responsibilities.

1.2 To furnish the erector, who may not be familiar with engineered pipe supports, a guide for the proper installation of these supports.

1.3 To serve as a companion document to MSS SP-58 which provides recommendations for materials, design and manufacture of pipe hangers and supports.

1.4 To serve as a companion document to MSS SP-69 which provides recommendations for the selection and application of pipe hangers and supports.

2. SCOPE

2.1 This Standard Practice establishes recommended procedures for detailing, fabrication and installation of pipe hangers and supports. These procedures supplement, but do not replace, those of the manufacturer.

3. PIPE HANGER ASSEMBLY DRAWINGS

3.1 Description

3.1.1 This section contains recommendations for minimum data which should appear on hanger drawings to enable the fabricator to furnish, and the erector to install the hanger assembly, as intended by the job specification or purchase order conditions.

3.2 General

3.2.1 The conventional 8 ½ x 11 inch hanger draw-ing shall contain the information necessary for shop fabrication and field installation of the hanger assembly. In the case of complex assemblies, supplementary or larger, 11 x 17 inch sheets may be used.

3.2.2 The data shown on the hanger drawing should consist of:

a) Drawing of the assembly (Subsection 3.3)
b) Bill of material (Subsection 3.4)
c) Load and movement data (Subsection 3.5)
d) Supplementary steel (Subsection 3.6)
e) Field and shop welds (Subsection 3.7)
f) Protective coating (Subsection 3.8)
g) Location plan (Subsection 3.9)
h) Identification (Subsection 3.10)
i) Reference drawings (Subsection 3.11)

3.3 Drawing of the Assembly

3.3.1 Drawing shall be a pictorial representation of the assembly showing each component part identified to a bill of material item.

3.3.2 Dimensioning of the hanger assembly depends upon the complexity of the design. As a minimum, the following data should be shown:

a) The overall dimension from the supporting structure to the center line or bottom of the pipe.

b) The orientation, elevation, size and type of supporting structure.

c) Pipe size (nominal pipe size unless otherwise noted) and insulation thickness as applicable.

d) Pipe elevation.

e) Other dimensions necessary for the fabrication and installation of the complete hanger assembly.

f) Unless otherwise required, all dimensions shall be to the nearest one eighth inch (3 mm).

3.4 Bill of Material

3.4.1 An itemized bill of material shall be provided listing all components of the hanger assembly. Identification of standard catalog

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components shall be made by manufacturers figure number, type and size. Appropriate material specification shall be shown for special components.

3.5 Load and Movement Data

3.5.1 When required, the maximum operating load to be supported by the assembly shall appear on the drawing. Hydrostatic test loads, greater than operating loads, shall also be shown. When special loading conditions are considered, these loads shall also be shown.

3.5.2 When variable spring or constant support hangers are used, the direction from hot to cold and amount of vertical movement shall be shown.

3.6 Supplementary Steel

3.6.1 When supplementary steel is furnished as a part of the hanger assembly, it shall be listed in the bill of material.

3.6.2 When supplementary steel is required, but not furnished as part of the hanger contract, it should be so noted.

3.7 Field and Shop Welds

3.7.1 All shop welds of non-catalog items and all field welds shall be indicated on the drawing.

3.7.2 It is recommended that American Welding Society (AWS) standard weld symbols be used.

3.7.3 Welds required to provide final installation, access around pipe, or necessary to accommodate shipping and handling limitations, shall be specified as field welds.

3.8 Protective Coatings

3.8.1 Where required, the type and/or specification of protective coating shall be indicated on the drawing, or other referenced documents.

3.9 Location Plan

3.9.1 The location plan shows the relationship of the pipe and hanger to applicable reference lines, such as column lines, center lines of equipment, etc. (See Figures 1 and 1A). The location of the structural attachment is usually indicated by an "X" and is dimensioned to the north-south and east-west reference lines. A north arrow is usually shown.

3.9.2 Where horizontal piping displacement exceeds 1 inch (25 mm), it is common practice to offset the pipe attachment or structural attachment by the amount of anticipated displacement or a percentage thereof (See Figures 1 and 1A, Illustrations 2, 4 and 6).

3.10 Identification

3.10.1 Identification on the hanger drawing shall consist of, but not be limited to, the following:

a) Project identification
b) Piping system
c) Hanger mark number
d) Drawing and revision number

3.11 Reference Drawings

3.11.1 As a minimum, reference should be made to pertinent piping and/or structural drawings, including revision number.

4. DIMENSIONAL TOLERANCES

4.1 Description

4.1.1 This section covers recommended maximum tolerances in fabricated pipe hangers and supports, including those shown in the Figure 1 Type Charts of MSS SP-58, SP-69 and SP-90, except for cast or forged products and cold wound springs.

4.2 General

4.2.1 Tolerances for raw materials such as strip, sheet, bar, plate, pipe, tubing, structural and bar size shapes, bolting, hot wound springs and cold wound springs shall be in accordance with recognized standards or specifications.

4.2.2 Tolerances for castings, forgings and extrusions shall be to the individual manufacturer's standard.

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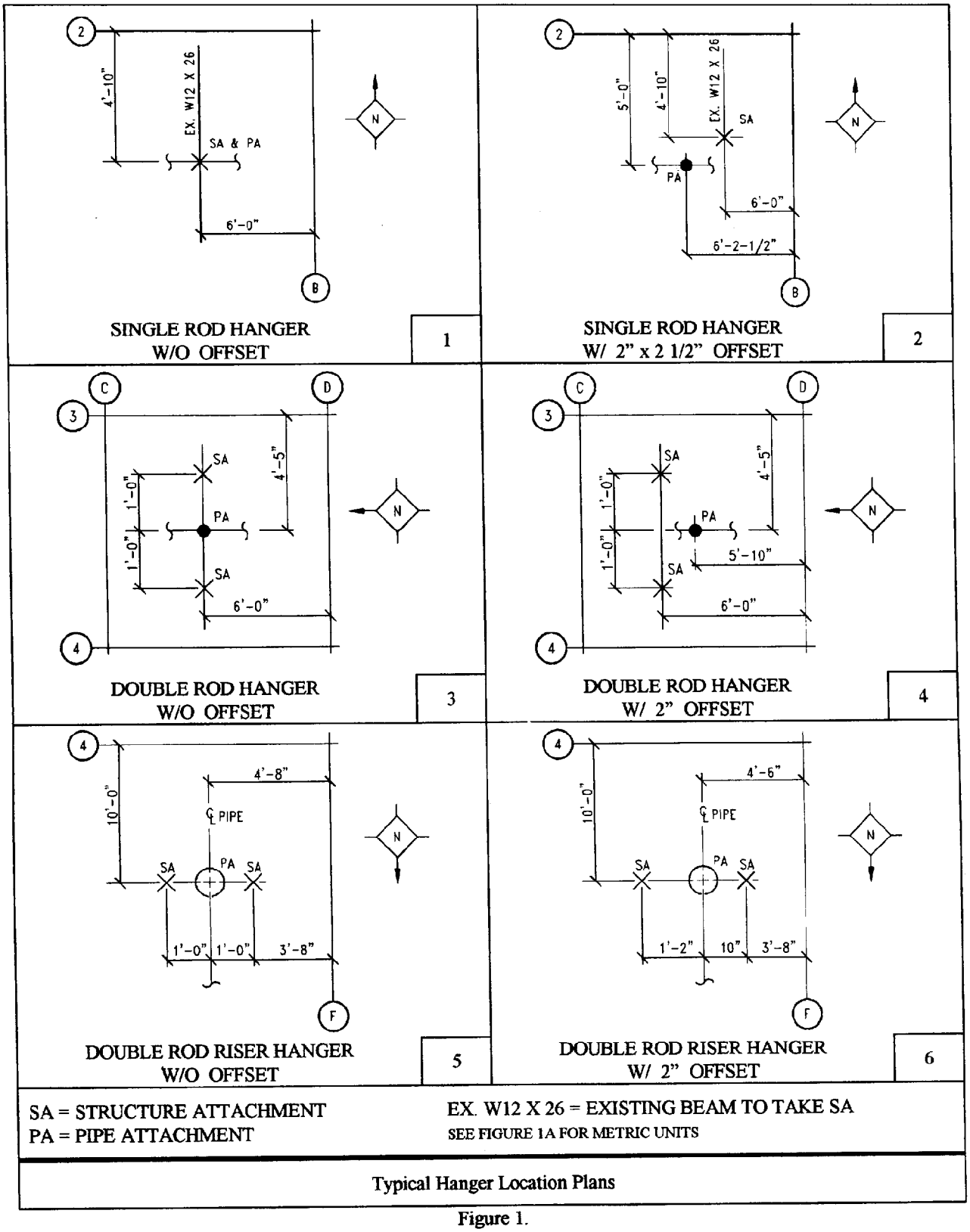

Figure 1.

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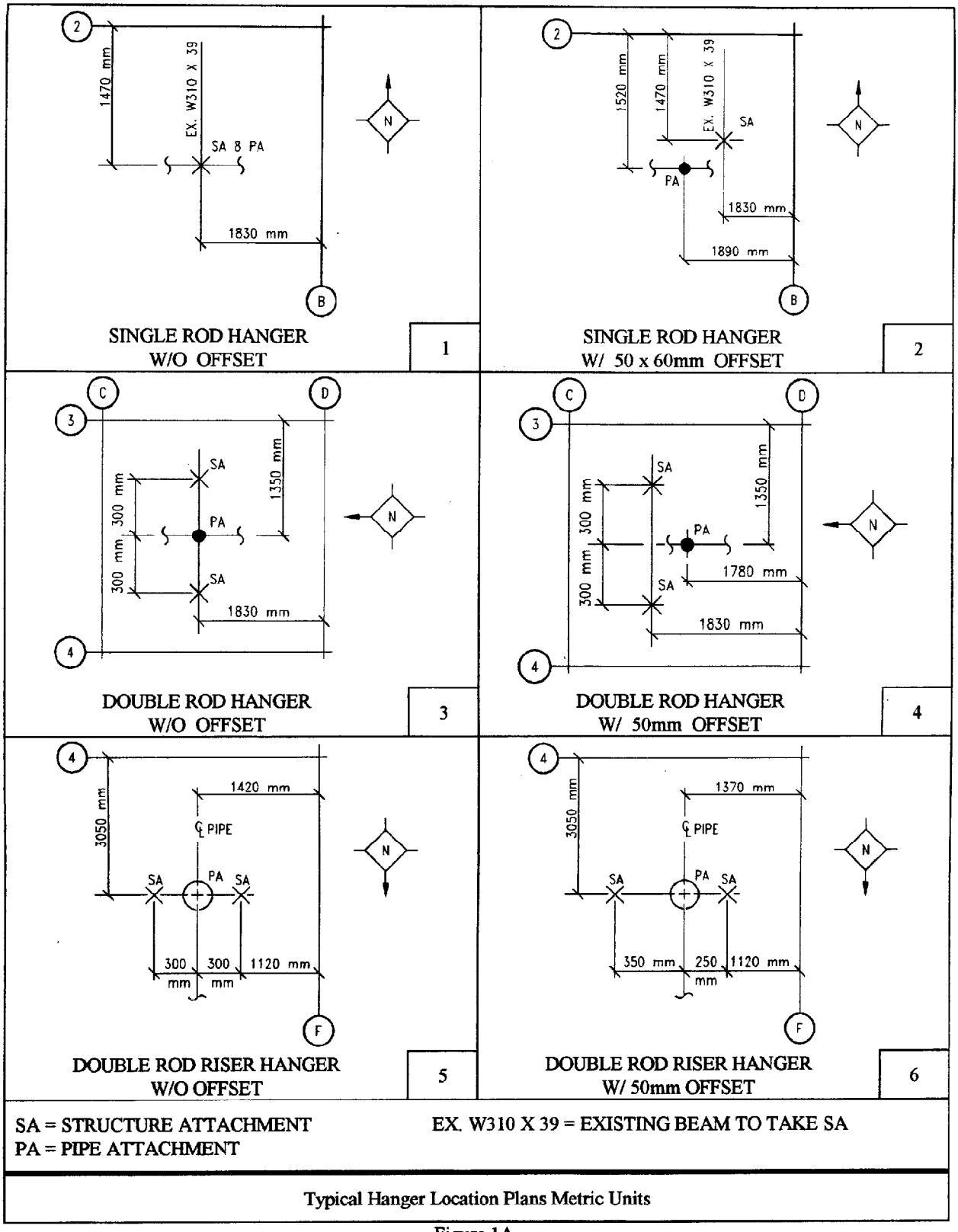

Typical Hanger Location Plans Metric Units

Figure 1A.

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TABLE 1. CLAMP TOLERANCES

Clamp, I.D.	Diameter	Pipe Centerline to Load Bolt Hole
up to 2 in. (51 mm)	± 1/16 in. (2 mm)	± 1/8 in. (3 mm)
over 2 in. to 4 in. (51 to 102 mm)	± 1/8 in. (3 mm)	± 1/8 in. (3 mm)
over 4 in. to 8 in. (102 to 305 mm)	± 3/16 in. (5 mm)	± 1/4 in. (6 mm)
Over 8 in. to 18 in. (305 to 457 mm)	± 1/4 in. (6 mm)	± 3/8 in. (10 mm)
Over 18 in. to 30 in. (457 to 762 mm)	± 3/8 in. (10 mm)	± 1/2 in. (13 mm)
Over 30 in. (762 mm)	± 1/2 in. (13 mm)	± 1/2 in. (13 mm)

Notes:
(a) Clamp I.D. equals pipe or tubing O.D. plus suitable clearance as established by the clamp manufacturer.
(b) Clamp I.D. measured at one half of the clamp width.
(c) Dimensions shown are in inches. Dimensions in parentheses are in millimeters.

4.3 Fabricating Tolerances

4.3.1 Cut to length - linear

a) Hanger rods ± ½ in. (13 mm)

b) Structural shapes, pipe and tubing for critical assembly make up dimensions ± 1/8 in. (3 mm). Squareness of cut 1 degree, not to exceed 1/8 in. (3 mm) offset.

c) Plates and bars for critical dimensions ± 1/8 in. (3 mm). Squareness of cut 1 degree, not to exceed 1/8 in. (3 mm) offset.

d) Tolerances for non-critical dimensions shall be to the individual manufacturer's standards.

4.3.2 Clamps for pipe and tubing, formed and fabricated, are shown in Table 1.

4.3.3 Threads

a) Screw threads - Shall be in conformance with ANSI/ASME B1.1-1989 or National Bureau of Standards Handbook H-28, UNC 2A / 2B for the coarse thread series and 8UN 2A / 2B for the eight thread series.

b) Pipe threads - Standard straight pipe threads for supports such as Type 38 shall be ANSI/ASME B1.20.1-1983 NPSM and NPSL, Standard Straight Pipe Threads.

c) Tapered pipe threads - Shall be in conformance with ANSI/ASME B1.20.1-1983 NPT

4.3.4 Weld Size

a) All welds - plus only, no minus.

4.3.5 Angularity

a) All forming operations ± 4 degrees.

4.3.6 Punched Holes

a) Location - center to edge, or center to center ± 1/8 in. (3 mm).

b) Diameter - plus 0.2 times metal thickness or minus 1/32 in. (1mm).

4.3.7 Drilled Holes

a) As specified on manufacturer's drawings.

4.3.8 Machined Parts

a) As specified on manufacturer's drawings.

5. FABRICATION

5.1 Description

5.1.1 This section covers shop fabrication of hanger components and assemblies.

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5.1.2 Where service conditions necessitate consideration of special treatment not covered in this section, such requirements should be a matter for individual discussion and agreement between the purchaser and the fabricator.

5.2 General

5.2.1 Fabrication tolerances shall be in accordance with Section 4.3 of this document.

5.2.2 Identification should be maintained during the fabrication process.

5.3 Material Cutting

5.3.1 Plates, rods, bars, etc. which are used for the fabrication of hanger assemblies may be cut to shape or size by shearing, sawing, machining, grinding or thermal cutting.

5.3.2 When required, material identification for each piece of material cut shall be maintained by color coding, tagging, stamping or other suitable means.

5.3.3 When thermal cutting is performed, the process shall be suitable for the material to which it is applied.

5.3.4 After thermal cutting, slag should be removed prior to further fabrication or use. Discoloration remaining on the cut surface is not considered to be detrimental.

5.4 Forming

5.4.1 Forming shall be performed in accordance with MSS SP-58, Section 5.

5.5 Machining, Drilling and Punching

5.5.1 These operations shall be performed as required by drawings and specifications.

5.6 Threading and Tapping

5.6.1 Screw threads shall be in conformance with ANSI/ASME B1.1 or National Bureau of Standards Handbook H-28, UNC 2A / 2B for the coarse thread series and 8UN 2A/2B for the eight thread series.

5.6.2 Standard straight pipe threads for supports such as Type 38 shall be ANSI/ASME B1.20.1 NPSM and NPSL, Standard Straight Pipe Threads.

5.6.3 Tapered pipe threads shall be in conformance with ANSI/ASME B1.20.1 NPT

5.6.4 Special thread forms and fits other than those specified by this subsection shall be used only when both male and female threaded members are furnished as part of a permanent assembly.

5.7 Welding

5.7.1 Welding shall be done in accordance with MSS SP-58 subsection 5.6.

6. PROTECTIVE COATINGS

6.1 Description

6.1.1 This section covers shop application of protective coatings.

6.1.2 Protective coatings fall into two general types: Metallic Coatings and Non-metallic Coatings.

6.1.3 The type of protective coating used for hanger material shall be the fabricator's standard coating unless otherwise specified.

6.2 Metallic Coatings

6.2.1 Electroplating, hot dip galvanizing and mechanical plating shall be in accordance with MSS SP-58, Subsection 6.1. Other metallic coatings may be selected for specific purposes.

6.3 Non-metallic Coatings

6.3.1 Non-metallic coatings for specific purposes shall be in accordance with the recommendations of MSS SP-58, Subsections 6.2.

6.3.2 When standard shop paint is required, fabricated hanger material shall receive one shop coat of good quality rust inhibitive primer (fabricator's standard paint).

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6.3.3 Special shop paints and surface prep shall be applied in accordance with approved procedures.

6.3.4 Material surfaces shall be prepared for coating by removal of loose scale, loose weld spatter and other foreign material. Removal may be done by scraping, wire brushing or other suitable means. Blasting or pickling need be done only when specified.

6.3.5 Application of coatings shall be in accordance with the coating manufacturer's recommendations.

6.3.6 Rod threads for field adjustment shall not be painted. Bolt threads in assembled components may be painted. When specified, external adjustment threads shall receive a coating of rust preventative compound.

6.3.7 Stainless steel or other corrosion resistant material need not be painted.

6.3.8 Small items such as beam attachments which are to be welded to existing steel need not be painted.

7. TESTING OF HANGER COMPONENTS

7.1 Description

7.1.1 This section defines the testing of hanger components and gives the purpose for tests in each category.

7.1.2 This section also recommends the type of records for each category of test.

7.2 Classification

7.2.1 Testing of hanger components falls into three categories:

a) Design Proof Test
b) Qualification Test
c) Calibration Test

7.3 Design Proof Test

7.3.1 Design Proof tests may consist of tests for both strength and function. Tests should be performed using calibrated test equipment.

7.3.2 Strength tests are performed to prove the adequacy of the final design as to allowable stress or safety factor criteria. Tests may be physical, analytical or a combination of both.

7.3.3 Physical Test Method (a or b)

a) This test shall consist of loading to destruction a sufficient number of hanger components of one size and design to establish a minimum failure load to which a factor can be applied for safe load rating purposes. A single test sample is permitted, but in this case, the load rating shall be decreased by 10%.

b) This test shall consist of loading to destruction a sufficient number of hanger components of one size and design to establish a failure mode that can be related to the results from standard test bars made from the same material as the hanger components. This test is used to establish a safe load rating at the allowable stress level of the hanger component material.

7.3.2.2 Analytical Test

a) This test shall consist of applying analytical methods and formulae to the structure of a hanger component to determine stress levels and conditions within that structure. This test is used to establish a safe load rating at the allowable stress level of the hanger component material.

7.3.2.3 Physical and Analytical Test

a) This test shall consist of physical tests described in 7.3.3 (b) and applying these results analytically to a family of hanger components of the same design form. This test is used to establish a safe load rating for each component size at the allowable stress level of the hanger component material.

7.3.3 Function tests are performed to prove the ability of a component to meet the design criteria at rated load.

7.3.4 Results of Design Proof Tests should be presented in report form. Since this report may contain proprietary information, a summary report is acceptable.

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7.3.5 After Design Proof Tests are complete, they need not be repeated unless significant dimensional or material changes are made in the hanger component.

7.4 Qualification Test

7.4.1 Qualification Tests are performed to assure that hanger components meet or exceed the minimum requirements of particular codes or approval agencies. Test equipment should be of the same type and condition as for Design Proof Test. Design Proof Tests may serve as Qualification Tests. Qualification Tests may be performed by the hanger component manufacturer or by an approval agency.

7.4.2 Results of Qualification Tests should be presented in a report form suitable for distribution.

7.4.3 Except as required by the approval agency, Qualification Tests need not be repeated unless significant dimensional or material changes are made in the hanger component.

TABLE 2. INSPECTION CHECK LIST

INSPECTION CATEGORIES	TYPES OF INSPECTION		
	Receiving	In Process	Final
1. Drawings and/or Specifications		X	X
2. Material Identification	X	X	X
3. Fabrication Procedure		X	
4. Dimensions	X	X	X
5. Surface Finish	X	X	X
6. Surface Preparation		X	
7. Protective Coating	X	X	X
8. Performance		X	X
9. Marking	X	X	X
10. Documentation	X	X	X
11. Packaging		X	X

7.5 Calibration Test

7.5.1 Calibration Tests are performed on some types of individual hanger components, such as constant supports, to assure that they are properly calibrated to meet specific installation requirements. Calibration Test equipment may be the same used for Design Proof and Qualification Test; or it may be specific equipment for the Calibration Tests performed. The test equipment shall be periodically calibrated to insure reliable results.

7.5.2 Records of Calibration Tests should be retained by the manufacturer.

7.6 Quality Control

7.6.1 Quality Control should be exercised over the procurement of raw materials, fabrication procedures and dimensions to assure the continued validity of Design Proof and Qualification Tests.

8. INSPECTION

8.1 Description

8.1.1 This section covers recommendations for quality control and inspection of pipe hanger components and assemblies.

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8.2 General

8.2.1 There should be an inspection program to ensure that all aspects of work performed comply fully with all specified requirements.

8.3 Inspection Program

8.3.1 Table 2 designates the suggested check points that should be included in an inspection program.

9. PACKAGING, MARKING, SHIPPING, RECEIVING AND STORAGE

9.1 Description

9.1.1 This section covers the recommendations for packaging, marking, shipping, receiving and storage of hanger components and assemblies.

9.1.2 Special requirements not covered in this section should be a matter for discussion and agreement between the purchaser and supplier.

9.2 Packaging

9.2.1 General

9.2.1.1 Hangers should be assembled to the degree practical, taking into account shipping and handling limitations. Constant supports, variable springs and similar items may be packaged, skidded or shipped loose, separate from the remaining assembly components.

9.2.1.2 Where possible, each hanger assembly should be shipped complete.

9.2.1.3 Hanger assemblies or subassemblies shall be properly marked with identifying numbers. Random material may be identified in bulk.

9.2.1.4 Each hanger shipment shall contain a packing list identifying the material included in the shipment, also noting the total number of boxes, bundles, bags, etc. making up the shipment.

9.2.2 Containers

9.2.2.1 Where size permits, hanger assemblies and subassemblies may be packed in the manufacturer's standard containers.

9.2.3 Bundles

9.2.3.1 Hanger assemblies, steel members, welded brackets, etc. which are too large for the standard containers should be bundled and banded for shipment.

9.2.4 Loose Components

9.2.4.1 Large rigid components, which do not require special protection during shipment, need not be packaged.

9.2.5 Bags

9.2.5.1 Small loose items may be placed in bags. The bags may be shipped separately or placed in containers for shipment.

9.2.6 Pallets and Skids

9.2.6.1 Hanger components may be palletized for shipment to facilitate handling as a compact unit.

9.3 Marking for Shipment

9.3.1 General

9.3.1.1 Marking shall be accomplished by use of labels, stamping, printing or tagging.

9.3.1.2 Marking shall be applied with waterproof ink or paint.

9.3.1.3 Labels shall be of water resistant type.

9.3.1.4 Tags may be cloth, paper, plastic or metal and affixed by waterproof adhesive, tacks or wire.

9.3.2 Container marking by stenciling, printing or labeling should appear in a minimum of two locations, preferably on one side and one end.

9.3.3 Bundles and bags shall be tagged.

9.3.4 Loose components, pallets and skids may be stenciled, labeled or tagged.

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9.3.5 Marking should include the following information when applicable:

a) Consignee name, street address, city, state, zip code and country.

b) Consignor name, street address, city, state and zip code and country.

c) Purchase order or contract number. Package number followed by the total number of packages in the shipment.

d) Material identification number, e.g., hanger mark numbers or manufacturers figure numbers and quantity. A packing list may be used in lieu of material identification. The container in which the packing list is enclosed shall be clearly identified.

e) Special handling instructions, e.g., use no hooks, lift points, keep dry, stacking limitations, etc.

f) Weight of package.

g) Special instructions.

9.4 Shipping

9.4.1 Shipping shall be in accordance with the method, routing and sequence as required by the purchase document.

9.4.2 The location of the packing list should be indicated on the bill of lading.

9.5 Consignee Receiving

9.5.1 The receiving clerk should be responsible for verifying agreement between the bill of lading and the shipment as received. Any damage or shortage should be noted on the bill of lading and the shipper and carrier immediately notified.

9.5.2 Unloading should be done with reasonable care, taking note of any precautionary notices on the containers. Items of shipment should not be dropped.

9.6 Consignee Storage

9.6.1 Storage should be in a dry area, enclosed for security purposes, and protected from the direct effects of weather and contaminants.

9.6.2 It is recommended that containers be opened and contents verified before they are placed in the storage area.

9.6.3 It is recommended that a system be established to facilitate retrieval of material from storage.

10. HANGER INSTALLATION PRACTICES

10.1 Description

10.1.1 This section outlines the recommended field practices for field personnel during hanger installation, adjustment, testing and inspection.

10.2 General

10.2.1 Installation control shall be as defined in the owners job specifications for each classification of piping.

10.2.2 Installation information may be in any of the following forms:

a) Completely engineered: individual hanger assembly drawings.

b) Semi-engineered: typical hanger type drawings and approximate locations for field fabricated supports using preselected bulk hanger material.

c) Random: guidelines for location, hanger type selection and installation of supports using preselected bulk hanger material where all operations are performed by the field forces.

10.2.3 Relocation and reorientation of any hanger or restraint from the specified location shall not be permitted beyond that which is established by the responsible hanger designer, without his expressed permission.

10.2.4 Installed hangers or hanger components shall be used for their intended purpose. They shall not be used for rigging or erection purposes.

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10.2.5 Recommended maximum applied torque for set screws in C-clamps (types 19 & 23) is listed below:

Thread Size		Torque	
Inch	(mm)	Inch Pound	(Nm)
1/4	6.4	40	4.5
3/8	9.6	60	6.8
1/2	12.7	125	14.1
5/8	15.8	250	28.2
3/4	19.0	400	45.2
7/8	22.2	665	75.1

Note: Caution should be taken not to overtighten the set screw.

10.2.6 Hangers that are installed with clearance for future insulation shall be properly supported with blocks at three points approximately 60 degrees apart around the lower circumference. These blocks shall be the thickness of the intended insulation to prevent distortion of the hanger assembly.

10.3 Planned Installation Sequence

10.3.1 The hanger designer assumes responsibility for avoiding hanger interference with all piping, electrical trays, ducts and equipment specifically dimensioned on drawings made available to him. Studies are made to avoid such interferences during the design phase of pre-engineered hangers; however, the hanger designer cannot assume responsibility for any resulting interference caused by field run piping, electrical conduits, instrumentation, added steel framing, etc.

10.3.2 The hanger installer should be cognizant of the total amount of piping and equipment to be installed in any given area. He should develop an installation sequence giving priority to major components and strata of piping closest to the supporting structure. The installer also should review routing of field run piping in order to reserve space for known components to be installed at some later date in order to minimize revamp work. He should coordinate erection of all piping with other trades to maintain erection clearances and availability of building structure for supporting functions.

10.4 Hanger Locations

10.4.1 Completely engineered hangers shall be located in strict accordance with the hanger design detail drawings. It is normal design practice to dimension the location of hanger attachments from the building structure column lines. Refer to Section 3, subsection 3.9 of this document for complete description.

10.4.2 Semi-engineered hangers for which approximate locations are designated shall be so located.

10.4.3 Random hangers shall be located by the hanger installer in accordance with the allowable support spacing in MSS SP-69, Table 3.

10.4.4 When initially installed, all hangers shall be adjusted to establish the piping at the designated elevation.

10.5 Hanger Installation

10.5.1 Rod Hangers

10.5.1.1 Rod hangers, either rigid or spring type, are adjustable vertical assemblies consisting of structural attachment, hanger rod (with or without intermediate components) and pipe attachment.

10.5.1.2 Installation of rod hangers requires either direct attachment to building structure or to supplemental framing.

10.5.1.3 Attachment to the building structure may be by beam clamps, welding of clips to steel members or concrete embedded plates and by use of concrete inserts or fasteners. Where there is a vibration or bending consideration, hanger rods should not be connected directly to driven or drilled concrete fasteners. In these instances an intermediate attachment should be used from which the rod can be suspended using a swing connection.

10.5.1.4 Supplemental framing may be angles, channels, tubular sections or beams either bolted or welded to existing steel structure or attached to concrete.

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10.5.2 Brackets

10.5.2.1 Brackets are cantilevered members with or without a kneebrace, designed to withstand the gravity load and horizontal forces.

10.5.2.2 When the installer has responsibility for design or selection of brackets, anticipated horizontal forces should be considered.

10.5.2.3 Brackets may be installed by welding or bolting to structure, poured in place embedments, or through the use of drilled concrete fasteners.

10.5.2.4 For bolted-on brackets, it is important to tighten threaded fasteners equally to assure proper load distribution.

10.5.3 Anchors

10.5.3.1 Anchors may be weldments or clamp type.

10.5.3.2 Anchors are used to fix selected points on a piping system in order to control forces, moments and thermal movement in each section of the total pipe run. Location shall be accurately maintained for both horizontal and vertical piping to preserve the designer's flexibility concept.

10.5.3.3 Anchors shall not be added or relocated without the approval of the piping designer.

10.5.3.4 Installation of anchors may be by bolting or welding to a rigid structure capable of withstanding all the design forces. Pipe is secured to the anchor by clamping, welding or both.

10.5.4 Guides

10.5.4.1 Guides may be sliding, rolling or spider types.

10.5.4.2 Guides are used to control piping movement, provide lateral stability, control sway and assure proper piping alignment at expansion joints and loops. Spider guides used in the horizontal position are not normally considered to be pipe support elements.

10.5.4.3 Design is based upon thermal movement, load, direction of travel and thickness of pipe insulation.

10.5.4.4 Installation of guides may be by bolting or welding the base, frame or shroud to the supporting structure. Care must be taken at time of initial installation to maintain the proper alignment elevation and clearances. On insulated lines, saddles or fins should be attached to piping to prevent damage to insulation.

10.5.5 Base Type Supports

10.5.5.1 Base type supports are used to support the piping from below. They encompass a family of supports, guides, slides, anchors, springs, etc.

10.5.5.2 Attachment to pipe may be by bolted on clamps, U-bolts or welding. Load is transferred through the use of a cradle, pipe or structural member which may be fastened directly to building structure or provided with a base plate suitable for incorporation into the particular type support involved.

10.5.5.3 When attaching to steel structure, proper piping elevation can be established by custom fitting the vertical member, or by using telescoping pipe or other means of adjustment.

10.5.5.4 When attaching to concrete structure, the use of leveling bolts under the base plate with subsequent grouting is an additional means to provide proper piping elevation.

10.5.5.5 During installation, the supported pipe should be adequately braced to maintain stability until the system is completely installed.

10.6 Hanger Adjustment

10.6.1 To compensate for pipe elevation discrepancies, hangers are usually provided with means to permit vertical adjustment during and after installation. Threaded devices using turnbuckles, clevises, etc. provide this feature or the adjustment is inherently available in the hanger design. No adjustment shall be made that will result in less than full usable thread engagement.

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10.6.2 Adjustability features also serve to facilitate pipe load distribution.

10.6.3 For small size piping, the necessity for adjustment can be detected visually. For large or heavy piping, the necessity for adjustment may not be as obvious and the installer must determine that each hanger or support substantially carries its proper load. Hanger drawings usually denote the operating and hydrostatic loads.

10.6.4 Upon completion of hanger installation, all adjustments having the possibility of turning shall be locked securely in place; double nutting being the most common means. It is not recommended to break threads or tack weld as a means of locking adjustment devices.

10.6.5 Hydrostatic testing, when required, should not be performed until all hanger assemblies have been properly installed, adjusted and loaded in accordance with the hanger drawings. Built in hydrostatic stops, or external means for supporting the added water weight, must be installed in accordance with the Hydro Test Procedures.

10.6.6 After completion of hydrostatic tests of the piping system, any devices (e.g., spring travel stops, temporary supports, etc.) furnished for hydrostatic test purposes must be removed.

10.6.7 Hangers for certain piping systems may be required to be checked for adjustment during initial run at operating temperature. Particular attention should be given to spring hangers and spring supports.

10.6.8 Constant type springs have specific load adjustment devices which can vary the spring effort by plus or minus some percentage from the factory set load. Variable type springs are usually provided with turnbuckles, threaded collars or adjustment nuts to enable varying the spring effort. Load/travel scales on variable and constant type spring units are usually marked to show the position of the load/travel indicator in both the cold and hot positions. Reference should be made to the particular spring suppliers catalog for the location and operation of these devices.

10.6.9 If, at operating temperature, the load/travel indicator does not line up with the hot position marking, further adjustment may be required. However, before any adjustment is considered, the position of the load/travel indicator on all spring units on the system should be recorded (see Figure 2 for suggested form). The cause for the misalignment should then be investigated.

10.6.9.1 Prior to initial operation all spring hanger units are set to the cold position. This position of the load/travel indicator should be the initial entry in a permanent formal log. (See figure 2 for suggested form)

10.6.9.2 When the system reaches operating temperature a second set of load/travel indicator position readings should be recorded.

10.6.9.3 If at operating temperature, the load/travel indicator does not line up with the hot position marking, it is recommended that a minor travel adjustment be made (either lengthen or shorten the hanger rod) to have the indicator line up with the hot marking. If the installation does not respond to this minor travel adjustment, then consult with an experienced hanger designer. A new set of load/travel position readings should be recorded with a notation on the log that adjustment has been made. This set of readings represents the system being supported in accordance with the designers initial design concept which is to have the piping properly supported in the hot position.

10.6.9.4 All future studies should use this final adjusted set of hot readings as the base line.

10.6.9.5 Subsequent sets of readings, taken after the system has been cycled through hot and cold conditions, will provide the opportunity to evaluate the possible need to make load adjustments on some group of adjacent hangers to bring a section of piping run to proper elevation. This evaluation should be made only by an experienced hanger designer.

10.6.9.6 The plant should establish a program to have a periodic inspection of critical piping support systems and load/travel indicator readings recorded and compared to the base line set of readings. Although the load/travel indicator may not line up exactly with the base line readings, the hanger may still be considered functional if the reading is close to the base reading.

10.6.9.7 Spring units must never be topped or bottomed out. This is an indication that the working travel range has been exceeded.

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10.6.10 Some possible causes for improper alignment of the load/travel indicator at operating temperature include:

a) Improper load adjustment of hanger.

b) Improper load adjustment of adjacent hangers.

c) System not at full operating temperature.

d) Pipe fabrication error.

e) Improper cold springing.

f) Frictional effects of guides or sliding supports.

g) Discrepancies between design and "as built" conditions affecting hanger loads or movement.

h) Improper hanger installation or failure to remove temporary supports, restraints, or hanger travel stops.

i) Failure to clear piping system of obstructions.

10.7 Inspection

10.7.1 Inspection after installation and prior to hydrostatic testing.

10.7.1.1 Each hanger assembly should be verified against the hanger drawing to assure that all components have been installed and are in their proper position. This also includes temporary hangers and supports that may be required for hydrostatic testing and spacer blocks for lines still to be insulated.

10.7.1.2 Threaded components of each hanger should be checked for proper thread engagement.

10.7.1.3 Locking nuts on threaded components, cotter pins, temporary locking devices (travel stops) and other locking means furnished with spring units should be properly engaged.

10.7.1.4 When possible, springs should be oriented for convenient reading of load/travel scales. Scales found to be damaged should be removed and replaced. Prior to removal, the exact position of the scale should be noted and replacement installed in the same location.

10.7.1.5 Restraint control devices utilizing hydraulic fluids should be checked for tight seals and proper amount of fluid. If it is found necessary to add fluid, it must be of the type specified by the restraint supplier.

10.7.1.6 Sliding supports using teflon, graphite, bronze, or steel to steel slide plates must be installed in strict accordance with hanger detail drawings with particular attention to offset dimensions and clearances when such are specified. All sliding surfaces must be free of foreign matter.

10.7.2 Inspection after hydrostatic testing and prior to heating up.

10.7.2.1 Spring locking devices and any temporary hangers and supports required for hydrostatic testing shall be removed.

10.7.2.2 Spring hangers should be checked to insure that their load/travel indicators are approximately in their cold position setting and that the pipe is at the proper elevation.

10.7.2.3 Restraint control devices should be checked to insure that their travel indicators are approximately at their cold position setting.

10.7.2.4 Actual cold positions of the load/travel indicators on springs and restraint control devices should be recorded in a permanent formal log. See Figure 2 for suggested form.

10.7.3 Inspection at operating conditions

10.7.3.1 Piping systems should be inspected in their entirety to verify that no interference exists between the pipe and/or the pipe insulation and the building structure or equipment.

10.7.3.2 Spring hangers should be checked to insure that their load/travel indicators are approximately in their hot position setting and that the pipe is at the proper elevation.

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10.7.3.3 Restraint control devices should be checked to insure that their travel indicators are approximately at their hot position setting.

10.7.3.4 Line temperature and actual hot positions of the load/travel indicators on springs and restraint control devices should be noted and recorded in a permanent formal log. See Figure 2 for suggested form. Upon completion of the work, this log should be made available to the owner.

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STD.MSS SP-89-ENGL 1998 ■ 5770640 0501024 315 ■

HANGER RECORD SHEET

PREPARED BY _____

COMPANY _____ SYSTEM _____ SHEET _____ OF _____

LOCATION _____ PLANT NAME _____ DATE _____

HANGER MARK NUMBER	N.S. E.W. (1)	HANGER DATA (2)				CONSTANT SUPPORT HANGER NAME PLATE DATA					VARIABLE SUPPORT NAME PLATE DATA		(5) ELEV. INITIAL COLD (ft.-in.)	HANGER SCALE READING (4)							
		SIZE	(3) TYPE	FIG. NO.	MFR	SERIAL NO.	CALIB. LOAD (lb)	TOTAL TRAVEL	FACTORY (4) POSITION		LOAD (lb)			READ DATE / COLD	BY	READ DATE / HOT	BY	READ DATE / COLD	BY	READ DATE / HOT	BY
									H	C	H	C									

NOTES:
(1) TO IDENTIFY THE SPECIFIC UNIT WITHIN A MULTIPLE SUPPORT ASSEMBLY WHERE N = NORTH, S = SOUTH, E = EAST, W = WEST
(2) HANGER SIZE TO BE TAKEN FROM NAMEPLATE
(3) FOR RIGID, ANCHOR, GUIDE, SLIDING OR OTHER TYPE ATTACHMENT, INDICATE BY LETTER R, A, G OR S, RESPECTIVELY.
(4) "O" INDICATES HIGHEST SCALE POSITION WITH "5" BEING MID-POINT AND "10" BEING LOWEST SCALE POSITION.
(5) ELEVATION OF CENTERLINE OF PIPE, OR OTHER REFERENCE POINT, AFTER COLD SPRINGING AND FINAL HANGER SETTINGS WITH LINE COLD.

Suggested Form for Hanger Record Sheet
Figure 2.

ANNEX A
Referenced Standards and Applicable Dates

This Annex is an integral part of this standard practice which is placed after the main text for convenience.

ASME, ANSI/ASME, ANSI, ASME/ANSI

B1.1-1989	Unified Inch Screw Threads (UN and UNR Thread Form)
B1.20.1-1983 (R1992)	Pipe Threads, General Purpose (Inch)

MSS

SP-58-1993	Pipe Hangers and Supports - Materials, Design and Manufacture
SP-69-1996	Pipe Hangers and Supports - Selection and Application

National Bureau of Standards

H-28, Part II (1978)	Screw-Thread Standards for Federal Service

Publications of the following organizations appear in the above list:

ANSI	American National Standards Institute 11 West 42nd Street, New York, NY 10036, Phone (212): 354-3300
ASME	American Society of Mechanical Engineers 345 East 47th Street, New York, NY 10017, Phone (212): 705-7500
MSS	Manufacturers Standardization Society of the Valve and Fitting Industry, Inc. 127 park Street, N.E., Vienna, VA 22180, Phone: (703) 281-6613

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STANDARD PRACTICE **SP-104**

1995
Edition

WROUGHT COPPER SOLDER JOINT PRESSURE FITTINGS

Developed and Approved
by the
Manufacturers Standardization Society
of the
Valve and Fittings Industry, Inc.
127 Park Street, N.E.
Vienna, Virginia 22180
(703) 281-6613

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WROUGHT COPPER SOLDER JOINT PRESSURE FITTINGS

1. SCOPE

This standard practice covers 1/8″ through 8″ straight and reducing size wrought copper solder joint seamless fittings, designed for use with copper water tube, ASTM B88 at pressures and temperatures shown in Table A1. The fittings in this standard practice have dimensions and ratings not covered in ASME/ANSI B16.22. Included in this standard practice are:

a) Pressure-temperature ratings
b) Abbreviations for end connections
c) Size and method of designating openings and fittings
d) Markings
e) Material
f) Dimensions and tolerances
g) Tests

2. PRESSURE-TEMPERATURE RATINGS

2.1 Rating of Fitting. Fittings manufactured to this standard practice shall have pressure-temperature ratings that are the lowest of either the calculated tube rating (2.2) or the rating of the joint (2.3).

2.2 Calculated Tube Rating. The calculated pressure-temperature rating for ASTM B88 Type "M" Copper Water Tube, annealed, calculated as follows:

$$P = \frac{2Stm}{D-0.8tm}$$

Where: P = working pressure at temperature, psi
S = allowable stress at temperature, psi (per ANSI/ASME B31.1 or ANSI/ASME B31.9)
tm = minimum wall thickness, in. (per ASTM B88)
D = tube outside diameter, in.(1)

NOTE(1) including worst case tolerance

2.3 Rating of Joint. The working pressure-temperature rating for a solder joint piping system is dependent not only on fitting and tube strength, but also on the composition of the solder used for the joint.

Pressure-temperature ratings for solder joints to the dimensions of Table 2 made with typical commercial solders, are given in Annex A.

3. ABBREVIATIONS

3.1 The following symbols are used to designate the type of fitting end:

Symbol	
C	Solder joint fittings end made to receive copper tube diameter (female)
FTG	Solder joint fitting end made to copper tube diameter (male)
F	Internal ANSI Standard Taper Pipe Thread (female) NPTI
M	External ANSI Standard Taper Pipe Thread (male) NPTE

4. SIZE

4.1 The size of the fittings shown in Table 2 correspond to standard water tube size as shown in ASTM B88, Specification for Seamless Copper Water Tube. The size of the threaded ends correspond to nominal pipe size.

4.2 Fittings are designated by the size of the openings in the sequence illustrated in Figure 1.

5. MARKING

5.1 Each fitting shall be permanently marked with the manufacturer's name or trademark in accordance with MSS SP-25. Marking may be omitted from any fitting where it may damage soldering surfaces.

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6. MATERIAL

6.1 Fittings shall be made from Copper UNS nos. C10200, C12000, or C12200 for which allowable stresses are founded in ANSI/ASME B31.1 or B31.9.

6.2 Other coppers and copper alloys may be used provided they meet the chemical requirements of 84% minimum copper and 16% maximum zinc and provided the fittings produced from the copper materials meet all the mechanical and corrosion resistant properties for the end purposes of the fittings. The composition of the copper materials shall contain nothing which will inhibit joining to tube or to other fittings.

7. LAYING LENGTHS

Due to widely varying manufacturing processes, uniform laying length dimensions of fittings cannot be established. Consult the manufacturer for these dimensions.

8. INSPECTION TOLERANCE

8.1 Linear Dimensions. An inspection tolerance as shown in Table 1 shall be allowed on center-to-shoulder, center-to-center, center-to-threaded end, and shoulder-to-threaded end dimensions on all fittings having female solder (solder cup) ends, and on center-to-solder end and solder end-to-threaded end dimensions on all fittings having male solder (fitting) ends.

Coupling inspection limits for shoulder-to-shoulder and shoulder-to-end dimensions shall be double those shown in Table 1 except that the minus tolerance applied to dimension "L" shall not result in a dimension less than 0.06 inch.

8.2 Ovality. Maximum ovality shall not exceed 1% of the maximum diameters shown in Table 2. The average of the maximum and minimum diameters must be within the dimensions shown in the Table.

TABLE 1. INSPECTION TOLERANCE

Standard Water Tube and Thread Sizes	Tolerance, Plus or Minus, in.
⅛, ¼, ⅜[1]	0.05
½, ⅝, ¾	0.06
1, 1¼, 1½, 2	0.08
2½, 3, 3½	0.11
4 and 5	0.12
6 and 8	0.16

NOTE:
[1] ⅛ size is ¼ O.D. seamless copper tube for refrigeration service, etc., as listed in ASTM B280.

8.3 Minimum Wall Thickness. The average of the wall thickness shall not be less than the thickness shown in Table 2 and the wall at any given point shall not be less than 90% of the wall thickness shown in the table.

9. THREADED ENDS

9.1 Fitting threads shall be right-hand, conforming to ANSI/ASME B1.20.1, American National Standard for Pipe Threads, General Purpose (Inch). They shall be taper threads (NPT.)

9.2 Countersink or Chamfer. All internal threads shall be countersunk a distance not less than one-half the pitch of the thread at an angle of approximately 45 degrees with the axis of the thread, and all external threads shall be chamfered at an angle of 30 degrees to 45 degrees from the axis, for the purpose of easier entrance in making a joint and protection of the thread. Countersinking and chamfering shall be concentric with the threads.

The length of threads shall be measured to include the countersink or chamfer.

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9.3 Threading Tolerances. Tapered pipe threads (NPT) shall be checked by use of working plug or ring gages in either standard or limit types. Gages shall be threaded on/in hand tight. The reference point for gaging internal product threads depends upon the chamfer diameter. When the internal chamfer diameter exceeds the major diameter of the internal thread, the reference point is the last thread scratch on the chamfer cone. Otherwise, when the internal chamfer diameter does not exceed the major diameter of the internal thread, the reference point is the end of the fitting. On the external thread it shall be flush with the end of the fitting.

Tolerance for an internal threaded end having an internal shoulder shall be from the gage reference point (notch) to one turn small. Tolerance for an internal threaded end without shoulder and for an external threaded end shall be from one turn small to one turn large.

0. DESIGN OF THREADED ENDS

The wrenching section of internal threaded ends shall be polygonal, and the wrenching section of external threaded ends shall be furnished with a polygon or flats, at the manufacturer's option.

11. ALIGNMENT

The maximum allowable deviation in the angular alignment of any opening shall be 0.06 in./ft. (0.5%).

12. TEST

When required, these fittings shall be tested with air at a gage pressure of 60 psi minimum while under water or at a hydrostatic gage pressure of 250 psi.

13. GAGING

13.1 Standard Gaging Method of Solder Joint Ends. The standard method of gaging the diameter tolerance for male and female ends shall be by the use of plain plug and ring gages designed to hold the product within the limits established in Table 2.

13.2 Optional Gaging Method of Solder Joint Ends. For gaging the diameter tolerance of male and female ends, the manufacturer may use direct reading instruments instead of ring and plug gages as specified in paragraph 13.1. When gaging the diameters of male and female ends, using direct reading instruments, refer to paragraph 8.2.

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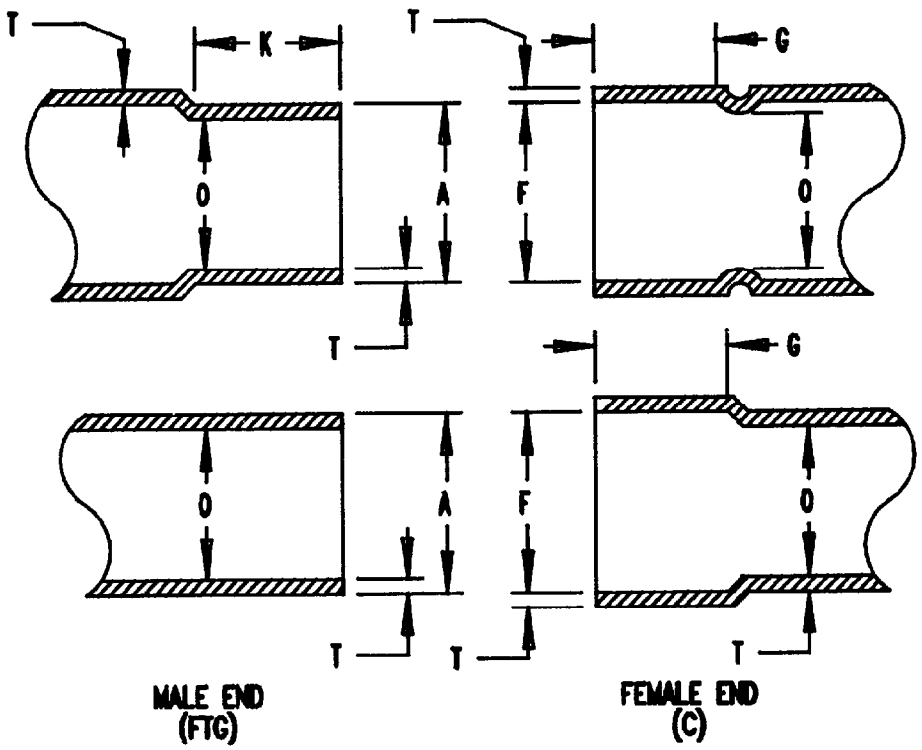

TABLE 2. DIMENSIONS OF SOLDER JOINT FITTINGS[1]

Standard Water Tube Size[2]	Male End			Female End			Wall[4] Thickness T	Inside Diameter of Fitting O
	Outside Diameter A		Length K	Inside Diameter F		Depth G		
	Min.	Max.[3]	Min.	Min.	Max.[3]	Min.	Avg.	Min.
⅛	0.248	0.251	0.38	0.252	0.256	0.31	0.019	0.18
¼	0.373	0.376	0.38	0.377	0.381	0.31	0.023	0.30
⅜	0.497	0.501	0.44	0.502	0.506	0.38	0.026	0.39
½	0.622	0.626	0.56	0.627	0.631	0.50	0.029	0.52
⅝	0.747	0.751	0.69	0.752	0.756	0.62	0.031	0.63
¾	0.872	0.876	0.81	0.877	0.881	0.75	0.033	0.74
1	1.122	1.127	0.97	1.128	1.132	0.91	0.040	0.98
1¼	1.372	1.377	1.03	1.378	1.382	0.97	0.044	1.23
1½	1.621	1.627	1.16	1.628	1.633	1.09	0.051	1.47
2	2.121	2.127	1.41	2.128	2.133	1.34	0.059	1.94
2½	2.621	2.627	1.53	2.628	2.633	1.47	0.067	2.42
3	3.121	3.127	1.72	3.128	3.133	1.66	0.075	2.89
3½	3.621	3.627	1.97	3.628	3.633	1.91	0.086	3.37
4	4.121	4.127	2.22	4.128	4.133	2.16	0.096	3.84
5	5.121	5.127	2.72	5.128	5.133	2.66	0.111	4.70
6	6.121	6.127	3.22	6.128	6.133	3.09	0.124	5.72
8	8.119	8.127	4.09	8.128	8.133	3.97	0.173	7.55

Dimensions are in inches.

[1] Drawings and designs of fittings are illustrative only. Dimensions herein shall govern in all cases.
[2] For size designation of fittings see Section 4.
[3] For ovality see Section 8.2.
[4] See Section 8.3.

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Fittings are designated by size in the order: 1 x 2 x 3

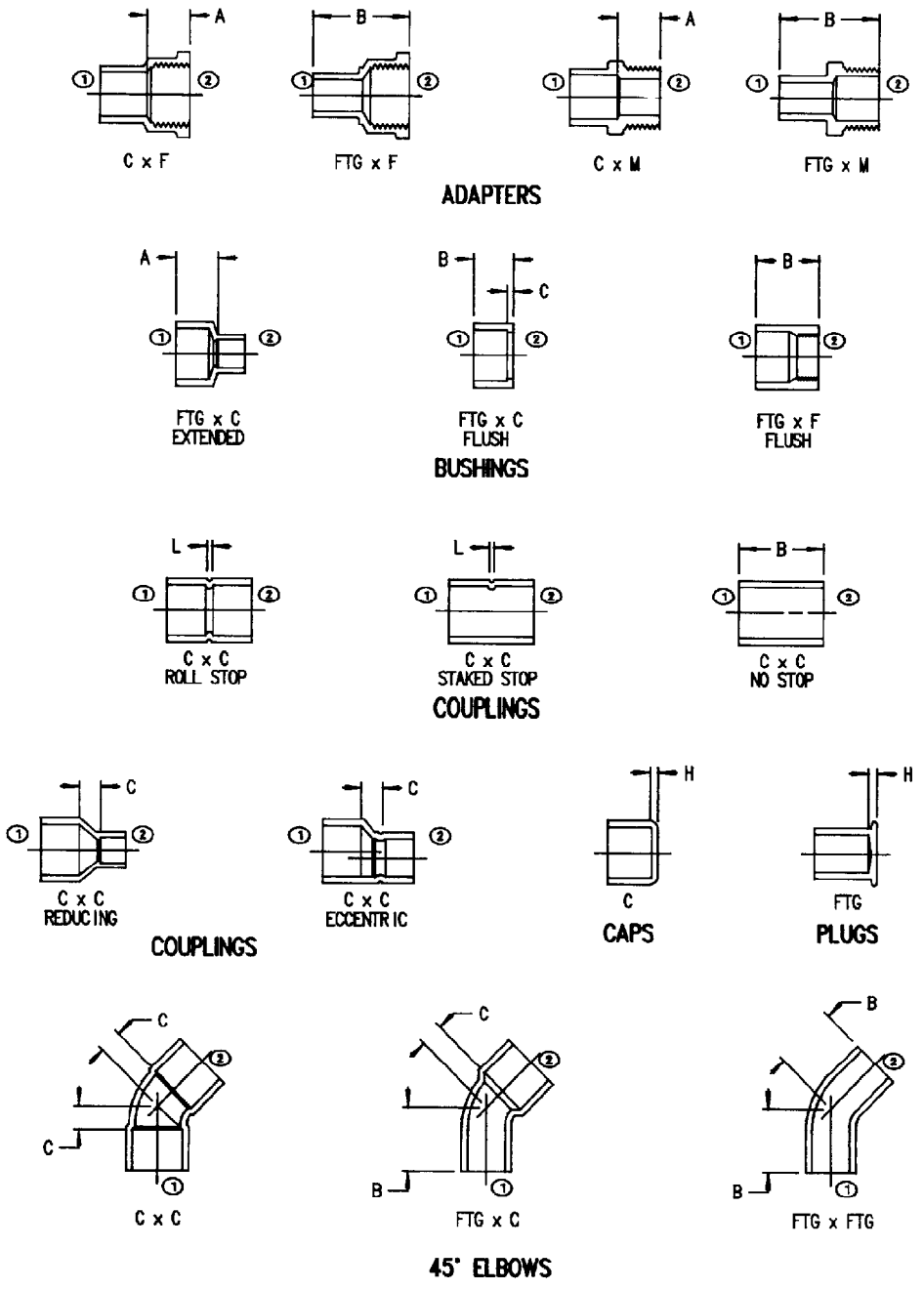

FIGURE 1. METHOD OF DESIGNATING LAYING LENGTHS OF FITTINGS AND OPENINGS OF FITTINGS

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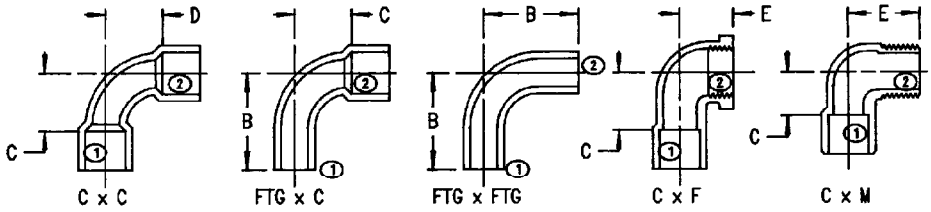
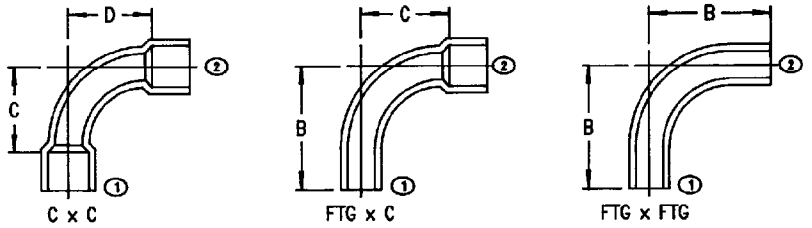
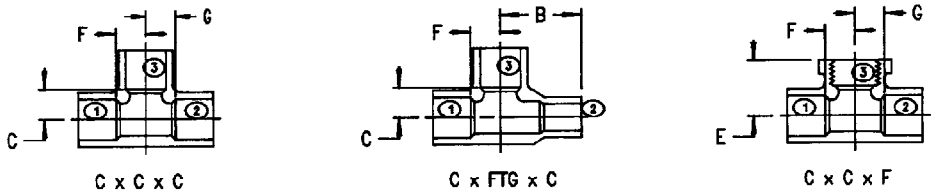
Fittings are designated by size in the order: 1 x 2 x 3



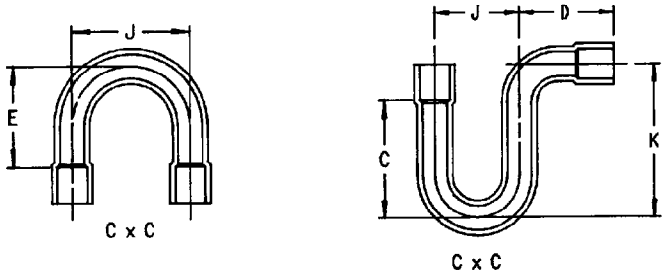
90° ELBOWS – SHORT RADIUS



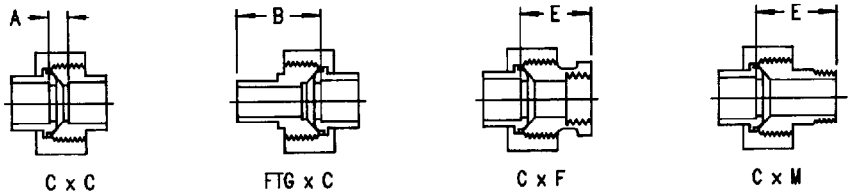
90° ELBOWS – LONG RADIUS



TEES



RETURN BENDS SUCTION LINE P-TRAPS



UNIONS

FIGURE 1 (CONT.) METHOD OF DESIGNATING LAYING LENGTHS OF FITTINGS AND OPENINGS OF FITTINGS

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ANNEX A

STRENGTH OF SOLDER JOINTS

This Annex is an integral part of MSS Standard Practice SP-104 and is placed after the main text for convenience.

The maximum pressure-temperature ratings for solder joints made with copper tube and wrought copper and copper alloy pressure fittings, using representative commercial solders, are listed below.

TABLE A1. PRESSURE-TEMPERATURE RATINGS OF SOLDER JOINTS

Joining Material	Working Temperature	Maximum Working Gage Pressure (psi)			
	Degrees F	Size ⅛ thru 1[1]	Size 1¼ thru 2[1]	Size 2½ thru 4[1]	Size 5 thru 8[1]
50-50 Tin-Led Solder[2][5]	100	200	175	150	135
	150	150	125	100	90
	200	100	90	75	70
	250	85	75	50	45
95-5 Tin-Antimony Solder[3]	100	300	300	275	250
	150	275	250	225	200
	200	250	200	200	180
	250	200	175	150	135
Joining[4] Materials Melting at or above 1100° F	Pressure-temperature ratings consistent with the materials and procedures employed.				

[1] Standard Water tube sizes.

[2] ASTM B32 Alloy Grade 50A.

[3] ASTM B32 Alloy Grade 95TA.

[4] These joining materials are defined as "brazing alloys" by the American Welding Society.

[5] The Safe Drinking Water Act Amendment of 1986 prohibits any solder with a lead content in excess of 0.2% for use on potable water systems.

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LIST OF MSS STANDARD PRACTICES

NUMBER	
SP- 6-1990	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP- 9-1992	Spot Facing for Bronze, Iron and Steel Flanges
SP-25-1993	Standard Marking System for Valves, Fittings, Flanges and Unions
SP-42-1990 (R 1995)	Class 150 Corrosion Resistant Gate, Globe, Angle and Check Valves with Flanged and Butt Weld Ends
SP-43-1991	Wrought Stainless Steel Butt-Welding Fittings
SP-44-1991	Steel Pipe Line Flanges
SP-45-1992	Bypass and Drain Connections
SP-51-1991	Class 150 LW Corrosion Resistant Cast Flanges and Flanged Fittings
SP-53-1985 (R 1990)	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Magnetic Particle Examination Method
SP-54-1985 (R 1990)	Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components — Radiographic Examination Method
SP-55-1985 (R 1990)	Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components — Visual Method
SP-58-1993	Pipe Hangers and Supports — Materials, Design and Manufacture
SP-60-1991	Connecting Flange Joint Between Tapping Sleeves and Tapping Valves
SP-61-1992	Pressure Testing of Steel Valves
SP-65-1994	High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets
SP-67-1990	Butterfly Valves
SP-68-1988	High Pressure-Offset Seat Butterfly Valves
SP-69-1991	Pipe Hangers and Supports — Selection and Application
SP-70-1990	Cast Iron Gate Valves, Flanged and Threaded Ends
SP-71-1990	Cast Iron Swing Check Valves, Flanged and Threaded Ends
SP-72-1992	Ball Valves with Flanged or Butt-Welding Ends for General Service
SP-73-1991	Brazing Joints for Wrought and Cast Copper Alloy Solder Joint Pressure Fittings
SP-75-1993	Specifications for High Test Wrought Butt Welding Fittings
SP-77-1984 (R 1990)	Guidelines for Pipe Support Contractual Relationships
SP-78-1987 (R 1992)	Cast Iron Plug Valves, Flanged and Threaded Ends
SP-79-1992	Socket-Welding Reducer Inserts
SP-80-1987	Bronze Gate, Globe, Angle and Check Valves
SP-81-1981 (R 1986, 91)	Stainless Steel, Bonnetless, Flanged Knife Gate Valves
SP-82-1992	Valve Pressure Testing Methods
SP-83-1987	Steel Pipe Unions, Socket-Welding and Threaded
SP-84-1990	Valves — Socket-Welding and Threaded Ends
SP-85-1994	Cast Iron Globe & Angle Valves, Flanged and Threaded Ends
SP-86-1987 (R 1992)	Guidelines for Metric Data in Standards for Valves, Flanges, Fittings and Actuators
SP-87-1991	Factory-Made Butt-Welding Fittings for Class I Nuclear Piping Applications
SP-88-1993	Diaphragm Type Valves
SP-89-1991	Pipe Hangers and Supports — Fabrication and Installation Practices
SP-90-1986 (R 1991)	Guidelines on Terminology for Pipe Hangers and Supports
SP-91-1992	Guidelines for Manual Operation of Valves
SP-92-1987 (R 1992)	MSS Valve User Guide
SP-93-1987 (R 1992)	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Liquid Penetrant Examination Method
SP-94-1992	Quality Standard for Ferritic and Martensitic Steel Castings for Valves, Flanges, and Fittings and Other Piping Components — Ultrasonic Examination Method
SP-95-1986 (R 1991)	Swage(d) Nipples and Bull Plugs
SP-96-1991	Guidelines on Terminology for Valves and Fittings
SP-97-1987	Forged Carbon Steel Branch Outlet Fittings — Socket Welding, Threaded and Buttwelding Ends
SP-98-1992	Protective Coatings for the Interior of Valves and Hydrants
SP-99-1994	Instrument Valves
SP-100-1988	Qualification Requirements for Elastomer Diaphragms for Nuclear Service Diaphragm Type Valves
SP-101-1989	Part-Turn Valve Actuator Attachment — Flange and Driving Component Dimensions and Performance Characteristics
SP-102-1989	Multi-Turn Valve Actuator Attachment — Flange and Driving Component Dimensions and Performance Characteristics
SP-103-1995	Wrought Copper and Copper Alloy Insert Fittings for Polybutylene Systems
SP-104-1995	Wrought Copper Solder Joint Pressure Fittings
SP-105-1990	Instrument Valves for Code Applications
SP-106-1990	Cast Copper Alloy Flanges and Flanged Fittings, Class 125, 150 and 300
SP-107-1991	Transition Union Fittings for Joining Metal and Plastic Products
SP-108-1991	Resilient Seated-Eccentric Cast Iron Plug Valves
SP-109-1991	Welded Fabricated Copper Solder Joint Pressure Fittings
SP-110-1992	Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
SP-111-1992	Gray-Iron and Ductile-Iron Tapping Sleeves
SP-112-1993	Quality Standard for Evaluation of Cast Surface Finishes — Visual and Tactile Method. This SP must be sold with a 10-surfac, three-dimensional Cast Surface Comparator, which is a necessary part of the Standard. Additional comparators may be sold separately.
SP-113-1994	Connecting Joint between Joint Tapping Machines and Tapping Valves

R-Year — Indicates year standard reaffirmed without substantive change.

Prices available upon request.

A large number of former MSS Practices have been approved by the ANSI or ANSI Standards, published by others. In order to maintain a single source of authoritative information, the MSS withdraws its Standard Practices in such cases.

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STANDARD PRACTICE **SP-106**

1990 Edition

Reaffirmed
1996

CAST COPPER ALLOY FLANGES AND FLANGED FITTINGS CLASS 125, 150 AND 300

Developed and Approved
by the
Manufacturers Standardization Society
of the
Valve and Fittings Industry, Inc.
127 Park Street, N.E.
Vienna, Virginia 22180
(703) 281-6613

Originally Approved November, 1990

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ASME The American Society of Mechanical Engineers
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ASTM American Society for Testing and Material
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CAST COPPER ALLOY FLANGES AND FLANGED FITTINGS CLASS 125, 150 AND 300

1. SCOPE

This standard practice covers cast copper alloy flanges and flanged fittings having dimensions, ratings and materials not included in ANSI B16.24. Specifically this standard includes the following:

1.1 Solder joint flanges when made of ASTM B62, UNS C83600, ASTM B584, UNS C83600, ASTM B584, UNS C83800 and ASTM B584, UNS C84400 for rating Class 125 and Class 150.

1.2 Threaded flanges and blind flanges when made of ASTM B584, UNS C83600, ASTM B584, UNS C83800 and ASTM B584, UNS C84400 for rating Class 150 and Class 300.

1.3 Flanged fittings when made of ASTM B584, UNS C83600, ASTM B584, UNS C83800, and ASTM B584, UNS C84400 for rating Class 150.

2. PRESSURE-TEMPERATURE RATINGS

2.1 Flanges or flanged fittings conforming to this Standard Practice shall have pressure-temperature ratings that are the lower of Table 5 or 6, as applicable, or Table 7. All ratings are the maximum allowable non-shock pressures at the tabulated service temperatures.

2.2 If the two flanges in a flanged joint do not have the same pressure-temperature rating because one or both is soldered, blind or threaded or made of another material, the rating of the joint at any temperature is the lower of the two flange ratings at that temperature.

2.3 The temperature shown for a corresponding pressure rating is the temperature of the pressure-containing shell of the flange or flanged fitting. In general, this temperature is the same as that of the contained fluid.

2.4 Ratings in this document apply to flanged joints which conform to the limitations on bolting in 6.2 or gaskets in 8.2.

3. GENERAL REQUIREMENTS

3.1 The ratings listed are based upon good practice for alignment and assembly. Use of the ratings for flanged joints not conforming with such practice is the sole responsibility of the user. Requirements for alignment and assembly of joints and considerations of leakage due to forces and moments developed in the connected piping or equipment are not covered in this Standard Practice.

4. SIZE

4.1 The "size" of the flanges shown in Table 1 correspond to "standard water tube size" as shown in the Standard Specification for Seamless Copper Water Tube, ASTM.B88.

4.2 The "size" of flanges and flanged fittings shown in Tables 2, 3 and 4 is identified by the corresponding "nominal pipe size."

4.3 Reducing fittings shall be designated by the size of the openings in their proper sequence as indicated in Figure 1.

5. REFERENCE STANDARDS

The following specifications, standards and standard practices incorporated in this Standard Practice by reference are:

5.1 ASTM Specifications

A307-94	Carbon Steel Externally Threaded Standard Fasteners
B32-95	Solder Metal
B62-93	Composition Bronze or Ounce Metal Castings

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B88-95	Seamless Copper Water Tube
B98-93	Copper-Silicon Alloy Rod, Bar and Shapes
B150-95	Aluminum Bronze Rod, Bar and Shapes
B164-93	Nickel-Copper Alloy Rod and Bar
B584-93	Copper Alloy Sand Castings for General Applications

5.2 ANSI, ANSI/ASME, ASME, ASME/ANSI Standards

B1.1-89	Unified Inch Screw Threads (UN and UNR Thread Form)
B1.20.1-83 (R 92)	Pipe Threads, General Purpose (Inch)
B16.1-89 (R 94)	Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250 and 800
B16.5-92	Pipe Flanges and Flanged Fittings
B16.18-84	Cast Copper Alloy Solder Joint Pressure Fittings
B16.24-91	Bronze Pipe Flanges and Flanged Fittings, Class 150 and 300
B16.42-87	Ductile Iron Pipe Flanges and Flanged Fittings
B18.2.1-81 (R 92)	Square and Hex Bolts and Screws, Inch Series
B18.2.2-87 (R 93)	Square and Hex Nuts (Inch Series)

5.3 MSS Standard Practices

SP-6-90	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP-9-92	Spot Facing for Bronze, Iron and Steel Flanges
SP-25-93	Standard Marking System for Valves, Fittings, Flanges and Unions

R indicates year reaffirmed.

6. MATERIALS

6.1 Castings

Castings shall be produced to meet the requirements of ASTM B62, UNS C83600, ASTM B584, UNS C83600, UNS C83800 or UNS C84400. When castings produced from ASTM B584, UNS C83600 are required to meet the ASME Boiler and Pressure Vessel Code, the certification of all testing is mandatory as is the testing of each lot number.

6.2 Bolting

Bolting materials used with these flanges shall conform to one of the following paragraphs.

6.2.1 Steel Bolting. Carbon steel bolting conforming to ASTM A307 shall not be used below -20° F nor above 400° F. See also 8.2.

6.2.2 Nonferrous Boltings. The following nonferrous materials may be used within the temperature limitation stated. See also 8.2. Other materials having at least 40 ksi specified minimum yield strength may be considered.

	ALLOY UNS NO.	CONDITION
ASTM		
a) B98	C65100	(Half Hard) - See Note (1)
	C65500	(Half Hard) - See Note (1)
	C66100	(Half Hard) - See Note (1)
b) B150	C61400	See Note (2)
	C63000	
	C64200	
c) B164	N04400	(Hot Finish)
	N04400	(Cold Drawn) - See Note (2)
	N04400	(Cold Drawn, Stress Relieved) - See Note (2)

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N04400	(Cold Drawn, Stress Equalized) - See Note (2)
N04405	(Hot Finish)
N04405	(Cold Drawn) - See Note (2)

Notes: (1) - Maximum Operating Temperature 350°
(2) - Maximum Operating Temperature 550°

7. DIMENSIONS

7.1 Interchangeability. Class 125 and Class 150 Cast Copper Alloy Flanges and Flanged Fittings are dimensionally interchangeable with American National Standard Class 125 Cast Iron Flanges (ANSI B16.1), with American National Standard Class 150 Steel and Alloy Flanges (ANSI B16.5), with Class 150 Copper Alloy Flanges (ANSI B16.24) and American National Standard Class 150 Ductile Iron Flanges (ANSI B16.42).

7.2 Class 300 Flanges are dimensionally interchangeable with American National Standard Class 250 Cast Iron Flanges (ANSI B16.1), with American National Standard Class 300 Steel and Alloy Flanges (ANSI B16.5), with Class 300 Copper Alloy Flanges (ANSI B16.24) and American National Standard Class 300 Ductile Iron Flanges (ANSI B16.42).

NOTE:
When used with steel, iron or ductile iron flanges or fittings the copper alloy pressure-temperature ratings shown in this standard should not be exceeded.

7.3 Flange bolt holes shall be in accordance with the dimensions shown in Tables 1, 2, and 3.

7.3.1 When flanges are integral with fittings, pairs of bolt holes shall straddle the center line.

7.4 Fitting Dimensions

7.4.1. Center-to-Face Dimensions

7.4.1.1 Side Outlet Fittings. Side outlet elbows and side outlet tees shall have all openings on intersecting center lines.

7.4.1.2 Elbows
The center-to-face dimensions for straight size 90 degree elbows, 90 degree long radius elbows, 45 degree elbows and side outlet 90 degree elbows are shown in Table 4.

Reducing 90 degree elbows and reducing side outlet 90 degree elbows shall have the same center-to-face dimensions as straight size fittings shown in Table 4, corresponding to the size of the largest opening.

Special degree elbows ranging from 1 to 45 degrees, inclusive, shall have the same center-to-face dimensions given for 45 degree elbows and those over 45 degrees and up to 90 degrees, inclusive, shall have the same center-to-face dimensions given for 90 degree elbows. The angle designation of an elbow is its deflection from straight line flow and is the angle between the flange faces.

7.4.1.3 Tees, Crosses and Laterals
The center-to-face dimensions for straight size tees, with or without side outlet, crosses and laterals are shown in Table 4.

Reducing tees, with or without side outlet, reducing crosses and reducing laterals shall have the same center-to-face dimensions as straight size fittings shown in Table 4, corresponding to the size of the largest opening. Tees, crosses and laterals, reducing on the run only, shall have the same center-to-face dimensions as straight size fittings shown in Table 4, corresponding to the size of the largest opening.

Tees reducing on both runs are generally known as bullhead tees and have the same center-to-face dimensions as straight size fittings corresponding to the size of the outlet.

7.4.1.4 True Y's. Center-to-face dimensions for straight size true Y's are shown in Table 4. Reducing sizes are considered special and should be made to suit conditions.

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7.4.1.5 Reducers and Eccentric Reducers. The face-to-face dimensions for all combinations of reducers and eccentric reducers shall be the same as given in Table 4, for the larger opening.

7.4.1.6 Crosses and Lateral Reinforcement. Crosses and lateral (Y-branches) both straight and reducing shall be reinforced where necessary to compensate for inherent weakness in the shape of these fittings.

7.5 Spot Facing

All flanges covered by this Standard Practice shall have bearing surfaces for bolting which shall be parallel to the flange face within 1 degree. Any back facing or spot facing required to accomplish parallelism shall not reduce the flange thickness, "B" or "C" below the dimensions given in Tables 1, 2 and 3. Diameter of spot facing shall be in accordance with MSS SP-9. When cutting into the hub of a flange with back facing tools, the intersection shall have a radius of not less than 1/16 inch.

8. BOLTS, NUTS AND GASKETS

8.1 For Carbon Steel and Non-Ferrous Bolts, smaller than three-quarter inch, ANSI standard square heads or ANSI standard heavy hex heads (ANSI B18.2.1) and ANSI standard heavy hex nuts (ANSI/ASME B18.2.2) are recommended. For Carbon Steel and Non-Ferrous Bolts, three-quarter inch and larger, ANSI standard hex heads or heavy hex heads (ANSI B18.2.1) and ANSI standard hex nuts, or ANSI heavy hex nuts (ANSI/ASME B18.2.2) are recommended.

All bolts and nuts shall be threaded in accordance with ANSI Standard Unified Screw Threads, (ANSI B1.1), Coarse Thread Series, Class 2A and Class 2B.

8.2 Full faced gaskets extending to the flange edge are required. Metallic gaskets shall not be used.

If bolting material is Carbon Steel or Non-Ferrous, compressed sheet gaskets less than 0.12 in. thick should not be used.

9. FLANGE CONNECTIONS

9.1 All solder joint connections shall be to the dimensions shown in Table 1. These dimensions are the same as solder joint dimensions shown in ANSI B16.18.

9.2 The standard method of gaging the diameter tolerances for Female Ends shall be by the use of plain plug gages designed to hold the product within the limits established in Table 1.

9.3 Optional Gaging Method
When gaging the diameters of Female solder cup ends, using direct reading instruments, refer to Note (5) of Table 1.

9.4 All threaded flanges shall have an American National Standard taper pipe thread conforming to ANSI/ASME B1.20.1.

9.5 All threads shall be countersunk a distance not less than one-half the pitch of the thread at an angle of approximately 45 degrees with the axis of the thread, and all external threads shall be chamfered at an angle of 30 to 45 degrees from the axis, for the purpose of easier entrance in making a joint and for protection of the thread. Countersinking and chamfering shall be concentric with the threads.

9.6 The length of threads specified in all tables shall be measured to include the countersink or chamfer.

9.7 Tapered pipe threads (NPT) shall be checked by use of working plug gages, either standard or limit types. Gages shall be threaded in hand tight.

The reference point for gaging internal product threads depends upon the chamfer diameter. When the internal chamfer diameter exceeds the major diameter of the internal thread, the reference point is the last thread scratch on the chamfer cone. Otherwise, when the internal chamfer diameter does not exceed the major diameter of the internal thread, the reference point is the end of the flange.

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10. ALIGNMENT

10.1 The maximum allowable deviation in the alignment of the inside diameter (female) of a solder joint end shall be 0.06 in. in one foot (0.5 percent).

10.2 The maximum allowable variation in the alignment of threads of threaded flanges shall be 0.06 in. per foot (0.5 percent).

11. FACING

11.1 Flanges covered herein shall have either a smooth or serrated face in accordance with MSS SP-6. Raised, male-and-female, and tongue and groove facings are not recommended. When copper alloy flanges are bolted to ductile iron or steel flanges which normally have raised faces, the raised faces should be removed.

12. TOLERANCES

12.1 Flange Thickness
Flange thickness at any point within the spot face area, as defined in MSS SP-9, shall not exceed the required minimum thickness, "B", or "C", by more than 0.12 in.

12.2 Wall Thickness
It is recognized that some variations are absolutely unavoidable in the making of patterns and castings. Equipment shall be designed to produce wall thickness given in the tables. Wall thickness shall not at any point be less than 90 percent of the thickness given in the tables.

12.3 Drilling

12.3.1 Bolt Circle diameter ±0.06 in.

12.3.2 Center-to-Center of adjacent bolt holes ±0.03 in.

12.4 Inside Diameter "I"

12.4.1 Nominal Sizes to 2" inclusive ±0.02 in.

12.4.2 Nominal Sizes 2-1/2" and larger ±.04 in.

12.5 Center-to-Face
The following tolerances shall be permitted on all center-to-contact surface dimensions of fittings:

Nominal Pipe Size	Plus or Minus
10 and smaller	0.03 in.
12	0.06 in

Tolerances for contact surface-to-contact surface dimensions shall be twice those given above. The largest opening in the fitting governs the tolerance to be applied to all openings.

13. MARKING

13.1 General

Except as modified herein, flanges shall be marked as required in MSS SP-25.

13.1.1 Name. The manufacturer's name or trademark shall be applied.

13.1.2 Rating Class. Numerals shall be applied giving the pressure rating class for which the product is designed.

13.1.3 Size. The nominal tube/pipe size shall be given.

13.1.4 The product shall be identified by the material alloy number, such as 836, 838 or 844.

14. TESTS

14.1 Hydrostatic tests of flanges are not required unless specified by the user.

14.2 All fittings shall be capable of withstanding, without showing leakage, the appropriate hydrostatic test pressure listing in Table 5 or 6. Each fitting shall be subjected to either a hydrostatic test at the appropriate pressure listed in Table 5 or 6 or a gas test at a minimum pressure of 80 psig.

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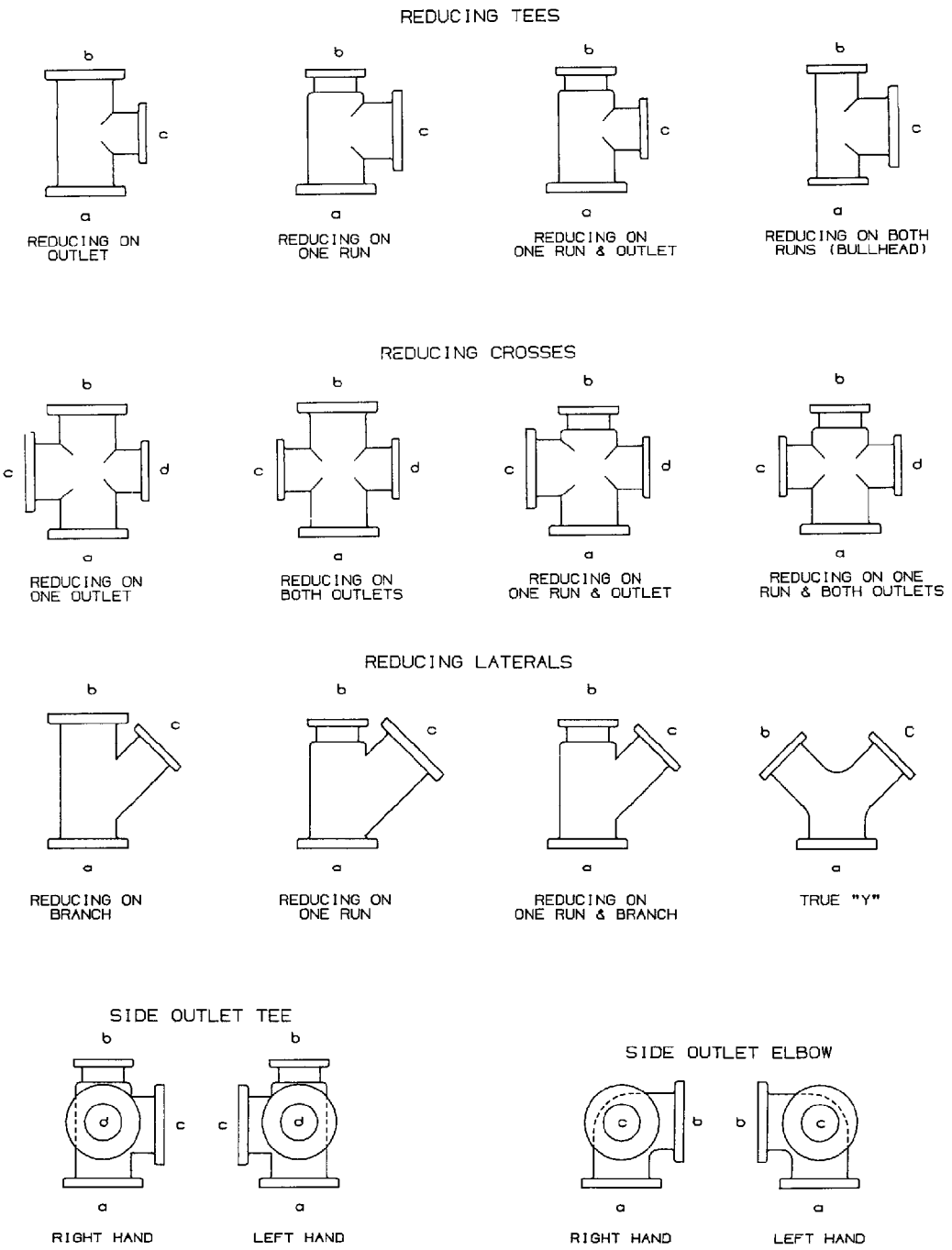

FIGURE 1. METHOD OF DESIGNATING OUTLETS OF REDUCING FITTINGS

In designating the openings of reducing fittings they should be read in the order indicated by the sequence of the letters a, b, c, and d. In designating the outlets of side outlet reducing fittings, the side outlet is named last and in the case of the cross which is not shown, the side outlet is designated by the letter e.

Note: The largest opening establishes the basic size of a reducing fitting. The largest opening is named first, except for bullhead tees which are reducing on both runs and for double branch elbows where both branches are reducing, the outlet is the largest opening and named last in both cases. (Double branch elbows are not included in this standard.)

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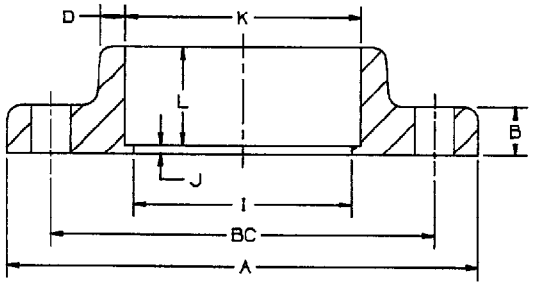
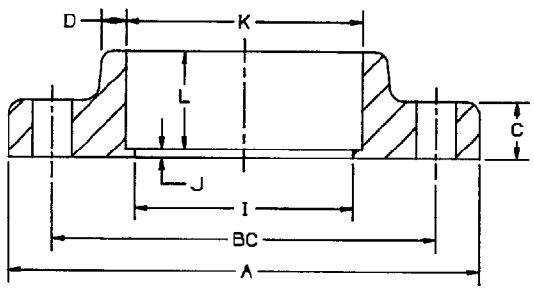


CLASS 125



CLASS 150

TABLE 1. DIMENSIONS OF CLASS 125 & 150 SOLDER JOINT FLANGES[1] [3]

Standard Water Tube Size	Diameter of Flange A	Class 125 Thickness of Flange[2] Min.[6] B	Class 150 Thickness of Flange[2] Min.[6] C	Bolt[6] Circle BC	Number of Bolts	Diameter of Bolts	Diameter of Bolt Hole	[6] Metal Thickness D	Diameter of Counter-bore[6] I	Thickness at Recess Min. J	Inside Diameter[4] K[5]		Dept. L
											Min.	Max.	Min.
⅜	3.50	0.19	0.31	2.38	4	½	0.62	0.05	0.43	0.06	0.502	0.506	0.38
½	3.50	0.19	0.31	2.38	4	½	0.62	0.05	0.54	0.06	0.627	0.631	0.50
¾	3.88	0.19	0.34	2.75	4	½	0.62	0.06	0.78	0.06	0.877	0.881	0.75
1	4.25	0.19	0.38	3.12	4	½	0.62	0.07	1.02	0.06	1.128	1.132	0.91
1¼	4.62	0.19	0.41	3.50	4	½	0.62	0.07	1.26	0.09	1.378	1.382	0.97
1½	5.00	0.25	0.44	3.88	4	½	0.62	0.08	1.50	0.09	1.628	1.633	1.09
2	6.00	0.31	0.50	4.75	4	⅝	0.75	0.09	1.90	0.09	2.128	2.133	1.34
2½	7.00	0.31	0.56	5.50	4	⅝	0.75	0.10	2.46	0.12	2.628	2.633	1.47
3	7.50	0.38	0.62	6.00	4	⅝	0.75	0.11	2.94	0.12	3.128	3.133	1.66
3½	8.50	0.38	0.69	7.00	8	⅝	0.75	0.12	3.42	0.12	3.628	3.633	1.91
4	9.00	0.38	0.69	7.50	8	⅝	0.75	0.13	3.90	0.12	4.128	4.133	2.16
5	10.00	0.38	0.75	8.50	8	¾	0.88	0.17	4.87	0.12	5.128	5.133	2.66
6	11.00	0.38	0.81	9.50	8	¾	0.88	0.20	5.84	0.12	6.128	6.133	3.09
8	13.50	0.50	0.94	11.75	8	¾	0.88	0.31	7.72	0.19	8.128	8.133	3.97
10	16.00	0.56	1.00	14.25	12	⅞	1.00	0.48	9.62	0.19	10.128	10.133	4.00
12	19.00	0.62	1.06	17.00	12	⅞	1.00	0.56	11.56	0.19	12.128	12.133	4.50

Dimensions are in inches.

(1) For flange facing, see 11.1.
(2) For flange spot facing and thickness, see 7.5 and 12.1.
(3) Flange diameters and drilling templates correspond to those prescribed in American National Standards B16.1, B16.5, B16.24 and B16.42.
(4) For solder cup dimensions, see 9.1.
(5) Maximum ovality shall not exceed 1% of the diameter in Table 1. The average of the maximum and minimum diameters must be within the dimensions shown in the Table.
(6) For tolerances, see Section 12.

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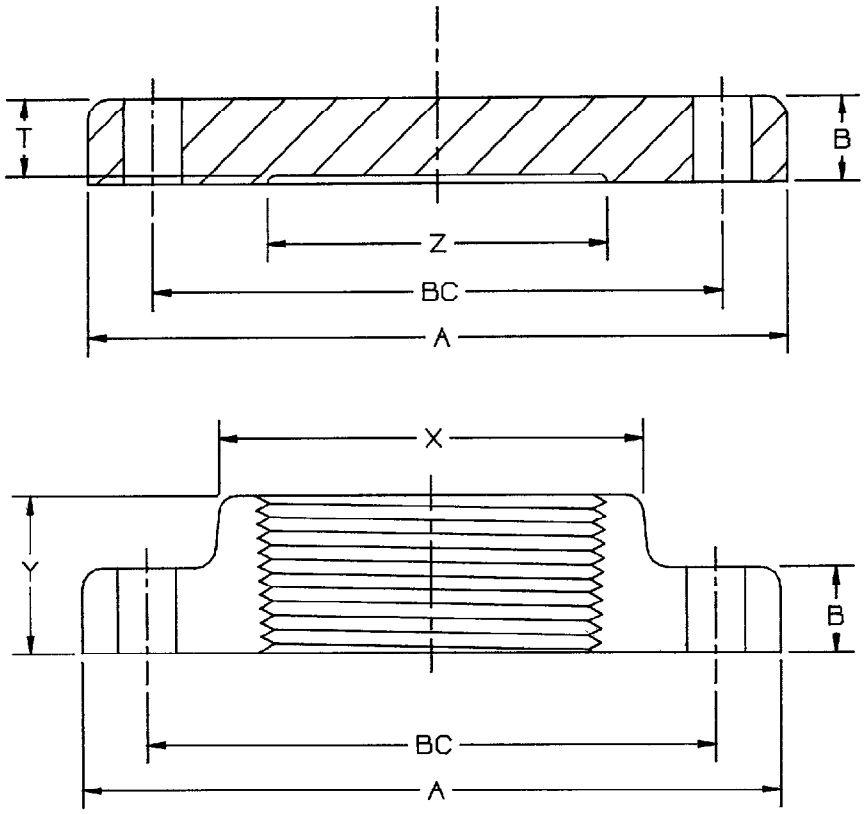

TABLE 2. DIMENSIONS OF CLASS 150 THREADED COMPANION AND BLIND FLANGES[(1) (4)]

Nominal Pipe Size	Diameter of Flange A	Thickness of Flange[(2)] Min.[(5)] B	Bolt Circle[(5)] BC	Number of Bolts[(3)]	Diameter of Bolts	Diameter of Bolt Hole	Diameter of Hub, Min. X	Length Overall Min. Y	Diameter of Counter-bore Max. Z	Thickness at Recess, Min. T
½	3.50	0.31	2.38	4	½	0.62	1.19	0.59	0.50	0.25
¾	3.88	0.34	2.75	4	½	0.62	1.50	0.62	0.75	0.28
1	4.25	0.38	3.12	4	½	0.62	1.94	0.69	1.00	0.31
1¼	4.62	0.41	3.50	4	½	0.62	2.31	0.81	1.25	0.34
1½	5.00	0.44	3.88	4	½	0.62	2.56	0.88	1.50	0.38
2	6.00	0.50	4.75	4	⅝	0.75	3.06	1.00	2.00	0.44
2½	7.00	0.56	5.50	4	⅝	0.75	3.56	1.12	2.50	0.50
3	7.50	0.62	6.00	4	⅝	0.75	4.25	1.19	3.00	0.56
3½	8.50	0.69	7.00	8	⅝	0.75	4.81	1.25	3.50	0.62
4	9.00	0.69	7.50	8	⅝	0.75	5.31	1.31	4.00	0.62
5	10.00	0.75	8.50	8	¾	0.88	6.44	1.44	5.00	0.69
6	11.00	0.81	9.50	8	¾	0.88	7.56	1.56	6.00	0.75
8	13.50	0.94	11.75	8	¾	0.88	9.69	1.75	8.00	0.88
10	16.00	1.00	14.25	12	⅞	1.00	12.00	1.94	10.00	0.94
12	19.00	1.06	17.00	12	⅞	1.00	14.38	2.19	12.00	1.00

Dimensions are in inches.

(1) For flange facing, see 11.1.
(2) For flange spot facing and thickness, see 7.5 and 12.1.
(3) For flanges integral with fittings or valves, see 7.3.1.
(4) Flange diameters and drilling templates correspond to those prescribed in American National Standards B16.1, B16.5, B16.24 and B16.42.
(5) For tolerances, see Section 12.

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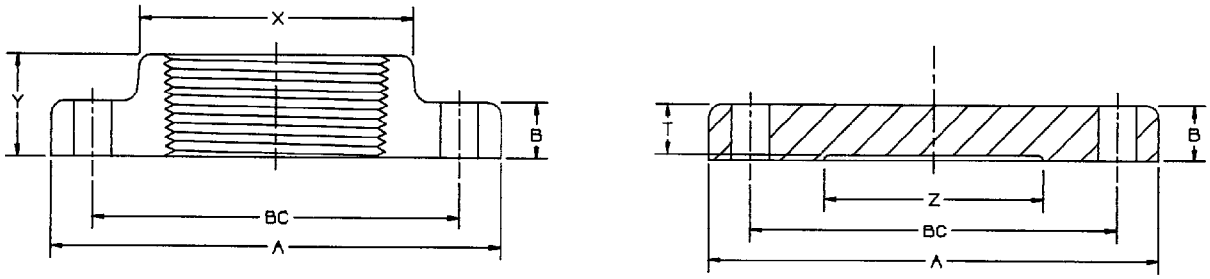

TABLE 3. DIMENSIONS OF CLASS 300 THREADED COMPANION AND BLIND FLANGES [1] [4]

Nominal Pipe Size	Diameter of Flange A	Thickness of Flange[5] Min.[2] B	Bolt Circle[5] BC	Number of Bolts[3]	Diameter of Bolts	Diameter of Bolt Hole	Diameter of Hub, Min. X	Length Overall Min.	Diameter of Counter-bore Max. Z	Thickness at Recess, Min. T
½	3.75	0.50	2.62	4	½	0.62	1.19	0.59	0.50	0.44
¾	4.62	0.53	3.25	4	⅝	0.75	1.50	0.62	0.75	0.47
1	4.88	0.59	3.50	4	⅝	0.75	1.94	0.69	1.00	0.53
1¼	5.25	0.62	3.88	4	⅝	0.75	2.31	0.81	1.25	0.56
1½	6.12	0.69	4.50	4	¾	0.88	2.56	0.88	1.50	0.62
2	6.50	0.75	5.00	8	⅝	0.75	3.06	1.00	2.00	0.69
2½	7.50	0.81	5.88	8	¾	0.88	3.56	1.12	2.50	0.75
3	8.25	0.91	6.62	8	¾	0.88	4.25	1.19	3.00	0.84
3½	9.00	0.97	7.25	8	¾	0.88	4.81	1.25	3.50	0.91
4	10.00	1.06	7.88	8	¾	0.88	5.31	1.31	4.00	1.00
5	11.00	1.12	9.25	8	¾	0.88	6.44	1.44	5.00	1.06
6	12.50	1.19	10.62	12	¾	0.88	7.56	1.56	6.00	1.12
8	15.00	1.38	13.00	12	⅞	1.00	9.69	1.75	8.00	1.31

Dimensions are in inches.

[1] For flange facing, see 11.1.
[2] For flange spot facing and thickness, see 7.5 and 12.1.
[3] For flanges integral with fittings or valves, see 7.3.1.
[4] Flange diameters and drilling templates correspond to those prescribed in American National Standards B16.1, B16.5, B16.24 and B16.42.
[5] For tolerances, see Section 12.

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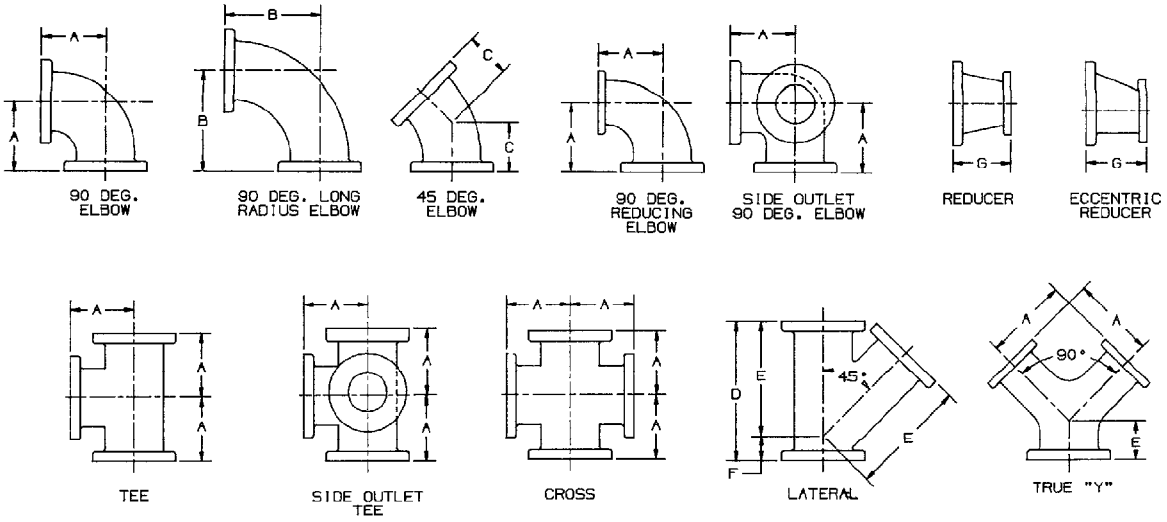

TABLE 4. DIMENSIONS OF CLASS 150 ELBOWS, TEES, CROSSES, LATERALS, TRUE Y'S (STRAIGHT SIZES), AND REDUCERS [1] [2]

Nominal Pipe Size	Center-To-Face A	Face-To-Face A+A	Center-To-Face B	Center-To-Face C	Face-To-Face D	Center-To-Face E	Center-To-Face F	Face-To-Face G	Wall Thickness	Minimum Port Diameter I
Notes	(3), (4), (7), (8), (9), (10), (11)		(3)	(3)	(8), (9)	(8), (9)	(8), (9)	(6)	(5)	
½	3.00	6.00	—	1.62	—	—	—	—	0.09	0.50
¾	3.25	6.50	—	1.75	—	—	—	—	0.11	0.75
1	3.50	7.00	5.00	1.75	7.50	5.75	1.75	—	0.12	1.00
1¼	3.75	7.50	5.50	2.00	8.00	6.25	1.75	—	0.14	1.25
1½	4.00	8.00	6.00	2.25	9.00	7.00	2.00	—	0.16	1.50
2	4.50	9.00	6.50	2.50	10.50	8.00	2.50	5.00	0.19	2.00
2½	5.00	10.00	7.00	3.00	12.00	9.50	2.50	5.50	0.20	2.50
3	5.50	11.00	7.75	3.00	13.00	10.00	3.00	6.00	0.22	3.00
3½	6.00	12.00	8.50	3.50	14.50	11.50	3.00	6.50	0.25	3.50
4	6.50	13.00	9.00	4.00	15.00	12.00	3.00	7.00	0.27	4.00
5	7.50	15.00	10.25	4.50	17.00	13.50	3.50	8.00	0.30	5.00
6	8.00	16.00	11.50	5.00	18.00	14.50	3.50	9.00	0.33	6.00
8	9.00	18.00	14.00	5.50	22.00	17.50	4.50	11.00	0.41	8.00
10	11.00	22.00	16.50	6.50	25.50	20.50	5.00	12.00	0.48	10.00
12	12.00	24.00	19.00	7.50	30.00	24.50	5.50	14.00	0.56	12.00

Dimensions are in inches.

(1) For flange and bolt hole dimensions, see Table 2 and 7.3.
(2) For center-to-face tolerance, see 12.5.
(3) For intersecting center lines of side outlet fittings, see 7.4.1.1.
(4) For center-to-face dimensions of reducing elbows, see 7.4.1.2.
(5) For wall thickness tolerance, see 12.2.
(6) For face-to-face dimensions of reducers and eccentric reducers, see 7.4.1.5.
(7) For center-to-face dimensions of special degree elbows, see 7.4.1.2.
(8) For reinforcement of crosses and laterals, see 7.4.1.6.
(9) For center-to-face dimensions of reducing tees, crosses and laterals, see 7.4.1.3.
(10) For center-to-face dimensions of tees reducing on both runs, see 7.4.1.3.
(11) For center-to-face dimensions of reducing side outlet tees having two different size reductions on the outlets, see 7.4.1.3.

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PRESSURE-TEMPERATURE RATINGS

These tables which are an integral part of MSS SP-106 are placed after the main text for convenience.

TABLE 5
PRESSURE-TEMPERATURE RATINGS FOR ASTM B-62, UNS C83600 AND ASTM B584, UNS C83600

Service Temperature	Working Pressure
	Class 150
	Psig
0 To 150 F	225
175 F	220
200 F	210
225 F	205
250 F	195
275 F	190
300 F	180
350 F	165
406 F	150
Test Pressure	350

TABLE 6
PRESSURE-TEMPERATURE RATINGS FOR ASTM B584, ALLOY C83800 AND ALLOY C84400

Service Temperature	Working Pressure		
	Class 125	Class 150	Class 300
	Psig	Psig	Psig
0 To 150 F	105	210	465
175 F	100	205	445
200 F	95	195	430
225 F	90	190	415
250 F	90	180	395
275 F	85	175	380
300 F	85	170	365
350 F	75	150	325
406 F	70	140	295
Test Pressure	155	315	700

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STRENGTH OF SOLDER JOINTS

This table is an integral part of MSS SP-106 and is placed after the main text for convenience.

The maximum recommended pressure-temperature ratings for solder joints made with copper tube and cast copper alloy flanges using representative commercial solders, are listed in the table below.

TABLE 7. PRESSURE-TEMPERATURE LIMITATIONS

Joining Material	Working Temperature	Maximum Working Gage Pressure				
		Size ⅛ thru 1[1]	Size 1¼ thru 2[1]	Size 2½ thru 4[1]	Size 5 thru 8[1]	Size 10 and 12[1]
	°F	psi	psi	psi	psi	psi
50-50 Tin-Lead Solder[2] [5]	100	200	175	150	135	100
	150	150	125	100	90	70
	200	100	90	75	70	50
	250	85	75	50	45	40
95-5 Tin-Antimony Solder[3]	100	500	400	300	270	150
	150	400	350	275	250	150
	200	300	250	200	180	140
	250	200	175	150	135	110
Joining[4] Materials Melting at or above 1000°F	Pressure-temperature ratings consistent with the materials and procedures employed					

NOTES:

(1) Standard water tube sizes.
(2) ASTM B32 Alloy Grade 50A.
(3) ASTM B32 Alloy Grade 95TA.
(4) These joining materials are defined as brazing alloys by the American Welding Society.
(5) Consult local codes relating to the use of solders containing lead in excess of EPA guidelines for potable water systems. (Reference: Federal Safe Drinking Water Act, Amendment of 1986 - Public Law 99-339). This Act limits the maximum lead content to 0.2%.

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LIST OF MSS STANDARD PRACTICES

NUMBER	
SP- 6-1990	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP- 9-1992	Spot Facing for Bronze, Iron and Steel Flanges
SP-25-1993	Standard Marking System for Valves, Fittings, Flanges and Unions
SP-42-1990 (R 1995)	Class 150 Corrosion Resistant Gate, Globe, Angle and Check Valves with Flanged and Butt-Weld Ends
SP-43-1991 (R 1996)	Wrought Stainless Steel Butt-Welding Fittings
SP-44-1996	Steel Pipeline Flanges
SP-45-1992	Bypass and Drain Connections
SP-51-1991 (R 1995)	Class 150 LW Corrosion Resistant Cast Flanges and Flanged Fittings
SP-53-1995	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Magnetic Particle Examination Method
SP-54-1995	Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components — Radiographic Examination Method
SP-55-1985 (R 1990)	Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components — Visual Method
SP-58-1993	Pipe Hangers and Supports — Materials, Design and Manufacture
SP-60-1991	Connecting Flange Joint Between Tapping Sleeves and Tapping Valves
SP-61-1992	Pressure Testing of Steel Valves
SP-65-1994	High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets
SP-67-1995	Butterfly Valves
SP-68-1988	High Pressure-Offset Seat Butterfly Valves
SP-69-1991	Pipe Hangers and Supports — Selection and Application
SP-70-1990	Cast Iron Gate Valves, Flanged and Threaded Ends
SP-71-1990	Cast Iron Swing Check Valves, Flanged and Threaded Ends
SP-72-1992	Ball Valves with Flanged or Butt-Welding Ends for General Service
SP-73-1991	Brazing Joints for Wrought and Cast Copper Alloy Solder Joint Pressure Fittings
SP-75-1993	Specifications for High Test Wrought Butt Welding Fittings
SP-77-1995	Guidelines for Pipe Support Contractual Relationships
SP-78-1987 (R 1992)	Cast Iron Plug Valves, Flanged and Threaded Ends
SP-79-1992	Socket-Welding Reducer Inserts
SP-80-1987	Bronze Gate, Globe, Angle and Check Valves
SP-81-1995	Stainless Steel, Bonnetless, Flanged Knife Gate Valves
SP-82-1992	Valve Pressure Testing Methods
SP-83-1995	Class 3000 Steel Pipe Unions, Socket-Welding and Threaded
SP-84-1990	Valves — Socket-Welding and Threaded Ends
SP-85-1994	Cast Iron Globe & Angle Valves, Flanged and Threaded Ends
SP-86-1987 (R 1992)	Guidelines for Metric Data in Standards for Valves, Flanges, Fittings and Actuators
SP-87-1991 (R 1996)	Factory-Made Butt-Welding Fittings for Class I Nuclear Piping Applications
SP-88-1993	Diaphragm Type Valves
SP-89-1991	Pipe Hangers and Supports — Fabrication and Installation Practices
SP-90-1986 (R 1991)	Guidelines on Terminology for Pipe Hangers and Supports
SP-91-1992 (R 1996)	Guidelines for Manual Operation of Valves
SP-92-1987 (R 1992)	MSS Valve User Guide
SP-93-1987 (R 1992)	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Liquid Penetrant Examination Method
SP-94-1992	Quality Standard for Ferritic and Martensitic Steel Castings for Valves, Flanges, and Fittings and Other Piping Components — Ultrasonic Examination Method
SP-95-1986 (R 1991)	Swage(d) Nipples and Bull Plugs
SP-96-1991	Guidelines on Terminology for Valves and Fittings
SP-97-1995	Integrally Reinforced Forged Branch Outlet Fittings — Socket-Welding, Threaded and Buttwelding Ends
SP-98-1992	Protective Coatings for the Interior of Valves and Hydrants
SP-99-1994	Instrument Valves
SP-100-1988	Qualification Requirements for Elastomer Diaphragms for Nuclear Service Diaphragm Type Valves
SP-101-1989	Part-Turn Valve Actuator Attachment — Flange and Driving Component Dimensions and Performance Characteristics
SP-102-1989	Multi-Turn Valve Actuator Attachment — Flange and Driving Component Dimensions and Performance Characteristics
SP-103-1995	Wrought Copper and Copper Alloy Insert Fittings for Polybutylene Systems
SP-104-1995	Wrought Copper Solder Joint Pressure Fittings
SP-105-1996	Instrument Valves for Code Applications
SP-106-1990 (R 1996)	Cast Copper Alloy Flanges and Flanged Fittings, Class 125, 150 and 300
SP-107-1991	Transition Union Fittings for Joining Metal and Plastic Products
SP-108-1996	Resilient-Seated Cast Iron-Eccentric Plug Valves
SP-109-1991	Welded Fabricated Copper Solder Joint Pressure Fittings
SP-110-1992	Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
SP-111-1992	Gray-Iron and Ductile-Iron Tapping Sleeves
SP-112-1993	Quality Standard for Evaluation of Cast Surface Finishes — Visual and Tactile Method. This SP must be sold with a 10-surface, three-dimensional Cast Surface Comparator, which is a necessary part of the Standard. Additional comparators may be sold separately.
SP-113-1994	Connecting Joint between Tapping Machines and Tapping Valves
SP-114-1995	Corrosion Resistant Pipe Fittings, Threaded and Socket Welding, Class 150 and 1000
SP-115-1995	Excess Flow Valves for Natural Gas Service

R-Year — Indicates year standard reaffirmed without substantive change. **Prices available upon request.**

A large number of former MSS Practices have been approved by the ANSI or ANSI Standards, published by others. In order to maintain a single source of authoritative information, the MSS withdraws its Standard Practices in such cases.

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MSS SP-114-2001

Corrosion Resistant Pipe Fittings Threaded and Socket Welding Class 150 and 1000

Standard Practice
Developed and Approved by the
Manufacturers Standardization Society of the
Valve and Fittings Industry, Inc.
127 Park Street, NE
Vienna, Virginia 22180
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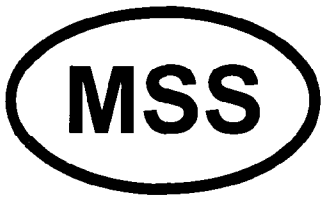

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This MSS Standard Practice was developed under the consensus of the MSS Technical Committee 108 and the MSS Coordinating Committee. The content of this Standard Practice is the result of the efforts of competent and concerned volunteers to provide an effective, clear, and non-exclusive specification that will benefit the industry as a whole. This MSS Standard Practice is intended as a basis for common practice by the manufacturer, the user, and the general public. The existence of an MSS Standard Practice does not in itself preclude the manufacture, sale, or use of products not conforming to the Standard Practice. Mandatory conformance is established only by reference in a code, specification, sales contract, or public law, as applicable.

Unless otherwise specifically noted in this MSS SP, any standard referred to herein is identified by the date of issue that was applicable to the referenced standard(s) at the date of issue of this MSS SP. (see Annex A).

In this Standard Practice all notes, annexes, tables, and figures are construed to be essential to the understanding of the message of the standard, and are considered part of the text unless noted as "supplemental". All appendices appearing in this document are construed as "supplemental". "Supplemental" information does not include mandatory requirements.

Substantive changes in this 2001 edition are "flagged" by parallel bars as shown on the margins of the affected text. The specific detail of the changes may be determined by comparing the material flagged with that in the previous edition.

Non-toleranced dimensions in this Standard Practice are nominal, and unless otherwise specified, shall be considered "for reference only".

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FOREWORD

This document established a standard for corrosion resistant pipe fittings, threaded and socket-welding, Class 150 and 1000, produced for a number of years by various manufacturers to somewhat different dimensions although basically similar in principal. Users should note that corrosion resistant pipe fittings, threaded and socket-welding, Class 150 and 1000, furnished from existing stocks, until depleted, may have slightly different dimensions than shown herein.

This standard, orginally approved May 1995, was revised in 2001 to include Class 150 and 1000 square head plugs, hex head plugs and bushings, locknuts, and threaded and socket-welding unions.

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CORROSION RESISTANT PIPE FITTINGS THREADED AND SOCKET WELDING CLASS 150 AND 1000

1. SCOPE

1.1 This Standard Practice for corrosion resistant pipe fittings, threaded and socket welding, Class 150 and 1000 establishes requirements for the following:

a) Pressure-temperature ratings
b) Size and method of designating openings of reducing fittings
c) Marking
d) Minimum requirements for materials
e) Dimensions and tolerances
f) Threading
g) Tests

2. PRESSURE-TEMPERATURE RATINGS

2.1 Pressure-temperature ratings for these fittings are shown in Table 1. Ratings are independent of the contained fluid and are the maximum allowable working pressures at the tabulated temperatures. Intermediate ratings may be obtained by linear interpolation between the temperatures shown.

2.2 The temperatures shown for the corresponding pressure rating shall be the material temperature of the pressure retaining structure. It is implied that the material temperature is the same as the fluid temperature. Use of a pressure rating at a material temperature other than that of the contained fluid is the responsibility of the user and subject to the requirements of any applicable code.

2.3 For purposes of this standard, castings are included for Class 150 fittings only.

2.4 The wall thickness of the fittings covered by this standard correspond to Schedule 40 pipe. When thinner pipe of equivalent material is used, its strength may govern the rating. When Schedule 40 pipe of equivalent material is used, the strength of the fitting governs the rating.

TABLE 1 - PRESSURE-TEMPERATURE RATINGS

Temperature (°F)	Class 150 (castings) PSIG	Class 1000 (Wrought) PSIG
-20 to 150	300	1000
200	265	910
250	225	825
300	185	735
350	150[a]	650
400	—	560
450	—	475
500	—	385
550	—	300

NOTE: [a]Permissible for service temperature up to 366 degrees Fahrenheit, reflecting the temperature of saturated steam at 150 psig.

3. SIZE

3.1 The size of the fittings listed in the following tables are identified by the corresponding nominal [b] pipe size (NPS).

NOTE: [b] the use of the word "nominal" as a modifier of a dimension or size is intended to indicate that the stated dimension or size is used for purposes of designation.

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3.2 For reducing tees, crosses, and Y-branches (laterals), the size of the largest run opening shall be given first, followed by the size of the opening at the opposite end of the run. Where the fitting is a tee or Y-branch (lateral), the size of the outlet is given last. The straight line sketches of Fig.1 illustrate how the reducing fittings are read.

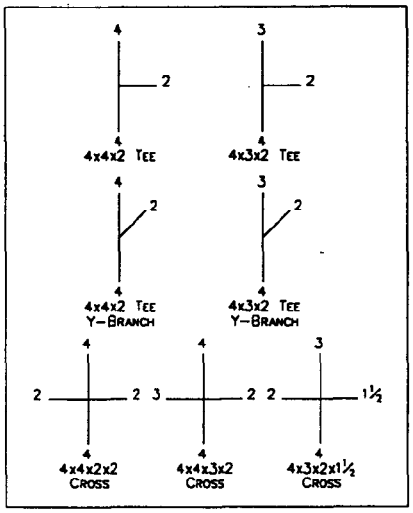

FIGURE 1 - IDENTIFICATION OF REDUCING FITTINGS

4. MARKING

4.1 ***Class 150 Fittings*** - Each Class 150 fitting shall be marked for identification with:

a) The manufacturer's name or trademark
b) Material identification
c) The symbol "SP114" to denote compliance with this standard
d) Class 150
e) Size
f) Other markings in accordance with MSS SP-25. Where size and shape of fittings do not permit all of the above markings, they may be omitted in the reverse order given.
g) The marking of plugs, bushings, and locknuts is not required by this standard.

4.2 ***Class 1000 Fittings*** - Each Class 1000 fitting shall be marked for identification with:

a) The manufacturer's name or trademark
b) Material identification
c) The symbol "SP114" to denote compliance with this standard
d) Class 1000 or 1M
e) Size
f) Other markings in accordance with MSS SP-25. Where size and shape of fittings do not permit all of the above markings, they may be omitted in the reverse order given.
g) The marking of plugs, bushings, and locknuts is not required by this standard.

5. MATERIAL

5.1 ***Castings*** - The chemical and mechanical properties of the castings shall be at least equal to the grades contained in ASTM A 351. Castings shall be heat treated by the solution annealing method specified in ASTM A 351. The castings shall be capable of passing the intergranular corrosion tests performed in accordance with practice B of ASTM A 262. The manufacturer shall be prepared to certify that the product has been so produced.

5.2 ***Wrought*** - Fittings, couplings, and caps shall be made from wrought forgings, seamless tubing, or bar stock. The chemical and mechanical properties shall be as a minimum equal to the grades contained in ASTM A 182, A 479 or A 511. Wrought material shall be heat

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treated by the solution method as specified in ASTM A 182, A 479, or A 511. The wrought material shall be capable of passing the intergranular corrosion tests performed in accordance with practice E of ASTM A 262. The manufacturer shall be prepared to certify that the product has been so produced.

6. DIMENSIONS AND TOLERANCES

6.1 ***General*** – The dimensions and tolerances of cast and wrought fittings are given in Tables 2 through 22.

6.2 ***Reducing Fittings*** - Reducing fittings shall have the same center-to-end dimensions and band diameter as the straight-size fittings corresponding to the largest size opening in the reducing fittings.

6.3 ***Tolerances*** - Unless otherwise noted, The dimensions in this standard are nominal and are subject to the designated manufacturing tolerances. The following tolerances apply:

a) ***Metal Thickness.*** Metal thickness at no point shall be less than 90% of the value given in Tables 3 through 10 and 12 through 22.

b) ***Center-to-End.*** Permitted center-to-end tolerances of fittings are shown in Table 2. Tolerances for end-to-end dimensions, lengths of couplings, and reducers shall be twice those given for center-to-end dimensions. The largest nominal pipe size in a reducing fitting governs the tolerance to be applied to all openings.

TABLE 2 - CENTER TO END TOLERANCES

NOMINAL PIPE SIZE	PLUS OR MINUS, IN.
1/8, ¼, 3/8	0.05
1/2, ¾	0.06
1, 1-1/4	0.07
1-1/2, 2	0.08
2-1/2, 3	0.10
4	0.12

7. THREADING

7.1 ***Types of Threads*** - All fittings, except locknuts, shall be threaded in accordance with ANSI/ASME B1.20.1, and shall have tapered threads. Locknut threads shall be NPSL straight pipe threads in accordance with ANSI/ASME B1.20.1.

7.2 ***Countersink or Chamfer*** - Internal threads shall be countersunk or chamfered a distance of not less than one half the pitch of the thread at an angle of approximately 45° with the axis of the thread, and external threads shall be chamfered at an angle of 30° to 45° with the axis, both for the purpose of easier entrance in making a joint and for protection of the thread. Countersinking and chamfering shall be concentric with the threads.

7.3 ***Thread Gaging***

7.3.1 ***External Threads*** - Variations in threading shall be limited to one turn large or one turn small from the gage face of the ring gage. The reference point for gaging shall be the end of the thread.

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7.3.2 ***Internal Threads*** - Variations in threading shall be limited to one turn large or one turn small from the gaging notch of the plug gage. The reference point for gaging is the last thread scratch on the chamfer cone.

7.4 ***Length*** - The thread length specified in all tables shall be measured to include the countersink or chamfer.

7.5 ***Alignment*** - The maximum allowable variation in the alignment of threads of all openings of threaded fittings shall be 0.06 in./ft.

8. SOCKET-WELDING

8.1 Dimensions for socket-welding fittings shall conform to Tables 2, 7, 13, 17, and 22 and the general values given in Tables 3, 5, 6, 14, and 16.

8.2 The ends of socket-welding fittings shall be flat and at right angles to the socket axis and shall provide a minimum of 75% of the socket wall thickness for the fillet welding surface.

8.3 The socket bore shall be of uniform depth and diameter and exhibit a good workmanship finish that is free of burrs.

9. RIBS

9.1 ***General*** - The addition of ribs or lugs is permitted. Where ribs are used, it is recommended that their thickness shall be the same as specified for the metal thickness of the fitting.

10. PLUGS, BUSHINGS, AND LOCKNUTS

10.1 For dimensions of plugs, bushings, and lock nuts, see Tables 8, 9, 10, 11, 18, 19, and 20.

11.1 FACE BEVEL

11.1 A bevel not exceeding 5 degrees is permitted on the faces of threaded fitting openings. Center-to-end, end-to-end, and width of band dimensions may include or exclude the bevel.

12. WELDING

12.1 Installation welding requirements are outside the scope of this standard practice.

13. TESTING

13.1 Hydrostatic testing of fittings is not required by this standard. All fittings shall be capable of withstanding, without leakage or impairment of serviceability, a pressure equal to that listed in Table 1 at the – 20 to 150 F pressure rating for the applicable Class.

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Class 150

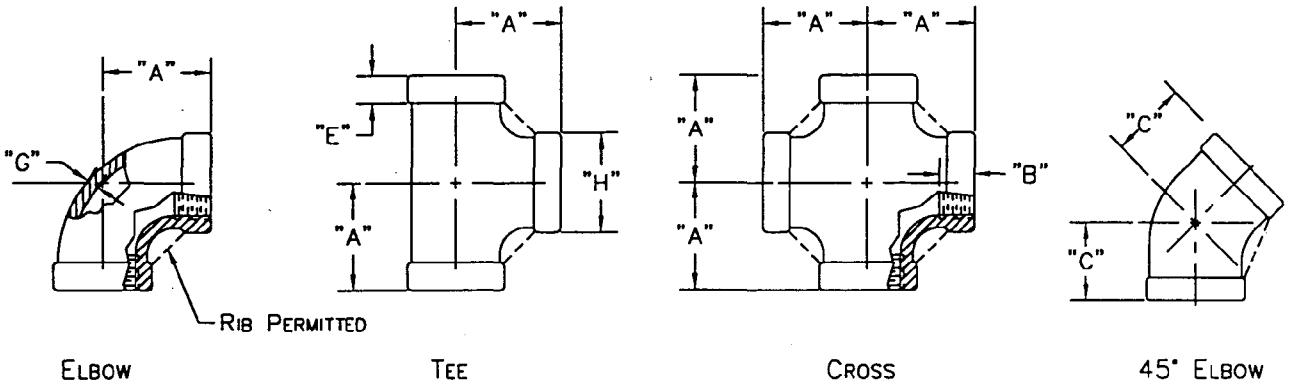

TABLE 3 - DIMENSIONS OF CAST 90 DEG. ELBOWS, TEES, CROSSES, AND 45 DEG. ELBOWS

Nominal Pipe Size	Center-to-End, Elbows, Tees, & Crosses A	Center-to End, 45 Deg. Elbows C	Length of Thread B, Min. [b]	Width of Band E, Min.	Metal Thickness G [a]	Outside Diameter of Band H, Min.
1/8	0.81	0.69	0.25	0.20	0.09	0.75
1/4	0.81	0.69	0.32	0.20	0.09	0.84
3/8	0.93	0.81	0.36	0.21	0.10	1.01
1/2	1.12	0.87	0.43	0.25	0.10	1.20
3/4	1.31	1.00	0.50	0.27	0.12	1.46
1	1.50	1.12	0.58	0.30	0.13	1.77
1-1/4	1.75	1.31	0.67	0.34	0.14	2.15
1-1/2	1.93	1.43	0.70	0.37	0.15	2.43
2	2.25	1.68	0.75	0.42	0.17	2.96
2-1/2	2.68	1.93	0.92	0.48	0.21	3.31
3	3.06	2.18	0.98	0.55	0.23	4.00
4	3.81	2.62	1.08	0.66	0.26	5.06

GENERAL NOTE: Dimensions are in inches.

[a] Patterns shall be designed to produce castings of metal thickness given in the Table. Metal thickness at no point shall be less than 90% of values given in the tables.

[b] The length of thread may extend beyond the width of band. However, minimum metal thickness (G) must be maintained at the end of the thread.

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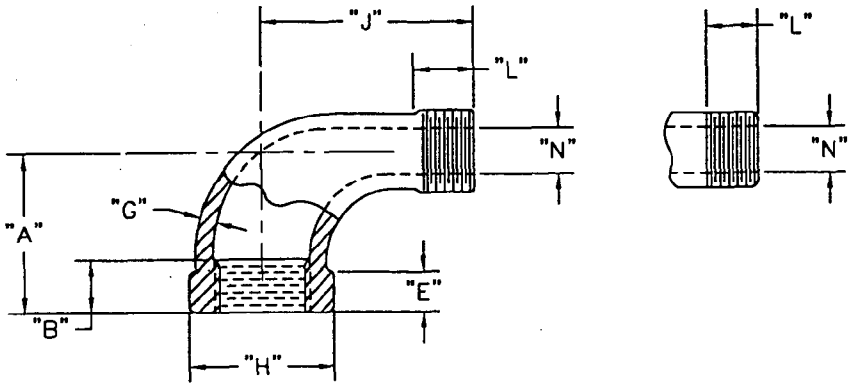

TABLE 4 - DIMENSIONS OF CAST 90 DEG. STREET ELBOWS

Nominal Pipe Size	Center-to-End A	Length of Internal Thread B, Min. (b)	Width of Band E, Min.	Metal Thickness G (a)	Outside Diameter of Band H, Min.	Center-to-End J	Length Of External Thread L, Min.	Port Diameter Male End N, Max.
1/8	0.81	0.25	0.20	0.09	0.75	1.06	0.26	0.20
1/4	0.81	0.32	0.20	0.09	0.84	1.18	0.40	0.26
3/8	0.93	0.36	0.21	0.10	1.01	1.43	0.41	0.37
1/2	1.12	0.43	0.25	0.10	1.20	1.62	0.53	0.51
3/4	1.31	0.50	0.27	0.12	1.46	1.87	0.55	0.69
1	1.50	0.58	0.30	0.13	1.77	2.12	0.68	0.91
1-1/4	1.75	0.67	0.34	0.14	2.15	2.50	0.71	1.19
1-1/2	1.93	0.70	0.37	0.15	2.43	2.75	0.72	1.39
2	2.25	0.75	0.42	0.17	2.96	3.25	0.76	1.79
2-1/2	2.68	0.92	0.48	0.21	3.31	3.87	1.14	2.20
3	3.06	0.98	0.55	0.23	4.00	4.50	1.20	2.78
4	3.81	1.08	0.66	0.26	5.06	5.68	1.30	3.70

GENERAL NOTE: Dimensions are in inches.

(a) Patterns shall be designed to produce castings of metal thickness given in the Table. Metal thickness at no point shall be less than 90% of values given in the tables.

(b) The length of thread may extend beyond the width of band. However, minimum metal thickness (G) must be maintained at the end of the thread.

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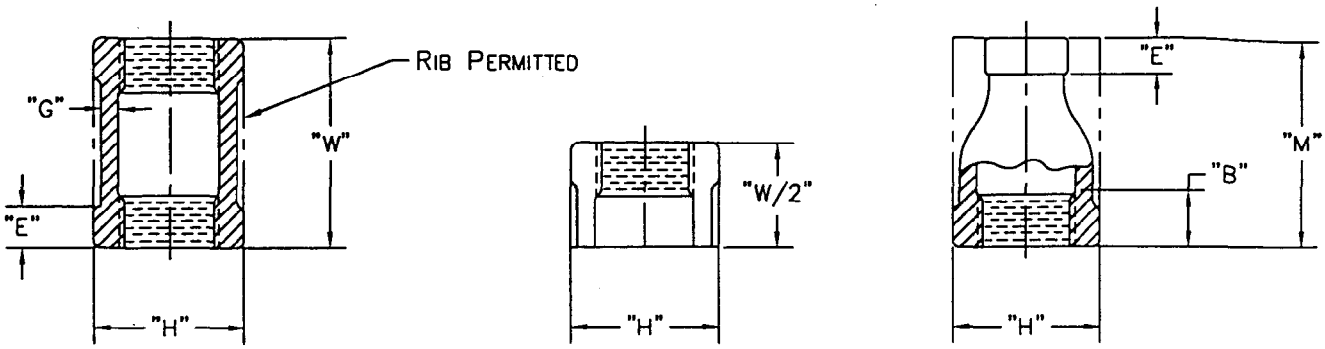

COUPLING HALF COUPLING REDUCER COUPLING

TABLE 5 - DIMENSIONS OF CAST COUPLINGS (STRAIGHT AND REDUCING SIZES)

Nominal Pipe Size	Length of Thread, B, Min. (b)	Width of Band E, Min.	Metal Thickness G (a)	Outside Diameter of Band H, Min.	Length of Straight Couplings W, Min.	Length of Concentric Reducing Couplings M, Min.
1/8	0.25	0.20	0.09	0.75	1.00	
1/4	0.32	0.20	0.09	0.84	1.00	1.00
3/8	0.36	0.21	0.10	1.01	1.12	1.12
1/2	0.43	0.25	0.10	1.20	1.38	1.38
3/4	0.50	0.27	0.12	1.46	1.50	1.50
1	0.58	0.30	0.13	1.77	1.62	1.62
1-1/4	0.67	0.34	0.14	2.15	2.00	2.00
1-1/2	0.70	0.37	0.15	2.43	2.12	2.12
2	0.75	0.42	0.17	2.96	2.50	2.50
2-1/2	0.92	0.48	0.21	3.31	2.87	3.25
3	0.98	0.55	0.23	4.00	3.18	3.68
4	1.08	0.66	0.26	5.06	3.68	4.38

GENERAL NOTE: Dimensions are in inches. Reducing couplings may be either bell or straight. The outside diameter (H) of straight reducing couplings shall correspond to the largest size end connection of the reducing fitting.

(a) Patterns shall be designed to produce castings of metal thickness given in the Table. Metal thickness at no point shall be less than 90% of values given in the tables.

(b) The length of thread may extend beyond the width of band. However, minimum metal thickness (G) must be maintained at the end of the thread.

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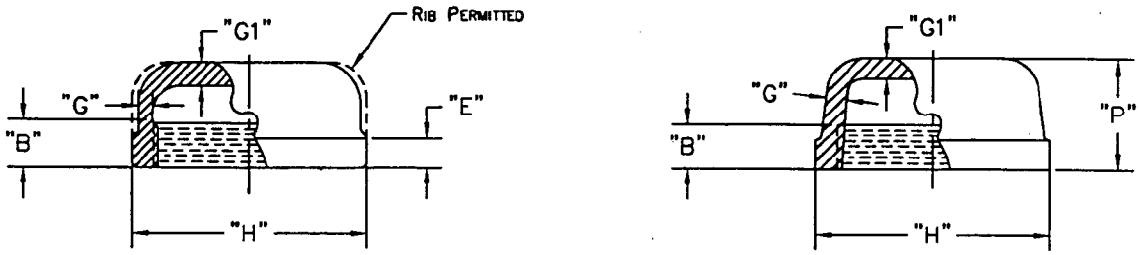

TABLE 6 - DIMENSIONS OF CAST CAPS

Nominal Pipe Size	Length of Thread B, Min. (b)	Width of Band E, Min.	Metal Thickness of Side G (a)	Outside Diameter of Band H, Min.	Height P, Min.	Thickness of Flat Top Caps G1, Min.
1/8	0.25	0.20	0.09	0.75	0.68	0.09
1/4	0.32	0.20	0.09	0.84	0.68	0.09
3/8	0.36	0.21	0.10	1.01	0.81	0.10
1/2	0.43	0.25	0.10	1.20	0.93	0.12
3/4	0.50	0.27	0.12	1.46	1.06	0.13
1	0.58	0.30	0.13	1.77	1.31	0.15
1-1/4	0.67	0.34	0.14	2.15	1.62	0.17
1-1/2	0.70	0.37	0.15	2.43	1.62	0.19
2	0.75	0.42	0.17	2.96	1.75	0.22
2-1/2	0.92	0.48	0.21	3.31	2.00	0.25
3	0.98	0.55	0.23	4.00	2.25	0.29
4	1.08	0.66	0.26	5.06	2.50	0.36

GENERAL NOTES: Dimensions are in inches. Caps may be made without recess. Caps so made shall be of such height P that the length of perfect thread shall not be less than B, and the length of useful thread (B plus threads with fully formed roots and flat crests) shall be not less than L2 (effective length of external thread) required by ANSI/ASME B1.20.1.

(a) Patterns shall be designed to produce castings of metal thickness given in the Table. Metal thickness at no point shall be less than 90% of values given in the tables.

(b) The length of thread may extend beyond the width of band. However, minimum metal thickness (G) must be maintained at the end of the thread.

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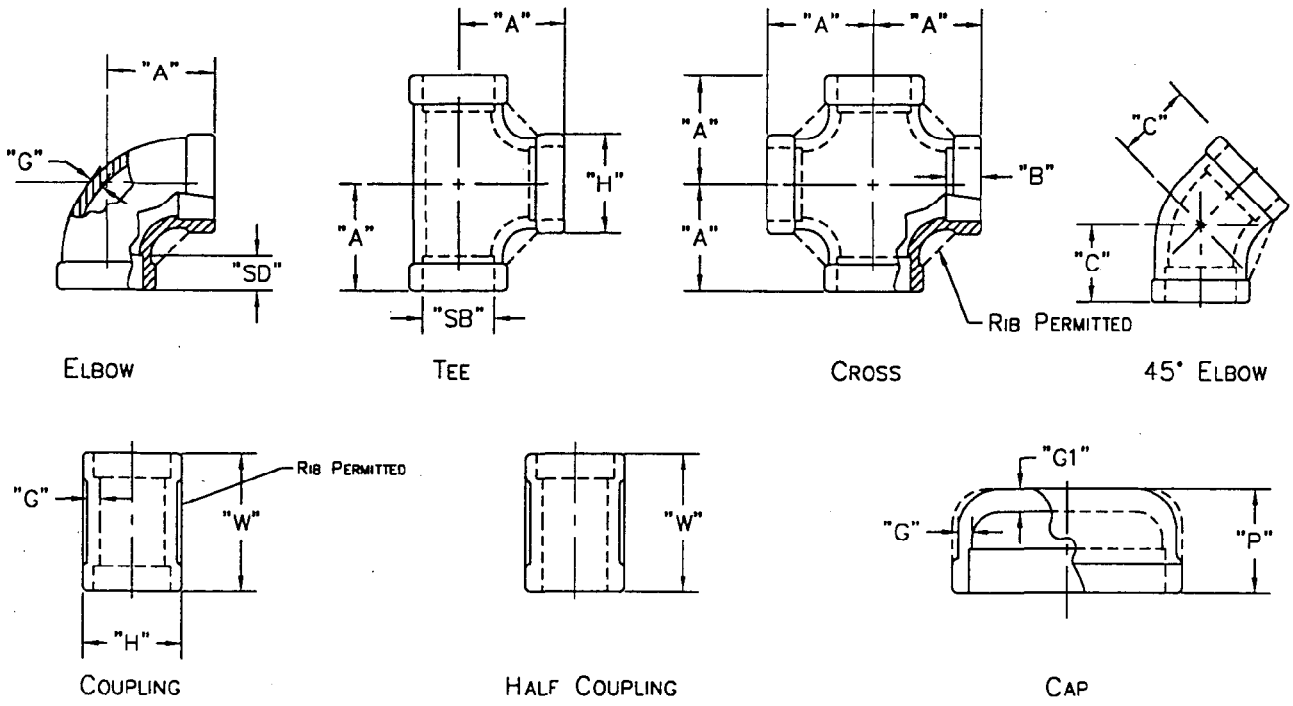

TABLE 7 - DIMENSIONS OF CAST CLASS 150 SOCKET-WELDING FITTINGS

Nominal Pipe Size	Center-To-End Elbows, Tees, & Crosses A	Center-To-End 45° Elbows C	Socket Bore SB	Socket Depth SD, Min. (b)	Metal Thickness G (a)	Outside Band Diameter H, Min.	Full Cplg. Length W, Min.	Cap Height P, Min.	Flat Top Cap Thickness G1, Min.
1/8	0.81	0.69	0.420 / .440	0.32	0.09	0.75	1.00	0.68	0.09
1/4	0.81	0.69	0.555 / .575	0.32	0.09	0.84	1.00	0.68	0.09
3/8	0.93	0.81	0.690 / .710	0.32	0.10	1.01	1.12	0.81	0.10
1/2	1.12	0.87	0.855 / .875	0.32	0.10	1.20	1.38	0.93	0.12
3/4	1.31	1.00	1.065 / 1.085	0.37	0.12	1.46	1.50	1.06	0.13
1	1.50	1.12	1.330 / 1.350	0.44	0.13	1.77	1.62	1.31	0.15
1-1/4	1.75	1.31	1.675 / 1.695	0.50	0.14	2.15	2.00	1.62	0.17
1-1/2	1.93	1.43	1.915 / 1.935	0.50	0.15	2.43	2.12	1.62	0.19
2	2.25	1.68	2.406 / 2.426	0.56	0.17	2.96	2.50	1.75	0.22
2-1/2	2.68	1.93	2.906 / 2.931	0.56	0.21	3.31	2.87	2.00	0.25
3	3.06	2.18	3.535 / 3.560	0.56	0.23	4.00	3.18	2.25	0.29
4	3.81	2.62	4.545 / 4.570	0.69	0.26	5.06	3.68	2.50	0.36

GENERAL NOTE: Dimensions are in inches.

(a) Patterns shall be designed to produce castings of metal thickness given in the Table. Metal thickness at no point shall be less than 90% of values given in the tables.

(b) The depth of socket may extend beyond the width of band. However, minimum metal thickness (G) must be maintained at the bottom of the socket

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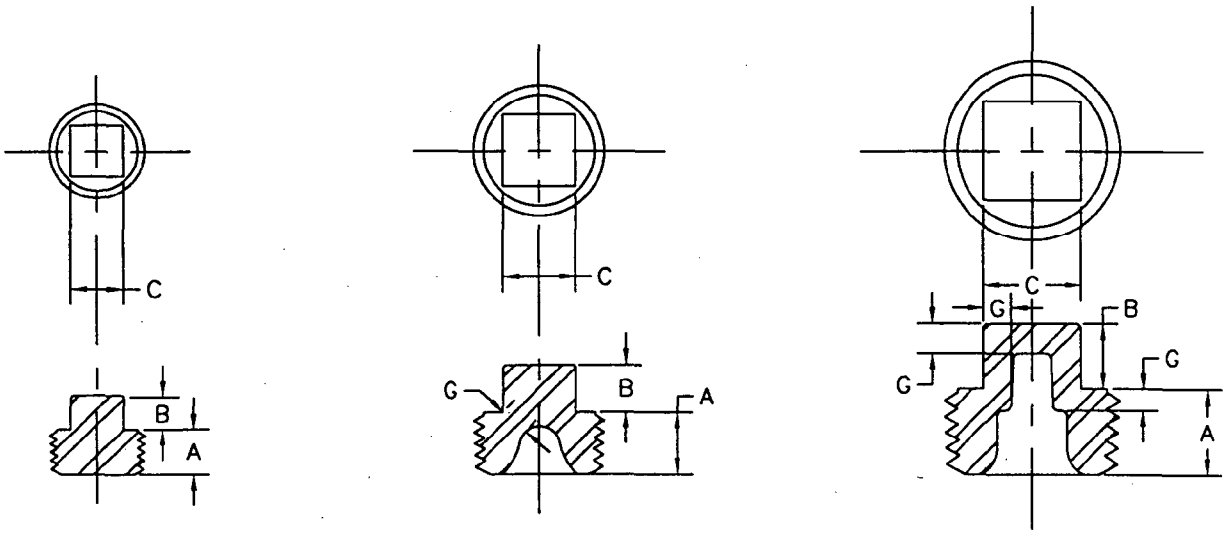

SOLID PLUGS CORED PLUGS

TABLE 8 - DIMENSIONS OF CAST SQUARE HEAD PLUGS

Nominal Pipe Size	Thread Length, Min. A	Height of Square, Min. B	Nominal Width Across Flats C (b)	Nominal Metal Thickness G (a)
1/8	0.37	0.24	9/32	....
1/4	0.44	0.28	3/8	....
3/8	0.48	0.31	7/16	....
1/2	0.56	0.38	9/16	0.16
3/4	0.63	0.44	5/8	0.18
1	0.75	0.50	13/16	0.20
1 1/4	0.80	0.56	15/16	0.22
1 1/2	0.83	0.62	1 1/8	0.24
2	0.88	0.68	1 5/16	0.26
2 1/2	1.07	0.74	1 1/2	0.29
3	1.13	0.80	1 11/16	0.31
4	1.22	1.00	2 1/4	0.38

GENERAL NOTE: Dimensions are in inches.

(a) Patterns shall be designed to produce castings of metal thickness given in the table. Metal thickness at no point shall be less than 90% of values given in the table.

(b) These dimensions are the nominal size of wrench as given in Appendix V of American National Standard, Square and Hex Bolts and Screws (ASME B18.2.1). Square head plugs are designed to fit these wrenches.

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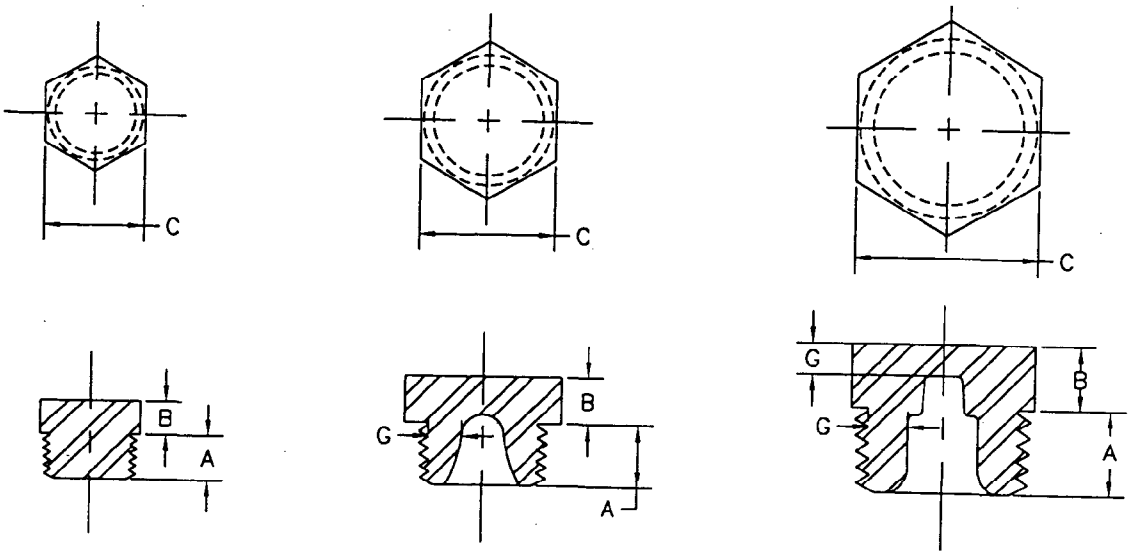

SOLID PLUGS

CORED PLUGS

TABLE 9 - DIMENSIONS OF CAST HEX HEAD PLUGS

Nominal Pipe Size	Thread Length, Min. A	Height of Head, Min. B	Nominal Width Across Flats C	Nominal Metal Thickness G (a)
1/8	0.37	0.14	.50	....
1/4	0.44	0.14	.62 (b)	....
3/8	0.48	0.16	.68 (b)	....
1/2	0.56	0.19	.87 (b)	0.16
3/4	0.63	0.22	1.20 (b)	0.18
1	0.75	0.25	1.43 (b)	0.20
1 1/4	0.80	0.28	1.76	0.22
1 1/2	0.83	0.31	2.00	0.24
2	0.88	0.34	2.48	0.26
2 1/2	1.07	0.37	2.98	0.29
3	1.13	0.40	3.86	0.31
4	1.22	0.50	4.62	0.38

GENERAL NOTE: Dimensions are in inches.

(a) Patterns shall be designed to produce castings of metal thickness given in the table. Metal thickness at no point shall be less than 90% of values given in the table.

(b) When made from bar stock, the dimensions may be 5/8, 11/16, 7/8, 1 1/8, and 1 7/16 In. respectively, in order to use regular bar stock sizes.

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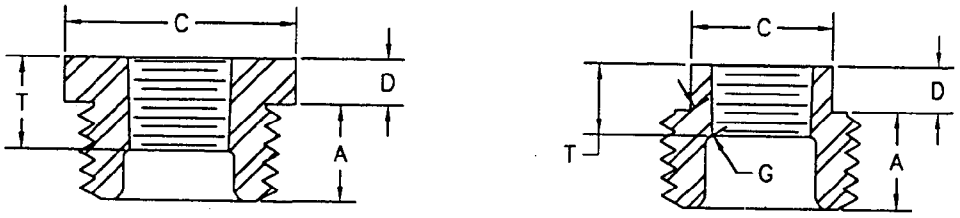

TABLE 10 - DIMENSIONS OF CAST HEX HEAD BUSHINGS

Nominal Pipe Size	Length of External Thread Min. A	Length of Internal Thread, Min. T	Nominal Metal Thickness G (a)	Height Of Head, Min. D (b)	Width of Flat Nominal C (c)
1/4 x 1/8	0.44	0.26	...	0.12	5/8
3/8 x 1/4	0.50	0.40	...	0.16	11/16
3/8 x 1/8	0.50	0.26	...	0.16	11/16
1/2 x 3/8	0.56	0.41	...	0.19	7/8
1/2 x 1/4	0.56	0.40	...	0.19	7/8
1/2 x 1/8	0.56	0.26	...	0.19	7/8
3/4 x 1/2	0.62	0.53	...	0.22	1 1/16
3/4 x 3/8	0.62	0.41	...	0.22	1 1/16
3/4 x 1/4	0.62	0.40	...	0.22	1 1/16
3/4 x 1/8	0.62	0.26	...	0.22	1 1/16
1 x 3/4	0.75	0.55	...	0.25	1 3/8
1 x 1/2	0.75	0.53	...	0.25	1 3/8
1 x 3/8	0.75	0.41	...	0.25	1 3/8
1 x 1/4	0.75	0.40	...	0.25	1 3/8
1 x 1/8	0.75	0.26	...	0.25	1 3/8
1 1/4 x 1	0.81	0.68	...	0.28	1 3/4
1 1/4 x 3/4	0.81	0.55	...	0.28	1 3/4
1 1/4 x 1/2	0.81	0.53	0.18	0.28	1 3/4
1 1/4 x 3/8	0.81	0.41	0.18	0.28	1 3/4
1 1/4 x 1/4	0.81	0.40	0.18	0.28	1 3/4
1 1/2 x 1 1/4	0.81	0.71	...	0.31	2
1 1/2 x 1	0.81	0.68	...	0.31	2
1 1/2 x 3/4	0.81	0.55	0.20	0.31	2
1 1/2 x 1/2	0.81	0.53	0.20	0.31	2
1 1/2 x 3/8	0.81	0.41	0.20	0.31	2
1 1/2 x 1/4	0.81	0.40	0.20	0.31	2

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Nominal Pipe Size	Length of External Thread Min. A	Length of Internal Thread, Min. T	Nominal Metal Thickness G (a)	Height Of Head, Min. D (b)	Width of Flat Nominal C (c)
2 x 1 1/2	0.88	0.72	...	0.34	2 1/2
2 x 1 1/4	0.88	0.71	...	0.34	2 1/2
2 x 1	0.88	0.68	0.22	0.34	2 1/2
2 x 3/4	0.88	0.55	0.22	0.34	2 1/2
2 x 1/2	0.88	0.53	0.22	0.34	2 1/2
2 x 3/8	0.88	0.41	0.22	0.34	2 1/2
2 x 1/4	0.88	0.40	0.22	0.34	2 1/2
2 1/2 x 2	1.06	0.76	...	0.38	3
2 1/2 x 1 1/2	1.06	0.72	...	0.38	3
2 1/2 x 1 1/4	1.06	0.71	0.24	0.38	3
2 1/2 x 1	1.06	0.68	0.24	0.38	3
2 1/2 x 3/4	1.06	0.55	0.24	0.38	3
2 1/2 x 1/2	1.06	0.53	0.24	0.38	3
3 x 2 1/2	1.12	1.14	...	0.41	3 1/2
3 x 2	1.12	0.76	...	0.41	3 1/2
3 x 1 1/2	1.12	0.72	0.26	0.41	3 1/2
3 x 1 1/4	1.12	0.70	0.26	0.41	3 1/2
3 x 1	1.12	0.68	0.26	0.41	3 1/2
3 x 3/4	1.12	0.55	0.26	0.41	3 1/2
3 x 1/2	1.12	0.53	0.26	0.41	3 1/2
4 x 3	1.25	1.20	...	0.50	4 5/8
4 x 2 1/2	1.25	1.14	0.31	0.60	4 5/8
4 x 2	1.25	0.76	0.31	0.60	4 5/8
4 x 1 1/2	1.25	0.72	0.31	0.60	4 5/8
4 x 1 1/4	1.25	0.70	0.31	0.60	4 5/8
4 x 1	1.25	0.68	0.31	0.60	4 5/8

GENERAL NOTE: Dimensions are in inches.

(a) Patterns shall be designed to produce castings of metal thickness given in the table. Metal thickness at no point shall be less than 90% of the values given in the table.

(b) When made from bar stock, the dimensions may be 5/8, 11/16, 7/8, 1 1/8, and 1 7/16 in. respectively, in order to use regular bar stock sizes.

(c) These dimensions are the nominal size of wrench as given in Appendix V of American National Standard, Square and Hex Bolts and Screws (ASME B18.2.1). Hex bushings are designed to fit these wrenches.

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Locknuts

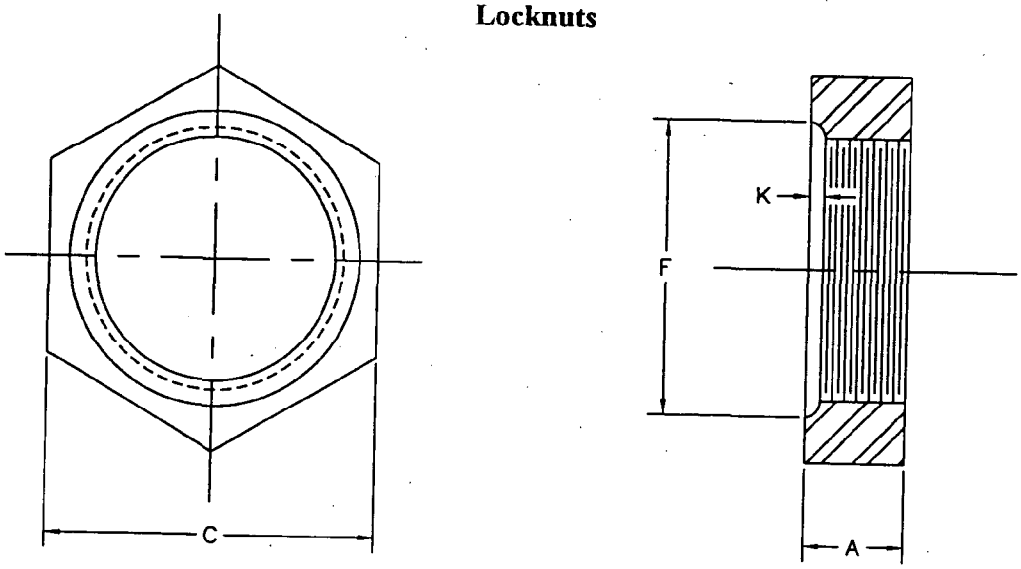

TABLE 11 - DIMENSIONS OF LOCKNUTS

Nominal Pipe Size	Nominal Thickness, Min. A	Width Across Flats		Diameter of Packing Recess (a) Min. F	Depth of Packing Recess (a) K
		Steel Min. (b) C	Cast Min. C		
1/8	0.19	0.69	....	0.50	0.04
1/4	0.25	0.84	....	0.66	0.06
3/8	0.28	1.00	....	0.77	0.06
1/2	0.31	1.18	....	0.97	0.06
3/4	0.34	1.43	....	1.23	0.06
1	0.38	1.75	....	1.50	0.06
1 1/4	0.42	2.10	....	1.86	0.06
1 1/2	0.47	2.35	....	2.12	0.06
2	0.53	2.88	....	2.63	0.09
2 1/2	0.59	3.50	3.86	3.18	0.09
3	0.67	4.27	4.62	3.84	0.09
4	0.80	5.38	5.79	5.00	0.13

GENERAL NOTES: Dimensions are in inches. Threads shall be NPSL straight Pipe threads in accordance with ANSI/ ASME B1.20.1

(a) The packing recess is cast finish (not tool finish).

(b) Locknuts in these sizes may be made from bar stock, in which case dimension C may be 11/16, 7/8, 1, 1 3/16, and 1 7/16, in., respectively, in order to conform with regular hexagon bar stock sizes.

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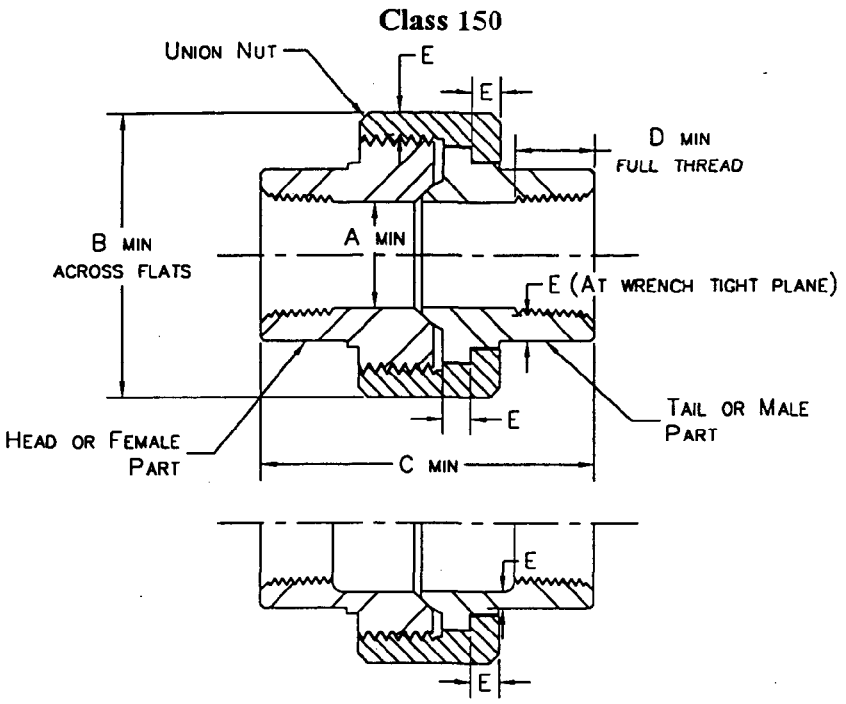

ALTERNATE DESIGN

TABLE 12 - DIMENSIONS OF CAST THREADED UNIONS

Nominal Pipe Size	A Min.	B Min.	C Min.	D Min. (b)	E Min. (a)
1/8	0.21	0.93	1.26	0.25	0.09
1/4	0.36	1.10	1.44	0.32	0.09
3/8	0.52	1.26	1.61	0.36	0.10
1/2	0.61	1.45	1.72	0.43	0.10
3/4	0.80	1.71	1.94	0.50	0.12
1	1.00	2.07	2.06	0.58	0.13
1 1/4	1.31	2.50	2.26	0.67	0.14
1 1/2	1.55	2.82	2.41	0.70	0.15
2	2.03	3.41	2.75	0.75	0.17
2 1/2	2.38	4.12	3.22	0.92	0.21
3	3.00	4.75	3.50	0.98	0.23
4	4.03	6.00	3.85	1.08	0.26

GENERAL NOTE: Dimensions are in inches.

(a) Patterns shall be designed to produce castings of metal thickness (E) given in the table. Metal thickness at no point shall be less than 90% of values given in the table.

(b) The length of thread may extend beyond the width of band. However, minimum metal thickness (E) must be maintained at the end of the thread.

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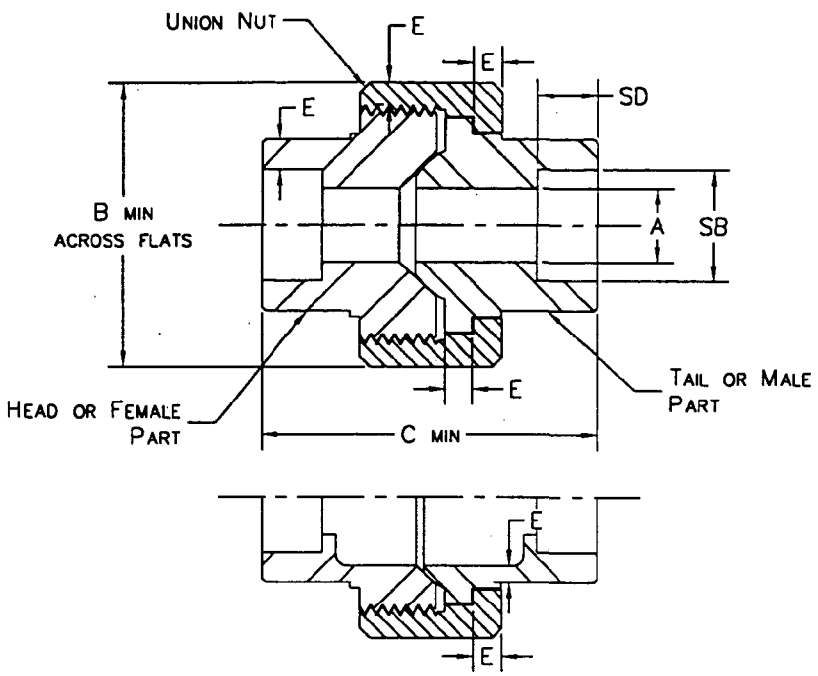

ALTERNATE DESIGN

TABLE 13 - DIMENSIONS OF CAST SOCKET WELDING UNIONS

Nominal Pipe Size	A Min.	B Min.	C Min.	E Min. (a)	SB	SD Min.
1/8	0.21	0.93	1.26	0.09	.420/.440	0.32
1/4	0.36	1.10	1.44	0.09	.555/.575	0.32
3/8	0.52	1.26	1.61	0.10	.690/.710	0.32
1/2	0.61	1.45	1.72	0.10	.855/.875	0.32
3/4	0.80	1.71	1.94	0.12	1.065/1.085	0.37
1	1.00	2.07	2.06	0.13	1.330/1.350	0.44
1 1/4	1.31	2.50	2.26	0.14	1.675/1.695	0.50
1 1/2	1.55	2.82	2.41	0.15	1.915/1.935	0.50
2	2.03	3.41	2.75	0.17	2.406/2.426	0.56
2 1/2	2.38	4.12	3.22	0.21	2.906/2.931	0.56
3	3.00	4.75	3.50	0.23	3.535/3.560	0.56
4	4.03	6.00	3.85	0.26	4.545/4.570	0.69

GENERAL NOTE: Dimensions are in inches.

(a) Patterns shall be designed to produce castings of metal thickness (E) given in the table. Metal thickness at no point shall be less than 90% of values given in the table.

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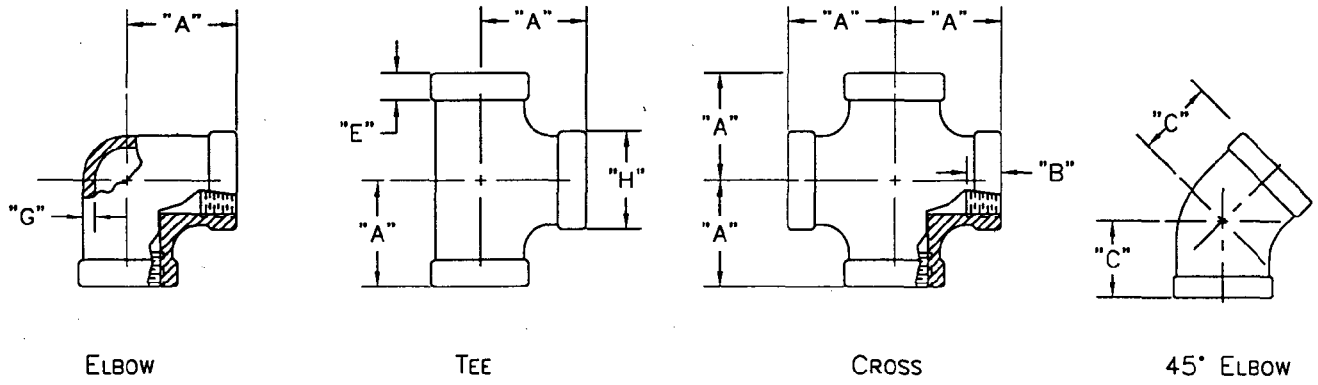

ELBOW TEE CROSS 45° ELBOW

TABLE 14 - DIMENSIONS OF WROUGHT 90 DEG. ELBOWS, TEES, CROSSES, AND 45 DEG. ELBOWS

Nominal Pipe Size	Center-to-End, Elbows, Tees, & Crosses A	Center-to-End, 45 deg. Elbows C	Length of Thread B, Min. (b)	Width of Band E, Min.	Metal Thickness G (a)	Outside Diameter of Band H, Min.
1/8	0.81	0.69	0.26	0.25	0.09	0.75
1/4	0.81	0.69	0.40	0.25	0.09	0.75
3/8	0.93	0.81	0.41	0.25	0.10	0.87
1/2	1.12	0.87	0.53	0.38	0.10	1.12
3/4	1.31	1.00	0.55	0.50	0.12	1.34

GENERAL NOTE: Dimensions are in inches.

(a) Forgings shall be designed to produce fittings of metal thickness given in the table. Metal thickness at no point shall be less than 90% of values given in the table.

(b) The length of thread may extend beyond the width of band. However, minimum metal thickness (G) must be maintained at the end of the thread.

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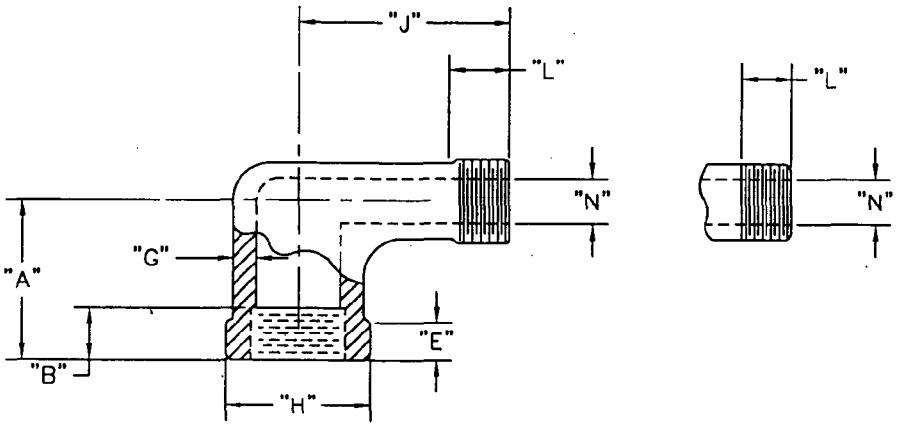

TABLE 15 - DIMENSIONS OF WROUGHT 90 DEG. STREET ELBOWS

Nominal Pipe Size	Center-to-End A	Length Of Internal Thread B, Min. (b)	Width of Band E, Min.	Metal Thickness G (a)	Outside Diameter of Band H, Min.	Center-to-End J	Length of External Thread L, Min.	Port Diameter Male End N, Max.
1/8	0.75	0.26	0.21	0.09	0.75	1.06	0.26	0.18
1/4	0.81	0.40	0.21	0.09	0.87	1.18	0.40	0.25
3/8	0.97	0.41	0.23	0.10	1.01	1.43	0.41	0.37
1/2	1.12	0.53	0.25	0.10	1.21	1.62	0.53	0.50
3/4	1.31	0.55	0.27	0.12	1.37	1.87	0.55	0.62

GENERAL NOTE: Dimensions are in inches.

(a) Forgings shall be designed to produce fittings of metal thickness given in the table. Metal thickness at no point shall be less than 90% of values given in the table.

(b) The length of thread may extend beyond the width of band. However, minimum metal thickness (G) must be maintained at the end of the thread.

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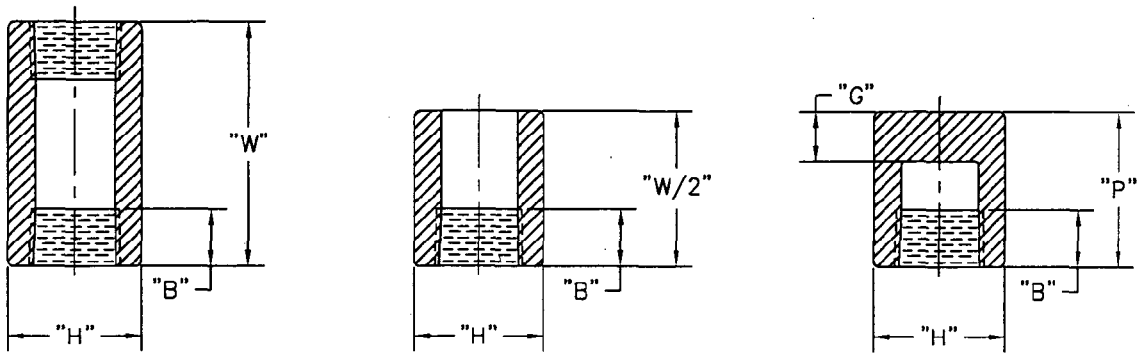

COUPLINGS HALF COUPLING CAP

TABLE 16 - DIMENSIONS OF WROUGHT COUPLINGS (STRAIGHT & REDUCING SIZES) AND CAPS

Nominal Pipe Size	Length of Thread B, Min.	Length of Couplings W, Min.	Outside Diameter H, Min.	End Wall Thickness G, Min.	Length of Cap P, Min.
1/8	0.26	1.00	0.55	0.09	0.68
1/4	0.40	1.00	0.74	0.09	0.68
3/8	0.41	1.12	0.86	0.10	0.81
1/2	0.53	1.38	1.05	0.12	0.93
3/4	0.55	1.50	1.30	0.13	1.06
1	0.68	1.62	1.61	0.15	1.31
1-1/4	0.71	2.00	1.86	0.17	1.62
1-1/2	0.72	2.12	2.17	0.19	1.62
2	0.76	2.50	2.74	0.22	1.75
2-1/2	1.14	2.87	3.31		
3	1.20	3.18	4.00		
4	1.30	3.68	5.06		

GENERAL NOTE: Dimensions are in inches.

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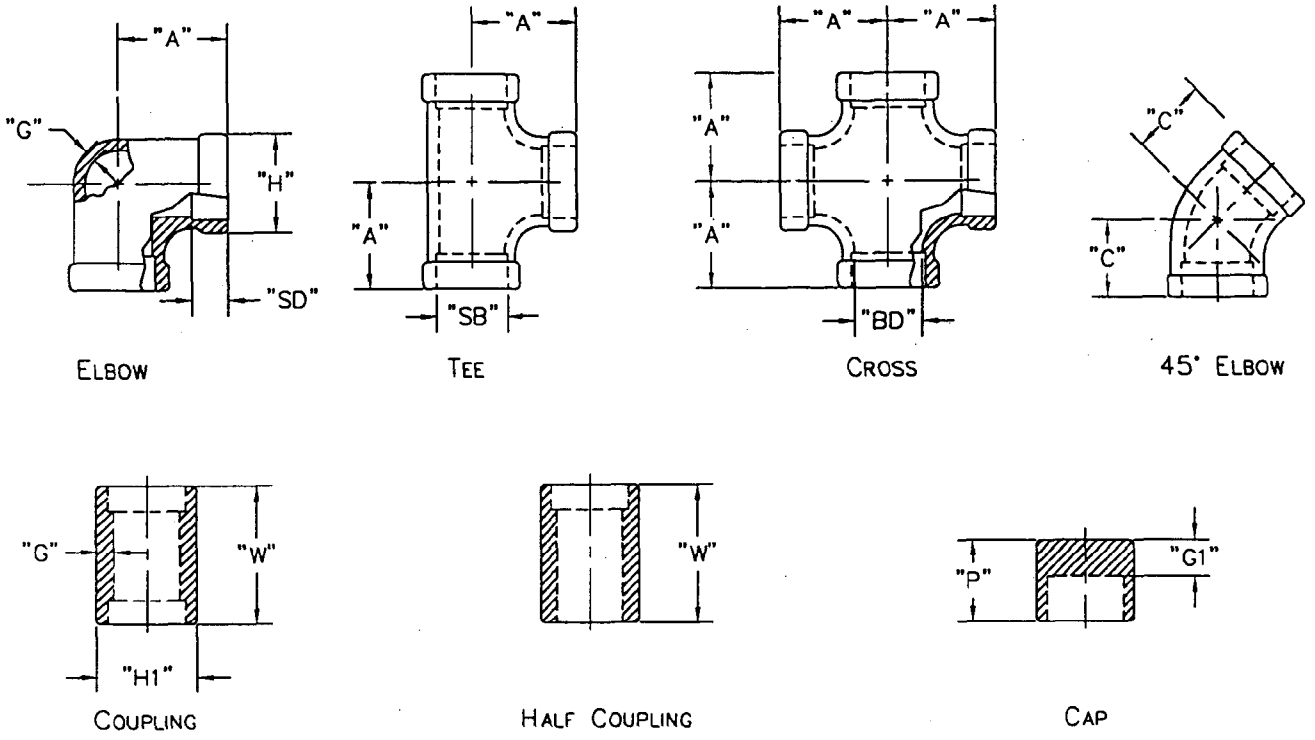

TABLE 17 - DIMENSIONS OF WROUGHT CLASS 1000 SOCKET-WELDING FITTINGS

Nom. Pipe Size	Center-to-End Elbows, Tees, & Crosses A	Center-to-End 45° Elbows C	Outside Band Diameter H, Min.	Socket Bore SB	Bore Diameter BD	Socket Depth SD, (b) Min.	Metal Thickness G (a)	Cplg. & Cap Outside Diameter H1, Min.	Cplg. Length W, Min.	End Wall Thickness G1, Min.
1/8	0.81	0.69	0.75	.420 / .440	.227 / .337	0.32	0.09	0.55	1.00	0.09
1/4	0.81	0.69	0.75	.555 / .575	.380 / .440	0.32	0.09	0.74	1.00	0.09
3/8	0.93	0.81	0.87	.690 / .710	.515 / .575	0.32	0.10	0.86	1.12	0.10
1/2	1.12	0.87	1.12	.855 / .875	.644 / .704	0.32	0.10	1.05	1.38	0.12
3/4	1.31	1.00	1.34	1.065 / 1.085	.854 / 914	0.37	0.12	1.30	1.50	0.13
1	N/A	N/A	N/A	1.330 / 1.350	1.067 / 1.127	0.44	0.13	1.61	1.62	0.15
1-1/4	N/A	N/A	N/A	1.675 / 1.695	1.412 / 1.472	0.50	0.14	1.86	2.00	0.17
1-1/2	N/A	N/A	N/A	1.915 / 1.935	1.652 / 1.712	0.50	0.15	2.17	2.12	0.19
2	N/A	N/A	N/A	2.406 / 2.426	2.127 / 2.187	0.56	0.17	2.74	2.50	0.22

GENERAL NOTE: Dimensions are in inches.

(a) Forgings shall be designed to produce fittings of metal thickness given in the Table. Metal thickness at no point shall be less than 90% of values given in the table.

(b) The depth of socket may extend beyond the width of band. However, minimum metal thickness (G) must be maintained at the bottom of the socket.

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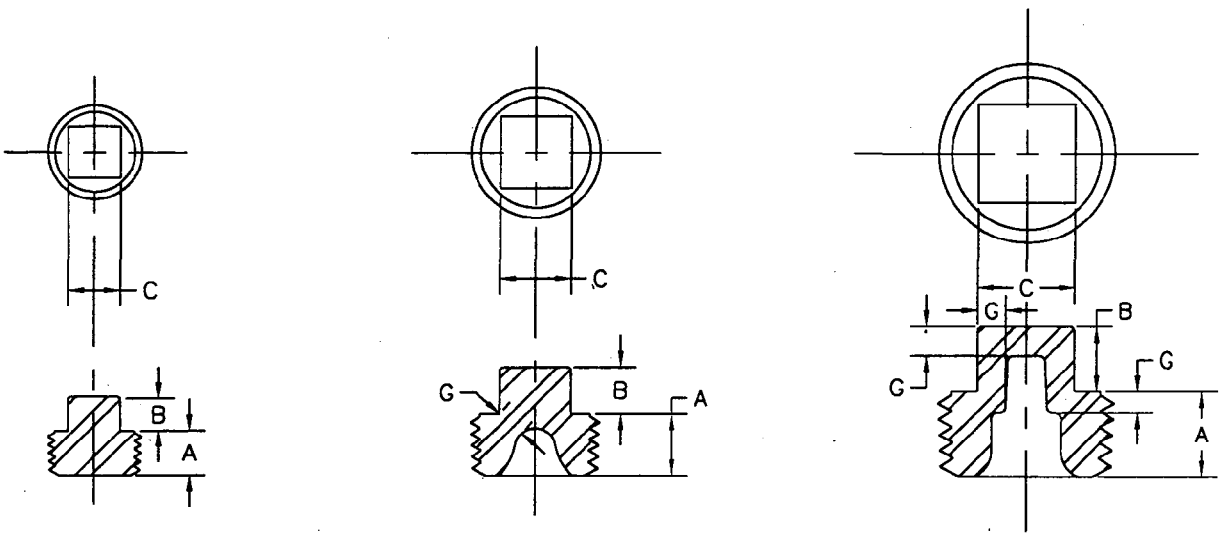

SOLID PLUGS CORED PLUGS

TABLE 18 - DIMENSIONS OF WROUGHT SQUARE HEAD PLUGS

Nominal Pipe Size	Thread Length, Min. A	Height of Square, Min. B	Nominal Width Across Flats C (b)	Nominal Metal Thickness G (a)
1/8	0.38	0.25	9/32	0.19
1/4	0.44	0.25	3/8	0.19
3/8	0.50	0.31	7/16	0.19
1/2	0.56	0.38	9/16	0.25
3/4	0.62	0.44	5/8	0.25
1	0.75	0.50	13/16	0.38
1 1/4	0.81	0.56	15/16	0.38
1 1/2	0.81	0.62	1 1/8	0.44
2	0.88	0.69	1 5/16	0.50
2 1/2	1.06	0.75	1 1/2	0.62
3	1.12	0.81	1 11/16	0.75
4	1.25	1.00	2 1/4	0.88

GENERAL NOTE: Dimensions are in inches.

(a) Forgings shall be designed to produce fittings of metal thickness given in the table. Metal thickness at no point shall be less than 90% of values given in the table.

(b) These dimensions are the nominal size of wrench as given in Appendix V of American National Standard, Square and Hex Bolts and Screws (ASME B18.2.1). Square head plugs are designed to fit these wrenches.

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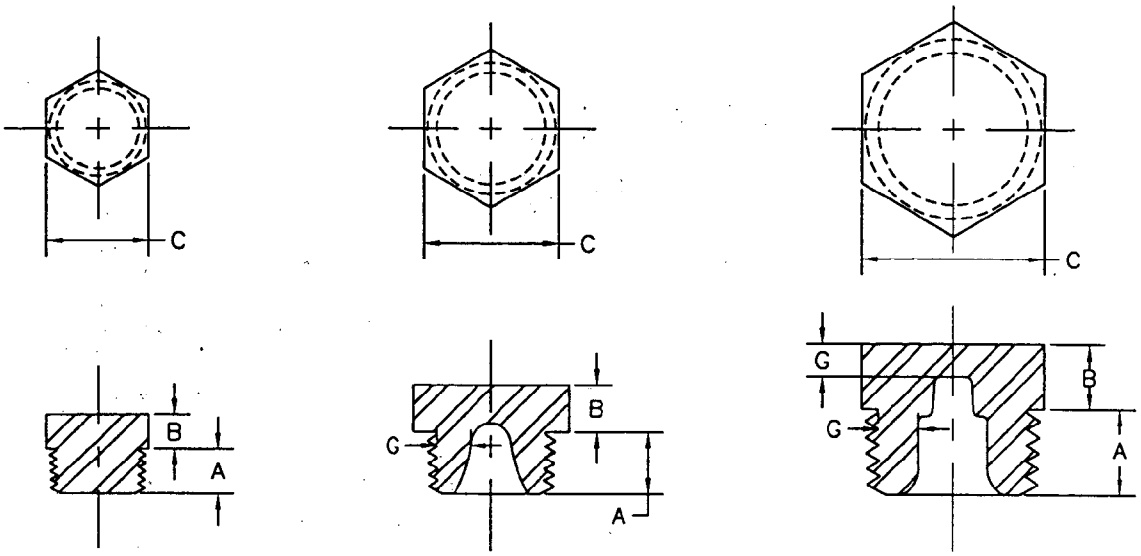

SOLID PLUGS CORED PLUGS

TABLE 19 - DIMENSIONS OF WROUGHT HEX HEAD PLUGS

Nominal Pipe Size	Thread Length, Min. A	Height of Head, Min. B	Nominal Width Across Flats C (b)	Nominal Metal Thickness G (a)
1/8	0.38	0.12	7/16	0.19
1/4	0.44	0.12	5/8	0.19
3/8	0.50	0.16	11/16	0.19
1/2	0.56	0.19	7/8	0.25
3/4	0.62	0.22	1 1/16	0.25
1	0.75	0.25	1 3/8	0.38
1 1/4	0.81	0.28	1 3/4	0.38
1 1/2	0.81	0.31	2	0.44
2	0.88	0.34	2 1/2	0.50
2 1/2	1.06	0.38	3	0.62
3	1.12	0.41	3 1/2	0.75
4	1.25	0.50	4 5/8	0.88

GENERAL NOTE: Dimensions are in inches.

(a) Forgings shall be designed to produce fittings of metal thickness given in the table. Metal thickness at no point shall be less than 90% of values given in the table.
(b) These dimensions are the nominal size of wrench as given in Appendix V of American National Standard, Square and Hex Bolts and Screws (ASME B18.2.1). Hex head plugs are designed to fit these wrenches.

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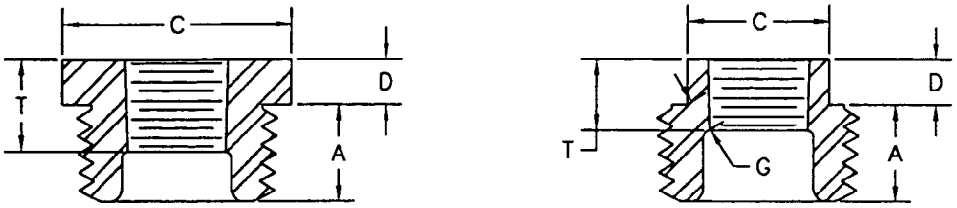

TABLE 20 - DIMENSIONS OF WROUGHT HEX HEAD BUSHINGS

Nominal Pipe Size	Length of External Thread Min. A	Length of Internal Thread, Min. T	Nominal Metal Thickness G (a)	Height Of Head, Min. D	Width of Flat Nominal C (b) (c)
1/4 x 1/8	0.44	0.26	...	0.12	5/8
3/8 x 1/4	0.50	0.40	...	0.16	11/16
3/8 x 1/8	0.50	0.26	...	0.16	11/16
1/2 x 3/8	0.56	0.41	...	0.19	7/8
1/2 x 1/4	0.56	0.40	...	0.19	7/8
1/2 x 1/8	0.56	0.26	...	0.19	7/8
3/4 x 1/2	0.62	0.53	...	0.22	1 1/16
3/4 x 3/8	0.62	0.41	...	0.22	1 1/16
3/4 x 1/4	0.62	0.40	...	0.22	1 1/16
3/4 x 1/8	0.62	0.26	...	0.22	1 1/16
1 x 3/4	0.75	0.55	...	0.25	1 3/8
1 x 1/2	0.75	0.53	...	0.25	1 3/8
1 x 3/8	0.75	0.41	...	0.25	1 3/8
1 x 1/4	0.75	0.40	...	0.25	1 3/8
1 x 1/8	0.75	0.26	...	0.25	1 3/8
1 1/4 x 1	0.81	0.68	...	0.28	1 3/4
1 1/4 x 3/4	0.81	0.55	...	0.28	1 3/4
1 1/4 x 1/2	0.81	0.53	0.18	0.28	1 3/4
1 1/4 x 3/8	0.81	0.41	0.18	0.28	1 3/4
1 1/4 x 1/4	0.81	0.40	0.18	0.28	1 3/4
1 1/2 x 1 1/4	0.81	0.71	...	0.31	2
1 1/2 x 1	0.81	0.68	...	0.31	2
1 1/2 x 3/4	0.81	0.55	0.20	0.31	2
1 1/2 x 1/2	0.81	0.53	0.20	0.31	2
1 1/2 x 3/8	0.81	0.41	0.20	0.31	2
1 1/2 x 1/4	0.81	0.40	0.20	0.31	2

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Nominal Pipe Size	Length of External Thread Min. A	Length of Internal Thread, Min. T	Nominal Metal Thickness G (a)	Height Of Head, Min. D	Width of Flat Nominal C (b) (c)
2 x 1 1/2	0.88	0.72	...	0.34	2 1/2
2 x 1 1/4	0.88	0.71	...	0.34	2 1/2
2 x 1	0.88	0.68	0.22	0.34	2 1/2
2 x 3/4	0.88	0.55	0.22	0.34	2 1/2
2 x 1/2	0.88	0.53	0.22	0.34	2 1/2
2 x 3/8	0.88	0.41	0.22	0.34	2 1/2
2 x 1/4	0.88	0.40	0.22	0.34	2 1/2
2 1/2 x 2	1.06	0.76	...	0.38	3
2 1/2 x 1 1/2	1.06	0.72	...	0.38	3
2 1/2 x 1 1/4	1.06	0.71	0.24	0.38	3
2 1/2 x 1	1.06	0.68	0.24	0.38	3
2 1/2 x 3/4	1.06	0.55	0.24	0.38	3
2 1/2 x 1/2	1.06	0.53	0.24	0.38	3
3 x 2 1/2	1.12	1.14	...	0.41	3 1/2
3 x 2	1.12	0.76	...	0.41	3 1/2
3 x 1 1/2	1.12	0.72	0.26	0.41	3 1/2
3 x 1 1/4	1.12	0.70	0.26	0.41	3 1/2
3 x 1	1.12	0.68	0.26	0.41	3 1/2
3 x 3/4	1.12	0.55	0.26	0.41	3 1/2
3 x 1/2	1.12	0.53	0.26	0.41	3 1/2
4 x 3	1.25	1.20	...	0.50	4 5/8
4 x 2 1/2	1.25	1.14	0.31	0.60	4 5/8
4 x 2	1.25	0.76	0.31	0.60	4 5/8
4 x 1 1/2	1.25	0.72	0.31	0.60	4 5/8
4 x 1 1/4	1.25	0.70	0.31	0.60	4 5/8
4 x 1	1.25	0.68	0.31	0.60	4 5/8

General Note: Dimensions are in inches.

(a) Forgings shall be designed to produce fittings of metal thickness given in the table. Metal thickness at no point shall be less than 90% of the values given in the table.

(b) May be made from bar stock.

(c) These dimensions are the nominal size of wrench as given in Appendix V of American National Standard, Square and Hex Bolts and Screws (ASME B18.2.1). Hex bushings are designed to fit these wrenches.

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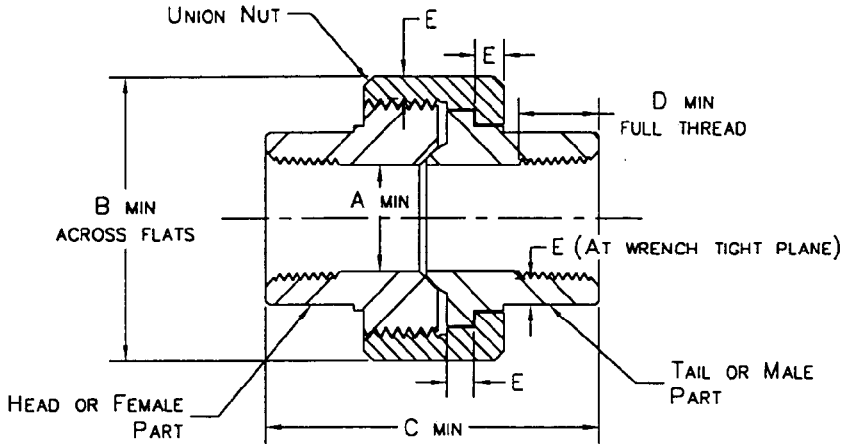

TABLE 21 - DIMENSIONS OF WROUGHT THREADED UNIONS

Nominal Pipe Size	A Min.	B Min.	C Min.	D Min. (b)	E Min. (a)
1/8	0.21	0.93	1.26	0.30	0.09
1/4	0.36	1.10	1.44	0.32	0.09
3/8	0.52	1.26	1.50	0.36	0.10
1/2	0.61	1.45	1.72	0.43	0.10
3/4	0.80	1.71	1.94	0.50	0.12
1	1.00	2.07	2.00	0.58	0.13
1 1/4	1.31	2.50	2.26	0.67	0.14
1 1/2	1.55	2.82	2.41	0.70	0.15
2	2.03	3.41	2.75	0.75	0.17
2 1/2	2.38	4.12	3.22	0.92	0.21
3	3.00	4.75	3.50	0.98	0.23
4	4.03	6.00	3.85	1.08	0.26

GENERAL NOTE: Dimensions are in inches.

(a) Forgings shall be designed to produce fittings of metal thickness (E) given in the table. Metal thickness at no point shall be less than 90% of values given in the table.

(b) The length of thread may extend beyond the width of band. However, minimum metal thickness (E) must be maintained at the end of the thread.

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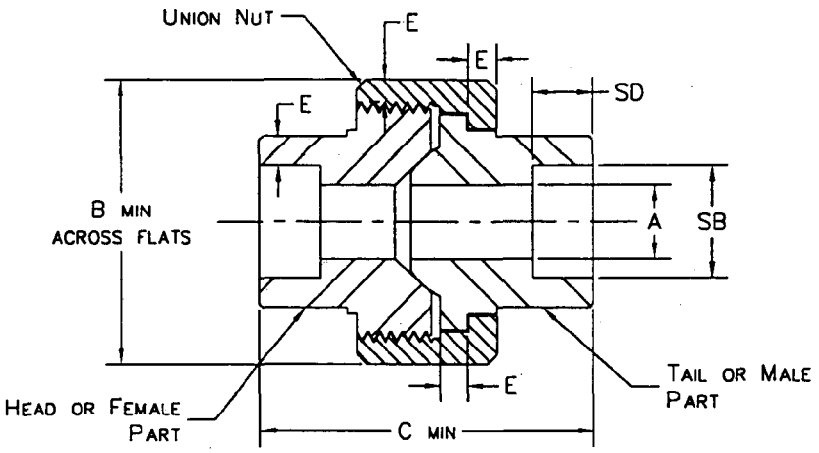

TABLE 22 - DIMENSIONS OF WROUGHT SOCKET WELDING UNIONS

Nominal Pipe Size	A Min.	B Min.	C Min.	E Min. (a)	SB	SD Min.
1/8	0.21	0.93	1.26	0.09	.420/.440	0.32
1/4	0.36	1.10	1.44	0.09	.555/.575	0.32
3/8	0.52	1.26	1.50	0.10	.690/.710	0.32
1/2	0.61	1.45	1.72	0.10	.855/.875	0.32
3/4	0.80	1.71	1.94	0.12	1.065/1.085	0.37
1	1.00	2.07	2.00	0.13	1.330/1.350	0.44
1 1/4	1.31	2.50	2.26	0.14	1.675/1.695	0.50
1 1/2	1.55	2.82	2.41	0.15	1.915/1.935	0.50
2	2.03	3.41	2.75	0.17	2.406/2.426	0.56
2 1/2	2.38	4.12	3.22	0.21	2.906/2.931	0.56
3	3.00	4.75	3.50	0.23	3.535/3.560	0.56
4	4.03	6.00	3.85	0.26	4.545/4.570	0.69

GENERAL NOTE: Dimensions are in inches.

(a) Forgings shall be designed to produce fittings of metal thickness (E) given in the table. Metal thickness at no point shall be less than 90% of values given in the table.

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ANNEX A
Referenced Standards and Applicable Dates

This annex is an integral part of this standard practice and is placed after the main text for convenience.

Standard Name or Description

ASME, ANSI/ASME, ASME, ANSI	
B1.20.1-1983 (R 1992)	Pipe Threads, General Purpose (Inch)
B18.2.1-1981 (R1996)	Square and Hex Bolts and Screws, Inch Series
ASTM	
A 182-00b	Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
A 262 – 98	Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels.
A 351-00	Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex) for Pressure Containing Parts
A 479-00	Specification for Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
A 511-96	Specification for Seamless Stainless Steel Mechanical Tubing
MSS	
SP-25-1998	Standard Marking System for Valves, Fittings, Flanges, and Unions

Publications of the following organizations appear in the above list:

ANSI	American National Standards Institute 25 West 43rd Street, Fourth Floor, New York, NY 10036
ASME	American Society of Mechanical Engineers Three Park Avenue, New York, NY 10016-5990
ASTM	American Society for Testing and Materials 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959
MSS	Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. 127 Park Street, N.E., Vienna, VA 22180

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List of MSS Standard Practices
(Price List Available Upon Request)

Number	
SP-6-2001	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP-9-2001	Spot Facing for Bronze, Iron and Steel Flanges
SP-25-1998	Standard Marking System For Valves, Fittings, Flanges and Unions
SP-42-1999	Class 150 Corrosion Resistant Gate, Globe, Angle and Check Valves with Flanged and Butt Weld Ends
SP-43-1991	(R 01) Wrought Stainless Steel Butt-Welding Fittings
SP-44-1996	Steel Pipeline Flanges
SP-45-1998	Bypass and Drain Connections
SP-51-2000	Class 150LW Corrosion Resistant Cast Flanges and Flanged Fittings
SP-53-1999	Quality Standard for Steel Castings and Forgings for Valves. Flanges and Fittings and Other Piping Componets - Magnetic Particle Examination Method
SP-54-1999	Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components - Radiographic Examination Method
SP-55-2001	Quality Standard for Steel Castings for Valves, Flanges, Fittings, and Other Piping Components - Visual Method for Evaluation of Surface Irregularities
SP-58-1993	Pipe Hangers and Supports - Materials, Design and Manufacture
SP-60-1999	Connecting Flange Joint Between Tapping Sleeves and Tapping Valves
SP-61-1999	Pressure Testing of Steel Valves
SP-65-1999	High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets
SP-67-1995	Butterfly Valves
SP-68-1997	High Pressure Butterfly Valves with Offset Design
SP-69-1996	Pipe Hangers and Supports - Selection and Application
SP-70-1998	Cast Iron Gate Valves, Flanged and Threaded Ends
SP-71-1997	Gray Iron Swing Check Valves, Flanged and Threaded Ends
SP-72-1999	Ball Valves with Flanged or Butt Welding Ends for General Service
SP-73-1991	(R 96) Brazing Joints for Wrought and Cast Copper Alloy Solder Joint Pressure Fittings
SP-75-1998	Specification for High Test Wrought Butt Welding Fittings
SP-77- 1995	(R 00) Guidelines for Pipe Support Contractual Relationships
SP-78-1998	Cast Iron Plug Valves, Flanged and Threaded Ends
SP-79-1999a	Socket-Welding Reducer Inserts
SP-80-1997	Bronze Gate, Globe, Angle and Check Valves
SP-81-2000	Stainless Steel, Bonnetless, Flanged, Knife Gate Valves
SP-82-1992	Valve Pressure Testing Methods
SP-83-1995	Class 3000 Steel Pipe Unions, Socket-Welding and Threaded
SP-85-1994	Cast Iron Globe & Angle Valves, Flanged and Threaded Ends
SP-86-1997	Guidelines for Metric Data in Standards for Valves, Flanges, Fittings and Actuators
SP-87-1991	(R 96) Factory-Made Butt-Welding Fittings for Class 1 Nuclear Piping Applications
SP-88-1993	(R 01) Diaphragm Valves
SP-89-1998	Pipe Hangars and Supports - Fabrication and Installation Practices
SP-90-2000	Guidelines on Terminology for Pipe Hangers and Supports
SP-91-1992	(R 96) Guidelines for Manual Operations of Valves
SP-92-1999	MSS Valve User Guide
SP-93-1999	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components-Liquid Penetrant Examination Method
SP-94-1999	Quality Std for Ferritic and Martensitic Steel Castings for Valves, Flanges, and Fittings and Other Piping Components-Ultrasonic Examination Method
SP-95-2000	Swage(d) Nipples and Bull Plugs
SP-96-1996	Guidelines on Terminology for Valves and Fittings
SP-97-1995	Integrally Reinforced Forged Branch Outlet Fittings-Socket Welding, Threaded and Buttwelding Ends
SP-98-2001	Protective Coatings for the Interior of Valves, Hydrants, and Fittings
SP-99-1994	Instrument Valves
SP-100-1997	Qualification Requirements for Elastomer Diaphragms for Nuclear Diaphragm Type Valves
SP-101-1989	Part-Turn Valve Actuator Attachment-Flange and Driving Component Dimensions and Performance Characteristics
SP-102-1989	Multi-Turn Valve Actuator Attachment - Flange and Driving Component Dimensions and Performance Characteristics
SP-103-1995	(R 00) Wrought Copper and Copper Alloy Insert Fittings for Polybutylene Systems
SP-104-1995	Wrought Copper Solder Joint Pressure Fittings
SP-105-1996	Instrument Valves for Code Applications
SP-106-1990	(R 96) Cast Copper Alloy Flanges and Flanged Fittings, Class 125, 150 and 300
SP-107-1991	(R 00) Transition Union Fittings for Joining Metal and Plastic Products
SP-108-1996	Resilient-Seated Cast Iron-Eccentric Plug Valves
SP-109-1997	Welded Fabricated Copper Solder Joint Pressure Fittings
SP-110-1996	Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
SP-111-2001	Gray-Iron and Ductile-Iron Tapping Sleeves
SP-112-1999	Quality Standard for Evaluation of Cast Surface Finishes - Visual and Tactile Method. This SP must be sold with a 10-surface, three dimensional Cast Surface Comparator, which is a necessary part of the Standard. Additional Comparators may be sold separately at $25.00 each. Same quantity discounts apply on total order.
SP-113-2001	Connecting Joint between Tapping Machines and Tapping Valves
SP-114-2001	Corrosion Resistant Pipe Fittings Threaded and Socket Welding, Class 150 and 1000
SP-115-1999	Excess Flow Valves for Natural Gas Service
SP-116-1996	Service Line Valves and Fittings for Drinking Water Systems
SP-117-1996	Bellows Seals for Globe and Gate Valves
SP-118-1996	Compact Steel Globe & Check Valves - Flanged, Flangeless, Threaded & Welding Ends (Chemical & Petroleum Refinery Service)
SP-119-1996	Belled End Socket Welding Fittings, Stainless Steel and Copper Nickel
SP-120-1997	Flexible Graphite Packing System for Rising Stem Steel Valves (Design Requirements)
SP-121-1997	Qualification Testing Methods for Stem Packing for Rising Stem Steel Valves
SP-122-1997	Plastic Industrial Ball Valves
SP-123-1998	Non-Ferrous Threaded and Solder-Joint Unions for Use With Copper Water Tube
SP-124-2001	Fabricated Tapping Sleeves
SP-125-2000	Gray Iron and Ductile Iron In-Line, Spring-Loaded, Center-Guided Check Valves
SP-126-2000	Steel In-Line Spring-Assisted Center Guided Check Valves
SP-127-2001	Bracing for Piping Systems Seismic-Wind-Dynamic Design, Selection, Application

(R YEAR) Indicates year standard reaffirmed without substantive changes

A large number of former MSS Practices have been approved by the ANSI or ANSI Standards, published by others. In order to maintain a single source of authoritative information, the MSS withdraws its Standard Practice in such cases.

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STD.MSS SP-119-ENGL 1996 ■ 5770640 0500850 870 ■

STANDARD PRACTICE **SP-119**

BELLED END SOCKET WELDING FITTINGS, STAINLESS STEEL AND COPPER NICKEL

Developed and Approved
by the
Manufacturers Standardization Society
of the
Valve and Fittings Industry, Inc.
127 Park Street, N.E.
Vienna, Virginia 22180-4602
(703) 281-6613

Approved November 1996

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Non-toleranced dimensions in this Standard Practice are nominal, and unless otherwise specified, shall be considered "for reference only."

Unless otherwise specifically noted in this MSS SP, any standard referred to herein is identified by the date of issue that was applicable to the referenced standard(s) at the date of issue of this MSS SP. See Annex A.

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STD.MSS SP-119-ENGL 1996 ■ 5770640 0500852 643 ■

FOREWORD

ASME B16.9 is the American Standard for steel butt-welding fittings and although not so stated, it is implied that its scope deals primarily with standard (Schedule 40) wall and heavier as it was developed for carbon steel and those grades of alloy steel piping that are selected for pressure and temperature considerations. In 1949 ASME approved standard B36.19 for Stainless Steel Pipe in which Schedule 10S was established. Schedule 5S pipe was recognized in the 1952 publication of B36.19. The companion fittings for Schedule 10S pipe used B16.9 shapes and proportions and were standardized by MSS SP-43 which was first published in 1950. In anticipation, the original 1950 edition of MSS SP-43 also standardized Schedule 5S fittings.

Since 1950 the use of lighter than standard wall stainless steel piping in new construction has become predominant. The reasons for this evolution include the rapid expansion of the process industries in the fields of chemicals, plastics, textiles, paper, etc.

Coincident with the greater utilization of light wall pipe and of more capable metal forming machinery, the need to reduce pipe assembly fabrication times brought about by world market competition led to the development of belled end socket welding fittings. As with the development of MSS SP-43, the shapes and proportions of B16.9 were reused for the belled end fitting bodies to the maximum extent possible.

In 1992 first work on belled end fittings for this standard included socket proportions, socket to fitting body transition geometry, fitting thickness, and the ability of U.S. industry to support manufacturing. Some of this work only standardized service proven relationships used in belled end fittings made for the pulp and paper industry without standards for over 20 years. In 1994 the U.S. Navy funded burst and fatigue testing prototype fittings in the first of a two-phase program. The second phase was for an increased thickness fitting and was never done. In 1995 mid-way through testing, the Navy directed that these belled end fittings be used on ship systems in new construction followed shortly thereafter by direction to use them on the repair of ship systems. The quality and configuration control of these fittings was done by an interim document, the requirements of which, with some improvements, are contained herein.

In keeping with recent trends wherein military procurement activities have been using more commercial material standards and because of recognized fabrication economies related to the use of these fittings, the U.S. Navy sponsored the writing of this Standard Practice in cooperation with fitting manufacturers.

This Standard Practice establishes dimensional uniformity for light wall belled end socket welding fitting designs qualified by burst and fatigue testing for both Military Service and Commercial Code Practice.

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BELLED END SOCKET WELDING FITTINGS, STAINLESS STEEL AND COPPER NICKEL

1. SCOPE

1.1 This Standard covers 1/4 through NPS 12 stainless steel and copper-nickel belled end socket welding fittings, including dimensions, tolerances, materials, socket end details, heat treating and marking requirements for use with the following pipe standards:

a) ASME B36.19 (Sch 5S and 10S)

b) ASTM B 466

c) ASTM B 467

d) MIL-T-16420 (Class 50 and Class 200 tube)

2. REFERENCES

2.1 Standards and specifications adopted by reference in this standard are shown in Annex A, for convenience of identifying edition number, date and source of supply.

3. SPECIAL CONSIDERATIONS

3.1 Tees fabricated by welding a branch to an outlet extruded from the run are allowable and shall be designed and manufactured in accordance with ASME B31 Codes for Pressure Piping as pipe fabrications. Thermometer well tees shown herein are pipe fabrications with envelopes dimensionally standardized by this Standard Practice. Refer to Section 12 for Fabrication Alternatives.

3.2 Partial Compliance Fittings may be made to special dimensions — such as unlisted reducing tees, sizes — such as NPS 3½, shapes — such as a street end tee, tolerances, or of wrought materials other than those covered by this Standard Practice by agreement between the manufacturer and the purchaser. When such fittings meet all other stipulations of this Standard Practice, they shall be considered as being in partial compliance herewith, provided they are appropriately marked (see Paragraph 19.4).

3.3 Laterals, wyes, mitered elbows, and tees of notch and point or saddle weld constructions are not covered by this standard.

4. DEFINITIONS

4.1 Belled End Socket Welding Fittings are a family of relatively thin wall wrought fittings which extend the advantages of socket welded joints through the common sizes of thin walled pipes. In this Standard Practice, "wrought" is used to denote fittings formed from tubular or flat starting materials as opposed to those that are either forged or cast to their final shape or machined from forgings or castings.

4.2 CUNI is a notation representing copper nickel alloy.

4.3 Electro-Etch is an electro-chemical marking process which consists of an electrical power unit that delivers current to a marking head. The marking head is covered with a pad that has been saturated with any one of several electrolytes formulated for marking various metals. When the marking head touches the fitting, the current and electrolyte flow through a stencil resulting in the replacement of metallic ions with a metal oxide forming an etched mark.

4.4 Controlled Dot Peen is a mechanical process using a carbide stylus to create a controlled depth dot matrix impression in the metal being marked.

4.5 Manufacturer's Heat Identification Number traces the starting material to a heat number or a lot number.

4.6 Definition reference for symbols, abbreviations and other definitions may be found in MSS SP-96.

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5. CLASSIFICATIONS

5.1 Fittings shall be one of three classes: MP, MARINE or CR. The classes are specified in Table 1 for ready reference. Fittings of Class MP shall be further subdivided into four subclasses, specifically: MP-S, MP-W, MP-WX and MP-WU, each reflecting unique manufacturing processes and inspection requirements. Class MARINE shall only apply to copper nickel fittings. Class CR shall only apply to stainless steel fittings.

5.2 Class MP or MARINE or CR shall be specified by the purchaser. If the purchaser does not define a MP subclass, any may be supplied by the manufacturer. Class CR fittings shall not be substituted for fittings marked MP, but Class MP may be substituted for Class CR.

6. PRESSURE RATINGS

6.1 The allowable pressure ratings for MP Class fittings designed in accordance with this Standard Practice shall be 87½% of those calculated for straight seamless pipe of minimum wall thickness and stress value in accordance with the rules established in the applicable sections of ASME B31, Codes for Pressure Piping. The pipe wall thickness, schedule or class and material type shall be that with which the fittings have been ordered to be used; their identity on the fittings is in lieu of pressure rating markings.

6.2 The allowable pressure ratings for MARINE class fittings shall be the same as those for MIL-T-16420 Class 200 tube.

6.3 The allowable pressure ratings for CR class fittings shall be the same as those listed for CR class fittings in MSS SP-43 for materials listed therein.

6.4 The pipe fitting manufacturer certifies that his pipe fitting complies with this Standard Practice when his name or trademark is marked on the body of the fitting.

7. FITTING DESIGN

7.1 The designs of MP Class fittings are qualified simultaneously with the qualifications of manufacturing methods for each fitting design and those qualifications shall be by proof test (see Paragraph 8).

8. FITTING DESIGN AND MANUFACTURING METHOD PROOF TESTING

8.1 The validity of each unique manufacturing method used to make each type of MP and MARINE Class fitting shall be affirmed by pressure testing in accordance with applicable sections herein.

8.2 Unique manufacturing methods are determined by the following attributes:

a) Fittings formed from tubular sections are unique from those formed directly from flat material, irrespective of whether such sections are seamless or welded construction.

b) Fittings formed employing one fabrication weld are unique from those employing two fabrication welds.

c) Fittings formed from a greater or lesser number of pieces are unique.

8.3 Retesting shall be required for any change in manufacturing method which directly affects the tested component in a way which could reasonably be concluded to reduce either pressure containment or fatigue performance. Examples include a localized reduction in fitting thickness or a localized decrease in surface curvature radius.

8.4 Fitting types include long radius elbows, short radius elbows, tees, reducing tees, concentric reducers, eccentric reducers, caps and couplings.

8.5 For each fitting type and unique method of manufacture, the pressure test of one NPS size

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qualifies fitting sizes from one half to twice the NPS size tested. Further, tests performed on 90° long radius elbows qualify 45° elbows. Tests performed on a straight tee qualify reducing tees. Tests performed on eccentric reducers qualify concentric reducers. Tests performed on short couplings qualify long couplings and vice versa.

8.6 Pressure test results shall be kept on file by the fitting manufacturer and shall be made available to the purchaser upon request.

8.7 Preparatory to pressure testing, straight pieces of pipe shall be welded on to the end of each fitting and these pieces shall be capped. The pipe pieces shall be no shorter than twice the pipe outside diameter. The pipe shall be of the same material as the fitting.

8.8 Hydrostatic pressure shall be applied until the fitting or pipe ruptures. The test pressure prior to rupture shall be at least equal to 105% of the minimum manufacturing proof test pressure defined as follows:

$P = 2St/D$, where:

S = Actual material tensile strength determined from a specimen representative of the test fitting in the same stress relieving heat treat condition,

t = Minimum allowable pipe wall thickness,

D = Specified outside pipe diameter, and

P = Minimum manufacturing proof test pressure.

9. PRODUCTION TESTING

9.1 Hydrostatic testing of fittings is not required in this standard; however, each fitting of either class MP or MARINE shall be capable of withstanding without failure, leakage or impairment of serviceability, a test pressure equal to that prescribed for the specified matching pipe of equivalent material and minimum wall thickness. Class CR fittings shall be capable of withstanding a hydrostatic test pressure equal to one and one-half times the pressure ratings listed in MSS SP-43 for class CR fittings.

10. SIZES

10.1 The sizes of fittings, excepting only short radius elbows and thermometer well tees shall be from NPS 1/4 through NPS 12. Short radius elbows shall be from NPS 1 through NPS 12. Thermometer well tees shall have a body size of no larger than NPS 2.

10.2 All combinations of reducing tees listed in ASME B16.9 are available from manufacturers, however the following sizing standard is established in the Tables herein and is encouraged in practice:

a) For reducing run tees: Use a standard tee with street reducer.

b) For reducing branch tees in sizes NPS 2 and smaller: Use straight size tees and a street reducer.

c) For reducing branch tees in sizes larger than NPS 2: Use straight size or half size reducing branch tees with street reducers to create all other combinations.

11. MATERIALS

11.1 Stainless steel fittings shall be made from tubular or flat starting material, or a combination of both, the chemical composition and mechanical properties of which conform to ASTM A 240, ASTM A 312, or ASTM A 358.

11.2 Copper nickel fittings shall be made from tubular or flat starting material, or a combination of both. Tubular starting material shall conform to the chemical composition and mechanical properties of Military Specification MIL-T-16420, or ASTM Designation B 466 or B 467. Sheet starting material shall conform to MIL-C-15726 or ASTM Designation B 122.

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12. FABRICATION ALTERNATIVES

12.1 Fabrications from Fittings: Stainless steel fittings may be fabricated from ASME B16.9 fittings wrought to class WP or from MSS SP-43 fittings wrought to CR requirements per ASTM A 403 on to which tangent ends have been butt welded. The tangent ends may be either street or bell and belling may be done either before or after attachment.

12.2 Branch Fabrications: Thermometer well tees and other tees utilizing extruded branch connections shall be fabricated in accordance with ASME B31 Code requirements for extruded outlets. The nominal pipe size of the bodies of thermometer well tee fittings shall not exceed NPS 2.

13. WELD DESIGN, INSPECTIONS AND REPAIR

13.1 Weld Design and Crown: Welds shall be made with a full penetration butt joint. The crowns of the welds shall rise no more than 1/16 inch above the fitting surface on the inside or on the outside. Permanent backing straps shall not be used. Fittings fabricated from half shells which are longitudinally welded shall have the interior and exterior crowns of the longitudinal welds removed for a distance of the socket and tne transition prior to the belling operation.

13.2 Weld Inspections

a) Fitting weld inspection requirements and starting material weld inspection requirements are specified in Table 1.

b) When required (see Table 1), welds shall be radiographically examined throughout their entire length in accordance with Paragraph UW-51 of Section VIII, Division I of the ASME Boiler and Pressure Vessel Code.

c) When required (see Table 1), welds shall be ultrasonically examined throughout their entire length in accordance with Appendix 12 of Section VIII, Division I of the ASME Boiler and Pressure Vessel Code.

d) When required (see Table 1), welds shall be liquid dye-penetrant inspected in accordance with S9074-AR-GIB-010/278.

13.3 Weld Repair: Weld repair is permitted only to longitudinal welds joining half shells or circumferential welds joining tangents to fittings. Repaired fittings shall be re-examined and re-heat treated. No other repairs by welding are permitted.

14. TOLERANCES AND DIMENSIONS

14.1 Tolerances are specified in Table 2.

14.2 Dimensions for sockets and fittings are specified in Tables 3 through 13.

14.3 Distances shown in the fitting sketches from the center of fittings to a pipe piece are pipe fabrication assembly design dimensions, thus are not assigned fitting manufacturing tolerances.

14.4 Squareness, off angle and off plane tolerances are as follows:

NPS range	Tolerance, +/- inches
1/4 to 1 1/2	1/16
2 to 6	1/8
6 to 12	3/16

15. SOCKET AND COUPLING END FACES

15.1 The socket end and coupling end faces shall be flat and perpendicular to the socket and coupling axes. The end face serves as a guide for pipe joint fillet weld thickness.

15.2 The socket end face shall be of a thickness no less than the minimum wall thickness specified in Table 2. The coupling end face shall be of a thickness no less than 1.09 times the minimum wall thickness specified in Table 2.

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15.3 The choice of materials and/or the forming process may produce a heavy end face thickness. The maximum thickness at the welding face shall not exceed 1.5 times the thickness values specified in Table 2. A chamfer not exceeding 15 degrees from the fitting axis is permitted on the outside diameter to achieve thickness requirements.

16. PIPE JOINT FILLET WELD

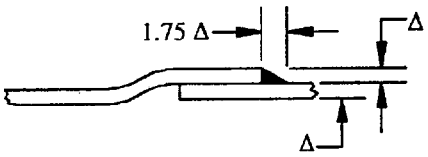

FIGURE 1 — JOINT FILLET WELD

16.1 Optimum fitting to pipe joint fatigue performance is attained when the height of the joint fillet is equal to the fitting socket face thickness (Δ) and extends 1.75 times that distance along the length of the pipe as shown in Figure 1. The slope of the weld face when measured from the pipe surface should be approximately 30 degrees.

17. FINISH

17.1 Fittings supplied under this Standard Practice shall be examined visually. Surface discontinuities shall be explored for depth. Surface discontinuities deeper than 5% of the minimum wall thickness or surface checks (fish scale) deeper than 1/64 inch (0.4 mm) or mechanical marks deeper than 1/16 inch (1.6 mm) shall be removed by machining or grinding to sound metal and the repaired areas shall be well faired. When the removal of a surface discontinuity reduces the wall thickness below the minimum wall limits, the fitting shall be rejected.

17.2 Stainless steel surfaces shall be free of scale and cleaned to ensure corrosion resistance. CUNI surfaces shall be free of black oxide.

18. HEAT TREATMENT

18.1 Each fitting shall be heat treated after completion of all welding or fitting body forming operations except that the forming of socket ends of fittings may be performed either prior to or after final heat treatment.

18.2 All stainless steel fittings shall be furnished heat-treated except as allowed in 18.1. The heat-treat procedure, except for those grades listed below, shall consist of solution annealing the fittings a minimum temperature of 1900°F (1040°C) until the chromium carbides go into solution, and then cooling at a sufficient rate to prevent re-precipitation. Grades 321H, 347H and 348H shall be solution annealed at 1925°F (1050°C) minimum. S31254 shall be solution annealed at 2100°F (1150°C) minimum. S33228 shall be solution annealed at 2050°F (1120°C) minimum. S34565 shall be solution annealed in the range 2050° F (1120° C) to 2140° F (1170° C). The maximum temperature for solution annealing grades 321, 321H, 347 and 347H shall be 2100°F (1150°C).

18.3 All copper nickel fittings shall be heat treated except as allowed in 18.1. Heat treating shall be performed at 1300 +/- 50°F for one hour at temperature per inch of thickness.

19. MARKING

19.1 All fittings shall be permanently marked by electro-etch, controlled dot peen or engraving pencil. The electrolyte shall not contain harmful amounts of chlorides, metals or metallic salts, such as zinc or copper, that would cause corrosive attack on heating. No metal impression stamps shall be used.

19.2 All fittings shall be marked with the prescribed information in accordance with MSS SP-25.

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19.3 Tangent ends of different heat numbers shall be additionally marked.

19.4 Partial compliance fittings shall be identified by use of the suffix-PC.

19.5 The prescribed information shall be as follows:

a) Manufacturer's Name or Trademark

b) NPS Size

c) Wall thickness, Schedule or Class designation

d) Material Grade Identification Symbol

e) Method of Manufacture — The Method of Manufacture shall be described by the fitting class specified in Table 1

f) MSS SP-119 and Manufacturer's Heat Identification Number

g) Date of Manufacture, month and year

19.6 The following are examples of fitting markings:

(CUNI fitting)
Manufacturer
NPS 6 Class 200
MARINE 90/10 CUNI
MSS-SP-119
MFR. HEAT #
7/96

(Stainless steel fitting)
Manufacturer
NPS 6 S10S
MP 304L-W
MSS-SP-119
MFR. HEAT #
7/96

(Partial compliance fitting)
Manufacturer
NPS 4 S10S
MP 316-WU-PC
MSS-SP-119
MFR. HEAT #
7/96

19.7 In those cases where the size of the fitting will not permit the complete marking, the size of the marking may be reduced. If complete marking is not possible, then lines of identification may be omitted in the following order:

a) Date of manufacture

b) Applicable MSS SP-119

c) NPS Size

d) Wall thickness Schedule or Class

19.8 Stainless steel fittings meeting the chemical and mechanical property requirements of ASTM Designation A 240, A 312 and/or A 358 for more than one class or grade may be marked with more than one class or grade designation, such as MP304/304L-S or MP304/304L/304N-W or MP304/304H-WX, etc.

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TABLE 1 — FITTING CLASSES

CLASS AND SUBCLASS	MATERIAL	STARTING PRODUCT	FABRICATION PROCESS AND WELD INSPECTION DETAILS
MP-S	Stainless Steel	Seamless pipe or seamless sheet	Seamless fabrication. No weld inspection.
MP-W	Stainless Steel	Seamless or welded pipe or sheet	Welds made by the fitting manufacturer shall be radiographically examined or ultrasonically tested throughout. Welds in the starting material made with the use of filler metal shall be radiographically examined throughout. Welds in the starting material made without the use of filler metal shall not require radiographic examination.
MP-WX	Stainless Steel	Seamless or welded pipe or sheet	All welds made by either the fitting manufacturer or the starting material manufacturer shall be radiographically examined throughout.
MP-WU	Stainless Steel	Seamless or welded pipe or sheet	All welds made by either the fitting manufacturer or the starting material manufacturer shall be ultrasonically tested throughout.
MARINE	Copper Nickel	Seamless or welded pipe or seamless sheet	Seamless or welded fabrication. All welds made by the fitting manufacturer shall be made in accordance with the requirements of S9074-AR-GIB-010/278 for Class P-1 piping except that radiographic examination is not required.
CR	Stainless Steel	Seamless or welded pipe or sheet	Seamless or welded fabrication. Inspections unspecified.

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TABLE 2 — TOLERANCES

Dimensions are in Inches

Nominal Pipe Size	Socket Depth B	Socket Inside Diameter	Center to End and End to End D,F, M,Q,R	Tangent T	Minimum Wall Thickness (a)	
					CUNI Class 200	Stainless Steel Schedule 10S
1/4	+.03 -.03	+.03 -0	+.03 -.03	+.03 -0	0.065	0.057
3/8					0.065	0.057
1/2					0.065	0.073
3/4					0.065	0.073
1					0.065	0.095
1 1/4					0.072	0.095
1 1/2					0.072	0.095
2		+.04 -0			0.083	0.095
2 1/2			+.06 -.06		0.083	0.105
3					0.095	0.105
4					0.109	0.105
5		+.05 -0			0.125	0.117
6				+.06 -0	0.134	0.117
8					0.151 (b)	0.130
10		+.06 -0			0.187	0.144
12					0.250	0.158

GENERAL NOTE: Street end outside diameter tolerances shall be the same as the pipe with which the fitting identifies.

(a) Multiply these values by 1.25 for short radius elbows.

(b) MIL-T-16420 K lists 0.151 for alloy 706 (90/10) and 0.148 for alloy 715 (70/30).

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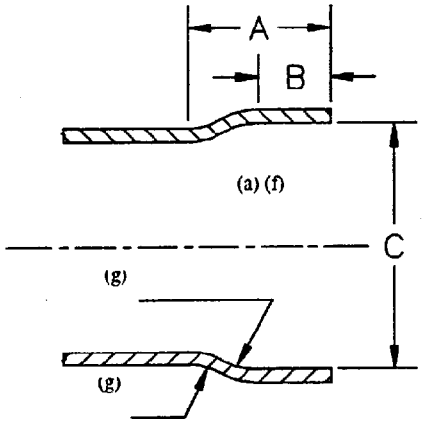

TABLE 3 — SOCKET DIMENSIONS

Dimensions are in Inches

NOMINAL PIPE SIZE	A (b)	B (c)	C (d)
1/4	0.62	0.38	0.55
3/8	0.62	0.38	0.68
1/2	0.75	0.38	0.85
3/4	0.75	0.38	1.06
1	0.81	0.44	1.32
1-1/4	1.00	0.50	1.67
1-1/2	1.12	0.62	1.91
2	1.12	0.62	2.38
2-1/2	1.50	0.81	2.88
3	1.50	0.81	3.51
4	1.62	0.88	4.51
5	1.75	1.00	5.57
6	1.81	1.06	6.63
8	2.19	1.31	8.63
10	2.50	1.50	10.76
12	2.62	1.62	12.76

(a) The maximum allowable offset between the fitting socket axis and the fitting body axis shall be the lesser of one quarter of the minimum socket wall thickness or .040 inches.

(b) Dimension A identifies the length of the transition and the socket.

(c) Dimension B specifies the socket depth.

(d) Dimension C specifies the socket inside diameter. The socket inside diameter shall be the average of the maximum and minimum inside diameters.

(e) Pipe piece cut lengths are 1/16 - 1/8 inch from the bottom of the socket to allow for expansion when welding.

(f) Any local/incidental forming discontinuities (tool marks) shall have a minimum radius of 0.06 inches while maintaining minimum wall thickness requirements.

(g) The changes in contour in the transition shall have a minimum radius of four times the socket wall thickness.

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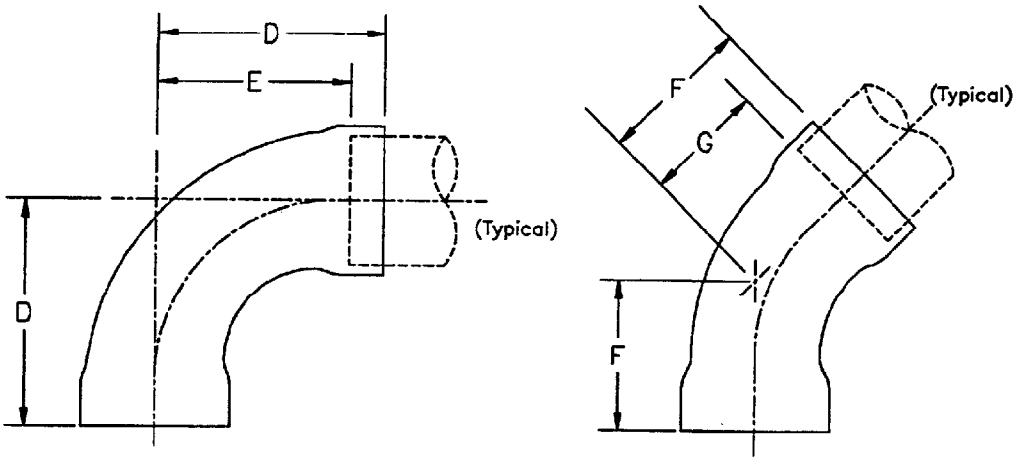

TABLE 4 — LONG (STANDARD) RADIUS ELBOW DIMENSIONS

Dimensions are in inches

NOMINAL PIPE SIZE	90 - DEG ELBOWS		45 - DEG ELBOWS	
	D [a]	E [b]	F [a]	G [b]
1/4	2.12	1.80	1.24	0.92
3/8	2.12	1.80	1.24	0.92
1/2	2.25	1.94	1.38	1.06
3/4	2.25	1.94	1.38	1.06
1	2.38	2.00	1.50	1.12
1-1/4	2.88	2.44	1.78	1.34
1-1/2	3.50	2.94	2.19	1.62
2	4.28	3.72	2.53	1.97
2-1/2	5.38	4.62	3.19	2.44
3	6.17	5.41	3.52	2.76
4	7.78	6.97	4.27	3.45
5	9.53	8.59	5.14	4.20
6	11.17	10.17	5.91	4.91
8	14.62	13.38	7.59	6.34
10	18.00	16.56	9.22	7.78
12	21.25	19.69	10.70	9.14

[a] Dimensions D and F are center to end of fitting.
[b] Dimensions E and G are center of fitting to end of pipe.

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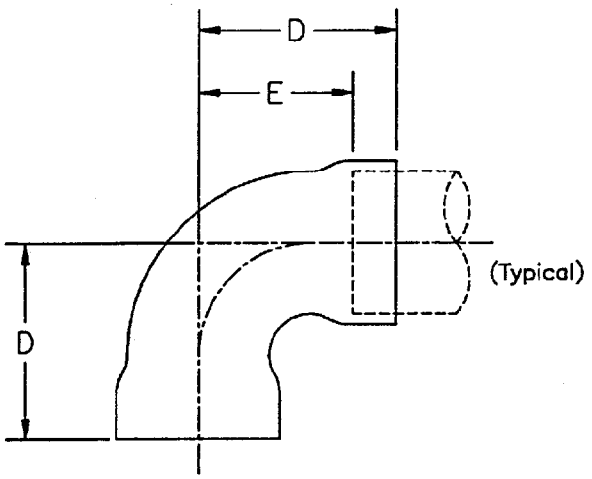

TABLE 5 — SHORT RADIUS ELBOW DIMENSIONS

Dimensions are in Inches

NOMINAL PIPE SIZE	SHORT RADIUS ELBOWS	
	D [a]	E [b]
1	1.81	1.43
1-1/4	2.00	1.56
1-1/2	2.62	2.06
2	3.12	2.56
2-1/2	4.00	3.25
3	4.50	3.75
4	5.62	4.80
5	6.75	5.81
6	7.81	6.81
8	10.19	8.94
10	12.50	11.06
12	14.62	13.06

[a] Dimension D is center to end of fitting.
[b] Dimension E is center of fitting to end of pipe.

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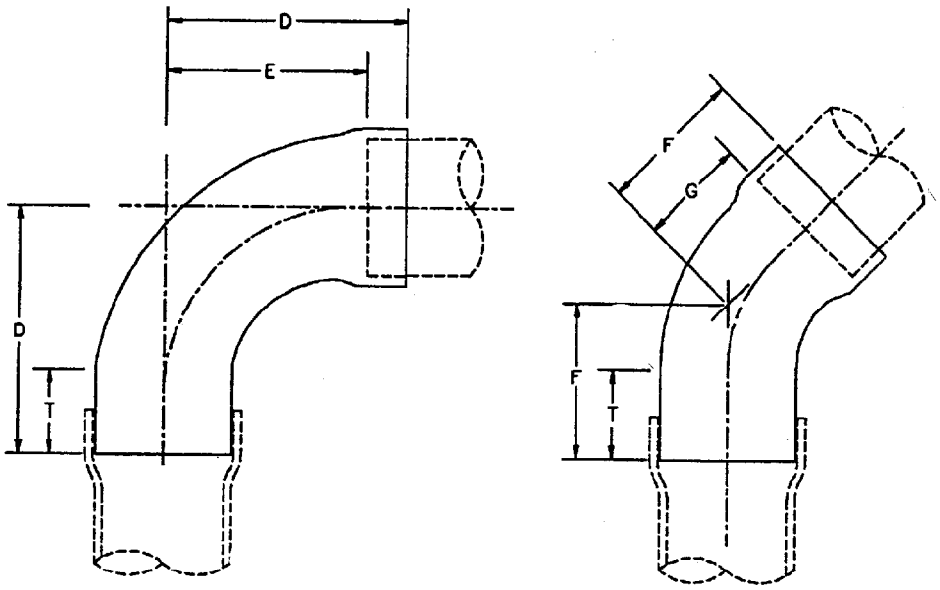

TABLE 6 — LONG (STANDARD) RADIUS STREET ELBOW DIMENSIONS

Dimensions are in Inches

NOMINAL PIPE SIZE	90 - DEG ELBOWS		45 - DEG ELBOWS		TANGENT
	D [a]	E [b]	F [a]	G [b]	T [c]
1/4	2.12	1.80	1.24	0.92	0.62
3/8	2.12	1.80	1.24	0.92	0.62
1/2	2.25	1.94	1.38	1.06	0.75
3/4	2.25	1.94	1.38	1.06	0.75
1	2.38	2.00	1.50	1.12	0.88
1-1/4	2.88	2.44	1.78	1.34	1.00
1-1/2	3.50	2.94	2.19	1.62	1.25
2	4.28	3.72	2.53	1.97	1.28
2-1/2	5.38	4.62	3.19	2.44	1.63
3	6.17	5.41	3.52	2.76	1.67
4	7.78	6.97	4.27	3.45	1.78
5	9.53	8.59	5.14	4.20	2.03
6	11.17	10.17	5.91	4.91	2.17
8	14.62	13.38	7.59	6.34	2.62
10	18.00	16.56	9.22	7.78	3.00
12	21.25	19.69	10.70	9.14	3.25

[a] D and F are center to end of the fitting.
[b] Dimensions E and G are center of fitting to end of pipe.
[c] Dimension T is the length of the tangent.

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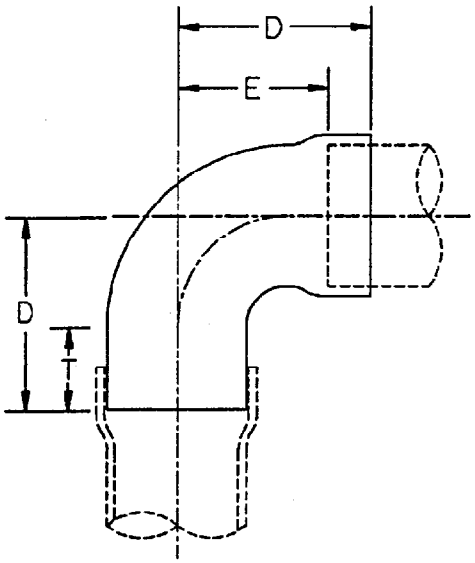

TABLE 7 — SHORT RADIUS STREET ELBOW DIMENSIONS

Dimensions are in Inches

NOMINAL PIPE SIZE	90 - DEG ELBOWS		
	D [a]	E [b]	TANGENT T [c]
1	1.81	1.43	0.81
1-1/4	2.00	1.56	1.00
1-1/2	2.62	2.06	1.12
2	3.12	2.56	1.12
2-1/2	4.00	3.25	1.50
3	4.50	3.75	1.50
4	5.62	4.80	1.62
5	6.75	5.81	1.75
6	7.81	6.81	1.81
8	10.19	8.94	2.19
10	12.50	11.06	2.50
12	14.62	13.06	2.62

[a] Dimension D is the fitting center to end.
[b] Dimension E is the fitting center to end of pipe.
[c] Dimension T is the length of the tangent.

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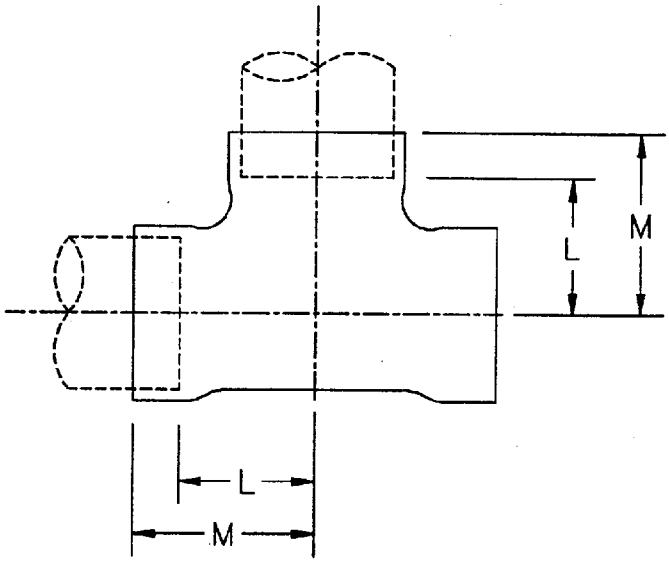

TABLE 8 — STRAIGHT TEE DIMENSIONS

Dimensions are in Inches

NOMINAL PIPE SIZE	STRAIGHT TEES	
	M [a]	L [b]
1/4	0.69	0.38
3/8	0.91	0.59
1/2	1.09	0.78
3/4	1.25	0.94
1	1.50	1.12
1-1/4	1.88	1.44
1-1/2	2.25	1.69
2	2.50	1.94
2-1/2	3.00	2.25
3	3.38	2.62
4	4.12	3.31
5	4.88	3.94
6	5.62	4.62
8	7.00	5.75
10	8.50	7.06
12	10.00	8.43

[a] Dimension M is the center to end of the fitting.
[b] Dimension L is the center of fitting to end of pipe.

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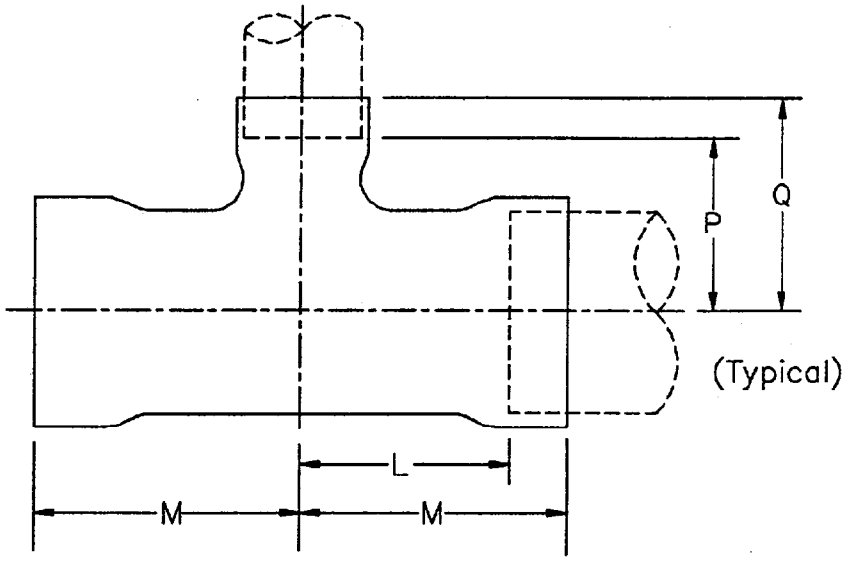

TABLE 9 — REDUCING TEE DIMENSIONS

Dimensions are in Inches

NOMINAL PIPE SIZE	REDUCING TEES			
	M [a]	L [b]	Q [a]	P [b]
2-1/2 x 2-1/2 x 1-1/4	3.00	2.25	2.50	2.06
3 x 3 x 1-1/2	3.38	2.62	2.88	2.32
4 x 4 x 2	4.12	3.31	3.50	2.94
5 x 5 x 2-1/2	4.88	3.94	4.25	3.50
6 x 6 x 3	5.62	4.62	4.88	4.13
8 x 8 x 4	7.00	5.75	6.12	5.30
10 x 10 x 5	8.50	7.06	7.50	6.56
12 x 12 x 6	10.00	8.43	8.62	7.62

[a] Dimensions M and Q are center to end of fitting.
[b] Dimensions L and P are center of fitting to end of pipe.

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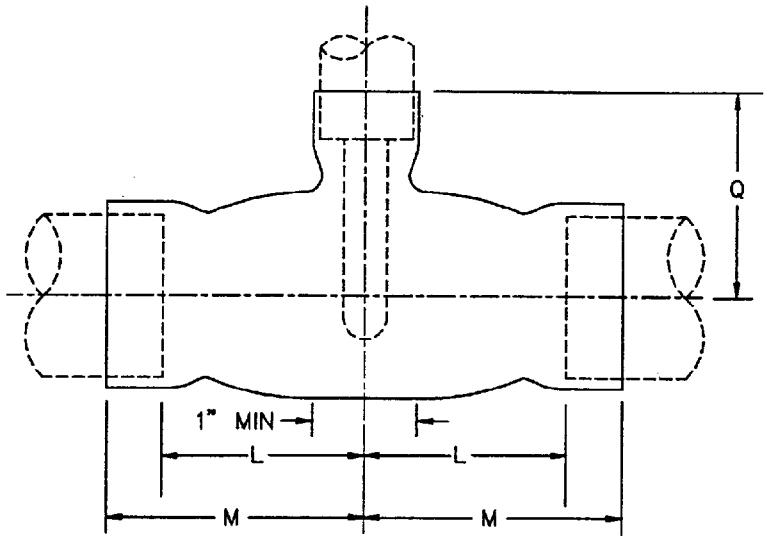

TABLE 10 — STRAIGHT THERMOWELL TEE DIMENSIONS

Dimensions are in Inches

END CONNECTION NOMINAL PIPE SIZE	STRAIGHT THERMOWELL TEES			
	BODY NOMINAL PIPE SIZE	L [a]	M [b]	Q [b]
1/2 x 1/2 x 3/4	1-1/2	2.18	2.5	2.19
3/4 x 3/4 x 3/4	1-1/2	2.18	2.5	2.19
1 x 1 x 3/4	1-1/2	2.12	2.5	2.19
1-1/4 x 1-1/4 x 3/4	2	2.56	3.0	2.38
1-1/2 x 1-1/2 x 3/4	2	2.44	3.0	2.38

[a] Dimension L is center of fitting to end of pipe.
[b] Dimensions M and Q are center to end of fitting.

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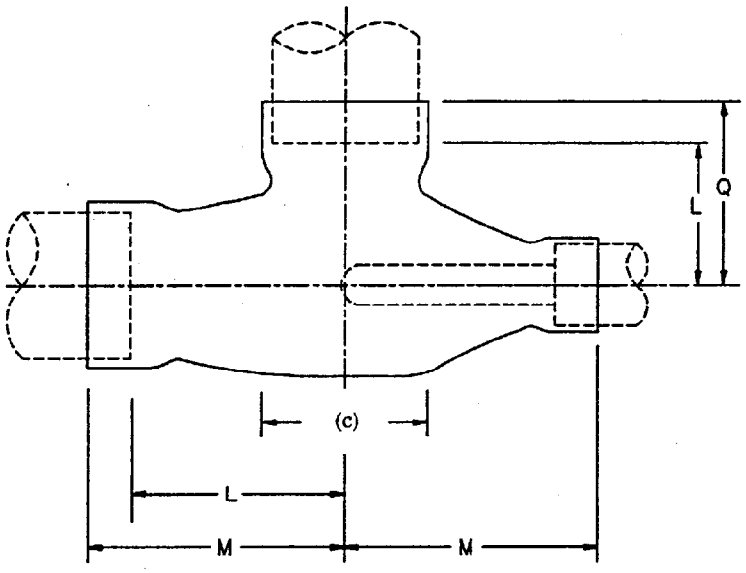

TABLE 11 — ANGLE THERMOWELL TEE DIMENSIONS

Dimensions are in Inches

END CONNECTION NOMINAL PIPE SIZE	ANGLE THERMOWELL TEES			
	BODY NOMINAL PIPE SIZE	L [a]	Q [b]	M [b]
1/2 x 3/4 x 1/2	1-1/2	1.88	2.19	2.50
3/4 x 3/4 x 3/4	1-1/2	1.88	2.19	2.50
1 x 3/4 x 1	1-1/2	1.82	2.19	2.50
1-1/4 x 3/4 x 1-1/4	2	1.94	2.38	3.00

[a] Dimension L is center of fitting to end of pipe.
[b] Dimensions Q and M are center to end of fitting.
[c] There shall be sufficient tangent length in the midbody of each fitting to form the branch and not affect the midbody to run transition shape.

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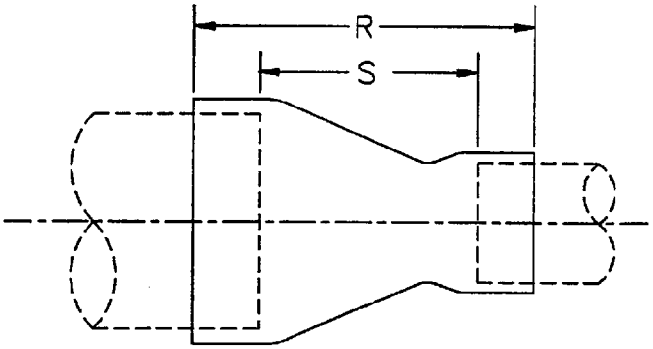

TABLE 12 — CONCENTRIC REDUCER DIMENSIONS

Dimensions are in Inches

CONCENTRIC REDUCERS					
SIZE	R [a]	S [b]	SIZE	R [a]	S [b]
3/8 x 1/4	1.84	1.22	2-1/2 x 1-1/4	4.53	3.34
1/2 x 1/4	1.90	1.27	2-1/2 x 1-1/2	4.53	3.22
1/2 x 3/8	1.90	1.27	2-1/2 x 2	4.53	3.22
3/4 x 1/4	1.90	1.27	3 x 1-1/2	4.72	3.40
3/4 x 3/8	1.90	1.27	3 x 2	4.72	3.40
3/4 x 1/2	1.90	1.27	3 x 2-1/2	4.72	3.22
1 x 1/4	2.60	1.91	4 x 2	5.25	3.87
1 x 3/8	2.60	1.91	4 x 2-1/2	5.25	3.69
1 x 1/2	2.60	1.91	4 x 3	5.25	3.69
1 x 3/4	2.60	1.91	5 x 2-1/2	6.32	4.63
1-1/4 x 1/4	2.75	2.00	5 x 3	6.32	4.63
1-1/4 x 3/8	2.75	2.00	5 x 4	6.32	4.57
1-1/4 x 1/2	2.75	2.00	6 x 3	6.80	5.05
1-1/4 x 3/4	2.75	2.00	6 x 4	6.80	4.99
1-1/4 x 1	2.75	1.94	6 x 5	6.80	4.86
1-1/2 x 1/4	3.37	2.50	8 x 4	7.45	5.39
1-1/2 x 3/8	3.37	2.50	8 x 5	7.45	5.26
1-1/2 x 1/2	3.37	2.50	8 x 6	7.45	5.20
1-1/2 x 3/4	3.37	2.50	10 x 5	8.75	6.38
1-1/2 x 1	3.37	2.44	10 x 6	8.75	6.32
1-1/2 x 1-1/4	3.37	2.37	10 x 8	8.75	6.06
2 x 1/2	3.84	2.97	12 x 6	9.87	7.31
2 x 3/4	3.84	2.97	12 x 8	9.87	7.06
2 x 1	3.84	2.90	12 x 10	9.87	6.87
2 x 1-1/4	3.84	2,84			
2 x 1-1/2	3.84	2.72			

[a] Dimension R is end to end of fitting.
[b] Dimension S is end of pipe to end of pipe.

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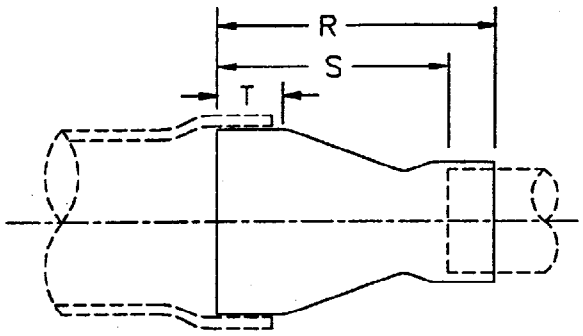

TABLE 13 — CONCENTRIC STREET REDUCER DIMENSIONS

Dimensions are in Inches

CONCENTRIC STREET REDUCERS							
SIZE	R [a]	S [b]	TANGENT T [c]	SIZE	R [a]	S [b]	TANGENT T [c]
3/8 x 1/4	1.84	1.52	0.38	2-1/2 x 1-1/4	4.53	4.09	0.88
1/2 x 1/4	1.90	1.58	0.44	2-1/2 x 1-1/2	4.53	3.97	0.88
1/2 x 3/8	1.90	1.58	0.44	2-1/2 x 2	4.53	3.97	0.88
3/4 x 1/4	1.90	1.58	0.47	3 x 1-1/2	4.72	4.16	0.91
3/4 x 3/8	1.90	1.58	0.47	3 x 2	4.72	4.16	0.91
3/4 x 1/2	1.90	1.58	0.47	3 x 2-1/2	4.72	3.97	0.91
1 x 1/4	2.60	2.28	0.50	4 x 2	5.25	4.69	0.97
1 x 3/8	2.60	2.28	0.50	4 x 2-1/2	5.25	4.50	0.97
1 x 1/2	2.60	2.28	0.50	4 x 3	5.25	4.50	0.97
1 x 3/4	2.60	2.28	0.50	5 x 2-1/2	6.32	5.57	1.09
1-1/4 x 1/4	2.75	2.43	0.56	5 x 3	6.32	5.57	1.09
1-1/4 x 3/8	2.75	2.43	0.56	5 x 4	6.32	5.50	1.09
1-1/4 x 1/2	2.75	2.43	0.56	6 x 3	6.80	6.05	1.17
1-1/4 x 3/4	2.75	2.43	0.56	6 x 4	6.80	5.98	1.17
1-1/4 x 1	2.75	2.37	0.56	6 x 5	6.80	5.86	1.17
1-1/2 x 1/4	3.37	3.05	0.69	8 x 4	7.45	6.63	1.38
1-1/2 x 3/8	3.37	3.05	0.69	8 x 5	7.45	6.51	1.38
1-1/2 x 1/2	3.37	3.05	0.69	8 x 6	7.45	6.45	1.38
1-1/2 x 3/4	3.37	3.05	0.69	10 x 5	8.75	7.81	1.56
1-1/2 x 1	3.37	3.00	0.69	10 x 6	8.75	7.75	1.56
1-1/2 x 1-1/4	3.37	2.93	0.69	10 x 8	8.75	7.50	1.56
2 x 1/2	3.84	3.52	0.72	12 x 6	9.87	8.87	1.69
2 x 3/4	3.84	3.52	0.72	12 x 8	9.87	8.62	1.69
2 x 1	3.84	3.46	0.72	12 x 10	9.87	8.43	1.69
2 x 1-1/4	3.84	3.40	0.72				
2 x 1-1/2	3.84	3.28	0.72				

GENERAL NOTE: This is standard reducer configuration and it is used with straight and half size reducing fittings to create all other reducing combinations.

[a] Dimension R is end to end of fitting.

[b] Dimension S is end of fitting to end of pipe.

[c] Dimension T is the length of fitting tangent.

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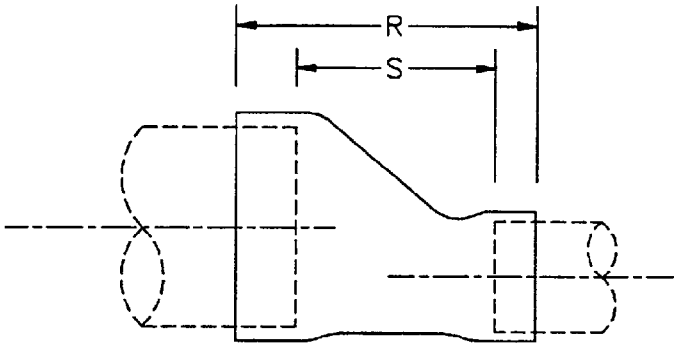

TABLE 14 — ECCENTRIC REDUCER DIMENSIONS

Dimensions are in Inches

ECCENTRIC REDUCERS					
SIZE	R [a]	S [b]	SIZE	R [a]	S [b]
3/8 x 1/4	1.84	1.22	2-1/2 x 1-1/4	4.53	3.34
1/2 x 1/4	1.90	1.27	2-1/2 x 1-1/2	4.53	3.22
1/2 x 3/8	1.90	1.27	2-1/2 x 2	4.53	3.22
3/4 x 1/4	1.90	1.27	3 x 1-1/2	4.72	3.40
3/4 x 3/8	1.90	1.27	3 x 2	4.72	3.40
3/4 x 1/2	1.90	1.27	3 x 2-1/2	4.72	3.22
1 x 1/4	2.60	1.91	4 x 2	5.25	3.87
1 x 3/8	2.60	1.91	4 x 2-1/2	5.25	3.69
1 x 1/2	2.60	1.91	4 x 3	5.25	3.69
1 x 3/4	2.60	1.91	5 x 2-1/2	6.32	4.63
1-1/4 x 1/4	2.75	2.00	5 x 3	6.32	4.63
1-1/4 x 3/8	2.75	2.00	5 x 4	6.32	4.57
1-1/4 x 1/2	2.75	2.00	6 x 3	6.80	5.05
1-1/4 x 3/4	2.75	2.00	6 x 4	6.80	4.99
1-1/4 x 1	2.75	1.94	6 x 5	6.80	4.86
1-1/2 x 1/4	3.37	2.50	8 x 4	7.45	5.39
1-1/2 x 3/8	3.37	2.50	8 x 5	7.45	5.26
1-1/2 x 1/2	3.37	2.50	8 x 6	7.45	5.20
1-1/2 x 3/4	3.37	2.50	10 x 5	8.75	6.38
1-1/2 x 1	3.37	2.44	10 x 6	8.75	6.32
1-1/2 x 1-1/4	3.37	2.37	10 x 8	8.75	6.06
2 x 1/2	3.84	2.97	12 x 6	9.87	7.31
2 x 3/4	3.84	2.97	12 x 8	9.87	7.06
2 x 1	3.84	2.90	12 x 10	9.87	6.87
2 x 1-1/4	3.84	2.84			
2 x 1-1/2	3.84	2.72			

[a] Dimension R is end to end of fitting.
[b] Dimension S is end of pipe to end of pipe.

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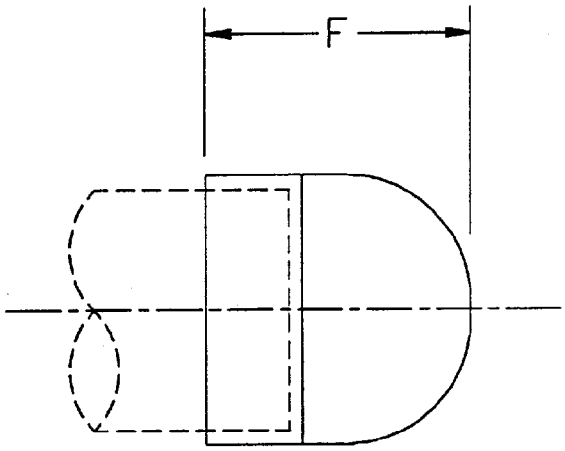

TABLE 15 — CAP DIMENSIONS

Dimensions are in Inches

NOMINAL PIPE SIZE	CAP
	F [a]
1/4	0.85
3/8	1.00
1/2	1.19
3/4	1.19
1	1.44
1-1/4	1.44
1-1/2	1.44
2	1.44
2-1/2	1.44
3	1.90
4	2.41
5	2.91
6	3.39
8	3.94
10	4.94
12	5.93

[a] Dimension F is the end to end of the fitting.

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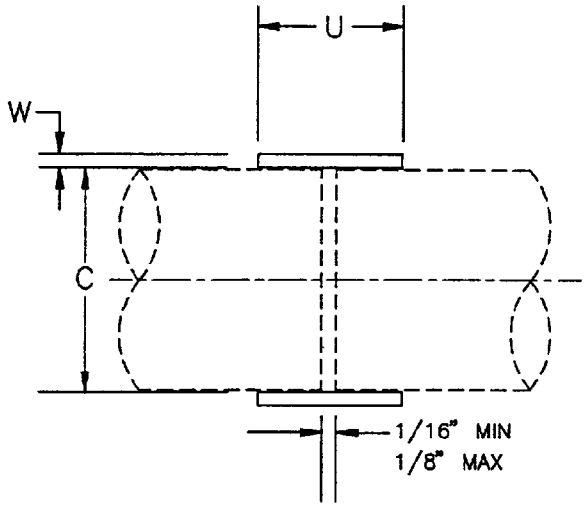

TABLE 16 — STANDARD COUPLING DIMENSIONS

Dimensions are in Inches

NOMINAL PIPE SIZE	C [a]	W [b]		U [c]
		CUNI	STAINLESS STEEL	
1/4	0.57	0.07	0.06	0.88
3/8	0.70	0.07	0.06	0.88
1/2	0.87	0.07	0.08	0.88
3/4	1.08	0.07	0.08	0.88
1	1.35	0.07	0.10	1.00
1-1/4	1.69	0.08	0.10	1.12
1-1/2	1.93	0.08	0.10	1.36
2	2.41	0.09	0.10	1.36
2-1/2	2.91	0.09	0.11	1.74
3	3.53	0.10	0.11	1.74
4	4.53	0.12	0.11	1.88
5	5.60	0.14	0.13	2.12
6	6.66	0.15	0.13	2.24
8	8.66	0.16	0.14	2.74
10	10.79	0.20	0.16	3.12
12	12.79	0.27	0.17	3.36

[a] Dimension C specifies the coupling inside diameter.
[b] Dimension W specifies the minimum coupling wall thickness, maximum thickness is +35%.
[c] Dimension U specifies the coupling end to end dimension.

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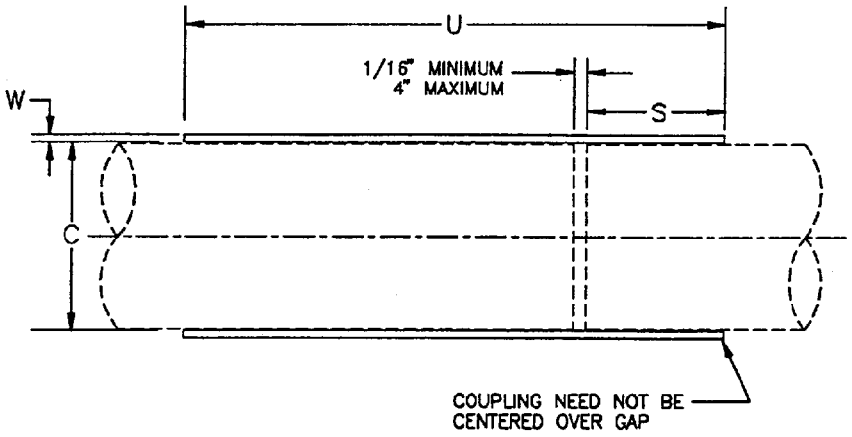

TABLE 17 — CLOSURE COUPLING DIMENSIONS

Dimensions are in Inches

NOMINAL PIPE SIZE	C [a]	W [b]		U [c]	S [d]
		CUNI	STAINLESS STEEL		
1/4	0.57	0.07	0.06	5	0.5
3/8	0.70	0.07	0.06	5	0.5
1/2	0.87	0.07	0.08	5	0.5
3/4	1.08	0.07	0.08	5.5	0.75
1	1.35	0.07	0.10	5.5	0.75
1-1/4	1.69	0.08	0.10	5.5	0.75
1-1/2	1.93	0.08	0.10	5.5	0.75
2	2.41	0.09	0.10	5.5	0.75
2-1/2	2.91	0.09	0.11	5.5	0.75
3	3.53	0.10	0.11	5.5	0.75
4	4.53	0.12	0.11	6	1
5	5.60	0.14	0.13	6	1
6	6.66	0.15	0.13	6	1
8	8.66	0.16	0.14	6	1
10	10.79	0.20	0.16	6	1
12	12.79	0.27	0.17	6	1

[a] Dimension C specifies the coupling inside diameter.
[b] Dimension W specifies the minimum coupling wall thickness, maximum thickness is +35%.
[c] Dimension U specifies the coupling end to end dimension.
[d] Dimension S specifies the minimum insertion depth.

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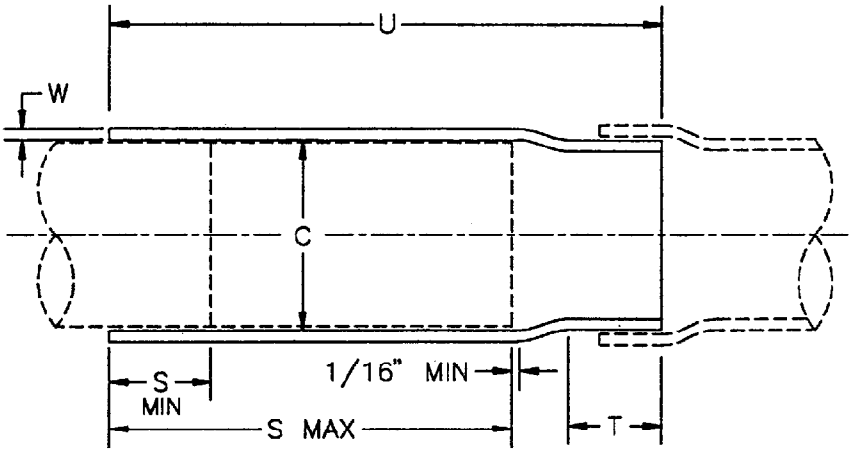

TABLE 18 — CLOSURE REPAIR COUPLING DIMENSIONS

Dimensions are in Inches

NOMINAL PIPE SIZE	C [a]	W [b]		U [c]	S [d] MIN	TANGENT T [e]
		CUNI	STAINLESS STEEL			
1/4	0.57	0.07	0.06	5	0.5	0.50
3/8	0.70	0.07	0.06	5	0.5	0.50
1/2	0.87	0.07	0.08	5	0.5	0.50
3/4	1.08	0.07	0.08	5.5	0.75	0.50
1	1.35	0.07	0.10	5.5	0.75	0.75
1-1/4	1.69	0.08	0.10	5.5	0.75	0.75
1-1/2	1.93	0.08	0.10	5.5	0.75	0.75
2	2.41	0.09	0.10	5.5	0.75	0.75
2-1/2	2.91	0.09	0.11	5.5	0.75	1.00
3	3.53	0.10	0.11	5.5	0.75	1.00
4	4.53	0.12	0.11	6	1	1.00
5	5.60	0.14	0.13	6	1	1.25
6	6.66	0.15	0.13	6	1	1.25
8	8.66	0.16	0.14	6	1	1.50
10	10.79	0.20	0.16	6	1	1.75
12	12.79	0.27	0.17	6	1	2.00

GENERAL NOTE: This fitting is designed to replace fittings in installed piping.

[a] Dimension C specifies the coupling inside diameter.

[b] Dimension W specifies the minimum coupling wall thickness, maximum thickness is +35%.

[c] Dimension U specifies the coupling end to end dimension.

[d] Dimension S specifies the insertion depths, maximum and minimum.

[e] Dimension T is the length of the tangent.

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STD.MSS SP-119-ENGL 1996 ■ 5770640 0500878 95T ■

ANNEX A
REFERENCE STANDARDS

The following is a list of standards and specifications referenced in the Standard showing the year of approval.

ASME Publications (Approved as American National Standards)

B16.9-1993	Factory-Made Wrought Steel Buttwelding Fittings
B31-1995	Codes for Pressure Piping
B36.19M-1985	Stainless Steel Pipe
BPV-1995	ASME Boiler and Pressure Vessel Code, Section VIII - Division 1

ASTM Publications

B 122-86	Standard Specification for Copper-Nickel-Tin Alloy, Copper-Nickel-Zinc Alloy, and Copper-Nickel Alloy Plate, Sheet, Strip, and Rolled Bar
A 240-95a	Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
A 312-94b	Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipes
A 358-94a	Standard Specification for Electric Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High Temperature Service
A 403-90	Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
B 466-92a	Standard Specification for Seamless Copper-Nickel Pipe and Tube
B 467-88	Standard Specification for Welded Copper-Nickel Pipe and Tube

MSS Publications

SP-25-78	Standard Marking System for Valves, Fittings, Flanges and Unions
SP-43-91	Wrought Stainless Steel Butt-Welding Fittings
SP-96-91	Guidelines on Terminology for Valves and Fittings

GOVERNMENT STANDARDS

MIL-C-15726F	Copper-Nickel Alloy, Sheet, Plate, Strip, Bar, Rod, and Wire
MIL-T-16420K	Tube, Copper-Nickel Alloy, Seamless and Welded
S9074-AR-GIB-010/278	Requirements for Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping, and Pressure Vessels

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Publications of the following organizations appear on the above list:

American Society of Mechanical Engineers
345 East 47th Street
New York, NY 10017

American Society for Testing and Materials
100 Barr Harbor Drive
West Conshohocken, PA 19428

Manufacturers Standardization Society of the Valve and Fittings Industry, Inc.
127 Park Street, NE
Vienna, VA 22180

Department of the Navy
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LIST OF MSS STANDARD PRACTICES

NUMBER	
SP- 6-1996	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP- 9-1992	Spot Facing for Bronze, Iron and Steel Flanges
SP-25-1993	Standard Marking System for Valves, Fittings, Flanges and Unions
SP-42-1990 (R 1995)	Class 150 Corrosion Resistant Gate, Globe, Angle and Check Valves with Flanged and Butt Weld Ends
SP-43-1991 (R 1996)	Wrought Stainless Steel Butt-Welding Fittings
SP-44-1996	Steel Pipeline Flanges
SP-45-1992	Bypass and Drain Connections
SP-51-1991 (R 1995)	Class 150 LW Corrosion Resistant Cast Flanges and Flanged Fittings
SP-53-1995	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Magnetic Particle Examination Method
SP-54-1995	Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components — Radiographic Examination Method
SP-55-1996	Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components — Visual Method for Evaluation of Surface Irregularities
SP-58-1993	Pipe Hangers and Supports — Materials, Design and Manufacture
SP-60-1991	Connecting Flange Joint Between Tapping Sleeves and Tapping Valves
SP-61-1992	Pressure Testing of Steel Valves
SP-65-1994	High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets
SP-67-1995	Butterfly Valves
SP-68-1988	High Pressure-Offset Seat Butterfly Valves
SP-69-1996	Pipe Hangers and Supports — Selection and Application
SP-70-1990	Cast Iron Gate Valves, Flanged and Threaded Ends
SP-71-1990	Cast Iron Swing Check Valves, Flanged and Threaded Ends
SP-72-1992	Ball Valves with Flanged or Butt-Welding Ends for General Service
SP-73-1991 (R 1996)	Brazing Joints for Wrought and Cast Copper Alloy Solder Joint Pressure Fittings
SP-75-1993	Specifications for High Test Wrought Butt Welding Fittings
SP-77-1995	Guidelines for Pipe Support Contractual Relationships
SP-78-1987 (R 1992)	Cast Iron Plug Valves, Flanged and Threaded Ends
SP-79-1992	Socket-Welding Reducer Inserts
SP-80-1987	Bronze Gate, Globe, Angle and Check Valves
SP-81-1995	Stainless Steel, Bonnetless, Flanged Knife Gate Valves
SP-82-1992	Valve Pressure Testing Methods
SP-83-1995	Class 3000 Steel Pipe Unions, Socket-Welding and Threaded
SP-85-1994	Cast Iron Globe & Angle Valves, Flanged and Threaded Ends
SP-86-1987 (R 1992)	Guidelines for Metric Data in Standards for Valves, Flanges, Fittings and Actuators
SP-87-1991 (R 1996)	Factory-Made Butt-Welding Fittings for Class I Nuclear Piping Applications
SP-88-1993	Diaphragm Type Valves
SP-89-1991	Pipe Hangers and Supports — Fabrication and Installation Practices
SP-90-1986 (R 1991)	Guidelines on Terminology for Pipe Hangers and Supports
SP-91-1992 (R 1996)	Guidelines for Manual Operation of Valves
SP-92-1987 (R 1992)	MSS Valve User Guide
SP-93-1987 (R 1992)	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Liquid Penetrant Examination Method
SP-94-1992	Quality Standard for Ferritic and Martensitic Steel Castings for Valves, Flanges, and Fittings and Other Piping Components — Ultrasonic Examination Method
SP-95-1986 (R 1991)	Swage(d) Nipples and Bull Plugs
SP-96-1996	Guidelines on Terminology for Valves and Fittings
SP-97-1995	Integrally Reinforced Forged Branch Outlet Fittings — Socket Welding. Threaded and Buttwelding Ends
SP-98-1996	Protective Coatings for the Interior of Valves, Hydrants. and Fittings
SP-99-1994	Instrument Valves
SP-100-1988	Qualification Requirements for Elastomer Diaphragms for Nuclear Service Diaphragm Type Valves
SP-101-1989	Part-Turn Valve Actuator Attachment — Flange and Driving Component Dimensions and Performance Characteristics
SP-102-1989	Multi-Turn Valve Actuator Attachment — Flange and Driving Component Dimensions and Performance Characteristics
SP-103-1995	Wrought Copper and Copper Alloy Insert Fittings for Polybutylene Systems
SP-104-1995	Wrought Copper Solder Joint Pressure Fittings
SP-105-1996	Instrument Valves for Code Applications
SP-106-1990 (R 1996)	Cast Copper Alloy Flanges and Flanged Fittings, Class 125, 150 and 300
SP-107-1991	Transition Union Fittings for Joining Metal and Plastic Products
SP-108-1996	Resilient-Seated Cast Iron-Eccentric Plug Valves
SP-109-1991	Welded Fabricated Copper Solder Joint Pressure Fittings
SP-110-1996	Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
SP-111-1996	Gray-Iron and Ductile-Iron Tapping Sleeves
SP-112-1993	Quality Standard for Evaluation of Cast Surface Finishes — Visual and Tactile Method. This SP must be sold with a 10-surface, three-dimensional Cast Surface Comparator, which is a necessary part of the Standard. Additional comparators may be sold separately.
SP-113-1994	Connecting Joint between Tapping Machines and Tapping Valves
SP-114-1995	Corrosion Resistant Pipe Fittings, Threaded and Socket Welding, Class 150 and 1000
SP-115-1995	Excess Flow Valves for Natural Gas Service
SP-116-1996	Service Line Valves and Fittings for Drinking Water Systems
SP-117-1996	Bellows Seals for Globe and Gate Valves
SP-118-1996	Compact Steel Globe & Check Valves — Flanged, Flangeless, Threaded & Welding Ends (Chemical & Petroleum Refinery Service)
SP-119-1996	Belled End Socket Welding Fittings, Stainless Steel and Copper Nickel

R-Year — Indicates year standard reaffirmed without substantive change.

Prices available upon request.

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NACE INTERNATIONAL
THE CORROSION SOCIETY

NACE Standard RP0286-97
Item No. 21032

Standard
Recommended Practice

Electrical Isolation of Cathodically Protected Pipelines

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Foreword

This standard recommended practice is to be used in conjunction with the latest revisions of NACE Standards RP0169, "Control of External Corrosion on Underground or Submerged Metallic Piping Systems"; RP0675, "Control of Corrosion on Offshore Steel Pipelines"; and RP0177, "Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems."[1,2,3] Each of these standards refers to electrical isolation or isolation joints, but details are not provided. This standard, which was prepared to supplement those standards, provides engineers, designers, and technical personnel dealing with pipelines the necessary information to electrically isolate cathodically protected pipelines.

This standard was originally prepared in 1986 by NACE International Task Group T-10A-15 on Electrical Isolation of Cathodically Protected Pipelines, a component of Unit Committee T-10A on Cathodic Protection, and was issued by NACE under the auspices of Group Committee T-10 on Underground Corrosion Control. The standard was revised in 1997, the current issue.

In NACE standards, the terms *shall*, *must*, *should*, and *may* are used in accordance with the definitions of these terms in the *NACE Publications Style Manual*, 3rd ed., Paragraph 8.4.1.8. *Shall* and *must* are used to state mandatory requirements. *Should* is used to state that which is considered good and is recommended but is not absolutely mandatory. *May* is used to state that which is considered optional.

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NACE International
Standard
Recommended Practice

Electrical Isolation of Cathodically Protected Pipelines

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Section 1: General

1.1 This standard explains the importance of pipeline electrical isolation in achieving and maintaining adequate, reliable, and economical corrosion control. The standard outlines the types of devices used for isolation; precautions to be observed; and selection of devices based on pipeline characteristics, site, and contents. The standard describes isolating flanges, gaskets, sleeves, washers, joints, unions, couplings, and spools, and discusses materials for pipeline casing isolation. Installation, field testing, and maintenance of isolating devices are also included.

This standard describes the application of isolating devices intended only for cathodic protection purposes where voltages across the isolating device are 1 to 2 volts DC and the AC exposure does not exceed 15 volts rms.[4]

This standard does not discuss situations in which isolating devices are incorporated purely for safety reasons; in those situations, reference should be made to relevant electrical safety codes. Isolating devices shall not be used in enclosed areas where combustible atmospheres are likely to be present.

1.2 Isolation of cathodically protected pipelines is recommended to minimize current requirements, facilitate testing and troubleshooting, and improve current distribution.

Section 2: Need for Isolation

2.1 Cathodic protection current intended for a given pipeline can flow to other underground facilities or equipment electrically connected to the pipeline. If protection of the other underground facilities is not intended, significant cathodic protection current can be lost unless preventive measures are taken. Generally called a current drain, this current loss can be reduced through electrical isolation of the pipeline.

2.2 Cathodic protection even of well-coated pipelines may not be economical or practical unless electrical isolation is achieved.

2.3 Pipeline casings should be electrically isolated from the carrier pipe.

2.4 If a pipeline passes through the wall of a valve pit or a building, metallic contact can occur between the pipe and the steel reinforcement in the concrete, causing a significant loss of protective current.

2.5 Electrical isolation can minimize or eliminate galvanic corrosion caused by dissimilar metals in contact with each other or caused by similar metals in contact with each other when one metal is bare or has a dielectric coating system while the other has a permeable (e.g., concrete or mortar) coating system.

2.6 If a pipeline is designed to be electrically continuous but is supported by another metallic structure in contact with soil or groundwater, the pipeline should be isolated from that structure. The isolating supports must prevent damage to the pipeline coating and must accommodate relative movement, vibrations, and temperature differentials.

2.7 Isolation of power and instrumentation grounding systems may be required where electrically operated valves and similar components form part of a pipeline system. All applicable safety codes and standards must be followed.

2.8 If a pipeline is to be protected by more than one type of cathodic protection system, isolation of one or more sections may be desirable.

2.9 Isolation of pipelines can be beneficial in controlling or limiting the effect of stray currents such as telluric currents, currents associated with an electric traction system, or currents from nearby structures under cathodic protection.

Section 3: Methods of Isolation

3.1 Electrically isolating devices may be specially manufactured or prefabricated. It may be possible for existing fittings to be retrofitted with isolating materials to serve as isolating devices. Selection of the type of isolating device depends on the mechanical forces due to its position in the system, the operating temperature range, pressure constraints, and other considerations. Provisions should be made for the connection of test cables for testing these isolating devices.

3.2 Flanges

3.2.1 A bolted pair of pipeline flanges may be converted into an electrically isolating device by

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inserting an isolating gasket between the flanges and isolating sleeves over the shanks of the bolts, and placing isolating washers under the external steel washers to isolate the bolts (see Figures 1a and 1b). Isolating gaskets may have diameters equal to or greater than the outside diameter of the flanges, or they may fit within the bolt circle of the flange faces or into the groove of ring-type joint flanges. Isolating sleeves (around bolts) and washers (over bolts and under nuts and bolt heads) may also be combined as one-piece units. In some underground applications, the nuts and bolts may be isolated from one flange only so that cathodic protection will also protect all bolts and nuts. In some applications, isolating flanges are required to be pressure tested after assembly. When isolating flanges are being considered for use below ground, special consideration should be given to the installation (see Paragraph 7.2.5). Should circumstances indicate that this type of installation would not be effective, an alternative device should be used.

3.3 Prefabricated Isolating Joints

3.3.1 Specially manufactured isolating joints should be available with pressure and electrical test certificates. Unless the isolating device is pressure tested as part of the pipeline system, a pressure test certificate may be required in order to comply with applicable codes. These codes include Parts 192 and 195 of U.S. Department of Transportation[1] Regulations, "Protection Against Accidental Overpressure," ANSI[2] B31.3, "Chemical Plant and Petroleum Refinery Piping," ANSI B31.4, "Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols," and ANSI B31.8, "Gas Transmission and Distribution Piping Systems."[5-8]

3.3.2 Isolating monolithic joints for pressure services over 1,000 kPa[3] (150 psi) (see Figure 2) consist of a pair of hubs on short pipe lengths; one hub is extended at its periphery by a barrel that overlaps the other hub. The two sections are aligned with the isolating materials and held in position with a large compressive force that is locked by welding, wedging, or swaging and is pressure-sealed. These units do not include any threaded components and cannot be disassembled on site.

3.3.3 Isolating monolithic joints for pressure services below 1,000 kPa (150 psi) are generally one of two types. One type consists of short lengths of pipe. The end of one length is enlarged and its internal surface serrated. An isolating sleeve bonded to the external serrated surface of the other pipe fits into the enlarged pipe, which is swaged to hold the assembly in position. The second type (see Figure 3) is similar to the higher pressure joint described in Paragraph 3.3.2.

3.3.4 Isolating yoke-type joints (see Figure 4) include two hub assemblies. The back of one hub is conical. The two hubs are sealed using O-rings and isolating rings or spacers. The hubs are held together under pressure by an encircling yoke clamped by bolts through lugs that are normally tack welded.

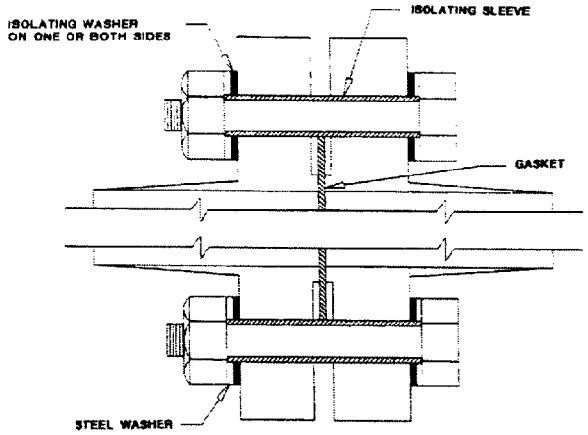

Figure 1a
This figure shows the use of full-length bolt sleeves.

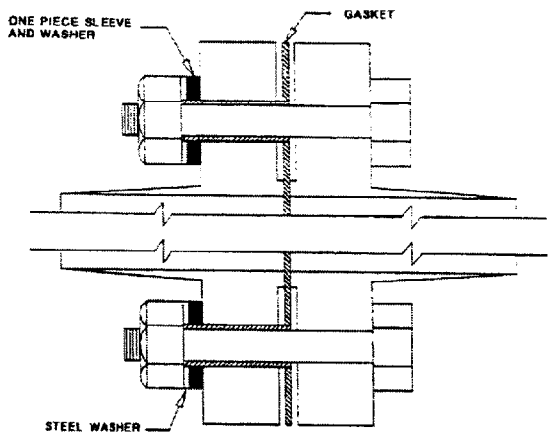

Figure 1b
This figure shows the use of one-half-length bolt sleeves.

[1] U.S. Department of Transportation (DOT), 400 7th St. SW, Washington DC 20590.
[2] American National Standards Institute (ANSI), 11 West 42nd St., New York, NY 10036.
[3] 1 kPa = 0.01 bar

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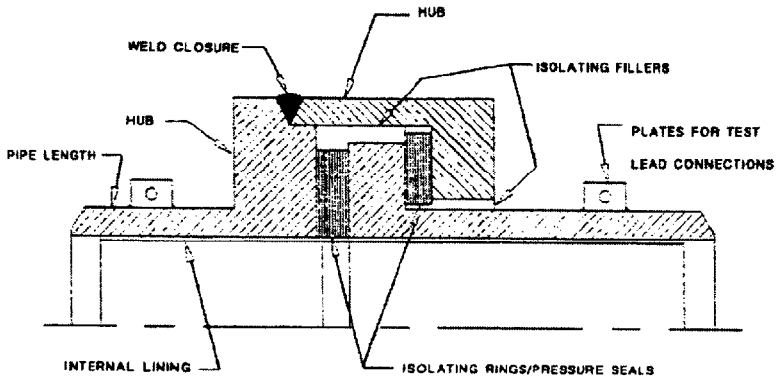

Figure 2
Typical Isolating Monolithic Device
High Pressure—Over 1,000 kPa (150 psi)

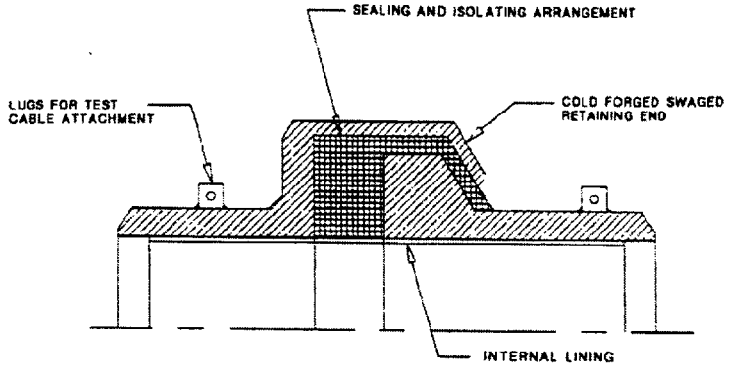

Figure 3
Typical Isolating Monolithic Joint
Pressure Service—Below 1,000 kPa (150 psi)
(Other methods of construction are available.)

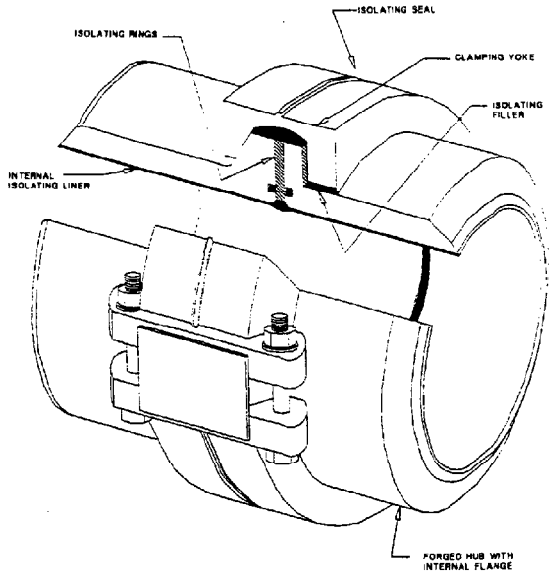

Figure 4
Typical Isolating Yoke-Type Device

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3.3.5 Prefabricated isolating flanges are factory-assembled isolating devices that are welded to a short pipe length with welded or screwed end preparations.

3.4 Unions (see Figure 5)

An isolating union consists of two flanged bodies screwed onto the end of each connecting pipe. One flanged end is externally threaded, and the joint is held in position by a nut that is electrically isolated from the other end. The pressure seal may be achieved by using a molded seal and/or a gasket between mating faces.

3.5 Spools (see Figure 6)

An isolating spool for pipelines carrying fluids may be made either by inserting a long piece of nonmetallic pipe into a piping system or by inserting a long piece of metallic pipe into the pipeline in combination with one or two of the devices described in Paragraphs 3.2 through 3.6. One of the isolating devices described in those paragraphs may also be used with an extended pipe length that has a high-electrical-resistance lining bonded to the isolating flange or joint and to the inside of the extended pipe length. When using this design, the extended length should also be the protected length.

3.6 Couplings (see Figure 7)

3.6.1 Bolted couplings consist of a cylindrical steel middle ring, two resilient gaskets, and steel follower rings connected by a set of steel trackhead bolts. Isolation may be provided by an isolating gasket under one of the follower rings and an isolating sleeve for one pipe end.

3.6.2 Screwed couplings consist of a forged steel or malleable iron body, an isolating gasket, two retainer cups, and two end nuts, with a combined isolating sleeve and end spacer provided for one pipe end.

3.6.3 A sleeved coupling with a hydraulic sealing system consists of a steel sleeve inside a pipe coupling with two isolating gaskets sealed by internal and external hydraulic pressure to the sleeve. The sleeve is equipped with an isolating gasket, an isolating sleeve, and an isolating pipe spacer.

3.7 Isolating Tapping Sleeve (see Figure 8)

3.7.1 An isolating tapping sleeve consists of a split sleeve installed over a pipe with the two halves connected by bolts and gaskets. One end of the fitting is equipped with isolating material.

3.8 Isolating Transition Fittings

3.8.1 Isolating transition fittings include a dielectric pipe fitting or a section of pipe or tubing that may be inserted in low-pressure pipeline systems.

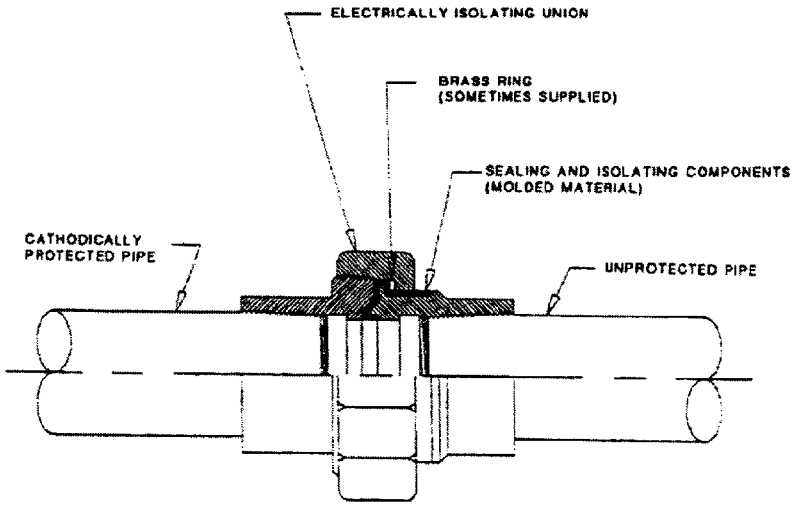

Figure 5
Typical Isolating Union

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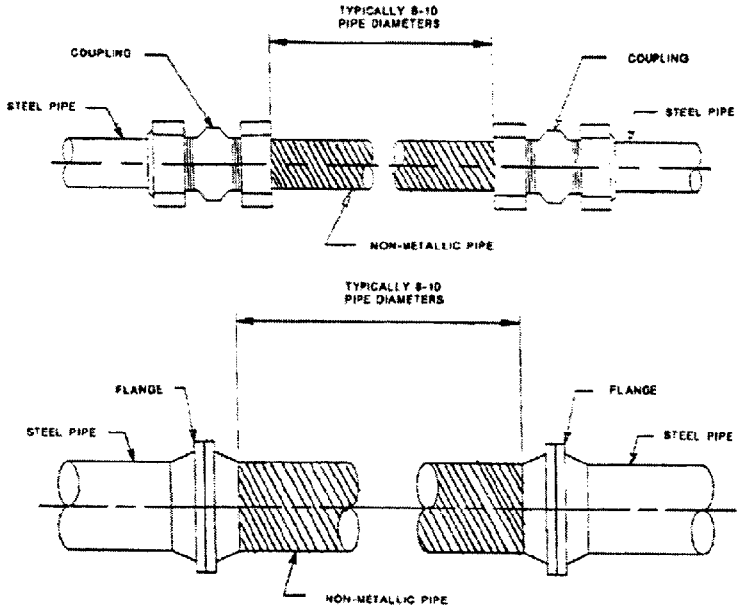
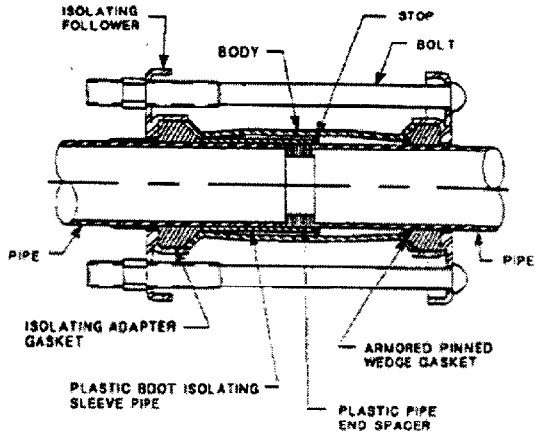
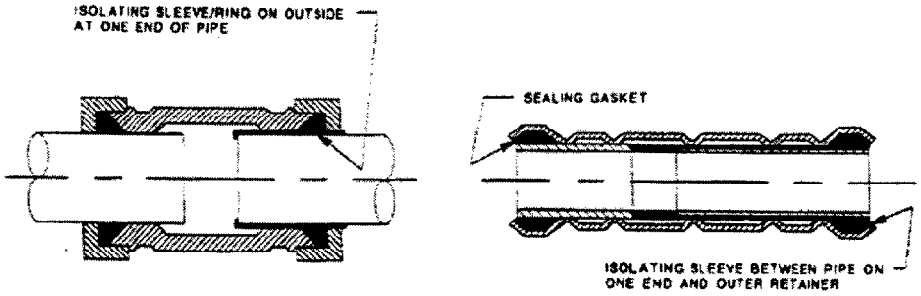


Figure 6
Typical Isolating Spools



(A) MECHANICAL BOLTED SEALING TYPE



(B) BOLTLESS SEALING TYPE (C) HYDRAULIC SEALING TYPE

Figure 7
Typical Isolating Couplings

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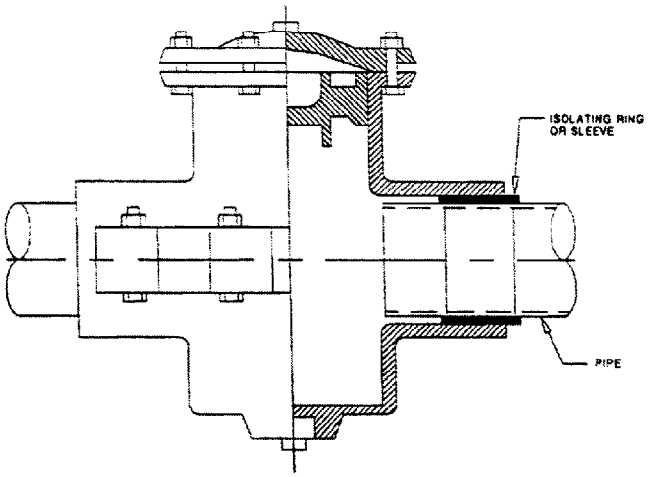

Figure 8
Typical Isolating Tapping Sleeve

Section 4: Isolation from Other Metallic Structures

4.1 Pipelines to be cathodically protected must be isolated from other metallic structures unless the cathodic protection system has incorporated sufficient current drain for other metallic structures.

4.1.1 Casings

4.1.1.1 Pipelines are commonly routed under roads and railways in steel casings. The casings are normally electrically isolated from the pipeline. Isolation is provided by isolating spacers located circumferentially around the pipe. After these isolators are placed at intervals along the carrier pipe, the pipe is inserted into the casing (see Figure 9). NOTE: Other methods, such as coating pipes with concrete, are also used for isolation. The effectiveness of methods other than isolating spacers should be evaluated on a case-by-case basis.

4.1.1.2 Electrical isolation of the casing and carrier pipe provided by the isolating spacers may be relied upon only as long as the carrier pipe remains physically separated from the casing pipe. Isolating spacers should be designed and spaced to withstand the loads caused by the movement of the carrier pipe under operational conditions.

4.1.1.3 The use of proper end-sealing and casing-filling methods can prevent possible contacts as well as the ingress of foreign substances.

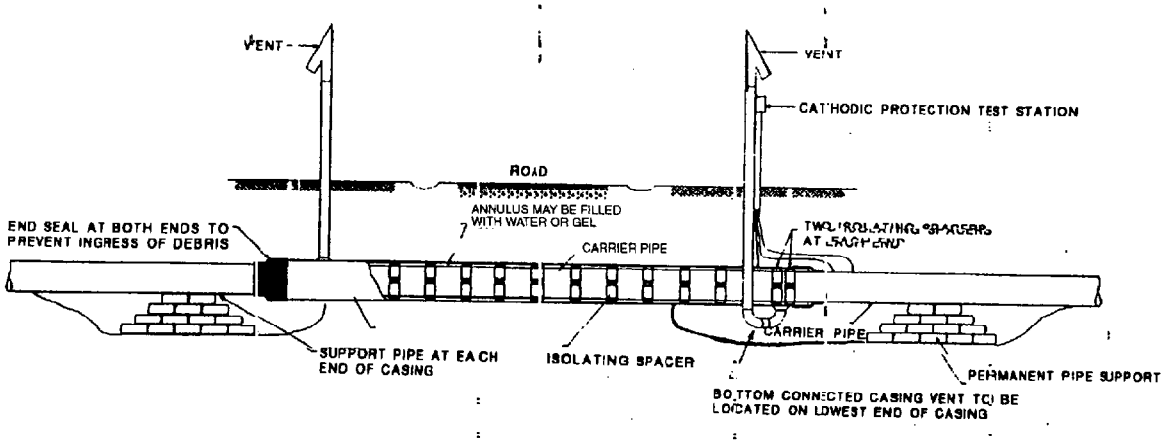

Figure 9
Typical Casing/Sleeve Installation

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4.1.2 Pipe Bridges

4.1.2.1 Pipeline supports on a metallic pipe bridge shall be provided with pads to isolate the pipe electrically from the support cradles. Plastics, neoprene, fiberglass-reinforced plastic, or glazed ceramics may be used for these pads. The material chosen should be the most suitable for the pipeline service and environmental conditions.

4.1.2.2 If the cathodic protection system is designed so that the portion of the pipeline on the pipe bridge is isolated from the underground portion of the pipeline, a jumper wire can be bonded to the pipeline at the isolating device (see Figure 10) to provide electrical continuity around the isolated section on the bridge. The jumper wire must be sized to conduct the required cathodic protection current.

4.1.3 Pipeline Crossings

4.1.3.1 A minimum separation of 30 cm (12 in.) should be maintained between all buried metallic structures at pipeline crossings. Where this is not possible, consideration should be given to installation of isolating materials between the structures.

4.1.4 Offshore Platform Riser Pipes

4.1.4.1 Pipelines rising from the ocean bed onto offshore platforms may require electrical isolation from the structure's steel jacket, support legs, or, in the case of concrete platforms, the concrete-reinforcing steel. If the riser support is designed to allow movement of the riser pipe, then roller guides, flexible collars, or other suitable parts made of isolating materials can be used to ensure effective electrical isolation.

4.1.5 Electrical Grounds and Supply Cable Sheathing

4.1.5.1 Installation of electric motorized valves and instrumentation transducers in a pipeline connects the pipeline with the electrical supply earth grounding. Electrical isolation can be obtained by using one of the following methods. Any measure taken should not conflict with applicable electrical codes.

4.1.5.1.1 Install a continuity bond cable around the assembly; then provide isolating joints on each side of the valve.

4.1.5.1.2 Ground the valve with appropriate devices; then isolate the electrical supply earth grounding from the valve.

4.1.5.1.3 Separately ground and connect the secondary side of the circuit to approved isolating equipment; then isolate the electrical supply earth grounding from the motor by terminating the supply on an isolating transformer or equipment approved for that application.

4.1.5.1.4 Ground separately, if necessary; then isolate the instrumentation transducer screen from the transducer.

4.1.5.1.5 Connect an approved electrical equipment device; then connect the electrical supply earth grounding by that means.

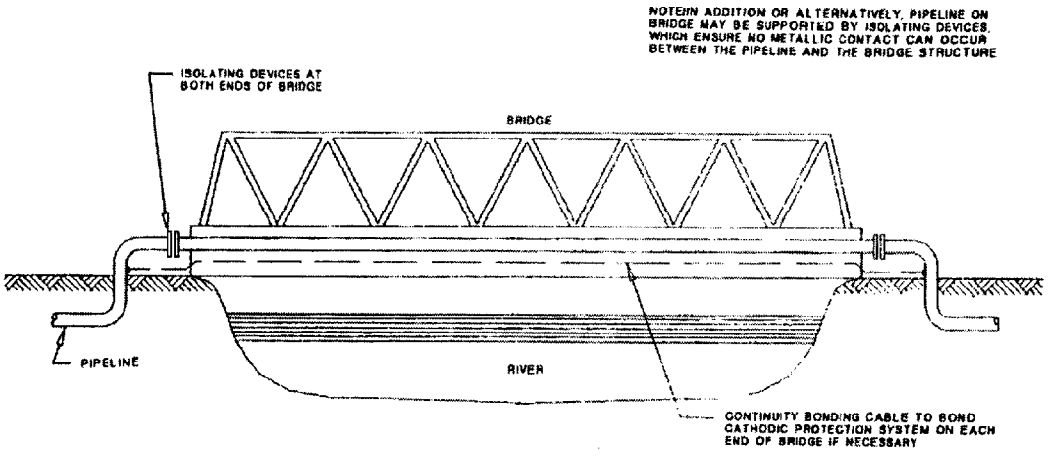

Figure 10
Typical Use of Isolating Devices at Each End of a Bridge for a Cathodically Protected Pipeline

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Section 5: Selection of Isolation Device or Method

5.1 The following factors should be carefully considered when selecting the isolating device or method to be used in any particular application.

5.1.1 Pipeline contents;

5.1.2 Pipeline temperature;

5.1.3 Pipeline pressure rating;

5.1.4 Location and orientation of isolating devices;

5.1.5 Piping configuration;

5.1.6 Isolation from foreign contact;

5.1.7 Necessity for field repair; and

5.1.8 Tensile, compression, and bending load requirements of the isolating devices;

Section 6: Equipment Specifications

6.1 This section defines the general requirements for materials for isolating devices and for the design and testing of isolating devices.

6.2 Isolating Flanges

6.2.1 Specifications - Material, design, manufacturing, testing, and marking specifications shall be agreed upon by the customer and the vendor and shall be based on recognized standards.

6.2.2 Procurement Information - The following information is normally required for purchasing:

6.2.2.1 Pipe nominal diameter and material;

6.2.2.2 Flange standard;

6.2.2.3 Pressure class;

6.2.2.4 Product carried;

6.2.2.5 Operating temperature range;

6.2.2.6 Wall thickness of pipe;

6.2.2.7 Flange dimensions, pitch circle diameter, bolt size, number of bolts, etc., if nonstandard;

6.2.2.8 Flange face details (e.g., raised or full face, ring joint);

6.2.2.9 Test requirements; and

6.2.2.10 Isolating materials.

6.2.3 Design

6.2.3.1 Gaskets may either be full face or may fit inside the bolt circle. They should be a minimum of 3.0 mm (120 mils) thick and may protrude into the bore of the pipe by 1.5 mm (60 mils) to prevent electrically conductive bridging over the isolation material. Thinner gaskets may be appropriate to reduce blowout potential.

6.2.3.2 Isolating bolt sleeves are normally designed for standard bolting in standard bolt holes and should be of sufficient length to extend halfway inside the steel washer. Care should be taken to ensure that the dimensions selected will allow the use of the standard-size bolt or one size smaller high-tensile-strength bolt.

6.2.3.3 Isolating bolt washers should be sized internally to accommodate the bolt sleeve, and the OD should be sized so that the washer will fit inside the flange spot facing.

6.2.3.4 Steel washers should be the same size as the isolating washer and should be treated to prevent corrosion.

6.2.3.5 A combined isolating sleeve/isolating washer may be used.

6.2.4 Materials

6.2.4.1 Gaskets should be manufactured from isolating material having low cold-flow characteristics, low water absorption, and high compressive strength. Preference should be given to materials with low *y* and *m* factors. The *y* factor is a measure of the compressive load required to establish an initial seal, while the *m* factor is an indication of the additional load required to hold the fluid pressure needed to keep the seal in operation. The smaller these factors are, the less pressure is required to establish and maintain the seal. (The *m* and *y* factors for various materials are included in the ASME[4]

[4] American Society of Mechanical Engineers (ASME), 345 E 47th St., New York, NY 10017-2392.

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Boiler and Pressure Vessel Code, Section 8, ANSI B16.5, and BS 1560.[9,10,11]) For pipelines carrying water or water-containing fluids, gaskets may consist of a laminate core material faced with a suitable sealing material (e.g., neoprene-faced phenolic), or with seals set into the laminate core material. For cryogenics, the core should be a suitable epoxy with either polytetrafluoroethylene (PTFE) or fluorinated ethylene propylene (FEP) seals, depending on the product and temperature. For high-pressure, high-temperature steam, gasket manufacturers should be consulted. For pipelines carrying hydrocarbons and other fluids, the gasket selected should be suitable for the particular application (product, pressure, temperature, etc.). Gaskets should have the highest compressive strength suitable for the service conditions.

6.2.4.2 Isolating bolt sleeves should be manufactured from materials having low water absorption (because of the limitations on thickness), high dielectric strength, and low cold-flow characteristics. They should be suitable for the service conditions of the particular application.

6.2.4.3 Isolating washers should be manufactured from materials having high compressive strength, low water absorption, high dielectric strength, and low cold-flow characteristics.

6.2.4.4 All materials should be selected to suit the operating conditions (product, pressure, temperature, etc.). Special consideration should be given to ensuring that the materials selected for the isolating sleeves and washers are not damaged during tightening at the time of installation.

6.2.5 Testing - The materials used should be supplied with suitable test certificates, if required, stating the compressive strength, *m* and *y* factors, temperature rating, pressure rating, water absorption, and dielectric strength.

6.3 Other Devices

6.3.1 Specifications - Material, design, manufacturing, testing, and marking generally shall be based on recognized standards.

6.3.2 Procurement Information - The following information is normally required for purchasing:

6.3.2.1 Pressure class;

6.3.2.2 Service temperature range;

6.3.2.3 Product carried;

6.3.2.4 Grade of pipe material;

6.3.2.5 Pipe dimensions;

6.3.2.6 Mandatory design standards and any unusual or high external forces (e.g., tension, bending, torsion, or thermal forces);

6.3.2.7 Internal and external coating;

6.3.2.8 Overall length of device;

6.3.2.9 Test/inspection requirements; and

6.3.2.10 Packing requirements.

6.3.3 Design

6.3.3.1 The design shall be such that under maximum working conditions, stress in any metallic part of the device shall not exceed the specified minimum yield strength of that part.

6.3.3.2 The procedures used by manufacturers in final assembly shall ensure that the joint sealing does not allow leakage and that the joint seal is not damaged during fabrication or by testing conditions. Elastomer seals shall have permanent residual elasticity to ensure leak tightness.

6.3.4 Manufacture

6.3.4.1 The manufacturer shall be responsible for the integrity of the manufacturing procedures and conformance to the specifications provided by the customer.

6.3.4.2 The following information may be required by the customer:

6.3.4.2.1 General arrangement drawing and material safety data sheets;

6.3.4.2.2 Detailed drawings showing all parts with material identification and stress/design calculations;

6.3.4.2.3 Full details of the manufacturing procedure;

6.3.4.2.4 Fabrication details including welding and inspection procedures;

6.3.4.2.5 Installation and maintenance instructions; and

6.3.4.2.6 Material and test certification, etc.

6.3.5 Testing - The acceptance criteria shall be set in accordance with the requirements of the customer and of applicable codes.

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6.3.5.1 Prototype testing should be conducted to prove the integrity of the design and manufacturing procedures; alternatively, independently witnessed test data may be satisfactory. For most applications, the following tests are conducted:

6.3.5.1.1 Hydrostatic cyclic pressure test;

6.3.5.1.2 Hydrostatic pressure plus bending test;

6.3.5.1.3 Vacuum test, where appropriate; and

6.3.5.1.4 Torsional test.

6.3.5.2 Common acceptance tests to be conducted on each device are:

6.3.5.2.1 Hydrostatic pressure test;

6.3.5.2.2 Dielectric and resistance tests; and

6.3.5.2.3 Holiday test on coatings/linings.

6.3.6 Marking - Each device may be identified using marking methods approved by the customer. The information given to identify the device could be as follows:

6.3.6.1 Purchase order number;

6.3.6.2 Joint serial number;

6.3.6.3 Manufacturer's name;

6.3.6.4 Nominal diameter;

6.3.6.5 Specification number;

6.3.6.6 Maximum design pressure;

6.3.6.7 Test pressure; and

6.3.6.8 Temperature rating.

6.4 Casing Isolator Spacers and End Seals

6.4.1 All isolating materials must be selected for the long-term retention of their compressive strength, dielectric properties, and resistance to ambient conditions. The primary function of the casing isolator is to electrically isolate and support the carrier pipe in the casing and protect the pipeline coating. The carrier pipe should be fully supported within each end of the casing and externally to the casing at either end (see Figure 9).

6.4.1.1 Specifications for the casing isolator should provide the following information:

6.4.1.1.1 Width and thickness of the casing isolator;

6.4.1.1.2 Coating specifications for metallic components;

6.4.1.1.3 Dielectric material composition, physical characteristics, and compressive strength;

6.4.1.1.4 Number and spacing of isolating segments of casing isolator;

6.4.1.1.5 Carrier pipe insulator inner liner isolating material and dimensions; and

6.4.1.1.6 Attachment hardware.

6.4.2 Procurement Information - The following information is normally required for purchasing:

6.4.2.1 Actual carrier pipe outside diameter, including coating;

6.4.2.2 Casing inside diameter;

6.4.2.3 Bell or flange diameter (if applicable);

6.4.2.4 Clearance desired between the outside diameter of the pipe, including any flange, bells, or protective coatings, and the casing inside diameter;

6.4.2.5 Position within casing (standard, centered, or restrained);

6.4.2.6 Casing length and the weight per linear meter (foot) of the carrier pipe;

6.4.2.7 Weight of the fluid/product carried, and

6.4.2.8 Operating temperatures and environment.

6.4.3 Materials

6.4.3.1 The materials selected must be compatible with the carrier pipe coating, the environment, and all operating conditions. The thickness, spacing, and components of the casing isolator should be designed to prevent contact between the carrier pipe and the casing.

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Section 7: Equipment Installation

7.1 This section discusses the procedures to be used when installing the equipment described in Section 3. The procedures are designed to ensure that:

7.1.1 A satisfactory degree of electrical isolation is achieved at the time of installation and that the joint is not damaged so as to cause an accelerated degradation rate with time;

7.1.2 The installed equipment is adequately protected against the effects of stray DC or induced AC voltages;

7.1.3 There is adequate provision for test leads to allow for field testing and maintenance (typical arrangements are shown in Figure 11); and

7.1.4 Electrical continuity is provided to all parts of bolted isolated couplings to ensure their inclusion in the cathodic protection system.

7.2 Installation

7.2.1 General - When installed, all equipment items should be properly supported and aligned so that any forces transferred from the adjoining pipe are minimized. This should be considered when equipment locations are selected. The equipment chosen must be suitable for the mechanical forces to be encountered at the selected site. Isolating devices should not be installed in gas systems at locations where the accumulation of internal moisture is likely. When feasible, the flanges and isolating devices should be assembled and tested before and after installation.

7.2.2 Monolithic Isolating Devices

7.2.2.1 Monolithic isolating devices may be supplied in a form suitable for welded, flanged, or threaded ends.

7.2.2.2 Monolithic isolating devices for welding should be ordered with the weld end preparation conforming to the main pipe-laying specifications. The manufacturer's special installation instructions must always be followed, particularly when welding joints with short overall lengths, to ensure that the heat generated does not damage the isolating materials used in the joint construction.

7.2.3 Yoke-Type Isolating Joints - These joints should be installed as described in Paragraph 7.2.1. Particular care should be taken in supporting the yoke joint and adjacent pipe to ensure that minimum strain is applied during welding and backfilling.

7.2.4 Isolating Spools (see Figure 6) - These joints must be installed as described in Paragraph 7.2.1. In the case of linings, additional care should be taken to ensure that the direction of the joint is correct. The side of the joint that has the longer length of internal lining must be attached to the protected side of the pipeline. Linings must be fused or bonded to the internal surface of the pipe.

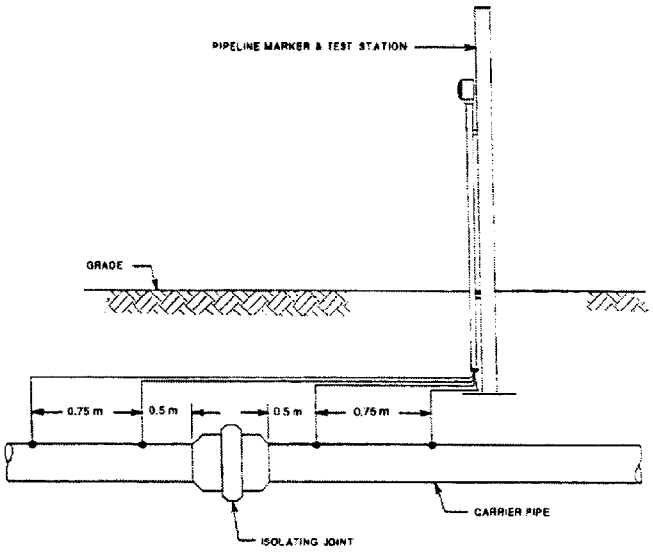

Figure 11
Isolating Joint Test Station

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7.2.5 Isolating Flange Joints

7.2.5.1 Factory Preassembled Joints - These are supplied with weld ends and should be installed as described in Paragraph 7.2.1.

7.2.5.2 Isolating Gasket Kits

7.2.5.2.1 Flanges are welded or screwed onto the pipeline, and the isolating gasket is supplied as a kit for on-site installation. Ideally, the installation should take place in clean, dry conditions. Flanges on which isolating gaskets are to be installed should be supplied as matched pairs or reamed on site to ensure correct alignment of bolt holes.

7.2.5.2.2 The flange faces should be clean and correctly aligned. Misaligned flanges will result in damage to the isolating sleeve during assembly or subsequent springing of the pipe. Flange faces should be square and free of burrs to allow for correct sealing of nuts, bolts, and washers.

7.2.5.2.3 The isolating gasket should be carefully aligned between the flange faces and the bolt holes. It may be easier to use one size smaller diameter, high-tensile-strength steel bolts, and/or special thin-walled sleeving to assist alignment.

7.2.5.2.4 Alignment pins should be inserted to ensure that flange alignment is maintained during installation of the isolating sleeves.

7.2.5.2.5 The isolating sleeves are then positioned in the correctly aligned holes. Isolating sleeves must be of the correct length. If they are too long, they may be damaged when the bolt nuts are finally tightened. If they are too short, they may fail to provide proper isolation. The length of the isolating sleeve shall normally include the two isolating washers, except where alignment allows only one flange to be isolated.

7.2.5.2.6 The bolts, complete with isolating washers adjacent to the flange and steel washers under the bolt and/or nut heads, are inserted through the sleeves and tightened by hand.

7.2.5.2.7 Final tightening to the tension recommended for the diameter and pressure rating of the flange shall be done in a sequence that provides for equal tension without distortion.

7.2.5.2.8 The original alignment pins may then be removed and bolts installed, complete with sleeves and washers as described above.

7.2.5.2.9 Before measures are taken to protect against the ingress of moisture, the effectiveness of the isolation achieved should be checked using appropriate methods.

7.2.5.3 Protection Against Ingress of External Moisture - The materials used for the isolating sleeves, washers, and gaskets may absorb water, and the construction of the joint may allow for moisture ingress, both of which reduce the electrical resistance of the assembly. Therefore, providing a protective coating is essential. A suitable material may be applied to fill in the crevices and gaps between flange faces and mold around the flange faces in underground installations. In this way, a smooth profile is achieved that may be coated or wrapped to the same standard as the pipeline, together with the adjacent pipe work.

7.2.6 Pipeline Casing Isolators

7.2.6.1 Pipeline casing isolators must be installed in accordance with the manufacturer's instructions. Special care should be taken to ensure that all subcomponents are correctly assembled and tightened and that no damage occurs during insertion of the carrier pipe.

7.2.6.2 The annulus between the carrier pipe and the casing should be sealed at each end of the casing to prevent electrolyte, debris, and the surrounding soil from entering the casing.

7.2.6.3 There must be no metallic contact between the casing and the carrier pipe. The spacing of isolators should ensure that the carrier pipe is adequately supported throughout its length, particularly at the ends, to prevent settling and possible shorting.

7.2.7 Pipeline Support Isolators - Care should be taken to ensure that isolating materials used in isolating supports are adequately secured so as to eliminate the possibility of dislodging, which would render the isolation ineffective.

7.3 High-Voltage Protection

7.3.1 Isolating devices and supports should be protected against damage from high-voltage surges. These surges may be caused by lightning, induced AC from adjacent or overhead high-voltage cables, fault conditions, power pipeline conditions, or switching surges (see NACE Standard RP0177[3]). If

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isolating joints exist in these corridors and must be maintained for cathodic protection design reasons, then they must be made conductive to AC currents by the use of capacitors, polarization cells, or any equivalent solid-state product. (See EPRI[5] Report EL 904 for more information.[12]) Protective devices (surge suppressors, lightning arresters, etc.) are usually designed for a specific purpose. Protective equipment must be selected and used in accordance with the intended purpose, following all manufacturer's specifications.

7.3.2 High-voltage surges may permanently damage the isolating materials used in the joint construction.

7.3.3 Isolating devices and supports may be protected with lightning arresters, electrolytic grounding cells, polarization cells, equivalent solid-state products, or combinations of these.

7.3.4 Electrical surges and fault currents of all types are potentially hazardous. Pipelines equipped with isolating devices may be protected from stray-current hazards originating from electrical power supplies through the use of grounding media and/or isolation protection equipment. Grounding media that should be considered for the discharge of induced AC, lightning, and fault current from a pipeline to earth include packaged galvanic anodes of magnesium or zinc and extruded ribbon of magnesium or zinc, with or without backfill. Electrically isolated bare steel pipeline casing, grounding grids, and ground rods should also be considered suitable grounds but must be separated from the cathodically protected pipeline by capacitors, zinc grounding cells, polarization cells, or equivalent solid-state products.

7.3.5 The manufacturer's instructions must be followed strictly when installing protective devices. In particular, the devices shall be physically secured and the connection cables properly sized.

7.3.6 The threshold rating of the protective device must be such that, even allowing for tolerances, the potential applied across the isolating device is below the device's minimum dielectric strength.

7.3.7 Lightning arresters and other protective devices shall be located to prevent the collection of dirt and moisture, which could lead to an external flashover at a relatively low surge voltage. Applicable electrical codes shall be consulted. To prevent incendiary spark hazards at fuel-transfer facilities, electrical isolation shall be avoided in areas where a combustible atmosphere may exist.

7.4 Provision for Field Testing

7.4.1 Methods of testing the effectiveness of the electrical isolation are described in Section 8. The following paragraphs describe the provision of test leads to facilitate these measurements. Test leads on buried devices should be attached on both sides of any isolating device and on the carrier pipe and casing of sleeved systems.

7.4.2 Attachment of Test Cables

7.4.2.1 Test leads on buried isolating devices shall be installed in accordance with NACE Standard RP0169, Paragraphs 4.5 and 8.6.[1]

7.4.2.2 Care should be taken when attaching test leads to prevent damage to the internal coating or lining by excessive heat.

7.4.3 Cable Type

7.4.3.1 The cable cross section and type of sheath insulation must be selected to take into account the location and expected (or future) current to be carried. Cables should be labeled for permanent identification.

Section 8: Field Testing and Maintenance

8.1 This section deals with the testing and maintenance of electrical isolation facilities. In testing the effectiveness of isolating devices installed on buried piping systems, the effect of pipe grounding and other equivalent electrical parallel circuit conditions that may exist must be considered. Conventional ohmic resistance measurements, as applied to the total isolating device, are not conclusive under field conditions. However, ohmic resistance measurements may have validity in checking individual components of an isolating device.

8.2 Field Testing

8.2.1 Several tests may be used to determine the effectiveness of an isolating device, depending on the following:

8.2.1.1 The experience and training of the staff conducting the tests;

8.2.1.2 The environment and location of the device; and

[5] Electric Power Research Institute (EPRI), P.O. Box 10412, Palo Alto, CA 94303.

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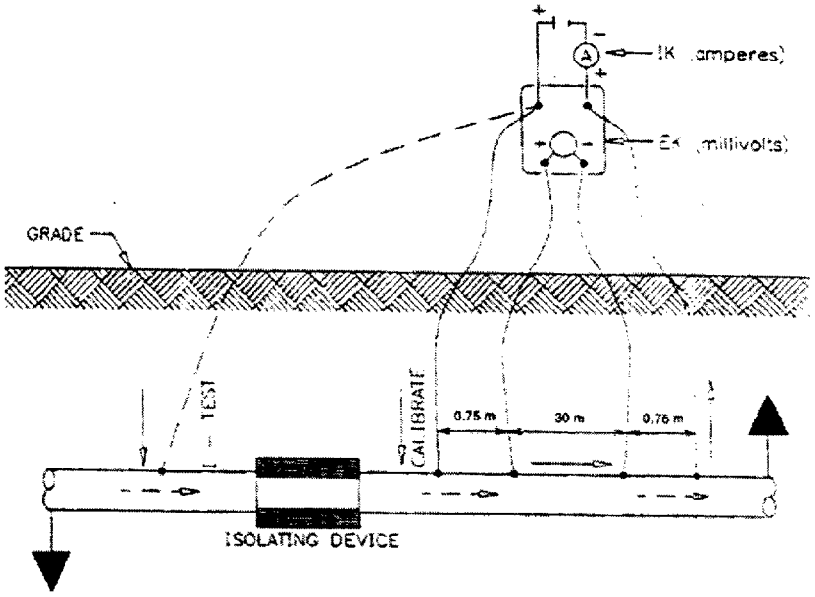
8.2.1.3 The local potential and magnitude of any cathodic or anodic electrical currents.

8.2.2 If the isolating device is installed and connected on both sides, a test may be conducted in which current is applied to the pipe on one side of the assembly and effectiveness is judged by the resulting difference in pipe-to-soil potentials measured on both sides of the device.

8.2.3 Where desired, a test can be conducted to obtain the percent of leakage at an isolating device (see Figure 12). However, if the isolating device is located adjacent to a section of above-grade piping, a voltage-drop measurement can be readily taken to determine isolating effectiveness.

8.2.4 Where the isolating device incorporates bolts that require full isolation from all other metal work (e.g., bolts used in an isolated flanged joint where an isolating washer is used beneath each bolt head or nut), it may be possible to check for proper isolation of each bolt. This check has considerable validity because bolt isolation is normally the part of the assembly that is most susceptible to failure. The test should be conducted by using an ohmmeter or other device to prove isolation between each bolt or stud and the metal against which it is to be isolated.

8.2.5 For cathodically protected pipelines, a good indication of performance may be the change in protection level adjacent to the isolating device that occurs when the isolating device is deliberately shorted. The results from such a test depend on the resistance to earth of the unprotected structure from which the protected pipeline is isolated. Where this resistance to earth is very low, a significant reduction in the level of protection may be expected.



1. Calculate the calibration factor: $K = \Delta IK/\Delta EK$ = Amps/mV

2. Calculate the percentage leakage: $\%\ \text{leakage} = \dfrac{K \times E(\text{test}) \times 100}{I(\text{test})}$

Example: Given the following data:

Calibration: IK = +6.42 Amps
EK = +3.55 mV

Test: Itest = +1.61 Amps
Etest = +.14 mV

Calculate:

$$K = \frac{6.42 \text{ Amps}}{3.55 \text{ mV}} = 1.81 \text{ A/mV}$$

$$\%\ \text{Leakage} = \frac{K \times \text{Etest} \times 100}{\text{Itest}} = \frac{1.81 \text{ A/mV} \times .14 \text{ mV} \times 100}{1.61 \text{ Amps}} = 15.7\%$$

Figure 12
Isolating Device Leakage Test

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8.2.6 Audio-frequency pipe locators may indicate the effectiveness of isolating devices.

8.2.7 Radio-frequency meters may also indicate the effectiveness of isolating devices.

8.2.8 A magnetometer system may be used for testing the effectiveness of isolating devices.

8.3 Isolating Devices in Parallel - Where a number of isolating devices are installed in parallel (e.g., several flanged joints at a manifold), IR drops or current measurements in each line may be the only method of proving effectiveness of an individual device. Techniques that measure magnetic fields in the flange area may also serve as an indication of the device's effectiveness. The use of audio-frequency and radio-frequency instruments may indicate the comparative effectiveness of each individual device.

8.4 Maintenance

8.4.1 Test stations and test wires attached at isolating devices should be subject to a regular maintenance program. Figure 11 shows the typical configuration of test stations.

8.4.2 Isolating devices that are aboveground and open to the weather should be inspected periodically and cleared of accumulated debris, which could bridge isolating material. Any protective barrier coatings provided to prevent water absorption by isolating materials should be kept in good condition. Paints, thermal barriers, and tracers and reinforcements with a metallic content such as aluminum or zinc should not be used as barrier coatings.

8.4.3 When the effectiveness of isolating devices is tested on site, the effectiveness of any high-voltage protection device should also be checked.

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Preface

Changes to the *National Electrical Code* affect all industries. As publisher of the code, NFPA is in a unique position to help users get up to speed on the new edition. To that end, we developed this guide to the major changes in the 1999 NEC. Our goal in developing this guide was to provide education for those whose success depends on their accurate and timely implementation of code requirements.

This changes guide brings a wealth of information together in one resource. The actual language of the code is provided, with changes highlighted. For easy cross-referencing, the relevant code page numbers are provided as well. The combination of five authors (representing over a century of code experience) results in a well-balanced perspective on the impact and application of code changes. For a complete guide to the features of this book, refer to the chart on pages viii and ix.

The criteria for selecting which changes to cover were considered carefully. The authors selected changes generated by new technologies; those with a major impact on the electrical industry; significant revisions to commonly used requirements; and those with widespread application. In addition, three broad areas of installation—residential, industrial, and commercial—were targeted. Even if a specific change does not apply directly to a code user's situation, the discussion of it should be productive.

The question "Who writes the code?" is frequently asked. The safety mission of the NEC impacts millions of people and the document is used on a daily basis by a myriad of electrical professionals including engineers, designers, manufacturers, electricians, and inspectors. These are the people who write the code. Like all of the NFPA codes and standards, the NEC is produced through a consensus standards-making process that is open to all persons who use and are impacted by the document. Beginning as proposals, new requirements make their way through a system that provides for periods of public review, technical committee review and actions, voting by the association membership, and finally issuance by the NFPA Standards Council. The National Electrical Code Committee is composed of approximately four hundred volunteers serving on twenty code-making panels and a technical correlating committee. These volunteers bring expertise from all facets of the electrical industry and the system is structured so that a balance of industry representation is provided on every panel.

Within the code text portions of this changes book, references are made to ROP, ROC, and TCC. These acronyms represent Report on Proposals, Report on Comments, and Technical Correlating Committee. The reports contain the proposals or comments, respectively, the Code Making Panel action(s), and any actions by the Technical Correlating Committee. We have provided these references as an invitation to readers to learn more about the code-making process by actually tracing the steps of a proposal that makes its way through the system and

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ultimately becomes a part of the 1999 NEC. The documents are available in hard copy and also at the NFPA homepage. All proposals for change are required to be provided with the technical substantiation. The quality of the NEC represents hours of intensive work by the hundreds of volunteers and NFPA staff with one goal in mind: "The practical safeguarding of persons and property from hazards arising from the use of electricity." Information on the NFPA codes and standards-making process is available at the NFPA homepage at www.nfpa.org or by contacting us at 1-617-770-3000.

We hope that the users of this book will find it a helpful productivity tool. We welcome comments and suggestions and wish you well with your use of the 1999 NEC.

ACKNOWLEDGMENTS

Many individuals contributed to the success of this project. A special thanks is given to former NFPA Chief Electrical Engineer Tim Croushore and the present members of the NFPA electrical staff.

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NEC® *Changes*

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1999

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A Guide to Using This Book

Subject covered in the NEC section under discussion. These topics are listed in the table of contents for quick access by the user.

The pages on which the code text appears in the 1999 NEC.

What happened to the code:
- *Relocation* means that the technical content did not change significantly, but the material was moved.
- *Revision* means that the requirements changed.
- *New* means that new requirements or clarification of requirements were added.

NEC section where this change occurred, numbered according to the 1999 edition. This book is arranged in 1999 NEC numerical sequence.

Information in the shaded box at the beginning of each change allows the user to navigate quickly through the new code.

NEC p. 88

250-50 Number of Grounding Electrodes Required

Type of Change Revision

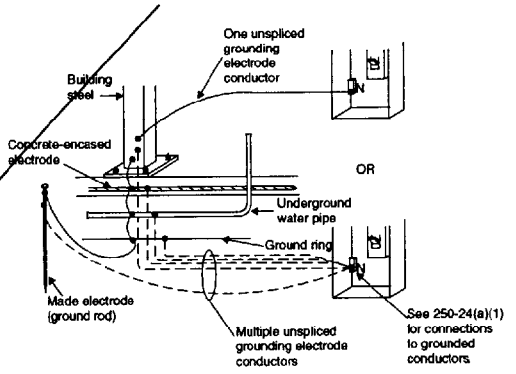
BRIEF SUMMARY

All installations. One or more grounding electrode conductors are permitted.

Code Language

250-50. Grounding Electrode System. If available on the premises at each building or structure served, each item (a) through (d), and any made electrodes in accordance with Sections 250-52(b), (c), and (d), shall be bonded together to form the grounding electrode system. The bonding jumper(s) shall be installed in accordance with Sections 250-64(a), (b), and (c) shall be sized in accordance with Section 250-66, and shall be connected in the manner specified in Section 250-70. (ROP 5-224a, 5-225) (ROC 5-100)

An unspliced grounding electrode conductor shall be permitted to be run to any convenient grounding electrode available in the grounding electrode system **or to one or more grounding electrode(s) individually.** It shall be sized for the largest grounding electrode conductor required among all the electrodes connected to it. (ROP 5-227)



Grounding Electrode Conductors

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Users will find two important pieces of information at a glance:
- The installations or occupancies affected by the change (e.g., commercial, residential, industrial, health care).
- A short description of the impact of the change—the bottom line. This allows users to quickly assess whether the change is important to them.

The new requirements as they appear in the 1999 NEC. New text is indicated by **boldface** type; deleted text is indicated by strikethrough type. When a long section of text has been completely rewritten, the user is referred to a chart or table diagramming changes.

ROP, ROC, TCC. Those who wish to trace the history of a change can use this information. For an explanation of the NEC code-making process, see the preface to this book.

Each change has been illustrated by an electrical draftsman.

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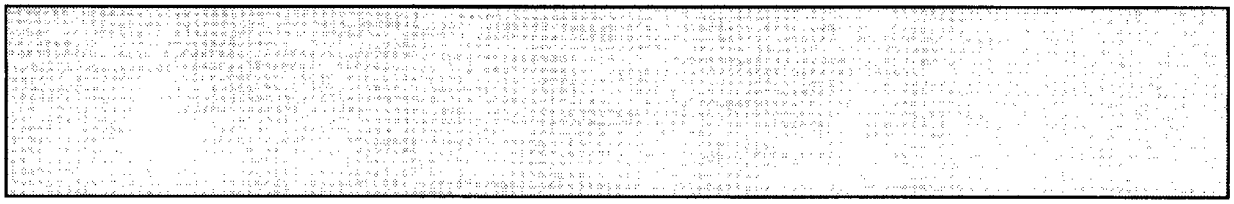

Wide margins provide a space for notes and bookmarks.

How do you apply this change in real life? The Application section discusses on-the-job situations in which the change is important. Whether you need to solve an actual installation problem or just need to know where the change might be important, turn to this section. Together with the illustration, it will show how to put code changes into effect.

The Background and Explanation text expands on the brief summary given above. This section includes:

- The NEC committee rationale for making the change
- The basic logic behind the change
- A problem that the change will fix
- Relevant technical information
- Cross-reference to other relevant code sections
- Historical perspective on the change

As publisher of the code, NFPA is the best source for the most accurate and timely information on the code changes.

Spiral binding allows the book to lie flat or fold to consume less space.

Application

The illustration shows a collection of the grounding electrodes listed in Sections 250-50(a) through (d) and 250-52. The solid lines indicate a single unspliced grounding electrode conductor run to one of the electrodes, in this case the building steel. The other electrodes are bonded together to form the grounding electrode system. The single grounding electrode conductor must be full sized according to Section 250-66. The bonding conductors can be sized on the basis of the electrodes they connect to. For instance, the bonding conductor between the ground ring and the ground rod would not have to be larger than No. 6 copper.

The dashed lines in the illustration show an alternative way of running grounding electrode conductors and bonding the electrodes together. Separate grounding electrode conductors may be run to each electrode. In this case, the grounding electrodes are bonded together in the service equipment. The individual conductors may be sized on the basis of the phase conductors and the electrodes they connect to. For example, the conductors to the water pipe and the building steel would have to be sized from Table 250-66, but the conductors to the ground rod, ground ring, and concrete-encased electrode are permitted to be smaller in accordance with Section 250-66(a), (b), or (c).

The illustration shows two extremes: one grounding electrode conductor; or one grounding electrode conductor for each electrode. The electrodes could also be grouped. For example, one conductor could be run to the ground ring and ground rod and sized for the ground ring. Another conductor could be run to the building steel, water pipe, and concrete-encased electrode and sized for the water pipe or building steel.

Background and Explanation

This change is intended to be a clarification. No technical requirement was actually modified by this change. However, some authorities interpreted the previous language (this was in Section 250-81 in the 1996 NEC) to require a single grounding electrode conductor. Others interpreted the previous language to mean that only one grounding electrode conductor had to be unspliced and the others were really just bonding conductors. This change should help to make interpretations more uniform. With this change it should be clear that each grounding electrode conductor must be run unspliced to an electrode, and there can be more than one. Note that the main difference between the alternatives in the illustration is the location of the bonding point between electrodes at the service equipment or at each electrode.

NFPA's 1999 NEC Changes 143

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About the Authors

The authors of NFPA's *1999 NEC Changes* provide an insider's perspective to interpreting and applying key changes to the *National Electrical Code*. As members of various NEC committees and state electricians licensing boards, the contributors to this book are nationally recognized experts in the field of electrical safety and on the *National Electrical Code* itself. Their backgrounds include engineering, electrical contracting, system design, and inspecting electrical installations. All five authors are instructors for NFPA's NEC seminars, publish interpretive and explanatory material on the NEC, and are closely involved with the NEC development process.

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Article 100 Definition of Receptacle

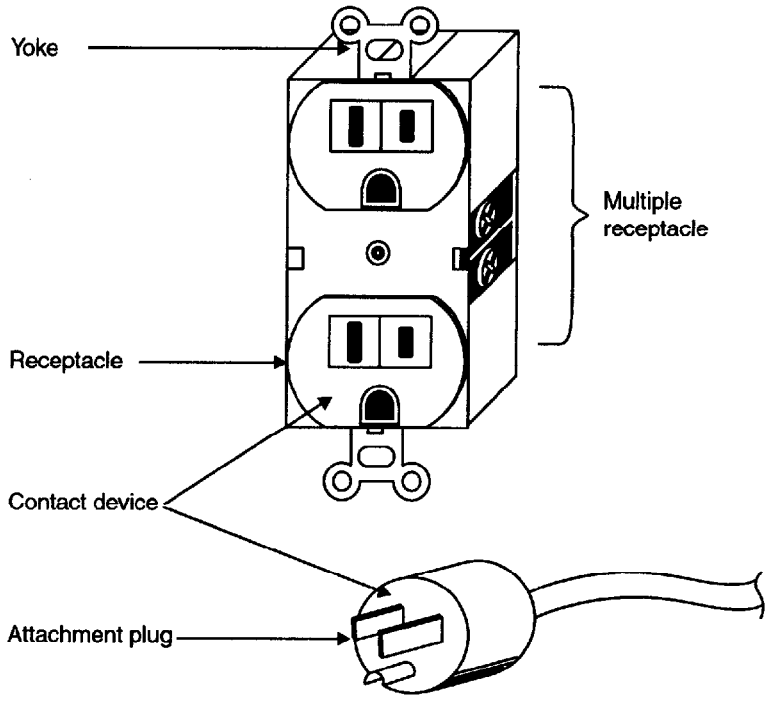
Type of Change Revision

BRIEF SUMMARY

All installations. The definitions of "receptacle" and "multiple receptacle" are revised.

Code Language

Receptacle. A receptacle is a contact device installed at the outlet for the connection of ~~a single contact device~~ **an attachment plug.** A single receptacle is a single contact device with no other contact device on the same yoke. A multiple receptacle is **two or more contact devices on the same yoke.** (ROP 1-127) (ROC 1-197)



Definition of Receptacle

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Application

The term "receptacle" is used throughout the code. Although "multiple receptacle" is used less frequently, clear definitions of both terms are necessary for proper interpretation and use of the code. The accompanying illustration shows the components of a multiple receptacle and illustrates the terms used in the definition.

Background and Explanation

The use of the term "contact device" twice in the first sentence could be confusing and did not properly distinguish between receptacles and attachment plugs, both of which are contact devices.

In the 1993 NEC, the last two sentences of this definition were a Fine Print Note (FPN). The FPN was converted to mandatory language by making it part of the definition in the 1996 NEC. This created some conflicts with uses of the terms "device," "equipment," and "multiple receptacle" elsewhere in the code. The substantiation for this change specifically mentioned Section 210-4(b), where a multiple receptacle is included in the description "more than one device or equipment on the same yoke." The revised definition explains that a multiple receptacle is more than one device but is a single piece of equipment.

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Article 100 Definition of Service Conductors

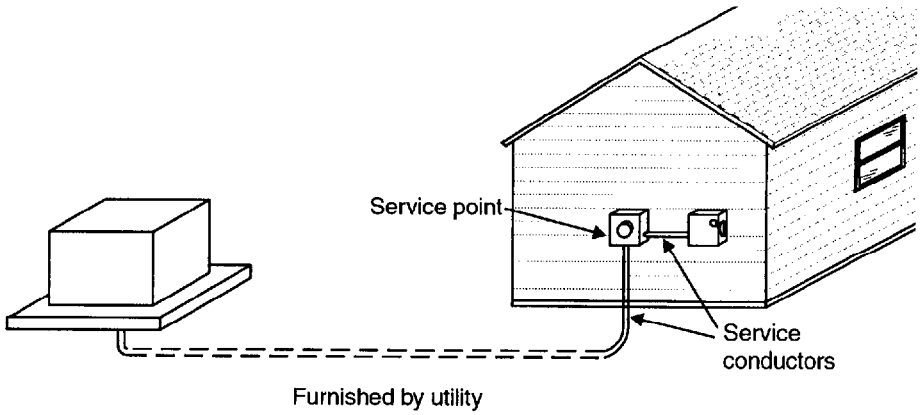
Type of Change Revision

BRIEF SUMMARY

All occupancies. This change clarifies where conductors are to be classified as service conductors.

Code Language

Service Conductors. The conductors from the service point ~~or other source of power~~ to the service disconnecting means. (ROP 1-134)



Definition of Service Conductors

Application

Conductors that supply power to a structure are classified as service conductors only when they are connected to a utility system. The term "service point" as used in this definition is also a defined term in Article 100. Service point is the point of connection between the facilities of the servicing utility and the premises wiring system. Where a building or structure is supplied by a customer-owned transformer, the supply is not a service and therefore is not covered by the requirements of Article 230. Such supply systems are feeders, taps, or transformer secondaries and are covered by Articles 215, 225, and 240.

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Background and Explanation

The 1996 definition included the phrase "other sources of power," which could be interpreted as including feeders, taps, and transformer secondary conductors supplied by customer-owned power sources. These supply systems are covered within other code articles and the requirements for services and service conductors (including service grounding requirements) are not applicable.

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110-10 Fault Current Ratings—Listed Equipment

Type of Change Revision

BRIEF SUMMARY

All installations. A new sentence has been added to this section to indicate that listed equipment is understood to comply with Section 110-10.

Code Language

110-10. Circuit Impedance and Other Characteristics.

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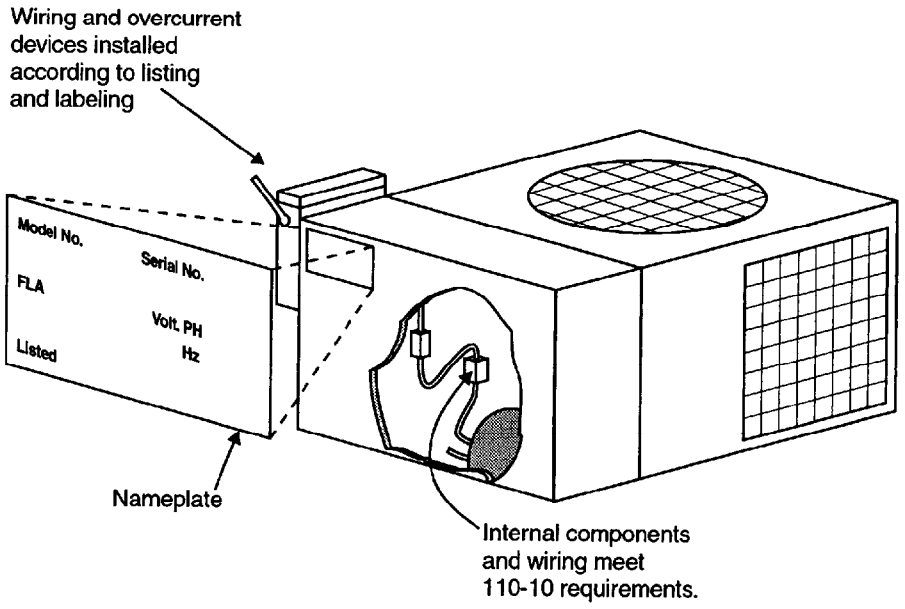
Listed products applied in accordance with their listing shall be considered to meet the requirements of this section. (ROP 1-176, 1-177, 1-178, TCC)



Listed Packaged A/C Unit

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Application

Most installations involve some listed equipment. Section 110-10 requires that the components of a circuit, especially the characteristics of overcurrent devices, be selected so that a fault can be cleared without extensive damage to the components of the circuit. If listed products are "applied in accordance with their listing," they need not be further investigated in the field for compliance with Section 110-10.

The illustration shows an air conditioning unit. The unit is listed and includes instructions for selection of overcurrent devices and conductors. If the listing and labeling instructions are complied with in the installation, the authority having jurisdiction can be assured that the internal wiring and components will be protected from the "extensive damage" mentioned in this section.

Background and Explanation

Without the new last sentence in this section, some inspectors were attempting to determine what was meant by extensive damage with regard to specific products. In many cases they applied their own definitions to equipment where the definition was already covered in product standards. The listing of a piece of equipment includes the evaluation of damage that may occur to the equipment in the event of a fault. Different types of equipment have different levels of damage that is considered "acceptable." Fires external to the equipment and shock hazards produced by faulted equipment are primary indicators of extensive damage. The evaluation of these factors is generally performed by qualified testing laboratories rather than by field inspectors.

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110-14(c) Converting Exceptions and Terminal Temperature Limits—Motors

Type of Change Revision

BRIEF SUMMARY

All occupancies. The exceptions to the rules for selecting conductor ampacity based on the temperature rating of the equipment terminals have been converted to positive code text. New rules have been added for motor circuit conductors.

Code Language

110-14. Electrical Connections.

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(c) Temperature Limitations. The temperature rating associated with the ampacity of a conductor shall be selected and coordinated so as not to exceed the lowest temperature rating of any connected termination, conductor, or device. Conductors with temperature ratings higher than specified for terminations shall be permitted to be used for ampacity adjustment, correction, or both.

(1) Termination provisions of equipment for circuits rated 100 amperes or less, or marked for Nos. 14 through 1 conductors, shall be used only for one of the following:

(a) Conductors rated 60°C (140°F), or

(b) Conductors with higher temperature ratings, provided the ampacity of such conductors is determined based on the 60°C (140°F) ampacity of the conductor size used, or (ROP 1-196a) (ROC 1-243, 1-248)

(c) Conductors with higher temperature ratings if the equipment is listed and identified for use with such conductors, or (ROC 1-243, 1-248)

(d) For motors marked with design letters B, C, D, or E, conductors having an insulation rating of 75°C (167°F) or higher shall be permitted to be used provided the ampacity of such conductors does not exceed the 75°C (167°F) ampacity. (ROC 1-248)

(2) Termination provisions of equipment for circuits rated over 100 amperes, or marked for conductors larger than No. 1, shall be used only for

(a) Conductors rated 75°C (167°F), or

(b) Conductors with higher temperature ratings provided the ampacity of such conductors does not exceed the 75°C (167°F) ampacity of the conductor size used, or up to their ampacity if the equipment is listed and identified for use with such conductors. (ROP 1-199a) (ROC 1-250)

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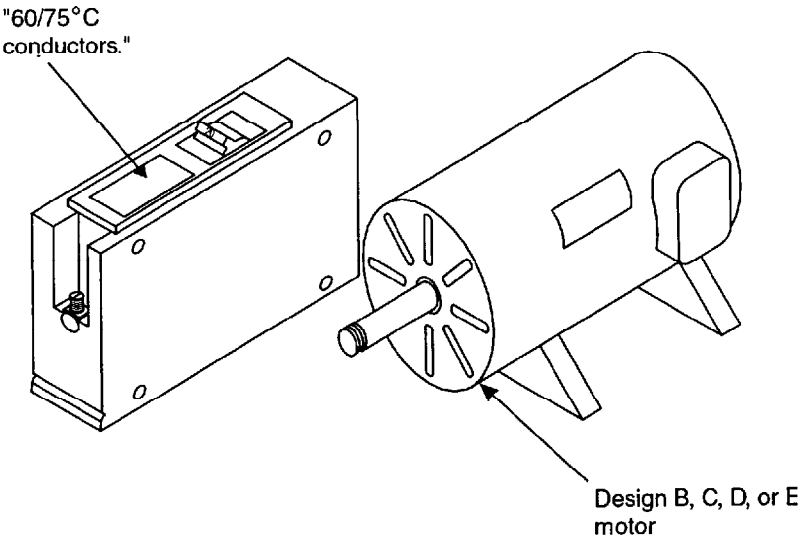

75°C Ampacities Permitted for Motor Circuits

Application

Where equipment terminals are rated 100 amperes or less or are marked for use with No. 14 through No. 1 conductors, the basic rule is that only 60°C rated conductors can be used. For terminals rated over 100A amperes or marked for conductors larger that No. 1, only 75°C conductors can be used.

In both cases conductors with higher temperature ratings can be used provided the conductor ampacity is selected based on the insulation rating corresponding to the rating of the terminals on the equipment. Higher conductor ratings may also be used if the equipment is listed and identified for use with the higher temperature ratings and corresponding increase in ampacity.

New language has been included in this section that provides guidance for selecting conductor temperature ratings and ampacities where they are directly connected to electric motors. Most motors are manufactured in accordance with the NEMA motor/generator standard and are generally not required to be listed. In previous editions of the code, the use of 75°C conductors for motors rated 100 amperes or less or connected with No. 14 through No. 1 conductors was permitted; however, the ampacity selection had to be made from the 60°C column. This section now specifically permits the use of 75°C conductors at the 75°C ampacity for motors marked with a design letter of B, C, D, or E. The terminals of the equipment from which the conductors to the motor receive their supply must be listed for use with the higher rated conductor.

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Background and Explanation

Section 110-14(c) is an example of a significant format change that is found in many sections of the 1999 NEC. Throughout the 1999 NEC, users of the document will find that material formerly expressed within exceptions is integrated into the main code language. Many of these changes were made because the language of the exception presented a mandatory rule. This revision to the exceptions was undertaken as part of the effort to enhance the usablity of the revision to the exceptions was undertaken as part of the effort to enhancethe usabilty of the NEC. Specific language has been added to clarify the temperature selection requirements for conductors directly connected to a motor.

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110-26 Locked Equipment Enclosures

Type of Change Revision

BRIEF SUMMARY

All installations. Equipment behind locked doors or in locked enclosures are considered to be accessible to qualified persons.

Code Language

110-26. Spaces About Electrical Equipment.

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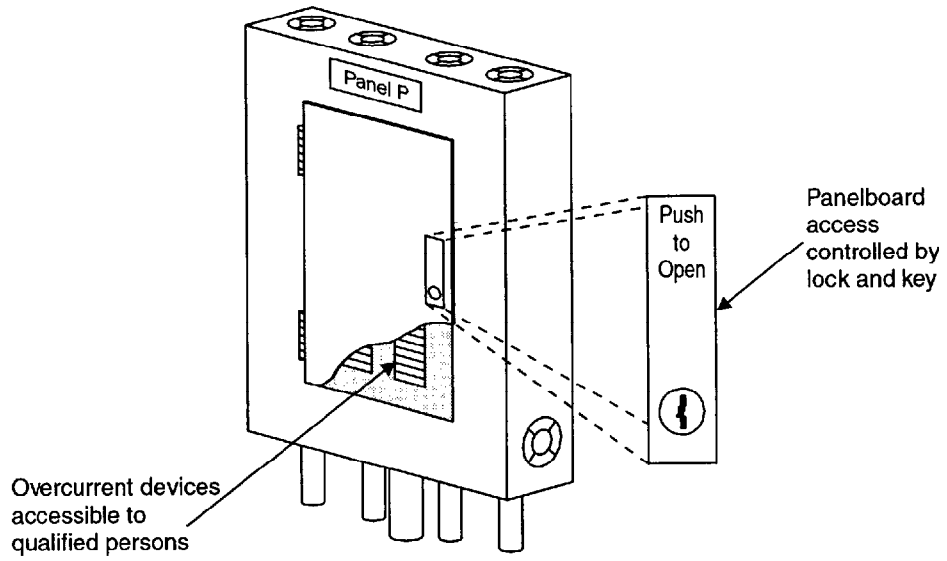
Enclosures housing electrical apparatus that are controlled by lock and key shall be considered accessible to qualified persons. (ROP 1-260, 1-225) (ROC 1-253, 1-294)



Locked Enclosures

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Application

Article 100 reads as follows: "Accessible: (as applied to equipment) Admitting close approach: not guarded by locked doors, elevation, or other effective means." This has often been interpreted as meaning that panelboards and similar equipment cannot be located behind locked doors or have locked doors. The new second sentence in Section 110-26 makes it clear that such installations are considered to be accessible to qualified persons. The obvious assumption is that qualified persons will have appropriate keys.

The illustration shows a panelboard access controlled by lock and key. The overcurrent devices inside the enclosure are considered to be accessible to qualified persons. The panelboard could also be installed behind a locked equipment room door and still be considered readily accessible.

Background and Explanation

A similar statement already existed in Section 110-31, but that section only covers installations over 600 volts. This new wording was added to cover installations for equipment of 600 volts or less. Inspectors have previously had to read between the lines to find this permission. Often they resorted to combining the definition of "accessible" as applied to equipment with the definition of "accessible, readily." Equipment that is readily accessible must be "Capable of being reached quickly . . ." by persons ". . . to whom ready access is requisite. . ." without having to remove obstacles. If the person to whom access is requisite has a key, then a locked door does not create an obstacle to quickly reaching the equipment.

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110-26(a) Equipment Extensions into Work Space

Type of Change Revision

BRIEF SUMMARY

All occupancies. The dimensions of the work space required in front of electrical equipment are clarified.

Code Language

110-26. Spaces About Electrical Equipment.

(a) Working Space. Working space for equipment operating at 600 volts, nominal, or less to ground and likely to require examination, adjustment, servicing, or maintenance while energized shall **comply with the dimensions of (1), (2), and (3)** or as required or permitted elsewhere in this *Code*. (ROP 1-225) (ROC 1-259)

(1) Depth of Working Space. The depth of the working space in the direction of access to live parts shall not be less than indicated in Table 110-26(a). Distances shall be measured from the live parts if such are exposed or from the enclosure front or opening if such are enclosed. (ROP 1-225)

(2) Width of Working Space. The width of the working space in front of the electric equipment shall be **the width of the equipment or** 30 in. (762 mm), **whichever is greater.** In all cases, the work space shall permit at least a 90 degree opening of equipment doors or hinged panels. (ROP 1-225)

(3) Height of Working Space. The work space shall be clear and extend from the grade, floor, or platform to the height required by Section 110-26(e). Within the height requirements of this section, **other equipment associated with the electrical installation located above or below the electrical equipment shall be permitted to extend not more than 6 in. (153 mm) beyond the front of the electrical equipment.** (ROP 1-214, 1-225)

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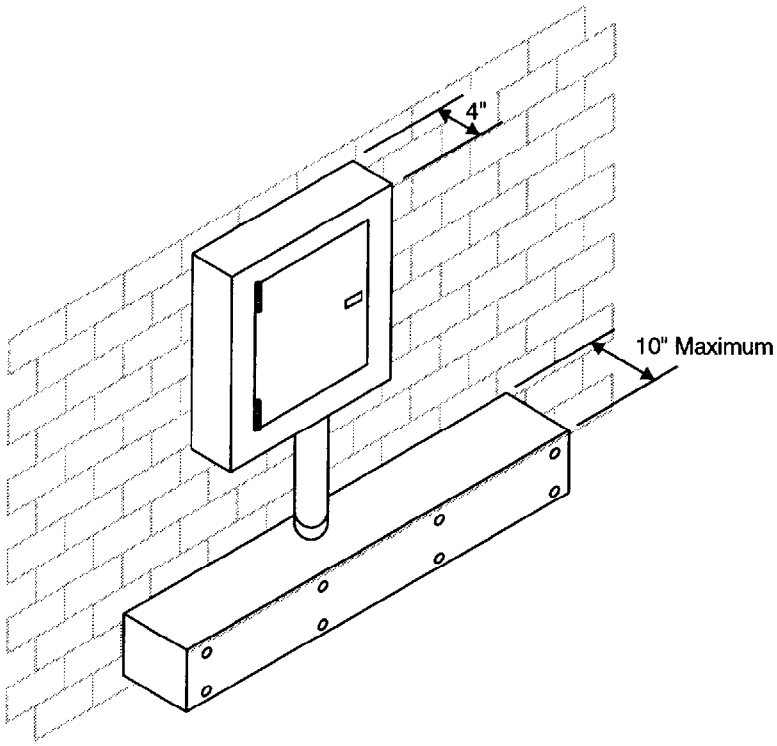

Associated Equipment Permitted to Extend ≤ 6 Inches into Work Space

Application

Where electrical equipment such as a wireway or auxiliary gutter is installed above or below equipment such as a panelboard, it is usually deeper than the panelboard cabinet. The revised wording in Section 110-26(a)(3) allows such equipment to extend up to 6 inches further into the work space required in front of the panelboard.

Revised wording of Section 110-26(a)(2) makes it clear that the minimum width of the work space is 30 inches. If the equipment is wider than 30 inches, the minimum width is based on the actual width of the equipment.

Background and Explanation

The wording contained in this section of the 1996 NEC indicated that other equipment (including electrical equipment) could not extend into the working space required in front of a specific piece of electrical equipment that is likely to be worked on while energized. The intent of the requirement was to preclude the installation of equipment, such as a large transformer, in the working space required for other electrical equipment, such as a panelboard. This type of installation impeded proper access and created an unsafe condition for personnel working on energized equipment. Small equipment that extends a few inches into the work space does not create the same hazard.

Other revisions were made in this section to make the rules easier to understand. In the 1996 edition both depth and width were covered in Section 110-16(a). There were 3 exceptions, all relating to depth. The revision divided this section into 110-26(a)(1) depth with 3 exceptions, (2) width, and (3) height.

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110-26(f) Panelboard and Switchboard Space

Type of Change Relocation

BRIEF SUMMARY

All installations. The rules for dedicated spaces around switchboards and panelboards was moved from Section 384-4.

Code Language

110-26. Spaces About Electrical Equipment.

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(f) Dedicated Equipment Space. Equipment within the scope of Article 384, and motor control centers, shall be located in dedicated spaces and protected from damage as covered in (1) and (2). (ROP 1-260)

Exception: Control equipment that by its very nature or because of other rules of the Code must be adjacent to or within sight of its operating machinery shall be permitted in those locations.

(1) Indoor. ***For indoor installations, the dedicated space shall comply with the following.***

(a) Dedicated Electrical Space. The space equal to the width and depth of the equipment and extending from the floor to a height of 6 ft (1.83 m) above the equipment or to the structural ceiling, whichever is lower, shall be dedicated to the electrical installation. No piping, ducts, or equipment foreign to the electrical installation shall be located in this zone.

Exception: Equipment that is isolated from the foreign equipment by height or physical enclosures or covers that will afford adequate mechanical protection from vehicular traffic or accidental contact by unauthorized personnel or that complies with b., shall be permitted in areas that do not have the dedicated space described in this rule.

(b) Foreign Systems. The space equal to the width and depth of the equipment shall be kept clear of foreign systems unless protection is provided to avoid damage from condensation, leaks, or breaks in such foreign systems. This zone shall extend from the top of the electrical equipment to the structural ceiling.

(c) Sprinkler Protection. Sprinkler protection shall be permitted for the dedicated space where the piping complies with this section.

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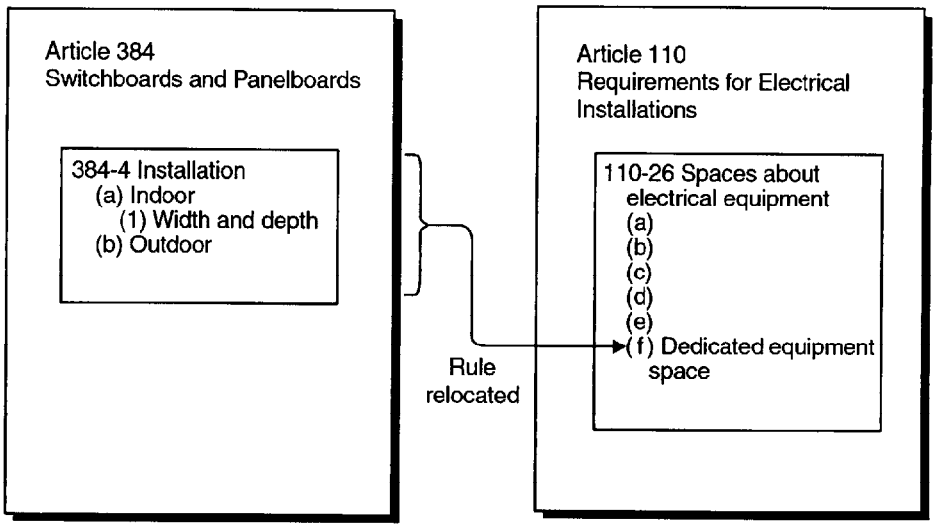
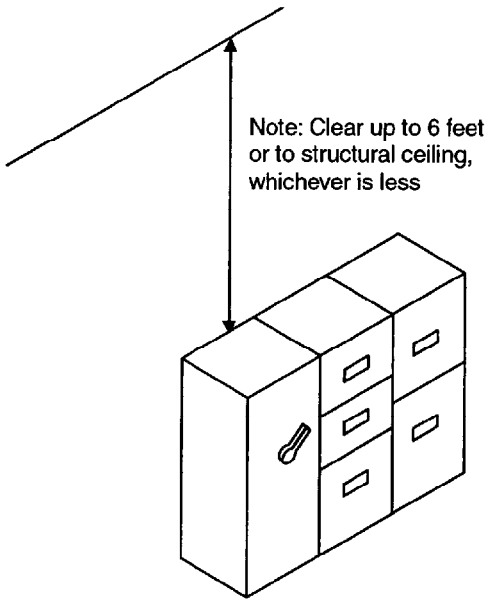
(d) Suspended Ceilings. A dropped, suspended, or similar ceiling that does not add strength to the building structure shall not be considered a structural ceiling. (ROC 9-76) (TCC 9-76)

(2) Outdoor. Outdoor electrical equipment shall be installed in suitable enclosures and shall be protected from accidental contact by unauthorized personnel, or by vehicular traffic, or by accidental spillage or leakage from piping systems. The working clearance space shall include the zone described in Section 110-26(a). No architectural appurtenance or other equipment shall be located in this zone. (ROP 1-260)



Dedicated Space for Panelboards



Required Clear Space Above Switchboards and Panelboards

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Application

The rules for working space and dedicated space are closely related. Working space is the area intended for use by personnel. Dedicated space is the area intended for use by the equipment itself. The working space requirements apply to equipment "likely to require examination, adjustment, servicing, or maintenance while energized." Such equipment includes panelboards, control panels, motor controllers, disconnects, and the like, some of which are routinely used in all types of occupancies. Horizontal and vertical dedicated space composed of an area equal to the footprint of the equipment is required for switchboards, panelboards, and motor control centers. With this change, the requirements for working space, access, illumination, headroom, and dedicated space are all grouped together. The illustration shows the content of Section 384-4 moved to Section 110-26(f).

Background and Explanation

These requirements were relocated to enhance the usability of the code. All of the rules in the revised Section 110-26 are related to the size, arrangement, access, and usability of spaces where electrical equipment is installed. Grouping these related requirements together makes the rules easier to locate and apply.

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110-26(f) Panelboard and Switchboard Space Alternative

Type of Change Revision

BRIEF SUMMARY

All occupancies. Height requirement for dedicated space above switchboards, panelboards, and motor control centers was revised.

Code Language

110-26. Spaces About Electrical Equipment.

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•
•

(f) Dedicated Equipment Space. Equipment within the scope of Article 384, and motor control centers, shall be located in dedicated spaces and protected from damage as covered in (1) and (2). (ROP 1-260)

Exception: Control equipment that by its very nature or because of other rules of the Code must be adjacent to or within sight of its operating machinery shall be permitted in those locations.

(1) Indoor. For indoor installations, the dedicated space shall comply with the following.

(a) Dedicated Electrical Space. The space equal to the width and depth of the equipment and extending from the floor to a height of **6 ft (1.83 m)** above the equipment or to the structural ceiling, whichever is lower, shall be dedicated to the electrical installation. No piping, ducts, or equipment foreign to the electrical installation shall be located in this zone.

Exception: Equipment that is isolated from the foreign equipment by height or physical enclosures or covers that will afford adequate mechanical protection from vehicular traffic or accidental contact by unauthorized personnel or that complies with (b), shall be permitted in areas that do not have the dedicated space described in this rule.

(b) Foreign Systems. The space equal to the width and depth of the equipment shall be kept clear of foreign systems unless protection is provided to avoid damage from condensation, leaks, or breaks in such foreign systems. This zone shall extend from the top of the electrical equipment to the structural ceiling.

(c) Sprinkler Protection. Sprinkler protection shall be permitted for the dedicated space where the piping complies with this section.

(d) Suspended Ceilings. A dropped, suspended, or similar ceiling that does not add strength to the building structure shall not be considered a structural ceiling. (ROC 9-76) (TCC 9-76)

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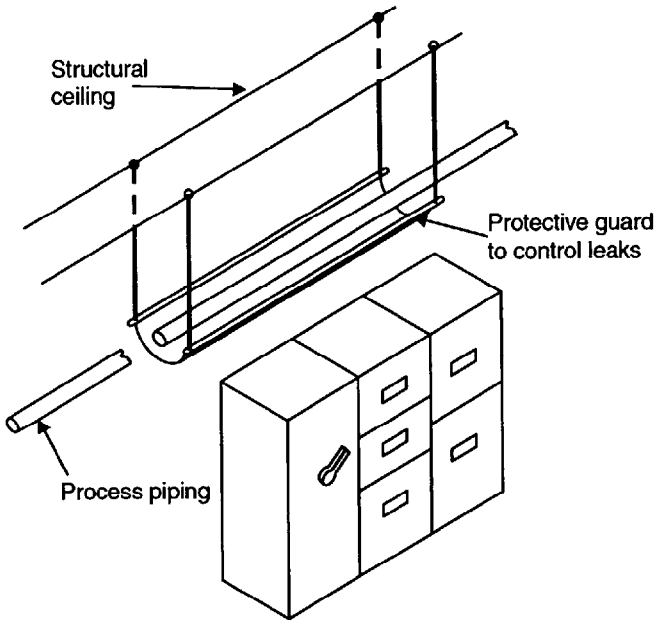

Foreign Piping with Spill Protection

Application

The major revision is to the amount of clear space requird for the equipment covered within this section. In the 1996 code, this section specified that the clear space was from floor to the structural ceiling or to up to 25 feet. The 1999 code requires that the clear space be from the top of the equipment to 6 feet above the equipment. As in previous editions, the clear space is only the equipment footprint. Equipment that is not associated with the electrical installation is not permitted to be installed within this space. The 6-foot clear space facilitates raceway or cable access into the top of equipment.

In addition, the concerns over accidental spillage have been addressed. The space above the 6-foot zone up to the structural ceiling is required to be kept clear of foreign systems whose failure could endanger the electrical equipment. The space above the 6-foot zone is permitted to contain foreign systems such as plumbing or mechanical systems, where guards or deflector shields are provided that prevent spillage onto the electrical equipment.

Background and Explanation

Many inspectors and installers felt the former 25-foot limit was not logical since a liquid flowing from a broken pipe would not evaporate within 25 feet. The revision reflects that logic by removing the 25-foot rule but allowing other protective measures and by requiring a 6-foot space above the specific types of equipment to facilitate future access for wiring additions into the equipment.

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NEC pp. 28–33

Article 110 Parts B, C, D Rules from Article 710

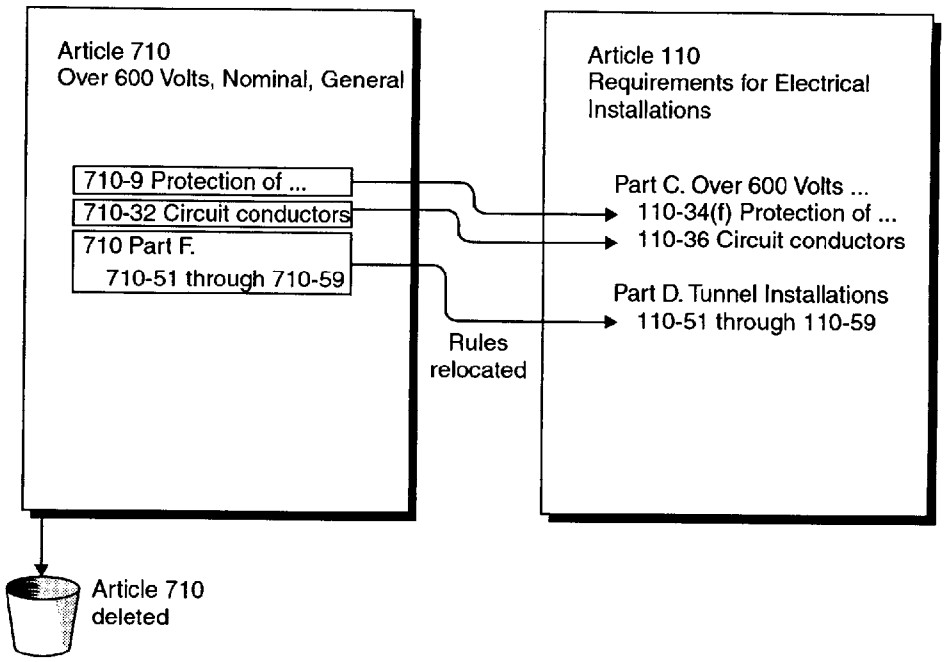
Type of Change Relocation

BRIEF SUMMARY

Commercial and industrial. General requirements from Article 710 were moved to Article 110 and Article 710 was deleted. Article 110 was reorganized into four parts.

Code Language

See flow chart.



Relocation of High Voltage Requirements

Application

Installations of equipment over 600 volts are most common in industrial establishments. However, such installations are also found in large commercial installations, especially where power is distributed through many buildings or to many floors of a high-rise building. The general requirements that apply to all such installations have been grouped together in Article 110.

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The existing rules of Part A of Article 110 have been divided into Part A, "General," and Part B, "600 Volts, Nominal, and Under." Section 110-30 was revised to refer to all of Part A. Sections 110-16 and 110-17 were renumbered as 110-26 and 110-27, respectively.

The illustration shows the origin and new locations of the relocated rules. The relocation of these sections adds general installation requirements for service equipment, metal-enclosed power switchgear, industrial control assemblies, and circuit conductors to the existing rules of what was Part B. Part B has been changed to Part C, "Over 600 Volts, Nominal." A new Part D, "Tunnel Installations," was also added. The new Part D contains the requirements that were previously in Part F of Article 710.

Background and Explanation

Prior to the 1999 NEC, the requirement for installations involving systems over 600 volts were located in several areas of the code. Some articles, such as Article 110, had special parts for over 600 volts. Other articles, such as Article 225, had the rules for over 600 volts located in numerous separate sections. Article 710 contained only requirements for over 600 volts. These numerous locations for the "high voltage" rules made it necessary to refer to several articles to find similar requirements. To improve this situation, the various sections of Article 710 were reexamined and moved to appropriate articles. Those sections dealing with general installation requirements not specific to wiring methods, overcurrent protection, or equipment, were moved to Article 110. They are now grouped with like requirements. For example, since 710-9 had to do with protection of equipment, it was moved to 110-34, which addresses work space and guarding for equipment over 600 volts.

In addition to the relocation of material from Article 710, Article 110 was reorganized to separate general requirements from those requirements that are specific to installations of 600 volts or less. This change and the rewording of Section 110-30 are intended to clarify that all of Part A applies to installations over 600 volts. For installations over 600 volts, Part A is supplemented or modified by Part C. Sections 110-16 and 110-17 were renumbered to locate the rules for work space and guarding of live parts for 600 volts and under into Part B.

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200-7(c) Switch Loop Conductor Identification

Type of Change Revision

BRIEF SUMMARY

All occupancies. Requirement for reidentification of white or natural gray conductors in switch loops was changed.

Code Language

200-7. Use of Insulation of a White or Natural Gray Color **or with Three Continuous White Stripes.**

(a) General. The following shall be used only for the grounded circuit conductor, unless otherwise permitted in (b) and (c):

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(c) Circuits of 50 Volts or More. The use of insulation that is white or natural gray **or that has three continuous white stripes for other than a grounded conductor for circuits of 50 volts or more shall be permitted only as in (1) through (3).**

(1) If part of a cable assembly and where the insulation is permanently re-identified to indicate its use as an ungrounded conductor, by painting or other effective means at its termination, and at each location where the conductor is visible and accessible.

(2) Where a cable contains an insulated conductor for single-pole, 3-way, or 4-way switch loops, and the conductor with white or natural gray **insulation or a marking of three continuous white stripes** is used for the supply to the switch, but not as a return conductor from the switch to the switched outlet. In these applications, **the conductor with white or natural gray insulation or with three continuous white stripes shall be permanently re-identified to indicate its use by painting or other effective means at its terminations and at each location where the conductor is visible and accessible.**

(3) Where a flexible cord, having one conductor identified by a white or natural gray outer finish **or three continuous white stripes** or by any other means permitted by Section 400-22, is used for connecting an appliance or equipment permitted by Section 400-7. This shall apply to flexible cords connected to outlets whether or not the outlet is supplied by a circuit that has a grounded conductor. (ROC 5-27)

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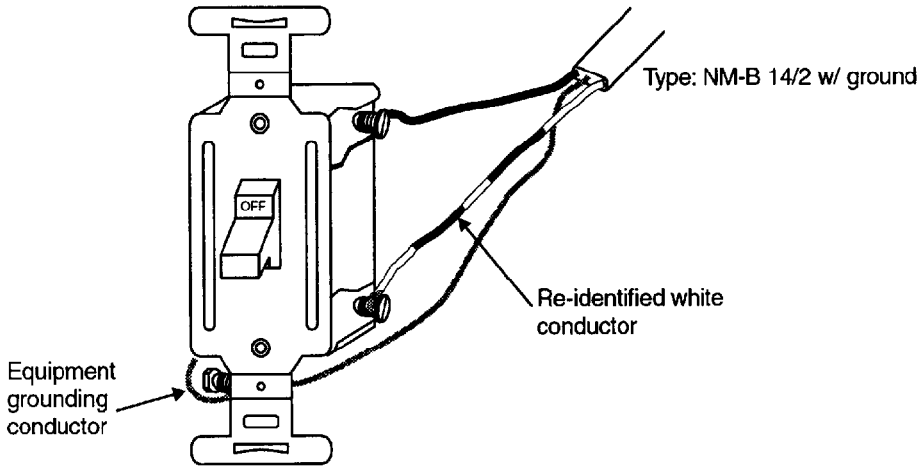

Permanent Identification of White Conductor in Switch Loop

Application

This change will prohibit the use of a white or gray conductor in a cable system to supply a switch unless re-identified. Where the white conductor is used in a switch loop it can only be used to supply the switch and it must be permanently re-identified. The identification must be done anywhere the conductor is visible or accessible.

Background and Explanation

While the change would apply to all occupancies, the principal reason for the change is safety in residential occupancies. It is not unusual for homeowners to undertake minor electrical repairs. By requiring re-identification where a white colored conductor is used as an ungrounded conductor, the chance of confusion and misconnection is reduced.

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Article 210 Reorganization and Relocation of Requirements

Type of Change Reorganization

BRIEF SUMMARY

All Installations. Article 210 was reorganized and some provisions were relocated from or to Article 220.

Code Language

See table.

Article 210 Reorganization

1996 NEC Section	*Section Heading or Description*	*1999 NEC Section*
220-4	Branch Circuits Required	210-11
220-4(a)	Number of Branch Circuits	210-11(a)
220-4(d)	Load Evenly Proportioned Among Branch Circuits	210-11(b)
	Dwelling Units	210-11(c)
220-4(b)	Small Appliance Branch Circuits	210-11(c)(1)
220-4(c)	Laundry Branch Circuits	210-11(c)(2)
210-52(d) (part)	Bathroom Branch Circuits	210-11(c)(3)
210-19	Conductors—Minimum Ampacity and Size	210-19
220-3(a), 210-22(c), 210-19 (part)	General (Continuous and Noncontinuous Loads)	210-19(a)
210-19(a) (part)	Multioutlet Branch Circuits	210-19(b)
210-19(b)	Household Ranges and Cooking Appliances	210-19(c)
210-19(c)	Other Loads	210-19(d)
210-20	Overcurrent Protection	210-20
210-22(c), 220-3(a)	Continuous and Noncontinuous Loads	210-20(a)
210-20(1)	Conductor Protection	210-20(b)
210-20(2)	Equipment	210-20(c)
210-20(3)	Outlet Devices	210-20(d)

Application

Article 210 applies to all installations that involve branch circuits unless they supply only motor loads. (See Section 210-1.) A new Section 210-11 provides the method for determining the number of branch circuits required. Most of Section 210-11 was relocated from Article 220, Section 220-4. A complete listing of the sections that were relocated either from Article 220 or within Article 210 is given in the table. There is no substantive change in the effect or application of these rules.

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Background and Explanation

This change was made as part of the effort to enhance the usability of the code. Article 220, which is titled Branch-Circuit, Feeder, and Service Calculations, contained material that was not directly related to calculations. Specifically, in the 1996 NEC, portions of Section 220-3 and all of Section 220-4 were about branch-circuit requirements and not about calculations. Those rules were moved into Article 210.

Section 210-22 also contained load calculation requirements, which were relocated to Article 220. Paragraph (c) of Section 210-22, which was concerned with continuous and noncontinuous loads, was combined with Section 220-3(a) and relocated to Section 210-20(a). In addition some sections in Article 210 were relocated to enhance clarity. For example, part of Section 210-52(d) was about requirements for the branch circuit and part was about required outlets. The rule requiring the outlets stayed in Section 210-52, "Dwelling Unit Receptacle Outlets," located in Part C, "Required Outlets." The rule requiring a 20 ampere-rated branch-circuit was moved to the new Section 210-11, "Branch Circuits Required," under Part A, "General Provisions."

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NEC pp. 37 & 38

210-4(d) & 210-5 Identification of Conductors/Multiwire

Type of Change Revision

BRIEF SUMMARY

Rules for identification of conductors are clarified.

Code Language

210-4. Multiwire Branch Circuits.

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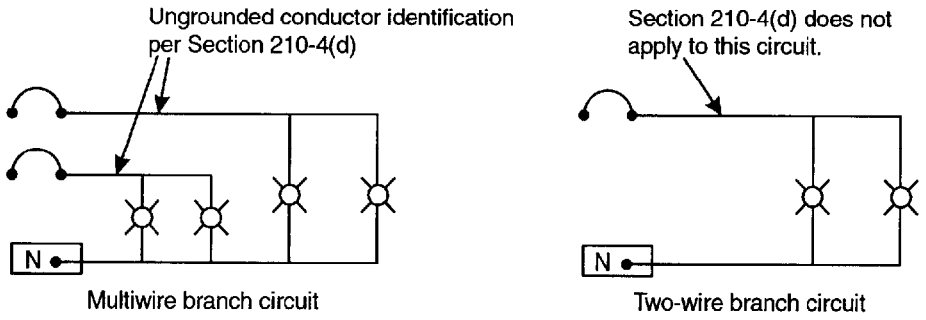
(d) Identification of Ungrounded Conductors. Where more than one nominal voltage system exists in a building, each ungrounded conductor **of a multiwire branch circuit, where accessible,** shall be identified by phase and system. This means of identification shall be **permitted to be by separate color coding, marking tape, tagging, or other approved means and** shall be permanently posted at each branch-circuit panelboard. (ROP 2-18) (ROC 2-9)

210-5. Identification for Branch Circuits. (ROP 2-23)

(a) Grounded Conductor. **The grounded conductor of a branch circuit shall be identified in accordance with Section 200-6.** (ROP 2-23)

(b) Equipment Grounding Conductor. **The equipment grounding conductor shall be identified in accordance with Section 250-119.** (ROP 2-23, TCC 2-23)



Ungrounded Conductor Identification—Multiwire Branch Circuits

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Application

Section 210-4 covers only multiwire branch circuits. Subsection 210-4(d) covers identification of conductors in multiwire branch circuits. The revision of 210-4(d) makes it clear that identification of ungrounded conductors is required in only multiwire branch circuits where there is more than one nominal voltage system in the building.

Although color coding of ungrounded conductors is a common industry practice, it is not required by the NEC. The marking required by this section could be color coding, tags, labels, or other effective means. Marking is not required for services, feeders or two-wire branch circuits. Marking is also not required for multiwire branch circuits if there is only one nominal voltage system in the building.

Background and Explanation

The term "multiwire branch circuit" was added to Section 210-4(d) to eliminate misinterpretation of this section. Section 210-4 covers the use of only multiwire branch circuits and 210-4(d) is one of the rules relating to that topic. When it is read out of context, the 1996 version of 210-4(d) seems to apply to all conductors. The revision should eliminate this misinterpretation.

Section 210-5 was revised to eliminate duplication of code text. Identification of grounding and grounded conductors was covered by Sections 210-5 and 310-12. The grounded conductor was also covered by Section 200-6 and the grounding conductor was covered by Section 250-57. The duplication of text has been eliminated by a series of changes leaving identification of grounded conductors in Section 200-6 and identification of grounding conductors covered by revised Section 250-119.

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210-8 (a)(2) Accessory Building GFCI

Type of Change Revision

BRIEF SUMMARY

Residential. New wording clarifies which areas of residential accessory buildings are required to have GFCI protection for personnel.

Code Language

210-8. Ground-Fault Circuit-Interrupter Protection for Personnel.

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(a) Dwelling Units. All 125-volt, single-phase, 15- and 20-ampere receptacles installed in the locations specified below shall have ground-fault circuit-interrupter protection for personnel.

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2. Garages, and **also accessory buildings that have a floor located at or below grade level not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use.** (ROP 2-60)

Application

According to 210-8(a), the receptacles subject to this rule are only those rated 125 volt, single phase, 15 and 20 ampere. Such receptacles installed in residential accessory buildings are required to have GFCI protection for personnel if the receptacles are located in rooms that are both (1) at or below grade level, and (2) used for storage areas, work areas, or similar uses. The Exceptions exclude receptacles that are not readily accessible or that are located in spaces dedicated to specific cord-and-plug-connected appliances that are not easily moved.

The illustrations show that receptacles in garages are required to be GFCI protected. Also, the areas of other accessory buildings that are at grade level and used as storage or work areas are required to have GFCI protection. In the illustration the area on grade level that is finished and used as an office is not required to have GFCI protection. The area that is at grade level and used as a storage or work area is required to have GFCI protection for receptacles. Work areas are intended to be those areas where portable power tools and appliances are likely to be used.

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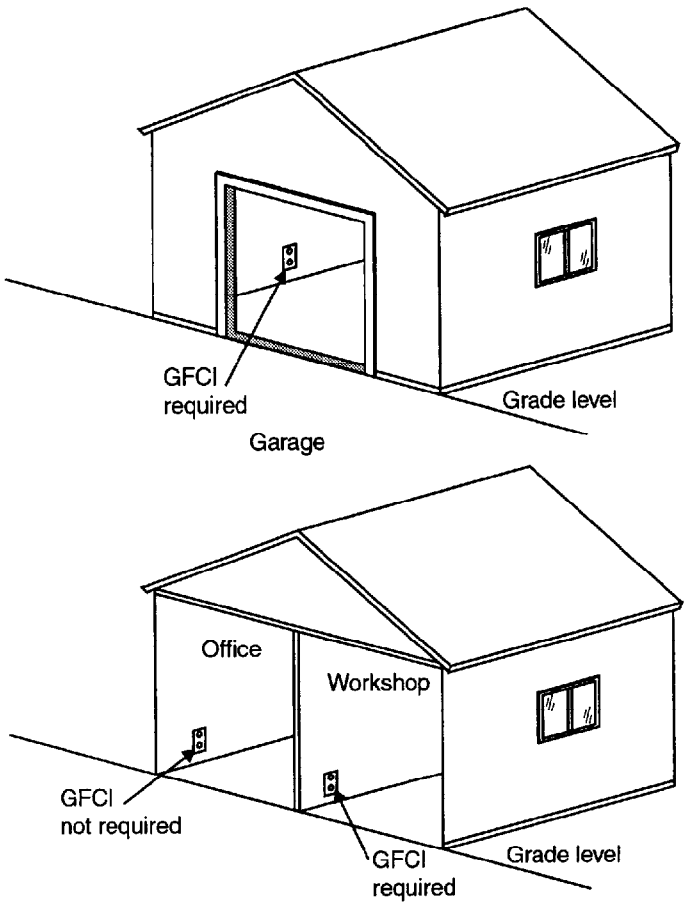

GFCIs in Accessory Buildings

Background and Explanation

The locations of receptacles requiring GFCI protection in accessory buildings are similar to those locations in the main dwelling that are required to have GFCI protection. In fact, the new wording in 210-8(a)(2) is intended to clarify what was meant by "unfinished" in the 1996 NEC and is essentially the same as the description of basement areas requiring GFCI protection for receptacles in 210-8(a)(5). The Exceptions to both sections are identical.

In general, GFCI protection is required in areas that are likely to be damp or wet, areas where people are likely to be in contact with earth or other nonelectrical surfaces or equipment at ground potential, areas where portable power tools or appliances are likely to be used, or where extension cords are likely to be used to extend power into these areas. The intent of this change is to identify those areas.

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210-8(a)(3) Exc. & (b)(2) Exc. Deicing Equipment GFCI Exceptions

Type of Change Revision; New Exception

BRIEF SUMMARY

All installations. Exceptions are clarified and added to allow receptacles for snow melting and deicing to be installed without GFCI protection where ground-fault protection of the equipment is provided as specified by Section 426-28.

Code Language

210-8. Ground-Fault Circuit-Interrupter Protection for Personnel.

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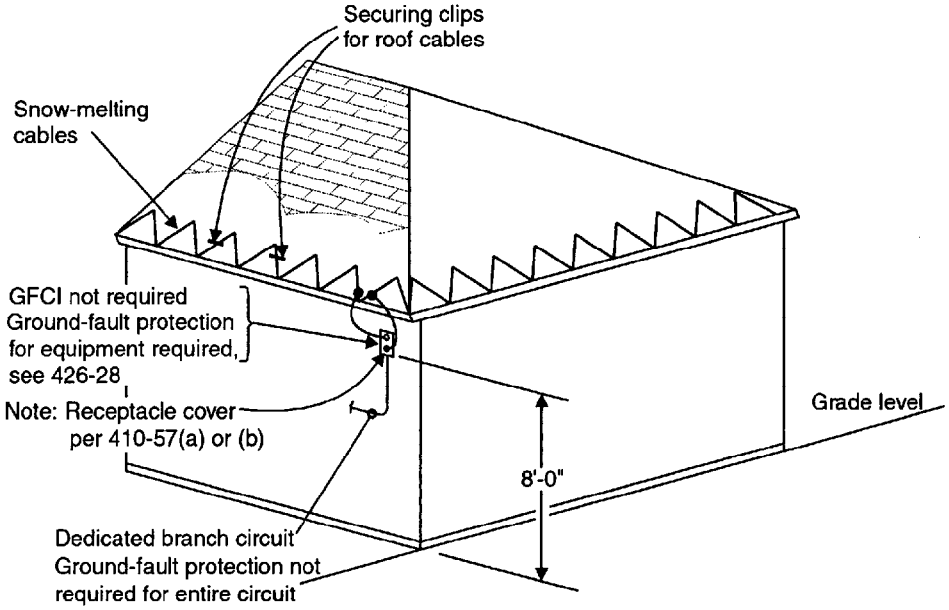
Exception: Receptacles that are not readily accessible and are supplied by a dedicated branch circuit for electric snow-melting or deicing equipment shall be permitted to be installed ***in accordance with the applicable provisions of Article 426.*** (ROP 2-67) (ROC 2-34)



Receptacles for Deicing and Snow Melting

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Application

Section 210-8(a)(3) applies to residential installations and Section 210-8(b)(2) applies to other than residential installations. Both sections cover 125-volt, single-phase, 15- and 20-ampere receptacles. Section 210-8(a)(3) requires such receptacles located outdoors on dwelling units to be GFCI protected. Section 210-8(b)(2) requires such receptacles installed on nondwelling rooftops to be GFCI protected. The exception to 210-8(a)(3) was revised to allow receptacles that are not readily accessible to omit GFCI protection where the receptacles are supplied by branch circuits dedicated to deicing and snow melting and the installation of the deicing and snow-melting equipment complies with the applicable provisions of Article 426. A new exception with identical wording allows similarly installed rooftop receptacles located on nondwelling occupancies to be installed without GFCI protection.

The illustration shows a dedicated circuit supplying a receptacle that is installed under the eave of a house to supply resistance-type deicing or snow-melting cables. GFCI protection for this receptacle is not required. An identical exception would apply if a receptacle supplying similar equipment were installed on a rooftop of a commercial building. Note, however, that the receptacle installed under the eave is made "not readily accessible" by mounting it so that it is out of normal reach. A receptacle on a rooftop may be considered readily accessible if a permanent roof access is provided. See the definition of "accessible, readily" in Article 100.

Background and Explanation

The primary purpose of this change is to make it clear that GFCI protection is not required for the receptacles that are not readily accessible and that are supplied by branch circuits dedicated to the electric deicing and snow-melting equipment. Section 426-28 requires ground-fault protection of equipment for resistance-type deicing and snow-melting equipment. This protection is permitted to be installed anywhere in the branch circuit or can be an integral component of the deicing and snow-melting equipment. GFCI protection is not usually suitable for such installations as the normal leakage currents may cause nuisance tripping. Where a 125-volt, single-phase, 15- or 20-ampere receptacle installed to supply this equipment is readily accessible and in a location covered by Sections 210-8(a)(2) or 210-8(b)(2), GFCI protection is required.

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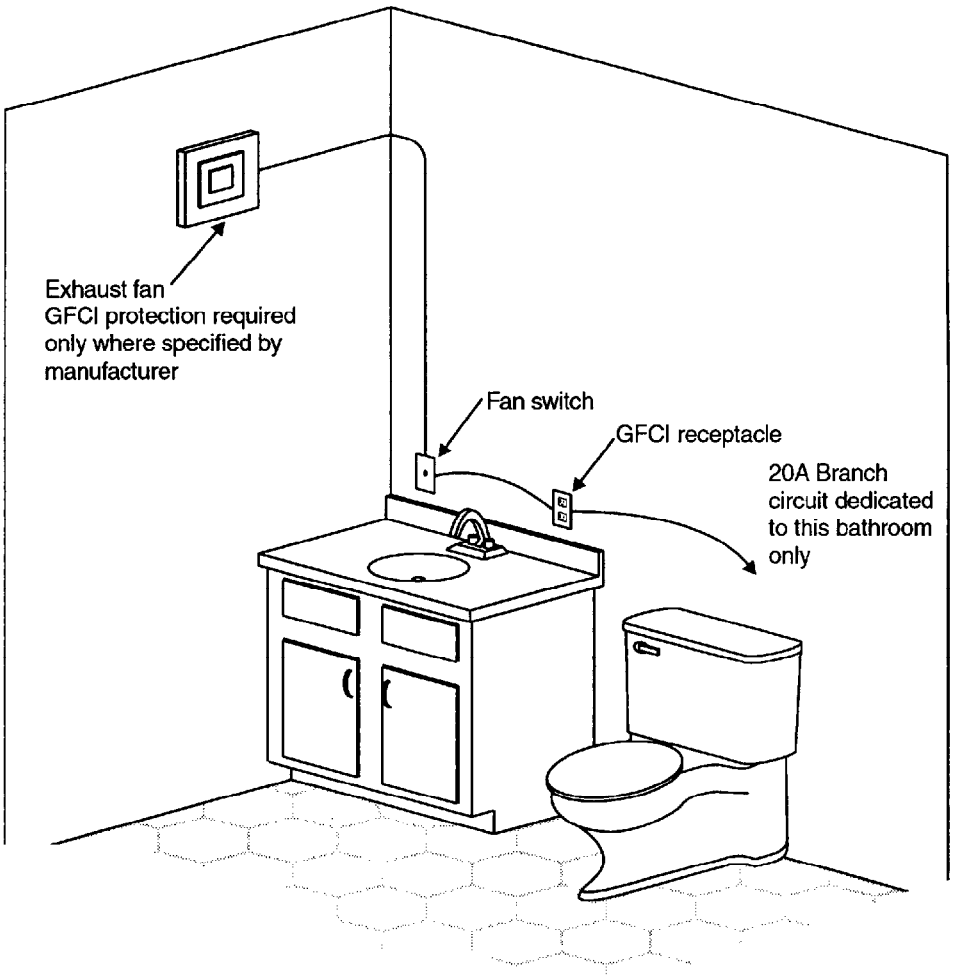
210-11(c)(3)

Exc. Relocated Requirements from 220-4 and 210-52

Type of Change New

BRIEF SUMMARY

Residential. Part of 210-52(d) was moved to 210-11(c)(3). A new exception allows the 20-ampere bathroom receptacle circuit to serve other equipment in the same bathroom if the circuit supplies only one bathroom.



Dedicated Circuits for Bathrooms

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Code Language

210-11. Branch Circuits Required.

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(3) Bathroom Branch Circuits. **In addition to the number of branch circuits required by other parts of this section,** at least one 20-ampere branch circuit shall be provided to supply the bathroom receptacle outlet(s). Such circuits shall have no other outlets. (ROP 2-5) (ROC 2-93)

Exception: Where the 20-ampere circuit supplies a single bathroom, outlets for other equipment within the same bathroom shall be permitted to be supplied in accordance with Section 210-23(a). (ROP 2-191)

Application

The illustration shows an exhaust fan fed from the same 20-ampere circuit that feeds the bathroom receptacle. This installation is permitted under the 1999 NEC as long as no other bathroom is on the same circuit. The other equipment that may be supplied is subject to the limitations of Section 210-23(a). In this example, 210-23(a) would limit the fan load to no more than 50 percent of the rating of the branch circuit, or 10 amperes. If the bathroom circuit is used as shown, an additional circuit or circuits would be required for any additional bathrooms.

Background and Explanation

The 1996 NEC added a new requirement for 20-ampere branch circuits in bathrooms. These circuits were allowed to feed more than one bathroom but were required to be dedicated to bathroom receptacles. A proposal was made for the 1999 NEC to allow ventilation fans that are listed to require GFCI protection to be supplied from the same GFCI that protects the bathroom receptacles. In response, the code panel added an exception to allow any other outlets in the same bathroom to be on the same circuit, subject to the load limitations of Section 210-23(a) for 20-ampere circuits. The panel also added the requirement that if a bathroom receptacle circuit serves other outlets in a bathroom, the 20-ampere circuit must be dedicated to that bathroom.

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210-12 Arc-Fault Circuit Interrupters

Type of Change New

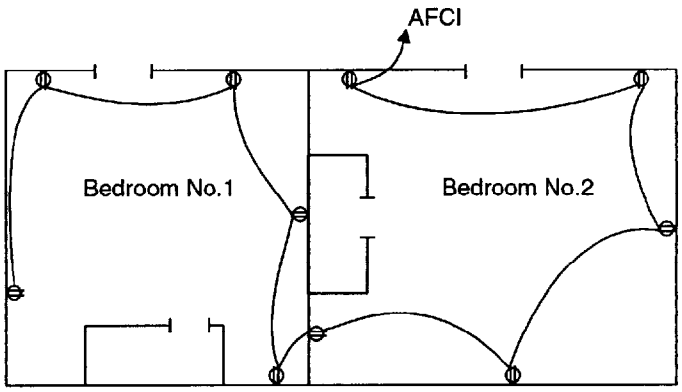
BRIEF SUMMARY

Residential. Requirements for the use of arc-fault circuit interrupter protection (AFCI) are introduced.

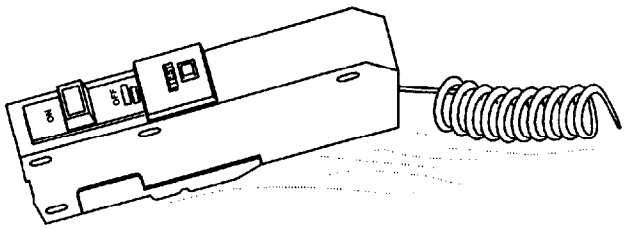
Code Language

210-12. Arc-Fault Circuit-Interrupter Protection.

(a) Definition. An *arc-fault circuit interrupter* is a device intended to provide protection from the effects of arc faults by recognizing characteristics unique to arcing and by functioning to de-energize the circuit when an arc fault is detected.



Requirement becomes effective 1/1/02



AFCI Protection for Receptacle Circuits in Bedrooms of Dwelling Units

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(b) Dwelling Unit Bedrooms. All branch circuits that supply 125-volt, single-phase, 15- and 20-ampere receptacle outlets installed in dwelling unit bedrooms shall be protected by an arc-fault circuit interrupter(s). This requirement shall become effective January 1, 2002. (ROC 2-65)

Application

This new requirement has an effective date of January 1, 2002.

As seen in the definition, these new devices are able to recognize the unique characteristics of some types of arcing faults and will distinguish between abnormal arcing, such as series arcing or line to neutral faults, and normal arcing, such as in switches and motors. When abnormal arcing occurs in a circuit, these devices de-energize the entire circuit before excessive damage occurs. This protection will be provided for the entire branch-circuit and utilization equipment connected to it. Once this requirement becomes effective, AFCI protection will be required for 15- and 20-ampere, 125-volt receptacle circuits in dwelling unit bedrooms.

Background and Explanation

The effective date was established to allow time for the industry to make the devices available. The requirement for AFCI protection was limited to residential bedrooms to introduce this new technology on a gradual basis. The statistics provided to the committee indicated that many residential fires where the electrical system was determined to be the source of ignition originated in bedrooms.

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210-19(a) Ampacity Adjustment and Correction Factors

Type of Change Relocation and Revision

BRIEF SUMMARY

All installations. Wording is changed to clarify how conductors are to be selected for continuous and noncontinuous loads.

Code Language

210-19. Conductors—Minimum Ampacity and Size.

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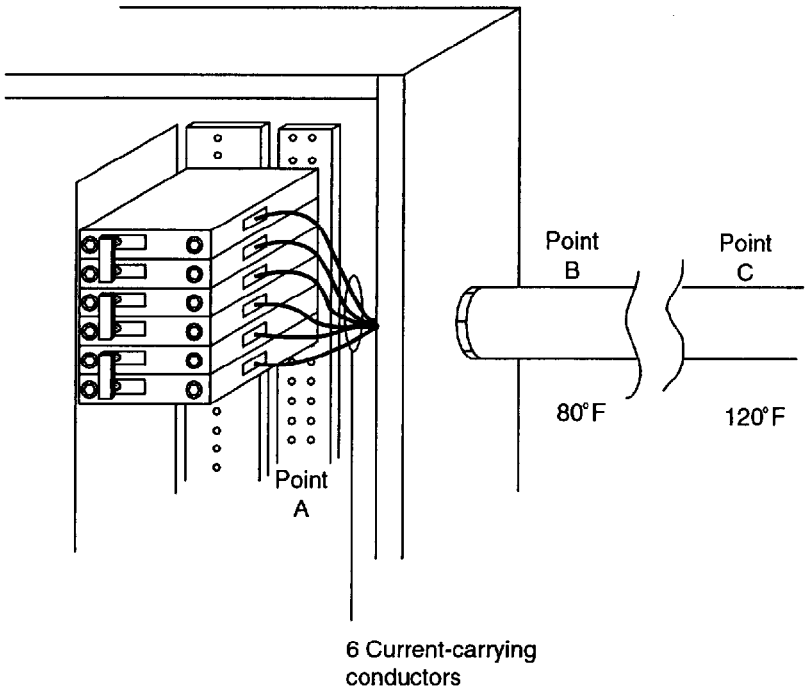
(a) General. Branch-circuit conductors shall have an ampacity not less than the maximum load to be served. Where a branch circuit supplies continuous loads or any combination of continuous and noncontinuous loads, the minimum branch-circuit conductor size, **before the** application of any adjustment or correction factors, shall have an allowable ampacity equal to or greater than the noncontinuous load plus 125 percent of the continuous load. (ROP 2-5, 2-143)



Conductors Supplying Continuous Loads

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Application

The illustration shows three different conditions for the conductors in the circuits shown. This example is based on the following conditions:

1. The circuit does not supply multiple receptacle outlets for cord- and plug-connected portable loads.
2. The load on each conductor is 16 amperes continuous and 16 amperes noncontinuous.
3. The conductors are copper with type THWN-Z insulation.

Conductor sizing at Point A must consider the termination provisions of the circuit breakers. A minimum conductor can be selected here "before" the conditions at Points B and C are considered.

The minimum conductor ampacity at Point A is found as follows:

> Minimum Ampacity for the load from 210-19(a):
> 16 A (noncontinuous) + 1.25 × 16A (continuous) = 16 + 20 = 36A

The minimum conductor size at Point A is found as follows (based on equipment marking):

> Terminal temperature rating from 110-14(c) = 60°C
> Smallest conductor from the 60°C column with an ampacity of at least 36A is No.8 AWG

Therefore, the minimum conductor size at Point A is No.8 AWG, which has an ampacity of 40A "before the application of any adjustment factors."

Because 110-14(c) says we must select an ampacity with the terminal temperature in mind, the minimum copper conductor size for the load is No. 8 AWG. We cannot use the 40A ampacity for a No. 10 from the 90°C column because the overcurrent device is not designed for the increased terminal temperatures associated with the use of the higher conductor ampacities. Note that 110-14(c) does not provide an adjustment factor, it is a rule about conductor ampacity selection relative to the terminal temperature rating.

Although the steps we have taken so far are sufficient to satisfy the requirements of 210-19(a), the conditions at Points B and C must still be considered in the final selection of a conductor size. At these two points, the ampacity must be adjusted for the ambient temperature that exceeds 30°C (86°F) and for more than three current carrying conductors in the raceway (310-15(b)(2)a). These ampacities can be determined using Section 310-15 as follows:

> Ampacity of a No.8 THWN-2 at 90°C from Table 310-16 = 55A
> Temperature correction factor at Point B = 1.00 (80°F, 90°C Column)
> Temperature correction factor at Point C = 0.82 (120°F, 90°C Column)
> Derating factor for six conductors in a raceway = 0.80

Using the factors determined above, we note that the No.8 conductor ampacities are

> 55A × 1.00 × 0.80 = 44A at Point B
> 55A × 0.82 × 0.80 = 36A at Point C

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According to 310-15(a)(2), because we have more than one ampacity that applies to the same circuit, the lowest ampacity must be used. We have found that the No.8 conductor has three applicable ampacities in this illustration: 40A at Point A, 44A at Point B, and 36A at Point C. Therefore, we select the 36A ampacity for the entire circuit. This ampacity must be adequate for the load. We also found that the minimum ampacity of the conductors to comply with 210-19(a) was 36A.

Finally, the overcurrent device size must be determined. The minimum size overcurrent device for a branch circuit supplying continuous and noncontinuous loads is given by 210-20(a). This rule requires the overcurrent protection to be not less than 125 percent of the continuous load plus 100 percent of the noncontinuous load. Because this example is based on the use of a circuit breaker installed in a panelboard, similar provisions of Section 384-16(d) also apply. This size matches the minimum ampacity of the conductors at Point A: 36A. Because 36 A is not a standard size according to Section 240-6 and the circuit is not a multioutlet circuit-supplying receptacle, Section 240-3(b) allows us to select the next larger size, 40A.

Let us summarize the requirements:

210-19(a)—Minimum ampacity for the branch circuit load : 36A
210-20(a)—Minimum overcurrent device for the load: 36A
310-15—Ampacity of No.8 conductors (lowest from Point C): 36A
240-3(b)—Maximum overcurrent device size: 40A
110-14(c)—Maximum ampacity of No.8 based on terminals: 40A

When we correlate the requirements listed here, we see that the minimum size conductors for this example would be No.8 with the specified THWN-2 insulation or an equivalent 90°C rated insulation. The maximum rating of the overcurrent device would be 40 amperes.

Background and Explanation

The relocation of this rule from 210-22(c) and 220-3(a) was discussed as part of the reorganization of Articles 210 and 220. The application of the rule has not changed from the 1996 NEC. Ampacity adjustments must be made for elevated ambient temperature and for more than three current-carrying conductors in a raceway. The wording change is meant to clarify that the adjustment factors need not be applied to conductor ampacities for the purpose of selecting a minimum size conductor to comply with 210-19(a). The ampacity adjustments still apply, but the selection of a minimum size conductor may be done "before" making the adjustments. The previous use of the word "without" led some code users to believe that the adjustment factors could be disregarded altogether as long as the conductor sizing was adequate for continuous and noncontinuous loads.

Selection of a conductor size involves more than one rule. The minimum conductor size determined under 210-19 is concerned with the application of a conductor to an overcurrent device. Similarly, the rules of 110-14(c) require ampacity selection to take into account the terminal temperature ratings at overcurrent devices as well as at utilization equipment terminals. These two rules must be coordinated with the ampacity selection covered by 310-15 and the overcurrent device selection covered by 240-3.

An identical wording change was made in the rules for sizing feeders in Section 215-2(a).

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210-23(a) Lighting Fixture Loads on Branch Circuits

Type of Change Revision

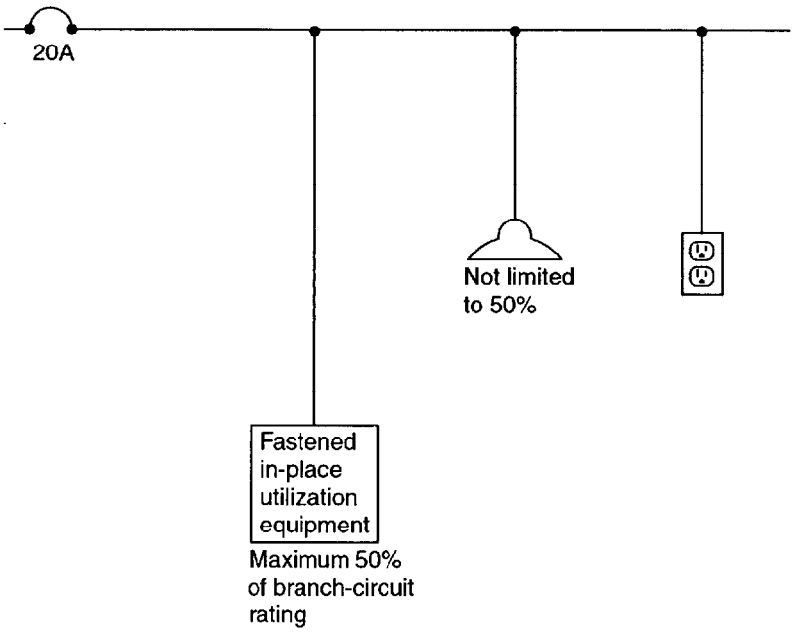
BRIEF SUMMARY

All occupancies. Loading restrictions on 15- and 20-ampere branch circuits are clarified.

Code Language

210-23. Permissible Loads.

(a) 15- and 20-Ampere Branch Circuits. A 15- or 20-ampere branch circuit shall be permitted to supply lighting units or other utilization equipment, or a combination of both. The rating of any one cord- and plug-connected utilization equipment shall not exceed 80 percent of the branch-circuit ampere rating. The total rating of utilization equipment fastened in place, **other than lighting fixtures,** shall not exceed 50 percent of the branch-circuit ampere rating where lighting units, cord- and plug-connected utilization equipment not fastened in place, or both, are also supplied. (ROP 2-146) (ROC 2-105)



Fixed Lighting Loads on 15- or 20-Ampere Multioutlet Branch Circuits

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Application

Section 210-23 requires branch circuits that supply more than one outlet to comply with 210-23(a) through (d). Section 210-23(a) limits the rating of any single cord- and plug-connected appliance to 80 percent of the circuit rating.

The rating of equipment fastened in place, other than lighting, must not exceed 50 percent where the circuit also supplies cord- and plug-connected equipment.

Background and Explanation

The revised wording makes it clear that lighting units fastened in place are not limited to 50 percent of the branch-circuit rating. This rule typically applies where an appliance that is fastened in place is connected to a general lighting circuit that also supplies convenience receptacles. The submitter of the proposal indicated that the rule was being interpreted to limit fixed lighting to 50 percent of the branch-circuit rating.

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210-52(b)(3) Small-Appliance Circuits—Multiple Kitchens

Type of Change Revision

BRIEF SUMMARY

Residential. Each kitchen must be supplied by at least two small-appliance branch circuits and any such circuit may serve only one kitchen.

Code Language

210-52. Dwelling Unit Receptacle Outlets.

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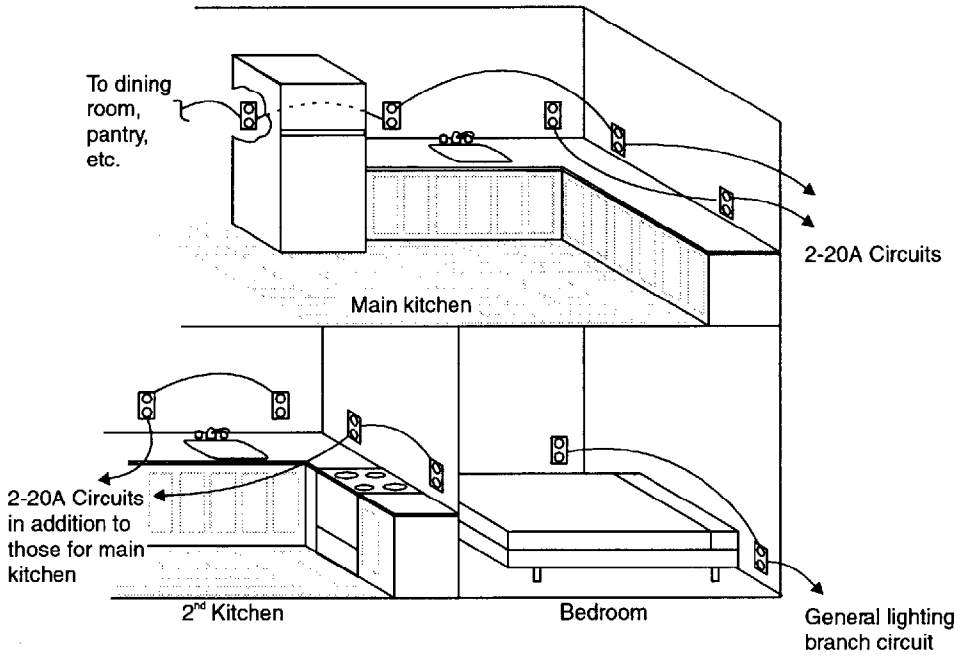
(3) Receptacles installed in a kitchen to serve countertop surfaces shall be supplied by not less than two small-appliance branch circuits, either or both of which shall also be permitted to supply receptacle outlets in the **same** kitchen and in other rooms specified in Section 210-52(b)(1). Additional small-appliance branch circuits shall be permitted to supply receptacle outlets in the kitchen and other rooms specified in Section 210-52(b)(1). **No small-appliance branch circuit shall serve more than one kitchen.** (ROP 2-174)



Circuits for More Than One Kitchen

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Application

Where a residence has more than one kitchen, each kitchen must have a minimum of two 20-ampere branch circuits to supply countertop receptacles. Although the small appliance circuits may serve other rooms listed in 210-52(b)(1), no small-appliance branch circuit may serve more than one kitchen. Additional small-appliance branch circuits may be used, but only two are required for each kitchen.

The illustration shows a dwelling unit with two kitchens. Each kitchen is shown with two small-appliance branch circuits. Other rooms are fed by general lighting circuits. The receptacle outlets in the dining room, pantry, breakfast nook, or similar area are required to be supplied by at least one small-appliance branch circuit, which can be one of the circuits that supplies the kitchen receptacles.

Background and Explanation

Some dwelling units have more than one kitchen. Dwelling units that have more than one kitchen may have both kitchens in use at the same time. Such use could easily result in overloading of the kitchen circuits if these circuits are shared by more than one kitchen. This change requires each kitchen to be treated individually.

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210-52(c)(5) Exc. Island and Peninsula Receptacle Outlets

Type of Change Revision

BRIEF SUMMARY

Dwelling units. This revision clarifies where receptacles serving the countertop may be located below the countertop.

Code Language

210-52. Dwelling Unit Receptacle Outlets.

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(c) Countertops. In kitchens and dining rooms of dwelling units, receptacle outlets for counter spaces shall be installed in accordance with (1) through (5).

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(5) Receptacle Outlet Location. Receptacle outlets shall be located **above, but** not more than 18 in. (458 mm) above the countertop. Receptacle outlets shall not be installed in a face-up position in the work surfaces or countertops. Receptacle outlets rendered not readily accessible by appliances fastened in place or appliances occupying dedicated space shall not be considered as these required outlets. (ROP 2-186)

Exception: ~~*Where acceptable to the Authority having jurisdiction and*~~ *To comply with the* ~~*special*~~ *conditions as specified in a. or b., receptacle outlets shall be permitted to be mounted not more than 12 in. (305 mm) below the countertop. Receptacles mounted below the countertop in accordance with this exception shall not be located where the countertop extends more than 6 in. (153 mm) beyond its support base.*

a. Construction for the physically impaired

b. On island and peninsular countertops ***where the countertop is flat across its entire surface (no backsplashes, dividers, etc.) and there are no means to mount a receptacle within 18 in. (458 mm) above the countertop, such as an overhead cabinet*** (ROP 2-186) (ROC 2-116)

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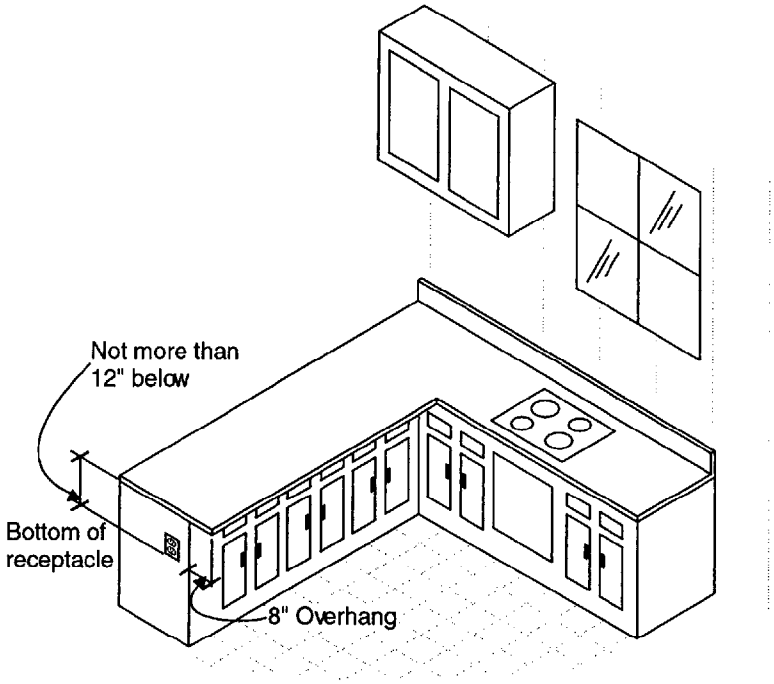

Island and Peninsula Countertop Receptacles

Application

Many island or peninsular countertops are flat across the entire surface. As a result it may be difficult to locate a receptacle above the counter. Where there are cabinets located not more than 18 inches above the island or peninsular counter, the receptacles must be mounted on (surface or flush) the overhead cabinets. If a backsplash is installed on the counter, the receptacle must be installed in or on the backsplash. In other installations the receptacle may be installed below the countertop in compliance with the exception. Note that the receptacle cannot be located below the 8-inch overhang that is shown in the illustration.

Background and Explanation

This section was revised to make it clear that the preferred location for receptacles is above the countertop. One concern with receptacles below the countertop is that children may pull cooking appliances off the counter. This section now recognizes this hazard by requiring receptacles to be located above the counter where practical. It now also recognizes that some installations do not allow for practical mounting above the counter.

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210-52(d) Bathroom Receptacle Outlets and Circuits

Type of Change Revision

BRIEF SUMMARY

Dwelling units. Requirement for receptacle outlets in bathrooms is clarified.

Code Language

210-52. Dwelling Unit Receptacle Outlets.

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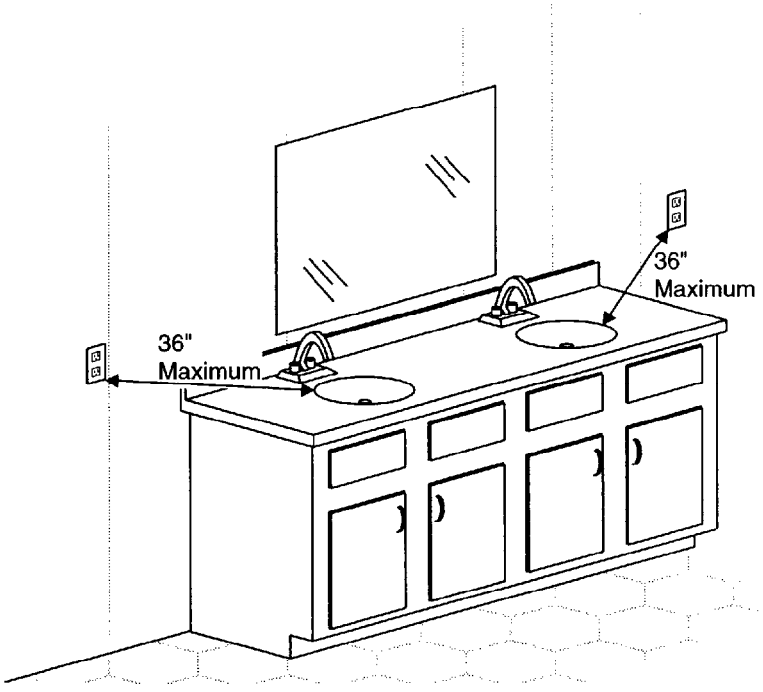
(d) Bathrooms. In dwelling units, at least one wall receptacle outlet shall be installed in bathrooms ~~adjacent to~~ **within 36 in. (914 mm) of the outside edge of** each basin. **The receptacle outlet shall be located on a wall that is adjacent to the basin location.** See Section 210-8(a)(1). (ROP 2-195) (ROC 2-123)

Receptacle outlets shall not be installed in a face-up position in the work surfaces or countertops in a bathroom basin location.



Bathroom Receptacle Location

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Application

Revised wording requires bathroom receptacles to be located within 36 inches of the basin. The 36-inch distance is to be measured from the edge of the basin. By changing the wording relative to the wall on which the receptacle is to be located, the committee clearly intends that receptacles be installed so that appliance cords in a bathroom will not present a tripping hazard. One receptacle outlet that is within 36 inches of each basin will meet this requirement.

Background and Explanation

The 1996 NEC required the receptacle to be located adjacent to the basin. Adjacent was considered by the code panel to be a vague and unenforceable term. The new wording clarifies what distance is required, how the measurement is to be made, and the wall space that is to be used. A receptacle located on a wall behind a person who is facing the basin does not satisfy the revised rule.

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210-52(g) Unfinished Basement Receptacle

Type of Change Revision

BRIEF SUMMARY

Residential. Partially finished basements are required to have a GFCI-protected receptacle in the unfinished portion.

Code Language

210-52. Dwelling Unit Receptacle Outlets.

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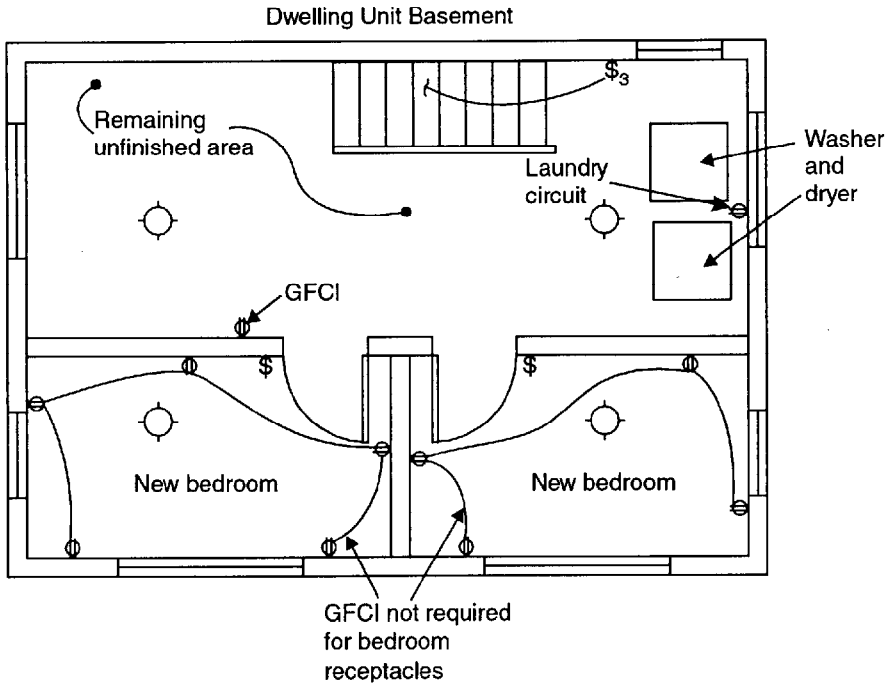
(g) Basements and Garages. For a one-family dwelling, at least one receptacle outlet, in addition to any provided for laundry equipment, shall be installed in each basement and in each attached garage, and in each detached garage with electric power. See Sections 210-8(a)(2) and (a)(5). **Where a portion of the basement is finished into a habitable room(s), the receptacle outlet required by this section shall be installed in the unfinished portion.** (ROP 2-211) (ROC 2-128, 2-129)



GFCIs in Partially Finished Basements

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Application

The illustration shows a basement that has been partially finished into bedrooms. The locations of receptacles, switches, and lighting outlets for the new bedrooms are dictated by Sections 210-52 and 210-70. Even though there are now receptacles in the basement bedrooms, these receptacles are not required to have GFCI protection. The code requires that a receptacle outlet be installed in the unfinished portion of the basement, and Section 210-8(a)(5) requires such outlets to be GFCI protected. Section 210-8(a)(5) also defines "unfinished basements" as "portions or areas of the basement not intended as habitable rooms and limited to storage areas, work areas, and the like."

Background and Explanation

When an unfinished basement is partially finished, the remaining portion of the basement is likely to continue to be used as storage and work areas. However, unless specifically required by Section 210-8(a), the receptacles installed in the newly finished areas are not required to have GFCI protection. The intent of Sections 210-52(g) and 210-8(a)(5) is to provide GFCI protection for persons using cord- and plug-connected appliances in the unfinished areas. Without the new provision of Section 210-52(g), users would likely extend cords from the non-GFCI-protected receptacles in the finished areas into the unfinished areas. The requirement to install a receptacle outlet in the unfinished portion ensures that the intended GFCI protection will still be provided for the unfinished area.

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210-60(b) Hotel/Motel Receptacle Outlets

Type of Change Revision

BRIEF SUMMARY

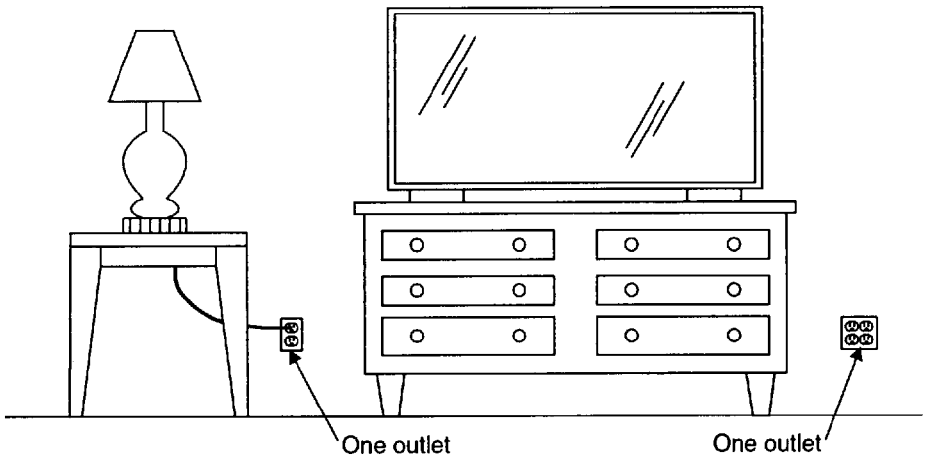
Hotels and motels. Receptacle placement in guest rooms is clarified.

Code Language

210-60. Guest Rooms.

(a) General. Guest rooms in hotels, motels, and similar occupancies shall have receptacle outlets installed in accordance with Section 210-52. See Section 210-8(b)(1).

(b) Receptacle Placement. In applying the provisions of Section 210-52(a), the total number of receptacle outlets shall not be less than the minimum number that would comply with the provisions of that section. These receptacle outlets shall be permitted to be located conveniently for permanent furniture layout. ~~and readily accessible~~. **At least two receptacle outlets shall be readily accessible. Where receptacles are installed behind the bed, the receptacle shall be located to prevent the bed from contacting any attachment plug that may be installed, or the receptacle shall be provided with a suitable guard.** (ROP 2-218, 2-219)



Readily Accessible Receptacles in Hotel and Motel Guest Rooms

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Application

In each hotel and motel guest room, at least two receptacle outlets must be readily accessible. "Ready access" is defined, in part, as capable of being reached quickly without the removal of obstacles. At least two receptacle outlets must be accessible to the occupant of the guest room without the moving of furniture. To prevent damage to attachment caps and cords, receptacle outlets installed behind beds are required to be located so that the bed will not contact attachment plugs connected to the outlet or guards must be installed on receptacle outlets.

Background and Explanation

The exception to Section 210-60 in the 1996 edition of the NEC required all guest room receptacles to be readily accessible. This requirement was considered to be excessive since some receptacles are installed for dedicated equipment. Two readily accessible outlets are considered to be adequate to allow the hotel guest to connect portable equipment. The requirement for location or guards for receptacles behind beds is intended to reduce the fire hazard created where attachment caps and cords are damaged and bedding may come into contact with exposed live or arcing parts.

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NEC pp. 45–46

210-70(a) & (c) Required Lighting Outlets

Type of Change Revision

BRIEF SUMMARY

Residential and equipment spaces. Section 210-70(a) was revised to clarify requirements in dwellings. Section 210-70(c) was revised to clarify the requirements for servicing equipment in attics and underfloor spaces and the permitted uses of fixtures with integral switches in such spaces.

Code Language

210-70. Lighting Outlets Required.

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(1) Habitable Rooms. At least one wall switch-controlled lighting outlet shall be installed in every habitable room **and bathroom**. (ROP 2-237) (ROC 2-136)

Exception No. 1: In other than kitchens and bathrooms, one or more receptacles controlled by a wall switch shall be permitted in lieu of lighting outlets. (ROP 2-237)

Exception No. 2: Lighting outlets shall be permitted to be controlled by occupancy sensors that are (1) in addition to wall switches or (2) located at a customary wall switch location and equipped with a manual override that will allow the sensor to function as a wall switch.

(3) Storage or Equipment Spaces. For attics, underfloor spaces, utility rooms, and basements, at least one lighting outlet **containing a switch or controlled by a wall switch** shall be installed where these spaces are used for storage or contain equipment requiring servicing. At least one point of control shall be at the usual point of entry to these spaces. The lighting outlet shall be provided at or near the equipment requiring servicing. (ROP 2-237)

(c) Other Locations. For attics and underfloor spaces containing equipment requiring servicing, such as heating, air-conditioning, and refrigeration equipment, at least one lighting outlet **containing a switch or controlled by a wall switch** shall be installed in such spaces. At least one point of control shall be at the usual point of entry to these spaces. The lighting outlet shall be provided at or near the equipment requiring servicing. (ROP 2-237)

Application

The basic requirements for dwelling units have not changed. The rules have been reorganized and grouped for easier use. Section 210-70(a) is now divided into three parts: (1) Habitable Rooms, (2) Additional Locations, and (3) Storage or Equipment Spaces. The table illustration summarizes where lighting outlets are required and what types of lighting outlets are permitted.

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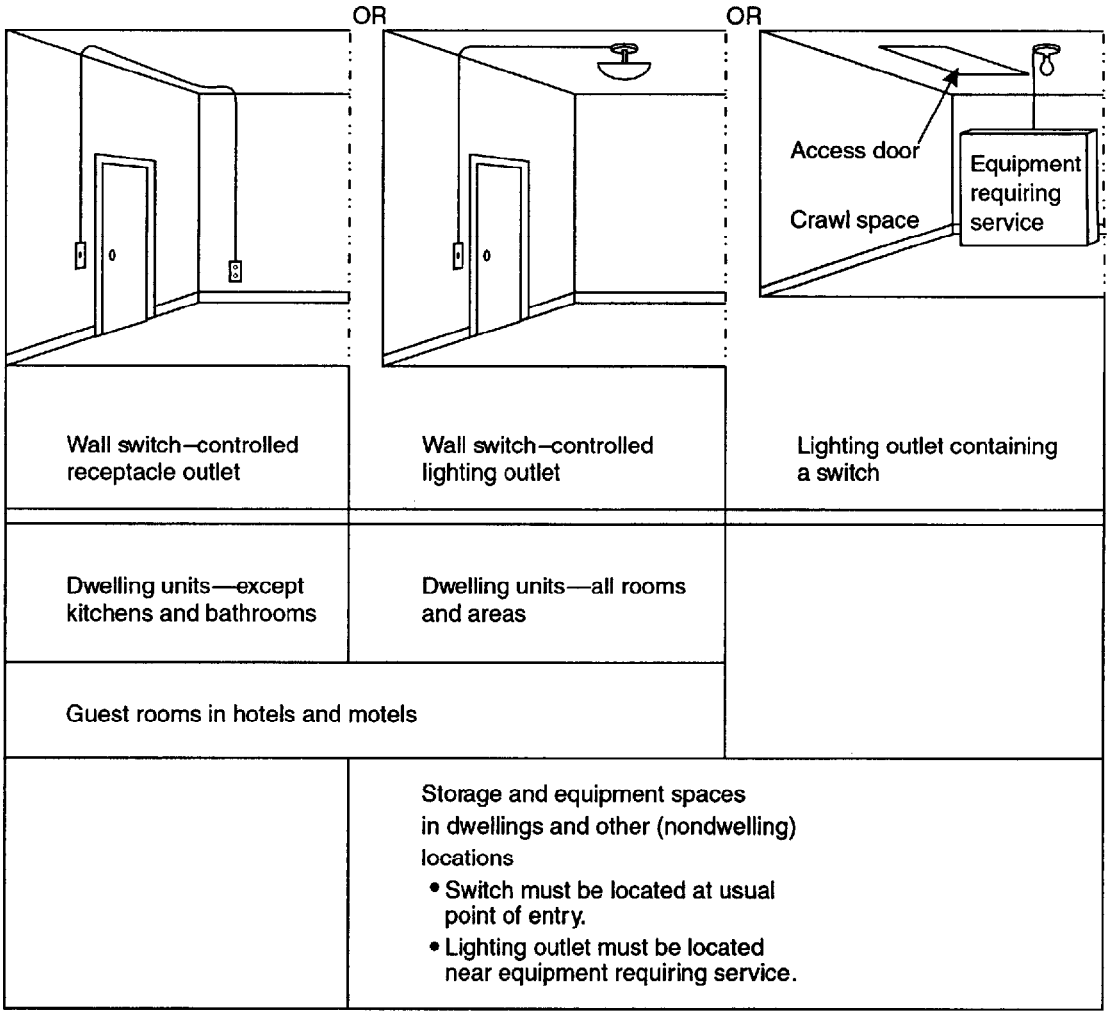
Habitable rooms are required to have a wall switch-controlled lighting outlet. A switched receptacle(s) in other than kitchens and bathrooms is permitted.

Additional locations where at least one wall switch-controlled lighting outlet is required include hallways, stairways, attached garages, and exterior entrances and exits. These locations require wall switch controlled-lighting outlets, although central controls are permitted for hallways, stairways, and outdoor entrances. Lighting outlets in stairways with six steps or more are still required to have controls at each floor level.

Storage and equipment spaces are required to have lighting outlets, but the switching may be provided by wall switches or as switches that are part of a lighting outlet. The lighting control must be provided near the "usual point of entry" and lighting fixtures must be located at or near the equipment requiring servicing. These revisions clearly permit a fixture containing a switch to be used if it is near both the equipment and the point of entry.

Attics and underfloor spaces in other than dwelling units that contain equipment requiring servicing are required to have lighting outlets. The rules for these spaces are similar to storage and equipment spaces in dwelling units as covered here. However, this requirement applies only to attic and underfloor spaces containing equipment that will require servicing or maintenance.



Required Lighting Outlets and Types Permitted

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Background and Explanation

The changes to Section 210-70 were made primarily to improve usability. The exceptions in this section have been relocated so that they immediately follow the rules they modify. The primary change in this section is to clarify the location of switches and fixtures in equipment spaces and to clarify that a fixture or lampholder with an integral switch is permitted in storage and equipment spaces in all occupancies.

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NEC pp. 46–47

215-2 & 215-3 Reorganization and Relocation of Requirements

Type of Change Reorganization

BRIEF SUMMARY

All installations. Article 215 was reorganized to include material relocated from Article 220.

Code Language

See table.

Article 215 Reorganization

1996 NEC Section	*Section Heading or Description*	*1999 NEC Section*
215-2	Minimum Rating and Size	215-2
220-10(b) (part)	General	215-2(a)
215-2(a)	For Specified Circuits	215-2(b)
215-2(b)	Ampacity Relative to Service Entrance Conductors	215-2(c)
215-2 (part)	Individual Dwelling Unit or Mobile Home Conductors	215-2(d)
220-10(b) (part)	Overcurrent Protection	215-3

Application

Article 215 provides requirements for feeders. Feeder sizes and loads are determined by calculations of the branch circuits they supply. The calculations for feeders are to be done in accordance with Part B of Article 220. A listing of the sections that were relocated by this change is given in the table. This reorganization did not result in any substantive changes to the way feeders are sized or installed.

Background and Explanation

This change was made as part of the effort to improve the usability of the code. Section 220-10(b) contained two rules about feeder conductor and overcurrent device sizing that were not directly related to the feeder calculation. Former Section 220-10(b) was divided into two parts and incorporated into Sections 215-2 and 215-3. Section 215-2 was renumbered to accommodate the additional text from Article 220. This change groups the basic requirements for feeder sizing and overcurrent protection into one location.

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215-10 Excs. 1 & 2 GFPE for Feeders

Type of Change New

BRIEF SUMMARY

Commercial and industrial. Exceptions to requirements for ground-fault protection of equipment for feeder disconnects have been added.

Code Language

215-10. Ground-Fault Protection of Equipment. **Each** feeder disconnect rated 1000 amperes or more **and installed on** solidly grounded wye electrical systems of more than 150 volts to ground, but not exceeding 600 volts phase-to-phase, shall be provided with ground-fault protection of equipment **in accordance with the provisions of Section 230-95.** (ROP 2-267)

Exception No. 1: The provisions of this section shall not apply to a disconnecting means for a continuous industrial process where a nonorderly shutdown will introduce additional or increased hazards. (ROP 2-267)

Exception No. 2: The provisions of this section shall not apply to fire pumps. (ROP 2-267)

Exception No. 3: The provisions of this section shall not apply if ground-fault protection of equipment is provided on the supply side of the feeder. (ROP 2-267)

Application

Ground-fault protection of equipment is required for each feeder disconnecting means rated 1000 amperes or higher and installed in solidly grounded wye distribution systems of over 150 volts to ground and not exceeding 600 volts phase to phase, unless exempted by one of the three exceptions. Installation of the GFPE device may be omitted for some continuous industrial processes, fire pumps, and where the required protection is installed on the supply side of the feeder other than as required by Section 517-17 for health-care facilities.

Background and Explanation

Exceptions 1 and 2 were added to clarify where ground-fault protection may be omitted from feeder disconnects rated 1000 amperes or higher. This revised text directly correlates with similar requirements for service disconnecting means found in Section 230-95.

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NEC pp. 48–49

Article 220 Reorganization and Relocation of Requirements

Type of Change

Reorganization

BRIEF SUMMARY

All installations. Article 220 was reorganized and some material was relocated from or to Article 210.

Code Language

See table.

Article 220 Reorganization

1996 NEC Section	*Section Heading or Description*	*1999 NEC Section*
220-3(b)	Lighting Load for Specified Occupancies	220-3(a)
220-3(c)	Other Loads—All Occupancies	220-3(b)
220-3(c)(1)	Specific Appliances or Loads	220-3(b)(1)
220-3(c)Exc.No.2 & No.5	Electric Dryers and Household Electric Cooking Appliances	220-3(b)(2)
220-3(c)(2)	Motor Loads	220-3(b)(3)
220-3(c)(3)	Recessed Lighting Fixtures	220-3(b)(4)
220-3(c)(4)	Heavy Duty Lampholders	220-3(b)(5)
220-3(c)(5)	Track Lighting (Deleted—See 410-102)	220-12(b)
220-3(c)(6)	Sign and Outline Lighting	220-3(b)(6)
220-3(c)Exc. No.3	Show Windows	220-3(b)(7)
220-3(c)Exc. No.1	Fixed Multioutlet Assemblies	220-3(b)(8)
220-3(c)(7)	Other Outlets	220-3(b)(9)
220-3(d)	Loads for Additions to Existing Installations	220-3(c)
Table 220-3(b) *Note	General use receptacles in dwellings and guest rooms of hotels and motels	220-3(b)(10)
Table 220-3(b)	General Lighting Loads by Occupancies	Table 220-3(a)
210-22	Maximum Loads	220-4
210-22(a)	Motor-Operated and Combination Loads	220-4(a)
210-22(b)	Inductive Lighting Loads	220-4(b)
210-22(c) (part)	Range Loads	220-4(c)

Application

Article 220 is the base for all load calculations covered by the NEC. The major difference in the use of Article 220 in the 1999 NEC will be in the use of Section 220-3. Section 220-3(b) is now Section 220-3(a), and Section 220-3(c) is now Section 220-3(b). Exceptions to Section 220-3(c) are now incorporated into the rules

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of Section 220-3(b). Also, the former rules of Section 220-4, which did not involve calculations, were moved to Article 210 and replaced by text that was in Section 210-22, "Maximum Loads." A complete listing of the sections that were relocated is given in the table.

Article 220 is now used only to compute branch-circuit, feeder, and service loads. Once the load is determined, the provisions of Articles 210, 215, 230, 240, and 310 can be used to size conductors and determine overcurrent device ratings. Article 220 will direct the user to other sections where specific rules apply to loads, such as motors or air conditioning equipment.

Background and Explanation

This change was made to transform Article 220 into an article that is exclusively about calculations as the title of the article implies. Sections that were not part of load calculations were moved to Articles 210 and 215. The basic organization of the Parts of Article 220 remain the same. Part A, "General," covers branch circuit calculations and forms the basis for Part B, "Feeders and Services." Parts C and D are "Optional Calculations for Computing Feeder and Service Loads" and "Method for Computing Farm Loads," respectively.

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220-2 Fraction of Ampere Calculation

Type of Change

Revision and Relocation

BRIEF SUMMARY

All installations. The rule regarding fractions of an ampere was relocated from Chapter 9 examples and the examples are moved to new Appendix D.

Code Language

See flow chart.

Application

The examples in Chapter 9 along with the examples from Articles 550 and 552 are now in Appendix D. Appendix D is not a part of the mandatory rules of the code, but one small part of the examples was still needed. That part, on the proper way to deal with fractions of an ampere, was relocated to Section 220-2 so that it would remain as part of the code. The illustration shows the origin and destination of the examples and the fractions of an ampere rule.

Section 220-2(a) now contains what used to be 220-2 and covers nominal voltages for use in calculations. Section 220-2(b) contains the permission to drop minor fractions from calculations.

Background and Explanation

Although the examples have long been a part of Chapter 9, Chapter 9 is a part of the code as outlined in Section 90-2. The examples are meant to be just that, examples. They do not represent the only correct approach to the given problems. However, the placement of the examples in Chapter 9 caused some confusion. For instance, some licensing exams have included test problems that were modeled on the examples, and any approach other than that taken in the examples may have been considered incorrect. The examples are more properly placed in the new Appendix D where they are clearly for reference and are less likely to be misinterpreted as mandatory calculation methods.

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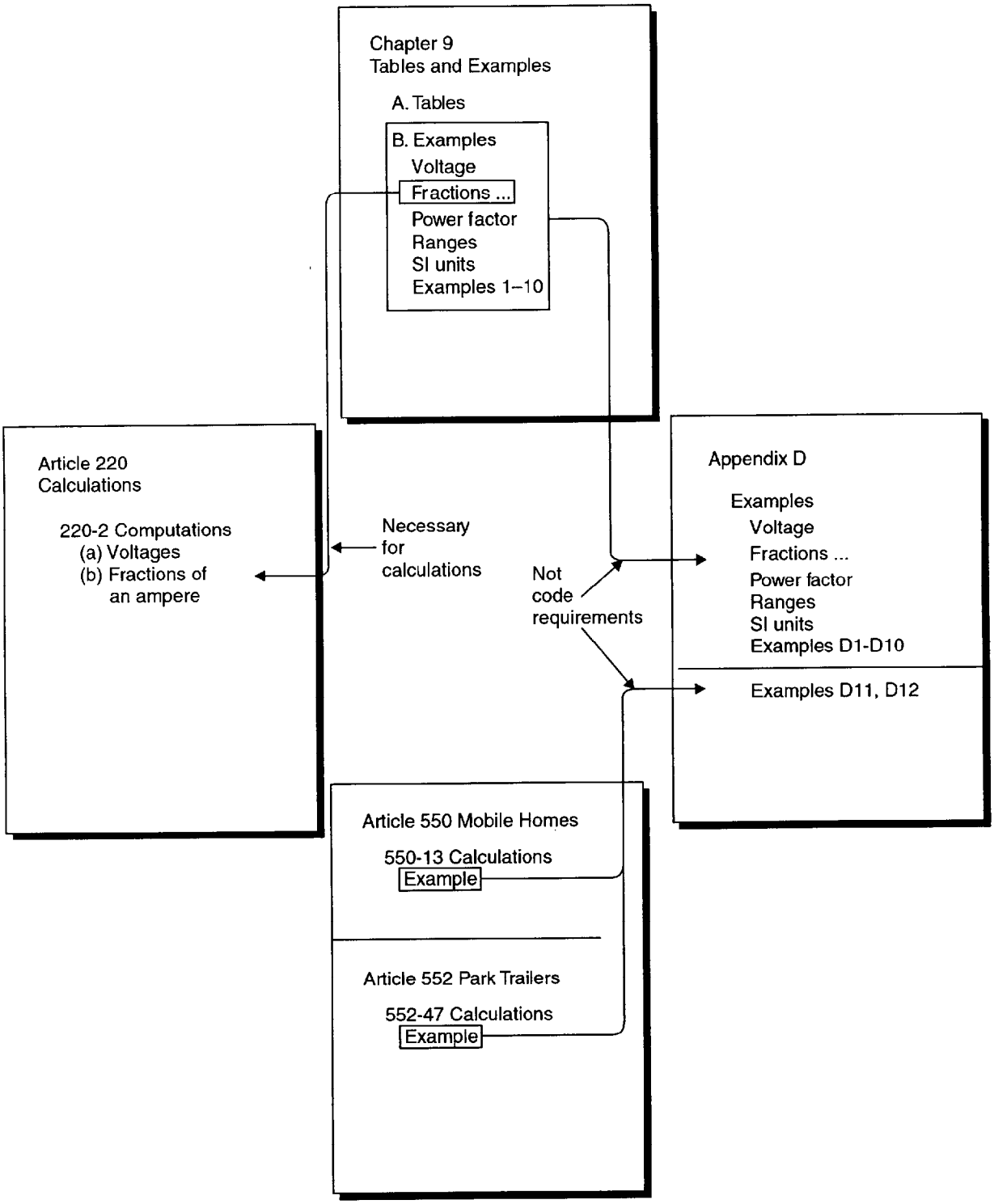

Relocation of Examples

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220-3 Load Requirements

Type of Change Revision

BRIEF SUMMARY

All occupancies. Extensive revision clarifies load calculation requirements.

Code Language

220-3. Computation of Branch Circuit Loads. Branch-circuit loads shall be computed as shown in (a) through **(c)**.

~~(a) Continuous and Noncontinuous Loads.~~ [Moved to Section 210-20(a)]

~~(b)~~**(a) Lighting Load for Specified Occupancies.** A unit load of not less than that specified in Table 220-3**(a)** ~~(b)~~ for occupancies specified therein shall constitute the minimum lighting load for each square foot (0.093 m^2) of floor area. . . .

FPN: The unit values herein are based on minimum load conditions and 100 percent power factor, and may not provide sufficient capacity for the installation contemplated.

(b) Other Loads—All Occupancies. In all occupancies, the minimum load for each outlet for general-use receptacles and outlets not used for general illumination shall not be less than **that computed in (1) through (11)**, the loads shown being based on nominal branch-circuit voltages. (ROP 2-5) (ROC 2-4)

Exception ~~No. 4~~: The loads of outlets serving switchboards and switching frames in telephone exchanges shall be waived from the computations. (ROP 2-5)

(1) **Specific Appliances or Loads.** An outlet for a specific appliance or other load not covered in **(2) through (11) shall be computed based on the** ampere rating of the appliance or load served. (ROP 2-5)

(2) **Electric Dryers and Household Electric Cooking Appliances. Load computations shall be permitted as specified in Section 220-18 for electric dryers and Section 220-19 for electric ranges and other cooking appliances.** (ROP 2-5)

(3) Motor Loads. Outlets for motor loads shall be computed in accordance with the requirements in Sections 430-22 and 430-24 and Article 440. (ROP 2-5)

(4) Recessed Lighting Fixtures. An outlet supplying recessed lighting fixture(s) shall be **computed based on** the maximum volt-ampere rating of the equipment and lamps for which the fixture(s) is rated. (ROP 2-5)

(5) Heavy Duty Lampholders. Outlets for heavy-duty lampholders shall be computed at a minimum of 600 volt-amperes. (ROP 2-5) (ROP 2-285)

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(6) Sign and Outline Lighting. Sign and outline lighting outlets shall be computed at a minimum of 1200 volt-amperes for each required branch circuit specified in Section 600-5(a). (ROP 2-5) (ROC 2-153)

(7) Show Windows. Show windows shall be computed in accordance with either (a) or (b).

(a) The unit load per outlet as required in other provisions of this section

(b) At 200 volt-amperes per linear foot of show window (ROP 2-5) (ROC 2-4)

(8) Fixed Multioutlet Assemblies. Fixed multioutlet assemblies used in other than dwelling units or the guest rooms of hotels or motels shall be computed in accordance with (a) or (b). (ROP 2-5)

(a) Where appliances are unlikely to be used simultaneously, each 5 ft (1.52 m) or fraction thereof of each separate and continuous length shall be considered as one outlet of not less than 180 volt-amperes. (ROP 2-5)

(b) Where appliances are likely to be used simultaneously, each 1 ft (305 mm) or fraction thereof shall be considered as an outlet of not less than 180 volt-amperes. (ROP 2-5)

(9) Receptacle Outlets. Except as covered in (10), receptacle outlets shall be computed at not less than 180 volt-amperes for each single or for each multiple receptacle on one strap. A single piece of equipment consisting of a multiple receptacle comprised of four or more receptacles shall be computed at not less than 90 volt-amperes per receptacle.

This provision shall not be applicable to the receptacle outlets specified in Sections 210-11(c)(1) and (2). (ROC 2-4)

(10) Dwelling Occupancies. In one-family, two-family, and multifamily dwellings and in guest rooms of hotels and motels, the outlets specified in (a), (b), and (c) are included in the general lighting load calculations of Section 220-3(a). No additional load calculations shall be required for such outlets.

(a) All general-use receptacle outlets of 20-ampere rating or less, including receptacles connected to the circuits in Section 210-11(c)(3)

(b) The receptacle outlets specified in Sections 210-52(e) and 210-52(g)

(c) The lighting outlets specified in Section 210-70(a) and (b)

(11) Other Outlets. Other outlets not covered in (1) through (10) shall be computed based on 180 volt-amperes per outlet. (ROC 2-4)

(c) Loads for Additions to Existing Installations. (ROP 2-5)

(1) Dwelling Units. Loads for structural additions to an existing dwelling unit or to a previously unwired portion of an existing dwelling unit, either of which exceeds 500 ft^2 (46.5 m^2), shall be computed in accordance with (b). Loads for new circuits or extended circuits in previously wired dwelling units shall be computed in accordance with either (a) or (b).

(2) Other than Dwelling Units. Loads for new circuits or extended circuits in other than dwelling units shall be computed in accordance with either (a) or (b).

Application

This revised section has integrated material that formerly appeared as exceptions into positive statement code text. The note for general lighting circuit calculation that used to appear at the bottom of Table 220-3(b) has been included in this section as Section 220-3(b)(10).

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Background and Explanation

In the 1996 NEC this section consisted of a series of rules and five exceptions. The extensive revision eliminated the exceptions by moving them into the main text. The new arrangement provides a more usable code section.

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220-3(b)(9) Calculation of Multiple Receptacle Devices

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Receptacle outlets with more than three receptacles on a strap are computed at 90VA per receptacle.

Code Language

220-3. Computation of Branch Circuit Loads.

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(9) Receptacle Outlets. Except as covered in (10), receptacle outlets shall be computed at not less than 180 volt-amperes for each single or for each multiple receptacle on one strap. A **single piece of equipment consisting of a multiple receptacle comprised of four or more receptacles shall be computed at not less than 90 volt-amperes per receptacle.**

This provision shall not be applicable to the receptacle outlets specified in Sections **210-11(c)(1) and (2).** (ROC 2-4)

Application

Convenience receptacle outlets in commercial and industrial occupancies are computed per outlet. This has been computed at 180VA per strap for receptacle outlets not intended for a specific appliance or other load. Multiple receptacles with more than three receptacles are increasingly common. The NEC now requires that a "fourplex" receptacle on a single strap be computed at 4 × 90VA = 360VA. Similarly, a "sixplex" receptacle on a single strap is computed at 6 × 90VA = 540VA. The illustration shows five common configurations of 125-volt 15-ampere receptacles.

These computations do not apply to residential load calculations. Most receptacles in dwelling units, other than those intended for specific appliances, which are covered by 220-3(b)(1), are included in the general lighting load, the small appliance load, or the laundry load. (See Section 220-3(b)(10).)

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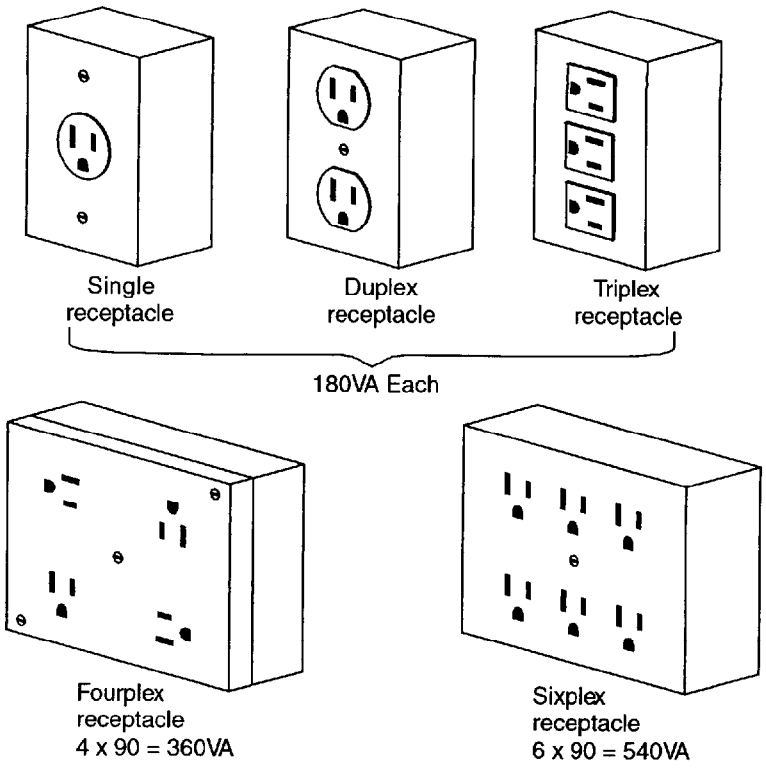

Calculation of Receptable Loads

Background and Explanation

Prior to the 1990 edition of the code, receptacle outlets were computed at 180 VA per outlet regardless of the number of receptacles at the outlet. A four-gang outlet box with four duplex receptacles counted the same as a single outlet in a single-gang box. (An "outlet" is defined in Article 100 as a location, not as a device or a piece of equipment.)

Since 1990 the computation of receptacle loads has been based on the number of straps, therefore two duplex receptacles in a box are computed at 2 × 180VA = 360VA. As multiple receptacles with up to six receptacles on a strap became more common, inspectors had no basis in the code for requiring a load calculation of more than 180VA per strap. This change addresses the newer style receptacle arrangements.

The reasoning behind this change is the same as the reasoning behind the 1990 change: If more receptacles are desired, more things are likely to be plugged in. If six cord- and plug-connected loads are connected to a single outlet, it makes sense to assume there is more load than if only two loads were connected to the same outlet.

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220-12 Track Lighting Feeder Calculation

Type of Change Relocated

BRIEF SUMMARY

All occupancies. Calculation of track lighting loads is relocated to the proper article.

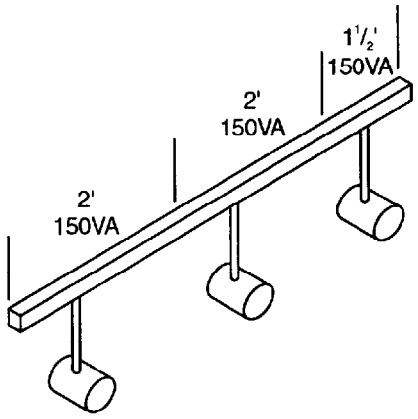
Code Language

220-12. Show-Window **and Track Lighting.**

(a) **Show Windows.** For show-window lighting, a load of not less than 200 volt-amperes shall be included for each linear foot (305 mm) of show window, measured horizontally along its base.

FPN: See Section **220-3(b)(7)** for branch circuits supplying show windows.

(b) Track Lighting. For track lighting in other than dwelling units or guest rooms of hotels or motels, an additional load of 150 volt-amperes shall be included for every 2 ft (610 mm) of lighting track or fraction thereof. (ROC 2-158a)



Calculation of Track Lighting Loads

Application

Track lighting in other than residential occupancies and guest rooms of hotels and motels is considered to be special-use lighting. This load is in addition to the normal lighting load calculated from Section 220-3(a). Track lighting loads are calculated at 150 volt-amperes per every 2 feet or fraction thereof.

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Background and Explanation

To aid the code user, this load calculation was relocated from Article 410 to Article 220. This change places the calculation with most other feeder calculations to enhance the usability of the code. This section provides the method to calculate track lighting loads on feeders and services and does not limit the linear footage of track permitted on a branch circuit. The branch-circuit sizing for track lighting is limited by the rating and listing of the track.

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220-15 Exc. Deleted Electric Heating Exception

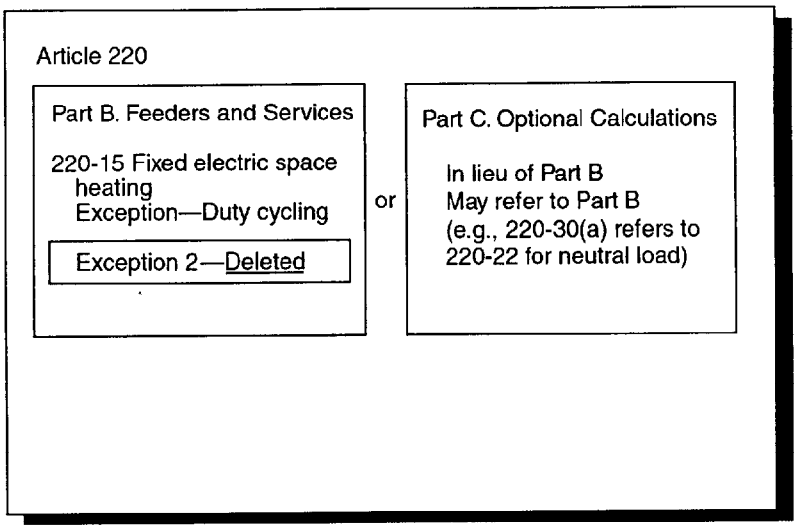
Type of Change Deletion

BRIEF SUMMARY

All installations. An exception referring to optional calculations for fixed electric space heating has been deleted.

Code Language

See flow chart.



Exception Deleted

Background and Explanation

Section 220-15 is located in Part B of Article 220. Part B is referred to as the standard method of computing feeder and service loads. The deleted exception seemed to imply that the optional calculation methods of Part C could be used as part of the standard method. For example, in Section 220-15 of Part B, fixed electric space heating is to be figured at 100 percent of the connected load. However, based on Section 220-15 Exception No. 2 in the 1996 NEC, a code user might infer that four or more baseboard heaters with separate thermostats could be computed at 40 percent of the nameplate load as allowed in the optional calculation in Section 220-30. Yet Section 220-30 said it was to be used "in lieu of the

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method specified in Part B . . . ." (The 1999 NEC says "instead of the method specified in Part B . . . .")

The deleted exception can be traced back to the 1971 NEC. Prior to the 1975 NEC, Article 220 had no lettered parts. All calculation methods were in one part. Exceptions were necessary to recognize the optional calculation methods. Section 220-7 in the 1971 NEC became Section 220-30 of Part C in the 1975 NEC. With the addition of Part C, which modifies Part B, the exceptions in Part B, which recognized the optional calculations, were rendered unnecessary. It was not intended to permit the mixing of components from the calculation methods of Parts B and C.

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220-16(a) Exc. Dwelling Unit Refrigerator Load

Type of Change

Revision and New

BRIEF SUMMARY

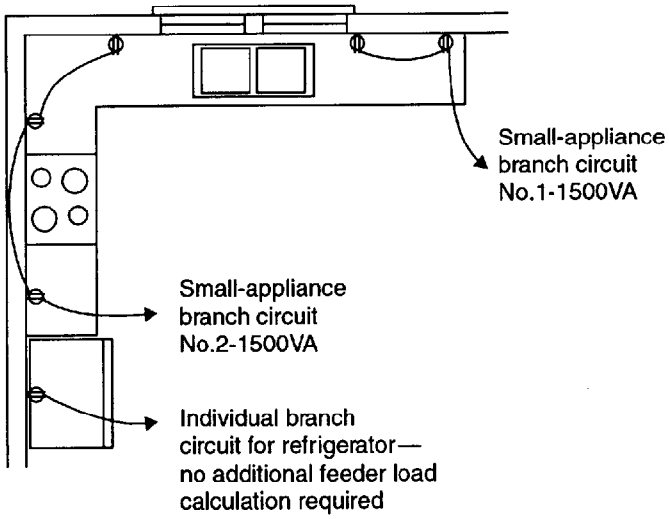
Residential. Calculations for small-appliance circuits in dwelling units are clarified.

Code Language

220-16. Small Appliance and Laundry Loads—Dwelling Unit.

(a) Small Appliance Circuit Load. In each dwelling unit, the ~~feeder~~ load shall be computed at 1500 volt-amperes for each 2-wire small-appliance branch circuit required by Section **210-11(c)(1)**. Where the load is subdivided through two or more feeders, the computed load for each shall include not less than 1500 volt-amperes for each 2-wire small-appliance branch circuit. These loads shall be permitted to be included with the general lighting load and subjected to the demand factors provided in Table 220-11. (ROP 2-5) (ROC 2-186)

Exception: The individual branch circuit permitted by Section 210-52(b)(1), Exception No. 2 shall be permitted to be excluded from the calculation required by Section 220-16. (ROP 2-312)



Individual Branch Circuit for Refrigerator

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Application

Section 210-52(b)(1) requires a minimum of two 20-ampere small-appliance branch circuits. These circuits are permitted to supply the refrigeration equipment. Section 220-16(a) requires a feeder calculation of 1500VA for each of these small-appliance circuits. Where the refrigeration equipment is connected to one of the required circuits, the refrigeration load is included in the 1500VA calculation.

Section 210-52(b)(1) Exception allows the refrigeration equipment to be supplied by a separate circuit rated 15 amperes or greater. The new exception in Section 220-16(a) clarifies that no additional load calculation is required for the separate circuit dedicated to the refrigeration equipment. In this case the load from the refrigeration is included in the 3000VA calculated for the required small-appliance circuits.

Background and Explanation

The main rule in Section 220-16(a) is revised to eliminate redundant requirements and update the references that have been renumbered. The new exception has been added to clarify that a separate refrigeration circuit in a dwelling unit does not require an additional load calculation. When Exception 2 to Section 210-52(b)(1) first appeared in the 1996 NEC, it was not clear whether an additional load calculation for the individual branch circuit was required.

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220-18 Dryer Calculations on 3-Phase Circuits

Type of Change Revision

BRIEF SUMMARY

Residential and multifamily. The application of demand factors to multiple household electric dryers connected to a 3-phase system is clarified.

Code Language

220-18. Electric Clothes Dryers in Dwelling Unit(s). The load for household electric clothes dryers in a dwelling unit(s) shall be 5000 watts (volt-amperes) or the nameplate rating, whichever is larger, for each dryer served. The use of the demand factors in Table 220-18 shall be permitted. **Where two or more single-phase dryers are supplied by a 3-phase, 4-wire feeder or service, the total load shall be computed on the basis of twice the maximum number connected between any two phases.** (ROP 2-344) (ROC 2-186)

Application

The illustration shows ten electric dryers connected to a 3-phase system. (Neutral connections are not shown.) Each dryer is 5000VA and the system is 208/120V. The demand load for the feeder or service conductors supplying these loads can be found as follows:

1. Identify the maximum number of dryers connected between any two phases. The illustrations shows four dryers connected A to B, three connected A to C, and three connected B to C. The maximum number connected between any two phases is four.
2. Select a demand factor based on twice the maximum number connected between any two phases. Four times two is eight. The demand factor from Table 220-18 for eight dryers is 60 percent.
3. Determine the total connected load. Ten dryers at 5000VA each is 50,000VA total connected load.
4. Apply the demand factor from Step 2 to the total connected load from Step 3 to determine the calculated or demand load. 50,000 × 60 percent = 30,000VA. The calculated load is 30,000VA.

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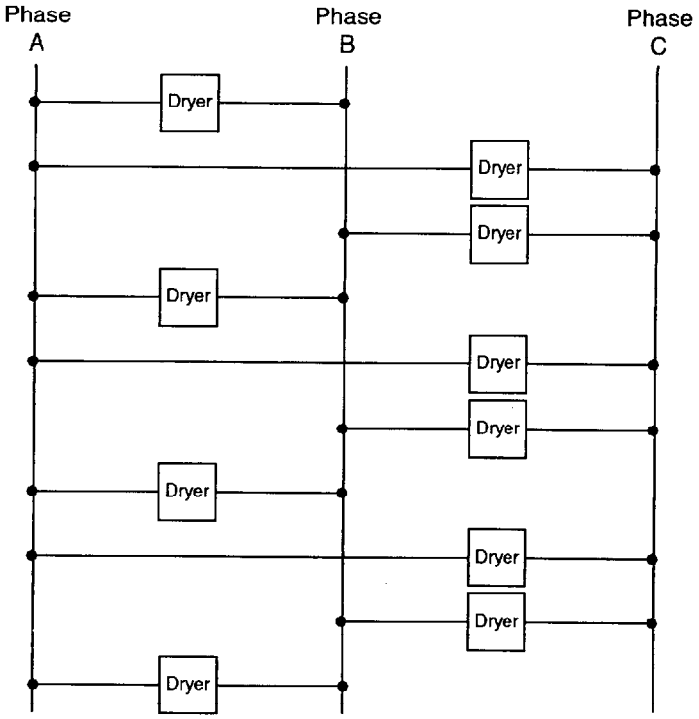

4 dryers connected between
Phase A and Phase B
4 x 2 = 8 dryers
8 dryers = 60% demand
10 dryers total x 5000VA = 50,000VA
50,000VA x 60% = 30,000VA demand load

Dryer Loads on Three-Phase System

Background and Explanation

This change is meant to clarify how 3-phase feeders or service conductors are to be sized when supplying multiple household electric dryers. Three-phase systems are often used to supply single-phase power to large multifamily dwellings. This makes 3-phase power available for house loads such as elevators and pool heaters, while still providing for single-phase systems to individual dwelling units.

Prior to the 1999 NEC, the code did not say how to deal with this issue. Using the total number of dryers to find a demand factor could result in undersized conductors on 3-phase systems because the load of the single-phase dryers will be distributed across the ungrounded conductors of a 3-phase system. Using only the number connected between any two phases to find a demand factor would, in the example given here, result in full-sized conductors (demand factor for four dryers = 100 percent), even though some diversity is highly likely with ten dryers. The change permitting the demand factor to be selected on the basis of twice the number connected between any two phases follows similar language used for household electric cooking equipment in 220-19.

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220-21 Loads Not in Use Simultaneously

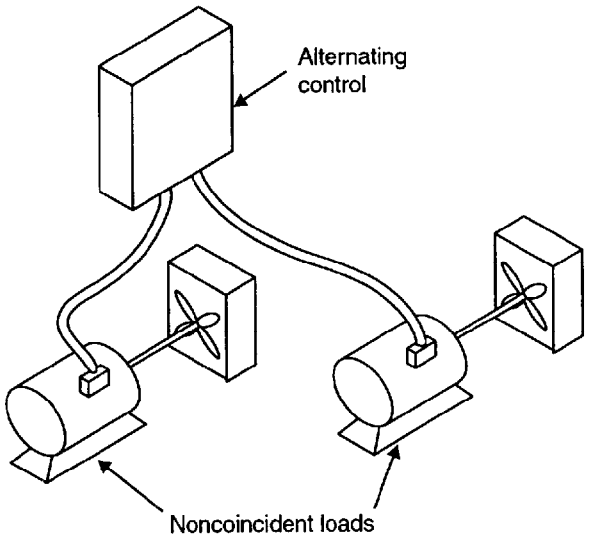
Type of Change Revision

BRIEF SUMMARY

All occupancies. Section is revised to clarify that noncoincident loads are not required to be dissimilar.

Code Language

220-21. Noncoincident Loads. Where it is unlikely that two **or more noncoincident** loads will be in use simultaneously, it shall be permissible to **use only the largest load(s) that will be used at one time,** in computing the total load of a feeder **or service.** (ROP 2-318) (ROC 2-161, 2-186)



Similar Loads Not in Simultaneous Use

Application

Where two similar loads, such as two heaters, are not operated at the same time, one of the loads may be omitted from the feeder of service calculation. When the loads are not the same size, the smaller load is to be omitted.

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It is important to note that Section 220-14 requires that motor calculations be in accordance with Sections 430-24, 430-25, and 430-26. Section 430-26 requires special permission from the authority having jurisdiction for the application of demand factors of this type.

Background and Explanation

The substantiation found in Proposal 2-318 suggested that there was no need to require loads to be dissimilar in order to allow a calculation reduction for nonsimultaneous operation. Motors were cited as an example in this proposal. Sections 220-14 and 430-26 were not changed, therefore special permission is still required for the application of demand factors where motors are involved.

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220-35 Adding to Existing Installations

Type of Change Revision

BRIEF SUMMARY

All installations. Section and exception were rewritten to clarify use of demand records to determine existing load.

Code Language

220-35. Optional Calculations for ~~Additional Loads to Existing Installations~~ **Determining Existing Loads. The calculation of a feeder or service load for existing installations shall be permitted to use actual maximum demand to determine the existing load under the following conditions.** (ROP 2-321) (ROC 2-167, 2-169)

1. The maximum demand data is available for a 1-year period.

Exception: If the maximum demand data for a 1-year period is not available, ***the calculated load shall be permitted to be based on the maximum demand (measure of average power demand over a 15-minute period)*** *continuously recorded over a minimum 30-day period using a recording ammeter* ***or power meter*** *connected to the highest loaded phase of the feeder or service,* ***based on the initial loading at the start of the recording.*** *The recording shall reflect the maximum demand of the feeder or service by being taken when the building or space is occupied and shall include by measurement or calculation the larger of the heating or cooling equipment load,* ***and other loads that may be periodic in nature due to seasonal or similar conditions.***

2. The **maximum** demand at 125 percent plus the new load does not exceed the ampacity of the feeder or rating of the service.

3. The feeder has overcurrent protection in accordance with Section 240-3, and the service has overload protection in accordance with Section 230-90.

Application

The illustration shows two basic methods of obtaining demand information. Demand information is usually available from utility records or power bills for commercial and industrial occupancies. Demand meters are less likely to be used by utilities for residential metering. Recording ammeters or recording power meters may also be used to obtain demand information.

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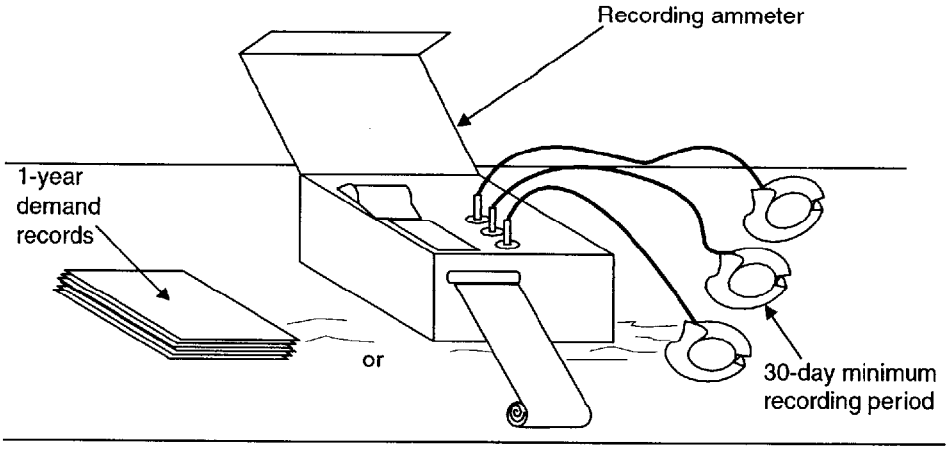

Measuring Existing Load for Additional Load

Section 220-35 is divided into three steps:

1. Obtain the maximum demand for a 1-year period. If the maximum demand is not available for a 1-year period, the demand information can be obtained by recording the usage over a 30-day period. The phase with the highest load at the time of the initial measurement must be recorded. The measurements shall be taken while the building is in use and must include the larger of heating or cooling loads and any other periodic or seasonal loads. Designers may include loads that are periodic or seasonal by actually measuring them or by calculating any loads not measured and adding them to the measured load.
2. Determine the required capacity of feeders or service conductors by adding the new load to 125 percent of the maximum demand load determined in Step 1. This value may then be compared to the existing feeder or service capacity to determine whether the existing installation is adequate for the new load. This value may also be used to size new services or feeders to handle the existing load plus the new load.
3. Verify that feeder and service overcurrent protection comply with 240-3 for the feeder and 230-90 for the service.

Background and Explanation

This change is meant to clarify four issues:

1. The title of this section was changed to "Optional Calculations for Determining Existing Loads" to clarify that the optional method of 220-35 is meant to measure "existing load," which may be supplied either by existing or new service or feeder conductors or distribution equipment.
2. The change clarifies that the highest loaded phase at the start of recording is considered to be the highest loaded phase for the purposes of recording maximum demand. This makes it clear that all phases do not have to be recorded for 30 days, and that a meter that records a single phase may be used.

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3. The change clarifies the meaning of "maximum demand" by explaining that it is the highest average demand over a 15-minute period. This is the method used by utilities to measure demand.
4. The change also explains that any periodic or seasonal loads must be included in the maximum demand, not just the larger of heating or air conditioning. The periodic loads and the maximum demand may be determined by measurement or calculation.

The proposal also included a provision to reduce the measurement period from 30 days to 7 days. This part of the proposal was rejected because of insufficient technical substantiation within the proposal to warrant a reduction in the monitoring period.

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NEC pp. 58 & 62

225-19(d)
230-9 Horizontal Clearances for Conductors from Platforms

Type of Change Revision

BRIEF SUMMARY

All installations. Vertical clearances from overhead service drops and outside feeders and branch circuits must be maintained over and near building projections and platforms.

Code Language

225-19. Clearances from Buildings for Conductors of Not Over 600 Volts, Nominal.

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(d) Final Spans. Final spans of feeders or branch circuits to a building they supply or from which they are fed shall be permitted to be attached to the building, but they shall be kept not less than 3 ft (914 mm) from windows that are designed to be opened, doors, porches, balconies, ladders, stairs, fire escapes, or similar locations. **Vertical clearance of final spans above, or within 3 ft (914 mm) measured horizontally of, platforms, projections, or surfaces from which they might be reached shall be maintained in accordance with Section 225-18.** (ROP 4-42a) (ROC 4-31)

Exception: Conductors run above the top level of a window shall be permitted to be less than the 3 ft (914 mm) requirement above.

Application

Overhead clearances are specified in Section 225-18 for outside branch circuits and feeders and in Section 230-24(b) for services. These clearances must be maintained where the conductors pass over platforms or projections from which the conductors could be reached.

In the illustration, two sets of conductors pass near a balcony. The conductors could be service conductors, feeders, or branch circuits. In this example the voltage to ground is 150 volts or less. The balcony is obviously only accessible to pedestrians, not vehicles. From Sections 225-18 or 230-24(b), the clearance that must be maintained is ten feet where the conductors pass above the balcony or pass above the area within 3 feet of the balcony. The 3-foot clearance required by Sections 225-19(d) or 230-9 must also be maintained.

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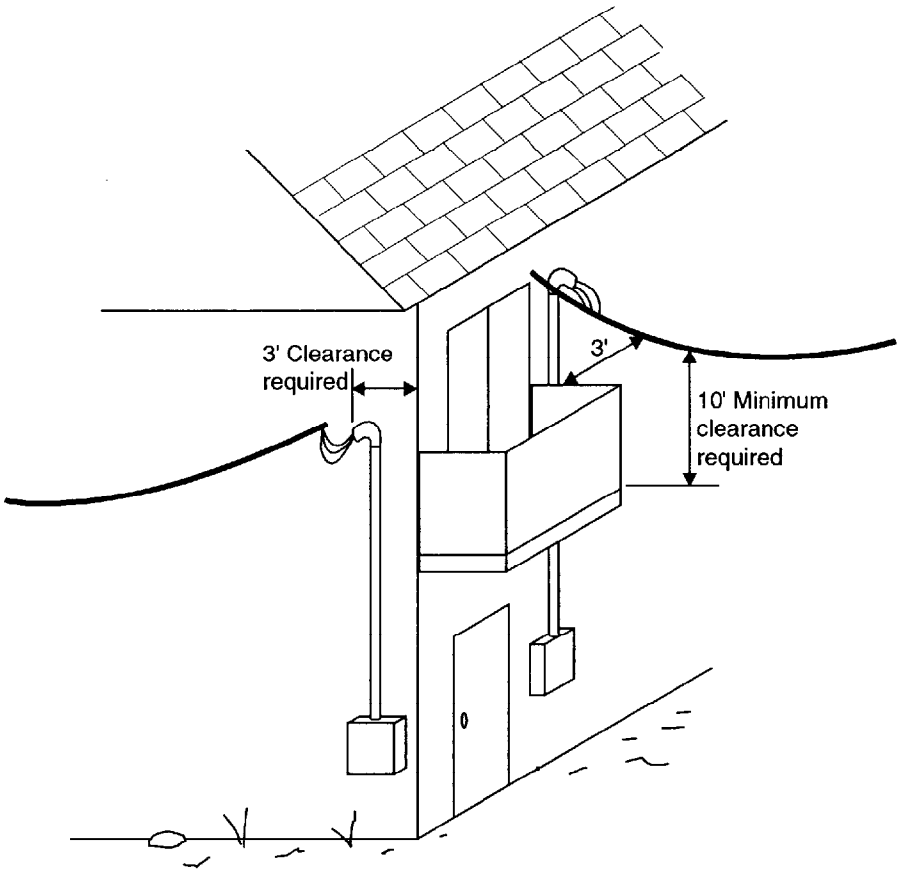

Clearances from Platforms or Projections

Background and Explanation

The substantiation for this proposal stated that the change was made "To clarify that the 10 ft must be maintained above platforms and surfaces." Section 225-18 already contained wording to that effect, but only under the 10-foot rule. Section 230-24(b) did not mention platforms or projections.

Under the new wording, the clearance that would apply to ground now also applies to platforms or surfaces, and the clearance is not limited to 10 feet. The applicable clearance must be maintained for 3 feet horizontally around the balcony. The required clearance depends on the voltage and the exposure. In some cases the required clearance might be 12 feet or 15 feet or even 18 feet if a projection was somehow subject to truck traffic. Sections 225-19(a) Exception No. 1 and 230-24(a) Exception No. 1 provide similar requirements for clearances above roofs.

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NEC pp. 59–60

Article 225
Part B Rules for Multiple Buildings

Types of Change
New and Relocation

BRIEF SUMMARY

All occupancies. Requirements where more than one building is supplied by a single service are clarified.

Code Language

B. More Than One Building or Other Structure.

225-30. Number of Supplies. Where more than one building or other struture is on the same property and under single management, each building or other structure served shall be supplied by one feeder or branch circuit unless permitted in (a) through (e). For the purpose of this section, a multiwire branch circuit shall be considered a single circuit.

(a) Special Conditions. Additional feeders or branch circuits shall be permitted to supply the following:

(1) Fire pumps

(2) Emergency systems

(3) Legally required standby systems

(4) Optional standby systems

(5) Parallel power production systems

(b) Special Occupancies. By special permission, additional feeders or branch circuits shall be permitted for

(1) Multiple-occupancy buildings where there is no available space for supply equipment accessible to all occupants, or

(2) A single building or other structure sufficiently large to make two or more supplies necessary.

(c) Capacity Requirements. Additional feeders or branch circuits shall be permitted where the capacity requirements are in excess of 2000 amperes at a supply voltage of 600 volts or less.

(d) Different Characteristics. Additional feeders or branch circuits shall be permitted for different voltages, frequencies, or phases, or for different uses, such as control of outside lighting from multiple locations.

(e) Documented Switching Procedures. Additional feeders or branch circuits shall be permitted to supply installations under single management where documented safe switching procedures are established and maintained for disconnection.

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225-35. Access to Occupants. In a multiple-occupancy building, each occupant shall have access to the occupant's supply disconnecting means.

Exception: In a multiple-occupancy building where electric supply and electrical maintenance are provided by the building management and where these are under continuous building management supervision, the supply disconnecting means supplying more than one occupancy shall be permitted to be accessible to authorized management personnel only.

225-36. Suitable for Service Equipment. The disconnecting means specified in **Section 225-31** shall be suitable for use as service equipment.

Exception: For garages and outbuildings on residential property, a snap switch or a set of 3-way or 4-way snap switches shall be permitted as the disconnecting means.

225-37. Identification. Where a building or structure has any combination of feeders, branch circuits, or services passing through it or supplying it, a permanent plaque or directory shall be installed at each feeder and branch-circuit disconnect location denoting all other services, feeders, or branch circuits supplying that building or structure or passing through that building or structure and the area served by each. See Section 230-2(b).

Exception No. 1: A plaque or directory shall not be required for large capacity multibuilding industrial installations under single management, where it is ensured that disconnection can be accomplished by establishing and maintaining safe switching procedures.

Exception No. 2: This identification shall not be required for branch circuits installed from a dwelling unit to a second building or structure.

225-38. Disconnect Construction.

(a) Manually or Power Operable. The disconnecting means shall consist of either (1) a manually operable switch or a circuit breaker equipped with a handle or other suitable operating means or (2) a power-operable switch or circuit breaker, provided the switch or circuit breaker can be opened by hand in the event of a power failure.

(b) Simultaneous Opening of Poles. Each building or structure disconnecting means shall simultaneously disconnect all ungrounded supply conductors that it controls from the building or structure wiring system.

(c) Disconnection of Grounded Conductor. Where the building or structure disconnecting means does not disconnect the grounded conductor from the grounded conductors in the building or structure wiring, other means shall be provided for this purpose at the location of disconnecting means. A terminal or bus to which all grounded conductors can be attached by means of pressure connectors shall be permitted for this purpose.

In a multisection switchboard, disconnects for the grounded conductor shall be permitted to be in any section of the switchboard, provided any such switchboard section is marked.

(d) Indicating. The building or structure disconnecting means shall plainly indicate whether it is in the open or closed position.

225-39. Rating of Disconnect. The feeder or branch-circuit disconnecting means shall have a rating of not less than the load to be carried, determined in accordance with Article 220. In no case shall the rating be lower than specified in (a), (b), (c), or (d).

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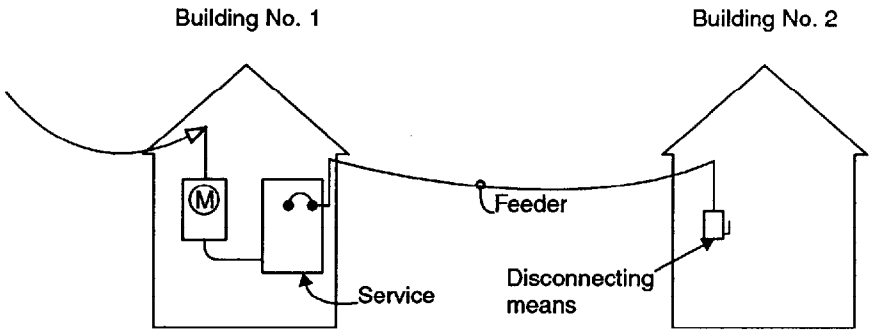
(a) One-Circuit Installation. For installations to supply only limited loads of a single branch circuit, the branch-circuit disconnecting means shall have a rating of not less than 15 amperes.

(b) Two-Circuit Installations. For installations consisting of not more than two 2-wire branch circuits, the feeder or branch-circuit disconnecting means shall have a rating of not less than 30 amperes.

(c) One-Family Dwelling. For a one-family dwelling, the feeder disconnecting means shall have a rating of not less than 100 amperes, 3-wire.

(d) All Others. For all other installations, the feeder or branch-circuit disconnecting means shall have a rating of not less than 60 amperes.

225-40. Access to Overcurrent Protective Devices. Where a feeder overcurrent device is not readily accessible, branch-circuit overcurrent devices shall be installed on the load side, shall be mounted in a readily accessible location, and shall be of a lower ampere rating than the feeder overcurrent device.



Disconnecting Means Required at Each Building

Application

Section 225-30 limits the number of electrical supplies to each building to one feeder or branch circuit. Provisions are included to allow multiple supplies similar to the Article 230 rules that allow multiple services.

Sections 225-31 through 225-34 have been relocated from Section 225-8 and no major changes were made.

Section 225-35 requires that the occupants have access to the building disconnect. This corresponds to the service requirement in Section 230-72(c). Sections 225-36 and 225-37 are relocated from Section 225-8.

Section 225-38 covers the rating of the disconnect and is similar to Section 230-79.

This extensive revision eliminated a number of cross references and clarifies the requirements for multiple buildings.

Background and Explanation

This revision is intended to limit the number of supply circuits to a building with exceptions similar to Section 230-2 for multiple services. A number of requirements from other articles are repeated in Part B to eliminate cross referencing. This group of rules plus the special rules for over 600 volts in new Part C, covers all outside branch-circuit and feeder installations.

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Article 225
Part C Requirements for Circuits Over 600 Volts

Type of Change New

BRIEF SUMMARY

Industrial. Requirements for outside feeders and branch circuits over 600 volts are provided.

Code Language

C. Over 600 Volts

225-50. Warning Signs. Signs with the following words "Warning—High Voltage—Keep Out" shall be posted in plain view where unauthorized persons might come in contact with live parts.

225-51. Isolating Switches. Where oil switches or air, oil, vacuum, or sulfur hexafluoride circuit breakers constitute a building disconnecting means, an isolating switch with visible break contacts and meeting the requirements of Section 230-204(b), (c), and (d) shall be installed on the supply side of the disconnecting means and all associated equipment.

Exception: The isolating switch shall not be required where the disconnecting means is mounted on removable truck panels or metal-enclosed switchgear units that cannot be opened unless the circuit is disconnected and that, when removed from the normal operating position, automatically disconnect the circuit breaker or switch from all energized parts.

225-52. Location. A building or structure disconnecting means shall be located in accordance with Section 225-32, or it shall be electrically operated by a similarly located remote-control device.

225-53. Type. Each building or structure disconnect shall simultaneously disconnect all ungrounded supply conductors it controls and shall have a fault-closing rating not less than the maximum available short-circuit current available at its supply terminals.

Where fused switches or separately mounted fuses are installed, the fuse characteristics shall be permitted to contribute to the fault closing rating of the disconnecting means. (ROC 4-36)

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Application

Premises wiring systems that employ over 600 volt distribution systems for multi-building complexes are commonplace in industrial and institutional settings. Within these installations it is also common to find branch circuits that supply equipment over 600 volts. These supply systems are not utility services, rather they are part of the premises wiring system and are frequently installed outdoors. This new set of rules provides requirements for outside branch circuits and feeders rated over 600 volts.

Background and Explanation

To clarify the requirements for installations over 600 volts, information has been located in this new part. Rules for these applications were located in other articles resulting in some confusion. This restructuring brings requirements together in a more usable format.

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NEC pp. 64 & 66

230-40 Excs. & 230-71(a) Number of Sets of Service-Entrance Conductors

Type of Change Revision

BRIEF SUMMARY

All occupancies. Restrictions on the number of sets of service-entrance conductors are clarified.

Code Language

230-40. Number of Service-Entrance Conductor Sets. Each service drop or lateral shall supply only one set of service-entrance conductors.

Exception No. 1: Buildings with one or more than one occupancy shall be permitted to have one set of service-entrance conductors ***for each class of service*** *run to each occupancy or group of occupancies.* (ROP 4-93)

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Exception No. 4: A two-family dwelling or a multifamily dwelling shall be permitted to have one set of service-entrance conductors installed to supply the circuits covered in Section 210-25. (ROP 4-93)

Exception No. 5: One set of service-entrance conductors connected to the supply side of the normal service disconnecting means shall be permitted to supply each or several systems covered by Section 230-82(3). (ROP 4-93)

230-71. Maximum Number of Disconnects.

(a) General. The service disconnecting means for each service permitted by Section 230-2, or for each set of service-entrance conductors permitted by Section 230-40, Exception Nos. 1 **or 3,** shall consist of not more than six switches or six circuit breakers mounted in a single enclosure, in a group of separate enclosures, or in or on a switchboard. There shall be no more than six disconnects per service grouped in any one location. For the purpose of this section, disconnecting means used solely for power monitoring equipment or the control circuit of the ground-fault protection system, installed as part of the listed equipment, shall not be considered a service disconnecting means. (ROP 4-144, 4-148, 4-149)(ROC 4-94)

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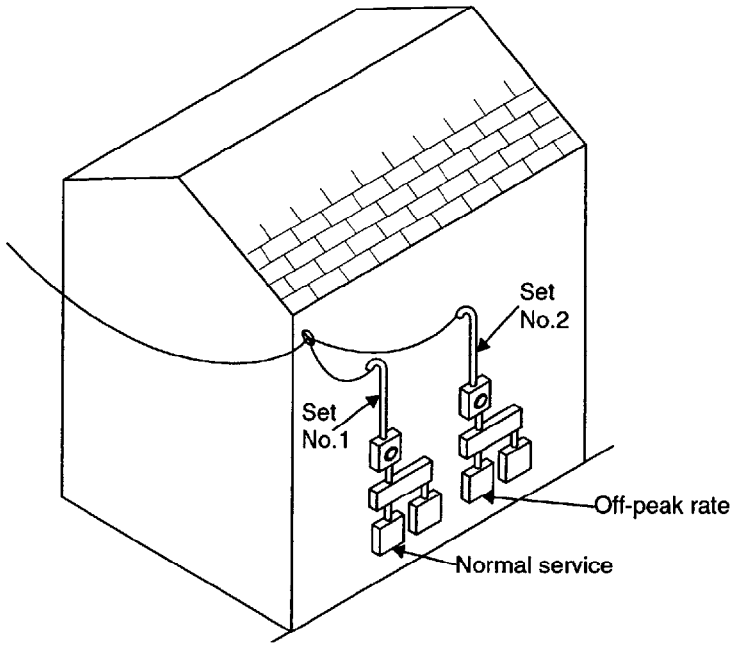

One Service Drop with Multiple Sets of Service Conductors

Application

Section 230-40 Exception No. 1: Where a building of one or more than one occupancy is supplied by several classes of service, each occupancy may have one set of service conductors for each class of service. A service drop or lateral for each class of service run to a building (for instance 120/240 volt, single phase and 480 Y/277 volt, 3 phase) is permitted to supply multiple sets of service-entrance conductors that are run to each occupancy.

Section 230-4 Exception No. 4: In two-family or multifamily dwellings, Section 210-25 requires a separate supply system for the common area equipment such as hallway lighting. This new exception allows a separate set of service conductors for this supply system.

Section 230-40 Exception No. 5: Section 230-82(5) allows a connection ahead of the service main for solar photovoltaic systems or interconnected electric-power production sources. This new exception allows a set of service-entrance conductors for the connections to these systems.

Section 230-71(a): Section 230-40 Exception No. 3 allows a set of service entrance conductors to be run to a separate building at a single-family dwelling. The disconnecting means at this separate structure may consist of up to six switches or circuit breakers.

Background and Explanation

The revisions were made to clarify the application of the rules and to provide for systems not covered here in the 1996 NEC. The revised Exception No. 1 recognizes a similar installation that is permitted for a single occupancy building in Section 230-2(d).

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230-42 Sizing of Service-Entrance Conductors

Type of Change Revision

BRIEF SUMMARY

All occupancies: Clarifies the sizing of the grounded service entrance conductor.

Code Language

230-42. Minimum Size and Rating.

(a) General. The ampacity of the service-entrance conductors before the application of any adjustment or correction factors shall not be less than either (1) or (2). Loads shall be determined in accordance with Article 220. Ampacity shall be determined from Section 310-15. The maximum allowable current of busways shall be that value for which the busway has been listed or labeled.

1. The sum of the noncontinuous loads plus 125 percent of continuous loads

2. The sum of noncontinuous load plus the continuous load if the service-entrance conductors terminate in an overcurrent device where both the overcurrent device and its assembly are listed for operation at 100 percent of their rating. (ROC 4-65)(TCC 4-65)

(b) Ungrounded Conductors. Ungrounded conductors shall have an ampacity of not less than **the minimum rating of the disconnecting means specified in Section 230-79.** (ROP 4-95b) (ROC 4-69)

Application

Section 230-42(b) requires the use of Section 230-79 for the selection of the ungrounded service-entrance conductors. Section 230-79 allows the rating of the service disconnect to be based on the load calculated from Article 220. The illustration gives an example of the sizing of various sevice components based on a noncontinuous load of 12,200VA and a continuous load of 16,200VA.

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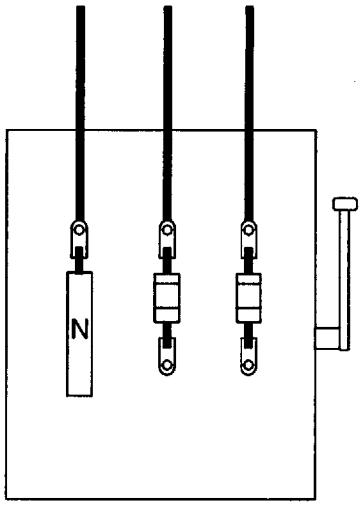

Total noncontinuous loads .....12,200 volt-amperes
Total continuous load @ 125%
16,200 x 1.25 .....20,250 volt-amperes
Total load .....32,450 volt-amperes

32,450 volt-amperes ÷ 240 volts = 135 amperes

The next higher standard size is 150 amperes (Section 240-6).

Minimum size disconnect: 135A 230-79
Minimum size ungrounded conductor: 135A 230-42(b), 230-79
Standard switch rating: 200A
Minimum standard fuse or circuit breaker: 150A 240-6

Determining Service Conductor Ampacity

Background and Explanation

The requirements for sizing the ungrounded service-entrance conductors and the service disconnecting means have contained similar language in past editions of the code. Section 230-79 was modified for the 1999 NEC and the panel decided that simply referencing Section 230-79 instead of repeating similar wording in Section 230-42 provided better correlation between the two sections. The requirements for service conductor sizing formerly located in Section 220-10(b) have been relocated to Section 230-42(a) as part of the effort to take conductor and overcurrent device-sizing requirements out of Article 220.

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230-46 Splicing of Service-Entrance Conductors

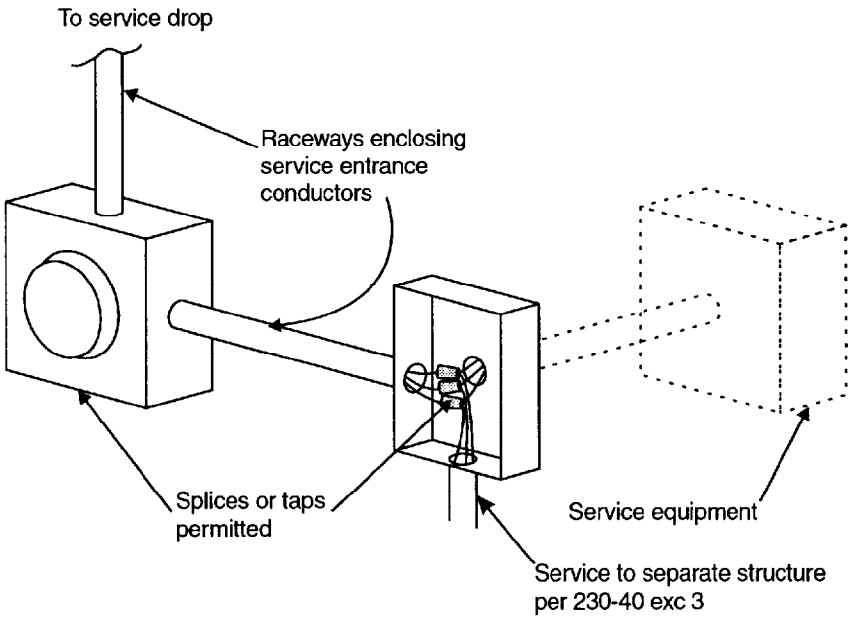
Type of Change Revision

BRIEF SUMMARY

All installations. Splices in service-entrance conductors are permitted.

Code Language

230-46. Spliced Conductors. **Service-entrance conductors shall be permitted to be spliced or tapped by clamped or bolted connections. Splices shall be made in enclosures or, if directly buried, with a listed underground splice kit. Splices of conductors shall be made in accordance with Sections 110-14, 300-5(e), 300-13, and 300-15.**



Splices in Service-Entrance Conductors

Application

The illustration shows service-entrance conductors run from an overhead service drop, through a meter base, through a junction box, and to the service equipment immediately inside the building. The splices in the junction box

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may have been made to facilitate a service change or move. The splices in the meter base would be necessary even for a new installation.

Service-entrance conductors may now be spliced or tapped as long as the splices or taps are enclosed and made by clamped or bolted connections. Underground splices need not have enclosures but must be made with devices listed for the purpose. The provisions of Sections 110-14, 300-5(e), 300-13, and 300-15 apply to the splices.

Background and Explanation

This section in the 1996 NEC was titled "Unspliced Conductors." The previous rule was that service-entrance conductors could not be spliced, with six exceptions. The splices shown in the junction box in the illustration would not have been permitted under the 1996 NEC as they would not fit any of the six exceptions. However, the splices in the meter base would have been permitted by Exception No. 1 in the 1996 code. The new rule recognizes the need for and common practice of splicing service-entrance conductors for repairs, to relocate equipment, or for any of the reasons covered by the previous exceptions.

One concern with splices in service-entrance conductors is that the conductors generally have no short-circuit or ground-fault protection. The former prohibition against splices was intended to increase the reliability of the conductors. Improperly made splices are of particular concern. Nevertheless, because the many exceptions that allowed splicing had not resulted in problems, the rule was changed to permit splices. Wording was added to specify the types of splicing devices permitted and the six exceptions were eliminated.

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230-50(a) Protection of Service Cables

Type of Change Deletion

BRIEF SUMMARY

All installations. The list of conditions that would expose service-entrance cables to physical damage have been deleted.

Code Language

230-50. Protection of Open Conductors and Cables Against Damage—Above Ground. Service-entrance conductors installed above ground shall be protected against physical damage as specified in (a) or (b).

(a) Service Cables. Service cables, where subject to physical damage, shall be protected by any of the following:

1. Rigid metal conduit
2. Intermediate metal conduit
3. Rigid nonmetallic conduit suitable for the location
4. Electrical metallic tubing
5. Other approved means (ROP 4-112a, 4-112b)

(b) Other Than Service Cable. Individual open conductors and cables other than service cables shall not be installed within 10 ft (3.05 m) of grade level or where exposed to physical damage. (ROP 4-112b)

Exception: Type MI and Type MC cable shall be permitted within 10 ft (3.05 m) of grade level where not exposed to physical damage or where protected in accordance with Section 300-5(d).

Application

Where service-entrance cables are subject to physical damage, they must be protected. Five methods of protection are listed: rigid metal conduit, intermediate metal conduit, rigid nonmetallic conduit, electrical metallic tubing, or by other approved means. What constitutes "subject to physical damage" is left to interpretation by the authority having jurisdiction.

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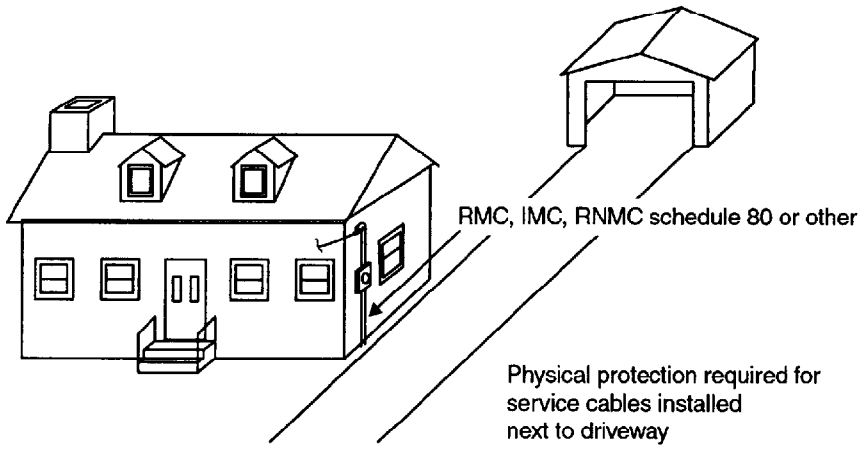

An Area Where Service Cables Require Physical Protection

Background and Explanation

This change eliminates the specific list of conditions under which service cables must be protected and substitutes the undefined phrase "where subject to physical damage." The substantiation stated that the reason for this change is to reserve judgment to the authority having jurisdiction to determine the locations where service conductors are subject to physical damage. The authority having jurisdiction may be the electrical inspector, utility company, or both.

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230-79 Minimum Rating of Service Disconnect for One-Family Dwelling Unit

Type of Change Revision

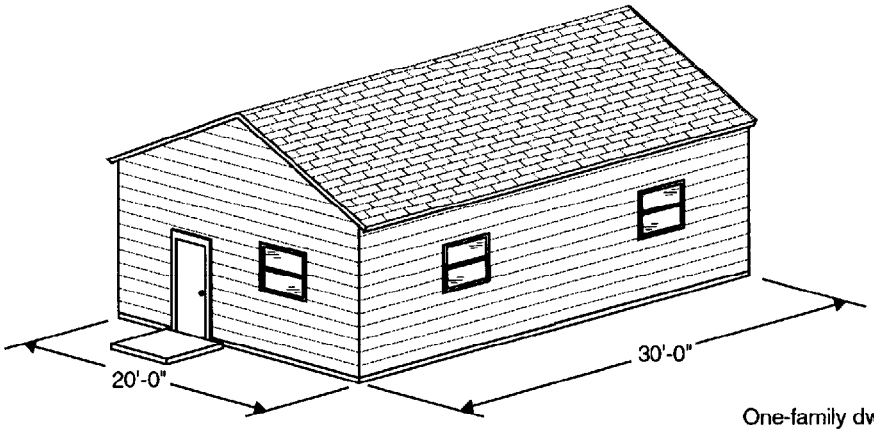
BRIEF SUMMARY

Residential. The minimum size service disconnect for a one-family dwelling unit is 100 amperes regardless of initial load or number of branch circuits.

Code Language

230-79. Rating of Service Disconnecting Means. The service disconnecting means shall have a rating not less than the load carried, determined in accordance with Article 220. In no case shall the rating be lower than specified in (a), (b), (c), or (d). (ROP 4-152b)

(c) One-Family Dwelling. For a one-family dwelling, the service disconnecting means shall have a rating of not less than 100 amperes, 3-wire. ~~under either of the following conditions: (1) where the initial computed load is 10k VA or more, or (2) where the initial installation consists of six or more 2-wire branch circuits.~~ (ROP 4-152b)



Minimum Residential Service Size

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Application

The illustration shows a small single-family dwelling unit. This dwelling has gas heat, a gas range, is plumbed for a gas dryer, and has no air conditioning. The gas furnace has a nameplate that lists the load at 120 volts, 12 amperes and requires a minimum 15-ampere branch circuit. Based on Article 220, the load would be computed as follows:

Floor area = 30 ft × 20 ft = 600 sq. ft	
1 General lighting circuit—(600 sq. ft × 3VA/sq. ft)	= 1800VA
2 Small-appliance branch circuits—(2 × 1500VA)	= 3000VA
1 Laundry circuit—(1 × 1500VA)	= 1500VA
Load subject to Table 220-11 demand factors	= 6300VA
Feeder load after demand factors (3000 @ 100% + 3300 @ 35%) = (3000VA + 1155VA)	= 4155VA
1 Central heating branch circuit—(12A × 120V)	= 1440VA
Initial net computed load	= 5595VA
5 Two-wire branch circuits total—Computed load (23A)	

This load is computed the same way under both the 1996 and 1999 codes.

According to 230-79(c) in the 1999 NEC, this dwelling unit is required to have a minimum 100-ampere service disconnect.

According to 230-79(c) and (d) in the 1996 NEC this dwelling would have been required to have a minimum 60-ampere service disconnect, because there are less than six 2-wire branch circuits and the initial net computed load is less than 10kVA.

Background and Explanation

The substantiation provided for this change was "To reflect current building practices." The example given here is obviously simplistic and is offered to illustrate the difference between the 1996 and 1999 codes. If a single-dwelling unit with the same characteristics were part of a multifamily dwelling, the 60-ampere rated disconnect would still be permitted.

Section 230-42(b) was also changed to require the ungrounded service-entrance conductors to have a rating equal to the service-disconnect rating. That change is discussed separately.

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230-92 Accessibility of Service Overcurrent Devices

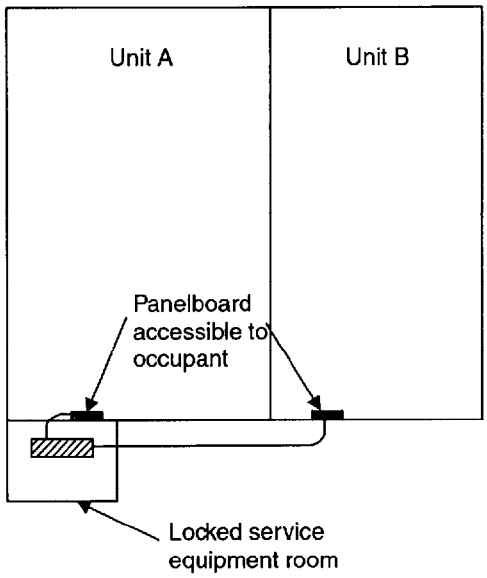
Type of Change Revision

BRIEF SUMMARY

All occupancies. Requirements where the service overcurrent device is not readily accessible or is locked or sealed are clarified.

Code Language

230-92. Locked Service Overcurrent Devices. Where the service overcurrent devices are locked or sealed, or not readily accessible **to the occupant,** branch-circuit overcurrent devices shall be installed on the load side, shall be mounted in a readily accessible location, and shall be of lower ampere rating than the service overcurrent device. (ROP 4-170)



Service Overcurrent Device Not Required to Be Accessible to Each Occupant

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Application

Section 230-72(c) Exception allows the service disconnect means to be under management control. In this situation the disconnect may not be readily accessible to each occupant of a multiple-occupancy building. In applications of this type the branch-circuit overcurrent devices must be readily accessible and of a lower rating than the service overcurrent protection.

Background and Explanation

Section 230-92 was revised to clarify the requirements for placement and accessibility of service overcurrent devices. The occupants of a multiple-occupancy building are not required to have access to the service overcurrent devices. This change correlates with similar language found in Section 240-24(b) 1.

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230-204 Visible-Break Contacts for Isolating Switches

Type of Change Revision

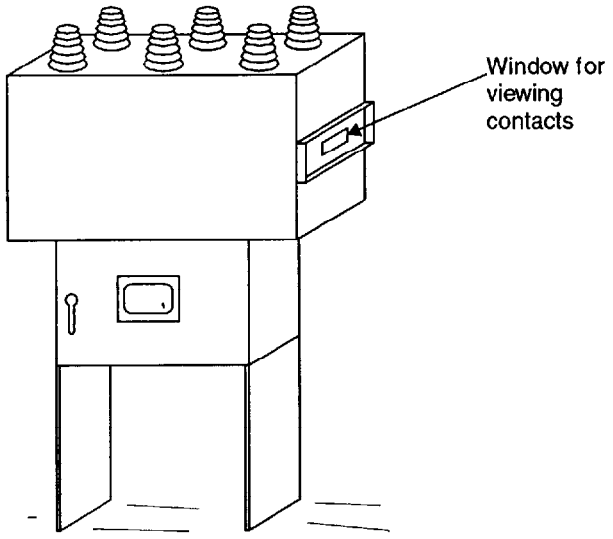
BRIEF SUMMARY

Industrial and commercial. Isolating switches must have visible-break contacts but are not required to be air-break types.

Code Language

230-204. Isolating Switches.

(a) Where Required. Where oil switches or air, oil, vacuum, or sulfur hexafluoride circuit breakers constitute the service disconnecting means, **an isolating switch with visible break contacts** shall be installed on the supply side of the disconnecting means and all associated service equipment. (ROP 4-172)



SF_6 Switch with visible break contacts

Isolating Switches

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Application

When oil switches or air, oil, vacuum, or sulphur hexafluoride circuit breakers are used as service disconnects on services over 600 volts, an isolating switch must be provided ahead of the service disconnect. This isolating switch must have visible-break contacts but is no longer required to be only the air-break type.

Background and Explanation

This change was made to provide additional options for isolating switches and to harmonize with the National Electrical Safety Code. The NEC has previously specified an air-break type of isolating switch, but this change allows other constructions with visible-break contacts. By requiring visible break contacts on the isolating switch, maintenance personnel can easily determine whether they are open or closed.

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230-205(c) Remote Control for Disconnects Over 600 Volts

Type of Change New

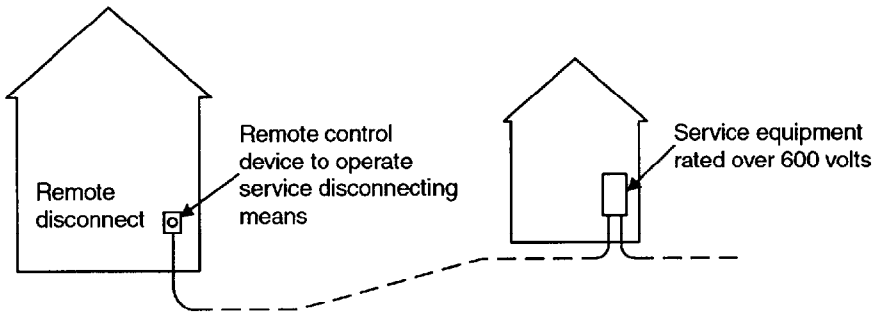
BRIEF SUMMARY

Industrial. Allows remote operation of medium-voltage disconnects.

Code Language

230-205. Disconnecting Means.

(c) Remote Control. For multibuilding, industrial installations under single management, the service disconnecting means shall be permitted to be located at a separate building or structure. In such cases, the service disconnecting means shall be permitted to be electrically operated by a readily accessible, remote-control device. (ROP 4-173) (ROC 4-108)



Service Disconnecting Arrangment for Over 600-Volt Multibuilding Industrial Complex

Application

In some industrial applications the service equipment is located in an outdoor substation. Each individual building is then supplied from one of the remotely located service disconnects. Remote operation of the service disconnect is permitted to be done from each building.

This method allows a means for safely disconnecting each building and eliminates the need to provide a medium-voltage switch at the termination of the conductors.

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Background and Explanation

Prior to the 1996 NEC this method was allowed. However, some Article 230 material was relocated to Articles 225 and 710 in 1996. The allowance for remote operation was deleted from the NEC in the 1996 edition. This new section with similar text from previous codes allows a common industry practice to continue.

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240-3(d) Small Conductor Overcurrent Protection Limits

Type of Change Relocation

BRIEF SUMMARY

All installations. The "obelisk note" information from the ampacity Tables 310-16 and 310-17 is relocated.

Code Language

240-3. Protection of Conductors.

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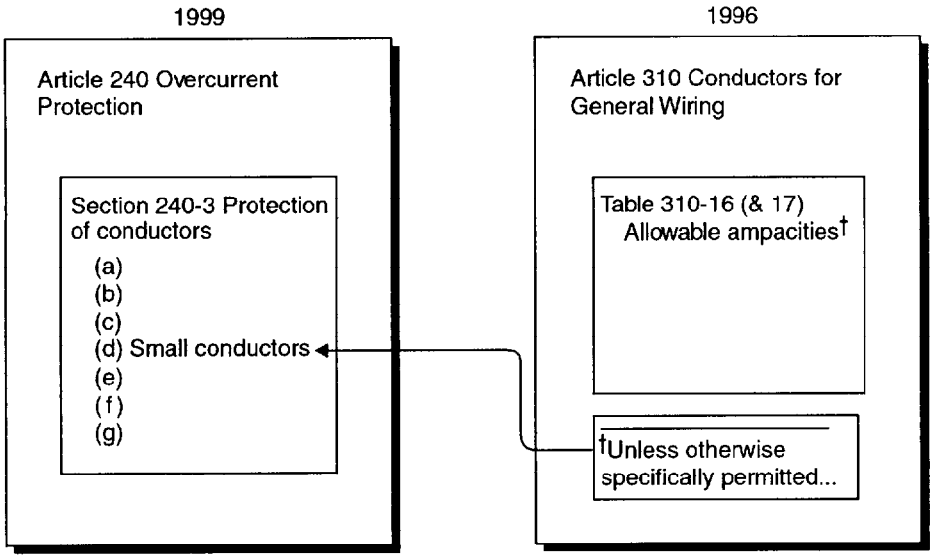
•
•

(d) Small Conductors. Unless specifically permitted in (e) through (g), the overcurrent protection shall not exceed 15 amperes for No. 14, 20 amperes for No. 12, and 30 amperes for No. 10 copper; or 15 amperes for No. 12 and 25 amperes for No. 10 aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied. (ROP 10-11)



"Obelisk Note" Relocated

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Application

The practical application of this rule has not changed. The overcurrent protection for small conductors, sizes No. 14, No. 12, and No. 10 AWG copper, are limited to 15, 20, and 30 ampere ratings, respectively. The overcurrent protection for small conductors sizes No. 12 and No. 10 AWG aluminum are limited to 15- and 25-ampere ratings, respectively. Other rules in Section 240-3, such as those for motors, air-conditioning equipment, and welders, permit the use of higher overcurrent device ratings for these conductor sizes.

Background and Explanation

This change was made primarily to improve the usability of the NEC. The obelisk note has been in Tables 310-16 and 310-17 in one form or another for over 30 years. Although the tables are used in determining ampacities, the obelisk note specifically limited the size of overcurrent protection for conductor sizes No. 14–No. 10 and was not a limit on the ampacity of small conductors. Moving this note to Article 240 puts the rule in a more appropriate location.

Much confusion has resulted from the obelisk note phrase "unless otherwise specifically permitted elsewhere in this code..." as well as from the fact that the rule had nothing to do with the ampacity of the conductors. Where would this specific permission be expected to be found? The specific permission was where it still remains, in Section 240-3. Section 240-3 gives specific permission to use the rules of Articles 430, 440, and 630 for sizing of conductor overcurrent protection. All of these articles provide separate rules for sizing conductors and selecting overcurrent protection. Conductors supplying motors and welders are usually allowed to have overcurrent protection rated at a value greater than the ampacity of the conductors they protect. Now the rule refers to the location of the specific permission, which can be found in Section 240-3 (e) through (g).

An asterisk note referencing Section 240-3 has been placed below Tables 310-16 and 310-17 to alert the user of the code where the requirements for overcurrent protection of small conductors (No. 14–No. 10) is now located.

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240-3(e) Tap Conductor Definition

Type of Change Revision

BRIEF SUMMARY

All occupancies. The meaning of the term "tap" as used in Article 240 is clarified.

Code Language

240-3. Protection of Conductors. Conductors, other than flexible cords and fixture wires, shall be protected against overcurrent in accordance with their ampacities as specified in Section 310-15, unless otherwise permitted or required in (a) through (g). (ROP 10-13a)

•
•
•

(e) Tap Conductors. Tap conductors shall be permitted to be protected against overcurrent in accordance with Sections 210-19(d), 240-21, 364-11, 364-12, and 430-53(d).

As used in this article, *a tap conductor* is defined as a conductor, other than a service conductor that has overcurrent protection ahead of its point of supply, that exceeds the value permitted for similar conductors that are protected as described elsewhere in this section. (ROP 10-11, 10-12)

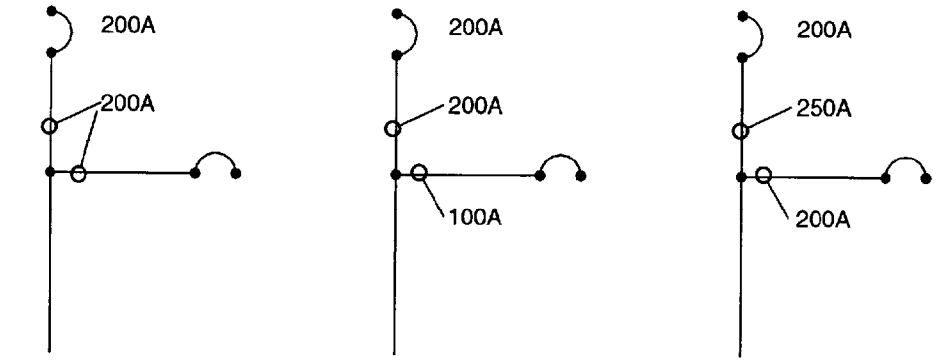

Figure B Meets New Definition of Tap Conductors.

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Application

The term "tap" is used throughout the code and several different meanings may be applied. The use of the term in Article 240 is only related to overcurrent protection. The Article 240 rules for tap conductors are to be applied only where the rating of the overcurrent is larger than the allowable rating of the device permitted for the conductor involved.

Background and Explanation

The term "tap" is used in many ways, both in the NEC and in the field. While not an Article 100 definition, this revision assigns a clear meaning to the term as used in Article 240. Branch circuit taps, feeder and transformer secondary taps, busway taps, and motor circuit taps are covered by this Article 240 definition.

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240-3(g) Revised Format for Overcurrent Protection Rules

Type of Change Reorganization

BRIEF SUMMARY

All installations. Section 240-3 has been reorganized, with many references to other articles placed in a table.

Code Language

240-3. Protection of Conductors.

(g) Overcurrent Protection for Specific Conductor Applications. Overcurrent protection for the specific conductors shall be permitted to be provided as referenced in the following list.

Air-conditioning and refrigeration equipment circuit conductors	Article 440, Parts C and F
Capacitor circuit conductors	Article 460, Sections 460-8(b) and 460-25(a) through (d)
Control and instrumentation circuit conductors (Type ITC)	Section 727-9
Electric welder circuit conductors	Article 630, Sections 630-12 and 630-32
Fire alarm system circuit conductors	Article 760, Sections 760-23, 760-24, 760-41 and Chapter 9, Tables 12(a) and 12(b)
Motor-operated appliance circuit conductors	Article 422, Part B
Motor and motor-control circuit conductors	Article 430, Parts C, D, E, F, and H
Phase converter supply conductors	Article 455, Section 455-7
Remote-control, signaling, and power-limited circuit conductors	Article 725, Sections 725-23, 725-24, 725-41, and Chapter 9, Tables 11(a) and 11(b)
Secondary tie conductors	Article 450, Section 450-6

(ROP 10-13a, ROC 10-8)

Application

Section 240-3 provides a list of rules for overcurrent protection of conductors. Much of Section 240-3 refers the user to other articles for the protection of conductors supplying specific types of loads. Those other articles are now listed in Section 240-3(g).

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Background and Explanation

This change makes Section 240-3 easier to use. No technical requirements other than the reference to Type ITC cable were changed by this reorganization. The former 240-3(i), concerning overcurrent protection for transformer secondary conductors, has been renumbered as 240-3(f). The remaining rules in 240-3(e) through (m) were just references to and permission to use other articles and have been replaced by a list of references to other articles. The format will make this section more user friendly.

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240-4(b)(3) Field-Assembled Extension Cord Sets

Type of Change Revision

BRIEF SUMMARY

All installations. Field-assembled cord sets with conductors size No. 16 or larger are permitted to be protected by 20-ampere overcurrent devices.

Code Language

240-4. Protection of Flexible Cords and Fixture Wires.

(3) Extension Cord Sets. Flexible cord used in listed extension cord sets, **or in extension cords made with separately listed and installed components,**

Cord Conductor Size	Listed Cord Set		Field-Assembled from Listed Components	
	Overcurrent Protection		Overcurrent Protection	
	1996 NEC	1999 NEC	1996 NEC	1999 NEC
No.16 AWG	20A	20A	10A Ampacity table 400-5(A)	20A
No.14 AWG	20A	20A	15A Ampacity table 400-5(A)	20A
No.12 AWG	20A or Table 400-5(A)	20A or Table 400-5(A)	20-25A Ampacity table 400-5(A)	20A or Table 400-5(A)

Protection of Cord Sets

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shall be permitted to be supplied by a branch circuit of Article 210 in accordance with the following: 20-ampere circuits—No. 16 and larger (ROP 10-26, 10-27) (ROC 10-17)

Application

Cord sets may be assembled in the field from listed components. Such cords, with conductors sized No. 16 or larger, may now be supplied and protected by 20-ampere circuits. The table illustration shows the differences between the protection requirements for flexible cords in the 1996 and 1999 edition of the NEC.

Background and Explanation

Prior to this change, only cords in listed extension cord sets were permitted to be protected by overcurrent devices rated higher than the ampacity of the cords. Other cords and field assembled extension cords were required to be protected at their ampacities. Cord ampacities are listed in Tables 400-5(A) and 400-5(B). This change allows No. 16 AWG cords assembled in the field using listed attachment plugs and receptacle bodies (also known as cord caps and connectors) to be protected by a 20-ampere overcurrent protection device.

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NEC pp. 73–76

240-21 Tap Conductor Rules

Type of Change Reorganization

BRIEF SUMMARY

All installations. The "tap rules" have been reorganized, with the rules for feeder taps separated from the rules for transformer secondary conductors.

Code Language

240-21. Location in Circuit. Overcurrent protection shall be provided in each ungrounded circuit conductor and shall be located at the point where the conductors receive their supply, **except as specified in (a) through (g). No conductor supplied under the provisions of (a) through (g) shall supply another conductor under those provisions, except through an overcurrent protective device meeting the requirements of Section 240-3.** (ROP 10-54, 10-56) (ROC 10-40)

Outline of revised Section 240-21:

240-21 Location in Circuit
- 240-21(a) Branch Circuit Conductors
- 240-21(b) Feeder Taps
  - 240-21(b)(1) Taps Not over 10 Ft. Long
  - 240-21(b)(2) Taps Not over 25 Ft. Long
  - 240-21(b)(3) Taps Supplying a Transformer
  - 240-21(b)(4) Taps over 25 Ft. Long
  - 240-21(b)(5) Outside Taps of Unlimited Length
- 240-21(c) Transformer Secondary Conductors
  - 240-21(c)(1) Protection by Primary Overcurrent Device
  - 240-21(c)(2) Transformer Secondary Conductors Not over 10 Ft. Long
  - 240-21(c)(3) Secondary Conductors Not over 25 Ft. Long
  - 240-21(c)(4) Outside Secondary Conductors
  - 240-21(c)(5) Secondary Conductors from a Feeder Tapped Transformer
- 240-21(d) Service Conductors
- 240-21(e) Busway Taps
- 240-21(f) Motor Circuit Taps
- 240-21(g) Conductors from Generator Terminals

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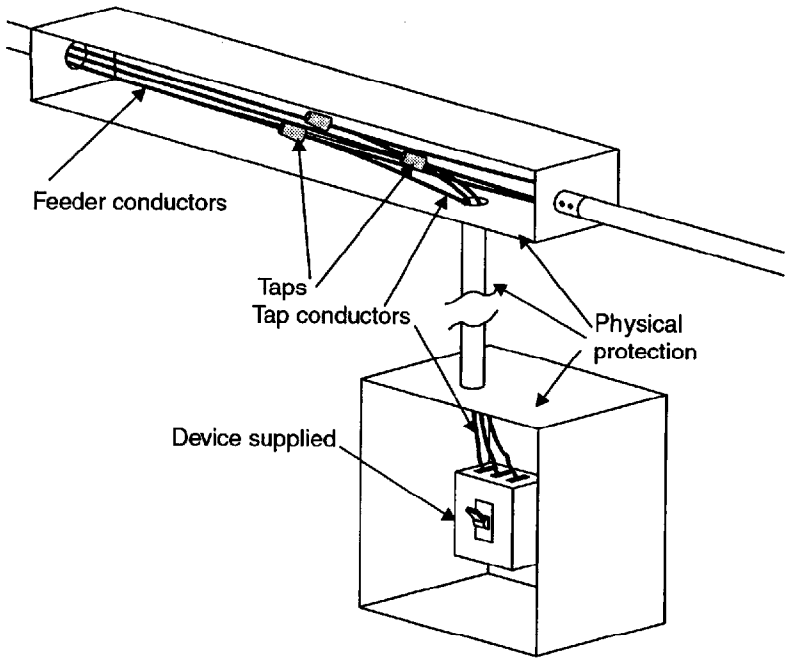

Figure 1. Tap Conductors

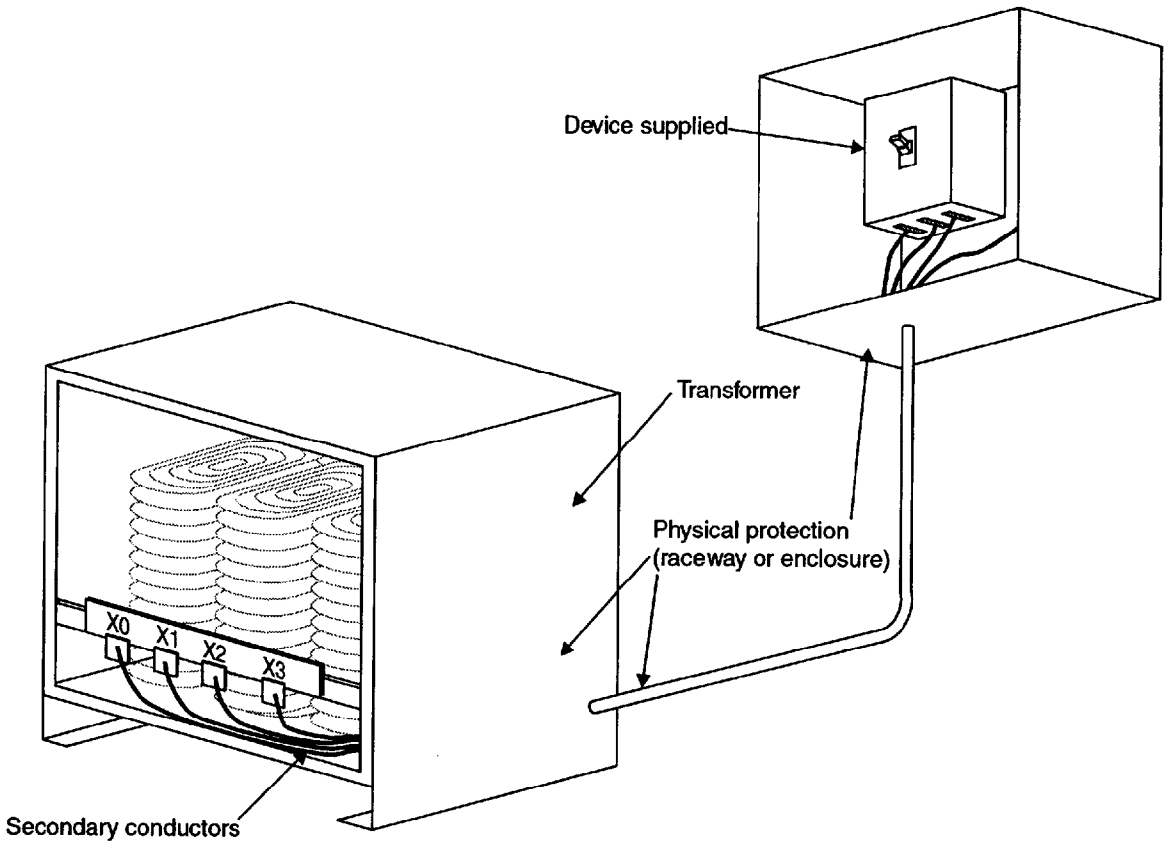

Figure 2. Transformer Secondary Conductors

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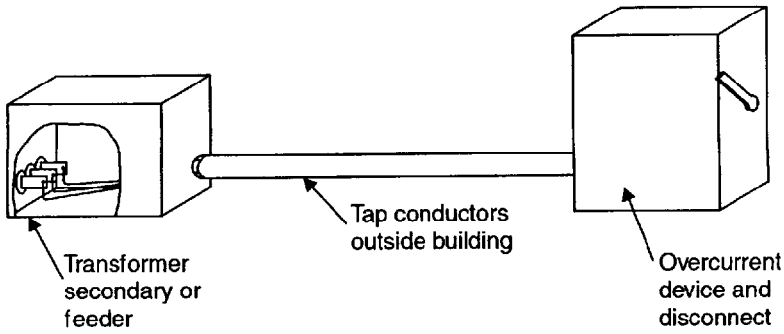

Figure 3. Outside Feeder Taps and Transformer Secondary Conductors

Application

This section contains what are often called the "tap rules." The effect and application of the tap rules have not been modified significantly by this reorganization. The outline of Section 240-21 shows that the rules for transformer secondary conductors have been separated from the rules for feeder taps. The general rule of Section 240-21 is that conductors will be protected where they receive their supply. Subsections 240-21(a) through 240-21(g) modify this general rule.

Figure 1 illustrates tap conductors connected to a feeder. Feeder taps are covered by Section 240-21(b), which is divided into five specific conditions. The variations in the five conditions in the feeder tap rules are based on five general factors: one, the length of the tap conductors; two, the ampacity of the tap conductors, including their adequacy for the load and their size relative to the protective device for the conductors from which the taps are made; three, the rating of the device or equipment supplied; four, the type of device or equipment supplied; and five, the physical protection provided by enclosure and sometimes elevation.

Figure 2 illustrates transformer secondary tap conductors. Transformer secondary conductors are covered by Section 240-21(c), which is also divided into five specific conditions. However, in this case the fifth condition, 240-21(c)(5), refers back to 240-21(b)(3) for taps supplying a transformer. The variations in the conditions for transformer secondary conductors are based on eight general factors: one, the length of the secondary conductors; two, the type of transformer; three, the rating of the primary overcurrent protection; four, the ampacity of the secondary conductors; five, the rating of the device or equipment supplied; six, the type of equipment or device supplied; seven, the location of the device supplied; and eight, the protection of the conductors by enclosure or location. Not all of these eight factors are considered by every rule.

Figure 3 illustrates an outside feeder tap of unlimited length. The conductors are required to terminate in a single set of fuses or a single circuit breaker that limits the load to the ampacity of the tap conductors.

A new Part H of Article 240 covers supervised industrial installations. The new part may modify some of the rules in this section for such installations. An example of such modifications is permission to use tap conductors at increased lengths. This change is covered separately.

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Background and Explanation

This change was made to improve the usability of Section 240-21. The previous intermixing of the rules for feeder taps and transformer secondary conductors have been sorted out to enable users of the code to determine specifically which rules apply to feeder tap conductors and which rules apply to transformer secondary conductors. In order to apply the rules of the previous version of Section 240-21 to transformer secondary conductors, it was necessary to identify transformer secondary conductors as "tap conductors" in order to apply the intended rules.

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240-21 Tapping a Tap Conductor Prohibited

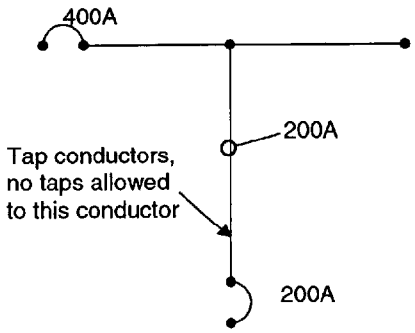
Type of Change Revision

BRIEF SUMMARY

All occupancies. Entire section has been clarified for ease of use.

Code Language

240-21. Location in Circuit. Overcurrent protection shall be provided in each ungrounded circuit conductor and shall be located at the point where the conductors receive their supply, **except as specified in (a) through (g). No conductor supplied under the provisions of (a) through (g) shall supply another conductor under those provisions, except through an overcurrent protective device meeting the requirements of Section 240-3.** (ROP 10-54, 10-56) (ROC 10-40)



Additional Tap Conductor Connections Cannot Be Made to Individual Tap Conductors.

Background and Explanation

The main rule of Section 240-21 has been revised. This rule now makes it clear that an additional connection cannot be made to a tap conductor ahead of the required overcurrent protection. Inspectors and users have frequently expressed the concept as "you can't tap a tap." This is of particular concern when conductors are tapped from a set of parallel conductors. The individual conductors that

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comprise the parallel circuit would themselves be considered as taps when a tap is not connected to all of the conductors (of a particular phase, grounded conductor, or neutral) in the parallel arrangement. The revised format makes a clear distinction between rules for conductors tapped to a feeder and those for conductors connected to the secondary of a transformer.

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240-86 Motor Contribution to Series Ratings

Type of Change New

BRIEF SUMMARY

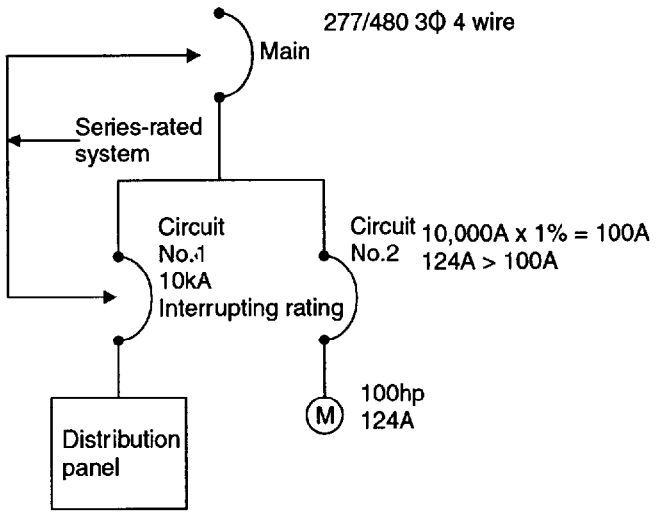
Commercial and industrial. Some use of series-rated systems where motor loads may contribute to short circuit current is restricted.

Code Language

240-86. Series Ratings.

(b) Motor Contribution. Series ratings shall not be used where

(1) Motors are connected on the load side of the higher-rated overcurrent device and on the line side of the lower-rated overcurrent device.
(2) The sum of the motor full-load currents exceeds 1 percent of the interrupting rating of the lower-rated circuit breaker. (ROP 10-114)



Impact of Motor Contribution to Series-Rated System

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Application

Where motor loads are connected between two series-rated devices, the lower-rated (downstream) device can be subjected to more fault current than it was during the series testing.The series rating of the overcurrent protection devices for the Main and Circuit No.1 in the illustration cannot be used where motor FLC exceeds 1 percent of Feeder No.1 OCPD interrupting rating.

This new section is intended to restrict the use of series-rated systems where motors are connected between series-rated devices.

Background and Explanation

This change recognizes that a motor becomes a generator when de-energized and still rotating and can contribute to the available fault current in the system. When series-rated systems are evaluated, it is not known whether there will be motors in a particular facility and, where there are motors, what the size will be. Therefore an accurate evaluation of the motor contribution to the available fault current can only be made on a case-by-case basis. This engineering information can then be used to select the properly rated equipment.

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NEC pp. 78–79

Article 240
Part H Supervised Industrial Installations

Type of Change New

BRIEF SUMMARY

Industrial. A new Part H, which includes Sections 240-90, 240-91, and 240-92, defines and provides special rules for supervised industrial installations.

Code Language

H. Supervised Industrial Installations

240-90. General. Overcurrent protection in areas of supervised industrial installations shall comply with all the applicable provisions of the other sections of this article, except as provided in Part H. The provisions of Part H shall only be permitted to apply to those portions of the electrical system in the supervised industrial installation used exclusively for manufacturing or process control activities. (ROP 10-115a) (ROC 10-93)

240-91. Definition of Supervised Industrial Installation. For the purposes of Part H, *Supervised Industrial Installation* is defined as the industrial portions of a facility where all of the following conditions are met.

(1) Where conditions of maintenance and engineering supervision ensure that only qualified persons will monitor and service the system.

(2) The premises wiring system has 2500 kVA or greater of load used in industrial process(es), manufacturing activities, or both, as calculated in accordance with Article 220.

(3) The premises has at least one service that is more than 150 volts to ground and more than 300 volts phase-to-phase.

This definition shall not apply to those installations in buildings used by the industrial facility for offices, warehouses, garages, machine shops, and recreational facilities that are not an integral part of the industrial plant, substation, or control center. (ROP 10-115b) (ROC 10-93)

240-92. Location in Circuit. An overcurrent device shall be connected in each ungrounded circuit conductor as follows. (ROP 10-115c)

(a) Feeder and Branch-Circuit Conductors. Feeder and branch-circuit conductors shall be protected at the point the conductors receive their supply, as permitted in Section 240-21, or as otherwise permitted in (b) or (c).

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(b) Transformer Secondary Conductors of Separately Derived Systems. Conductors shall be permitted to be connected to a transformer secondary of a separately derived system, without overcurrent protection at the connection, where the conditions of (1), (2), and (3) are met:

(1) Short-Circuit and Ground-Fault Protection. The conductors shall be protected from short-circuit and ground-fault conditions by complying with one of the following conditions.

(a) The length of the secondary conductors does not exceed 50 ft (15.24 m) and the transformer primary overcurrent device has a rating or setting that does not exceed 150 percent of the value determined by multiplying the secondary conductor ampacity by the secondary-to-primary transformer voltage ratio.

(b) The length of the secondary conductors does not exceed 75 ft (22.86 m) and the conductors are protected by a differential relay with a trip setting equal to or less than the conductor ampacity.

(c) The conductors shall be considered to be protected if the length of the secondary conductors does not exceed 75 ft (22.86 m) and if calculations, made under engineering supervision, determine that the system overcurrent devices will protect the conductors within recognized time vs. current limits for all short-circuit and ground-fault conditions.

(2) Overload Protection. The conductors shall be protected against overload conditions by complying with one of the following.

(a) The conductors terminate in a single overcurrent device that will limit the load to the conductor ampacity.

(b) The sum of the overcurrent devices at the conductor termination limits the load to the conductor ampacity. The overcurrent devices shall consist of not more than six circuit breakers or sets of fuses, mounted in a single enclosure, in a group of separate enclosures, or in or on a switchboard. There shall be no more than six overcurrent devices grouped in any one location.

(c) Overcurrent relaying is connected [with a current transformer(s), if needed] to sense all of the secondary conductor current and limit the load to the conductor ampacity by opening upstream or downstream devices.

(d) Conductors shall be considered to be protected if calculations, made under engineering supervision, determine that the system overcurrent devices will protect the conductors from overload conditions.

(3) Physical Protection. The secondary conductors shall be suitably protected from physical damage.

(c) Outside Feeder Taps. Outside conductors shall be permitted to be tapped to a feeder or to be connected at a transformer secondary, without overcurrent protection at the tap or connection, where all the following conditions are met.

(1) The conductors are suitably protected from physical damage.

(2) The sum of the overcurrent devices at the conductor termination limits the load to the conductor ampacity. The overcurrent devices shall consist of not more than six circuit breakers or sets of fuses mounted in a single enclosure, in a group of separate enclosures, or in or on a

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switchboard. There shall be no more than six overcurrent devices grouped in any one location.

(3) The tap conductors are installed outdoors, except at the point of termination.

(4) The overcurrent device for the conductors is an integral part of a disconnecting means or shall be located immediately adjacent thereto.

(5) The disconnecting means for the conductors are installed at a readily accessible location either outside of a building or structure or inside nearest the point of entrance of the conductors. (ROP 10-115c)

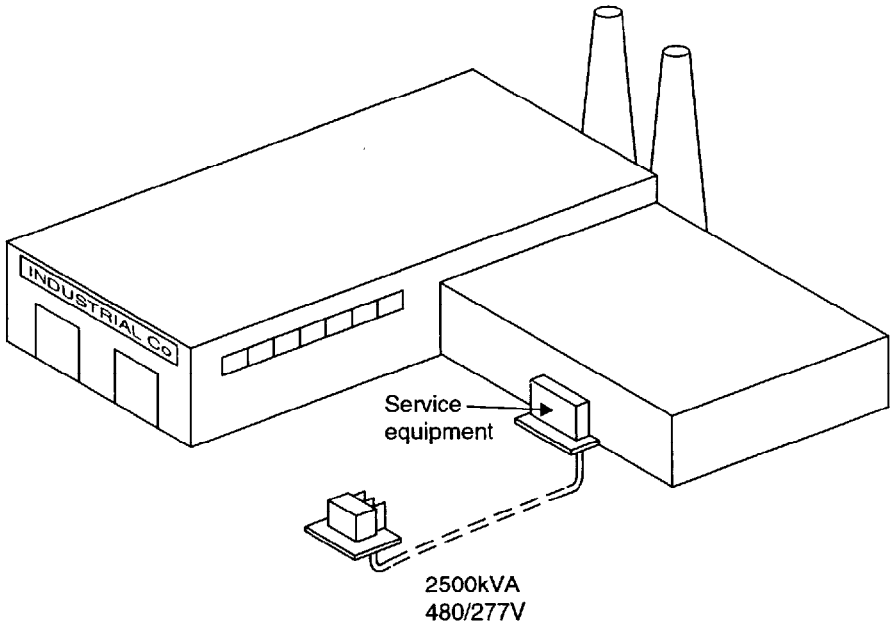

Figure 1. Supervised Industrial Installation

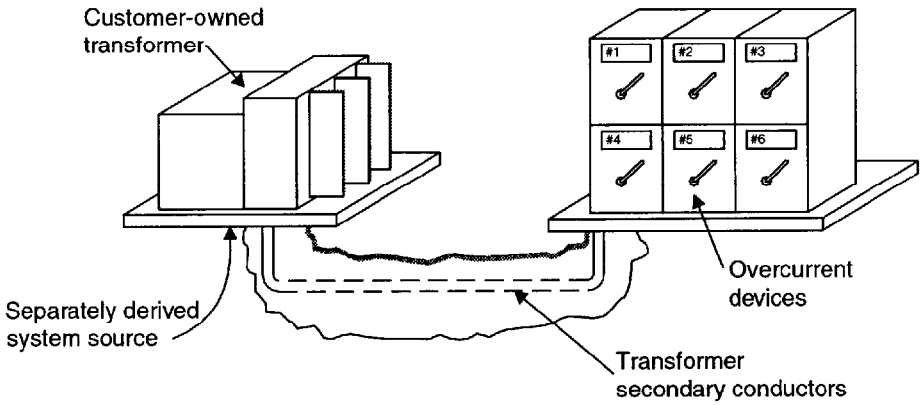

Figure 2. Supervised Industrial Installation—Separately Derived System

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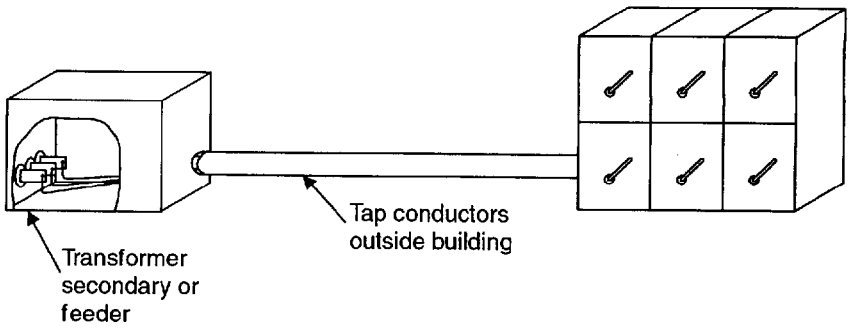

Figure 3. Supervised Industrial Installation—Outside Feeder Taps and Transformer Secondary Conductors

Application

A new Part H to Article 240 permits special rules for overcurrent protection to be used in supervised industrial locations. These rules modify some of the general requirements of Article 240, primarily those in Section 240-21. Except as modified by Part H, the provisions of Article 240 still apply to these installations.

Figure 1 illustrates the definition of a supervised industrial location as given in Section 240-91. A supervised industrial location must have three characteristics: It must be an industrial premises wiring system that supplies an industrial or manufacturing process or both; it must have engineering and maintenance supervision that ensures that servicing will be done only by qualified persons; and it must have at least one service at a voltage of not less than 150 volts to ground and not less than 300 volts phase to phase. The premises wiring system must serve a load of at least 2500kVA calculated according to Article 220. This minimum load would be approximately equivalent to a minimum 480/277-volt, 3-phase, 3000-ampere service. (2500000VA/(480V × 1.73) = 3011). Figure 1 shows a single service that meets the requirements of the definition. However, the load is not required to be served by a single service.

The rules of Part H apply only to those portions of an installation used exclusively for manufacturing or process control, and do not apply to parts of the facility used for other purposes.

A significant new rule of Part H is contained in Section 240-92. Section 240-92(a) states that branch-circuit and feeder conductors must be protected in accordance with Section 240-21 unless they qualify for coverage under the special tap rules in Section 240-92(b) or (c).

Figure 2 illustrates the conditions covered by Section 240-92(b). This section provides the rules for the overcurrent protection of transformer secondary conductors supplied by a separately derived system. These conductors need not meet the usual requirements of Section 240-21. If Section 240-92(b) is used, transformer secondary conductors are required to have short-circuit and ground-fault protection, overload protection, and physical protection.

Section 240-92(b)(1) allows short-circuit and ground-fault protection to be provided in one of the following three ways:

1. The conductors are subject to a 50-ft length limit, and the primary overcurrent device rating is not more than 150 percent of the product of the secondary conductor ampacity and the secondary-to-primary voltage ratio; or

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2. The conductors are subject to a 75-ft length limit, and the secondary conductors are protected by a differential relay with a trip setting not higher than the conductor ampacity; or
3. The conductors are subject to a 75-ft length limit, and engineering calculations determine that the secondary conductors are protected from short circuits and ground faults.

Section 240-92(b)(2) allows overload protection to be provided by limiting the load to the ampacity of the conductors in one of four ways:

1. By a single overcurrent device at the load end of the conductors; or
2. By the sum of up to six overcurrent devices grouped in one location; or
3. By overcurrent relays that operate either upstream or downstream overcurrent devices; or
4. By engineering calculations that determine that system overcurrent devices will protect the conductors from overload.

Section 240-92(b)(3) requires physical protection that is suitable for the conditions.

Figure 3 illustrates the conditions covered by Section 240-92(c). This section provides rules for overcurrent protection of outside feeder taps. The conductors in this case may be tapped from a feeder or a transformer secondary, must remain outdoors except at the point of termination, and must be protected from physical damage. In addition, overcurrent protection must be provided by not more than six overcurrent devices grouped in one location. The sum of the ratings of the overcurrent devices cannot exceed the ampacity of the conductors. The overcurrent device must be an integral part of the disconnecting means or be located immediately adjacent to the disconnecting means, and the disconnecting means must be located outside or inside the nearest point of entrance of the conductors into the building.

Background and Explanation

This new part was added to address the special needs of large industrial users. The definition of "supervised industrial locations" was intended to cover only large industrial installations and to exclude smaller industrial and all commercial installations. The main effect of the new part is to provide for special tap rules for large transformers and outside feeders.

The new tap rules for these large industrial installations vary from the usual rules in a number of different ways:

- First, overcurrent protection may be provided by engineering design and calculation without conformance to specific methods spelled out by the code.
- Second, overcurrent protection may be broken up into separate devices that provide short-circuit and ground-fault protection in one device and overload protection in another device. This concept is similar to the way motor circuits are protected: with short-circuit and ground-fault protection at the source, and separate overload protection near the load end of the conductors.

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- Third, different methods or devices are recognized for overcurrent protection. Whereas under the usual provisions of the code overcurrent devices are generally understood to be circuit breakers or fuses, these rules allow for the use of differential relays and overcurrent relaying as protective devices.
- Fourth, conductor length limits are generally longer than for other types of installations.

Like some other tap rules, overcurrent protection may be separate devices that provide short-circuit and ground-fault protection in one device and overload protection in another device.

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240-100 Overcurrent Protection for Circuits Over 600 Volts

Type of Change Relocation and Revision

BRIEF SUMMARY

Commercial and industrial. Article 240 Part H was changed to Part I, rearranged, and combined with overcurrent protection rules from the deleted Article 710.

Code Language

240-100. Feeders and Branch Circuits. (ROP 13-35)

(a) **Feeder and branch-circuit conductors shall have overcurrent protection in each ungrounded conductor located at the point where the conductor receives its supply or at a location in the circuit determined under engineering supervision. The overcurrent protection shall be permitted to be provided by one of the following.** (ROC 10-97)

(1) Overcurrent Relays and Current Transformers. Circuit breakers used for overcurrent protection of 3-phase circuits shall have a minimum of three overcurrent relays operated from three current transformers. On 3-phase, 3-wire circuits, an overcurrent relay in the residual circuit of the current transformers shall be permitted to replace one of the phase relays.

An overcurrent relay, operated from a current transformer that links all phases of a 3-phase, 3-wire circuit, shall be permitted to replace the residual relay and one of the phase-conductor current transformers. Where the neutral is not regrounded on the load side of the circuit as permitted in Section 250-184(b), the current transformer shall be permitted to link all 3-phase conductors and the grounded circuit conductor (neutral). (ROP 10-5, 13-35)

(2) Fuses. A fuse shall be connected in series with each ungrounded conductor. (ROP 13-35)

(b) Protective Devices. The protective device(s) shall be capable of detecting and interrupting all values of current that can occur at their location in excess of their trip setting or melting point.

(c) Conductor Protection. The operating time of the protective device, the available short-circuit current, and the conductor used shall be coordinated to prevent damaging or dangerous temperatures in conductors or conductor insulation under short-circuit conditions.

240-101. Additional Requirements for Feeders. (ROP 10-5)

(a) Rating or Setting of Overcurrent Protective Devices. The continuous ampere rating of a fuse shall not exceed three times the ampacity of the conductors. The long-time trip element setting of a breaker or the minimum trip setting of an electronically actuated fuse shall not exceed six times the ampacity of the

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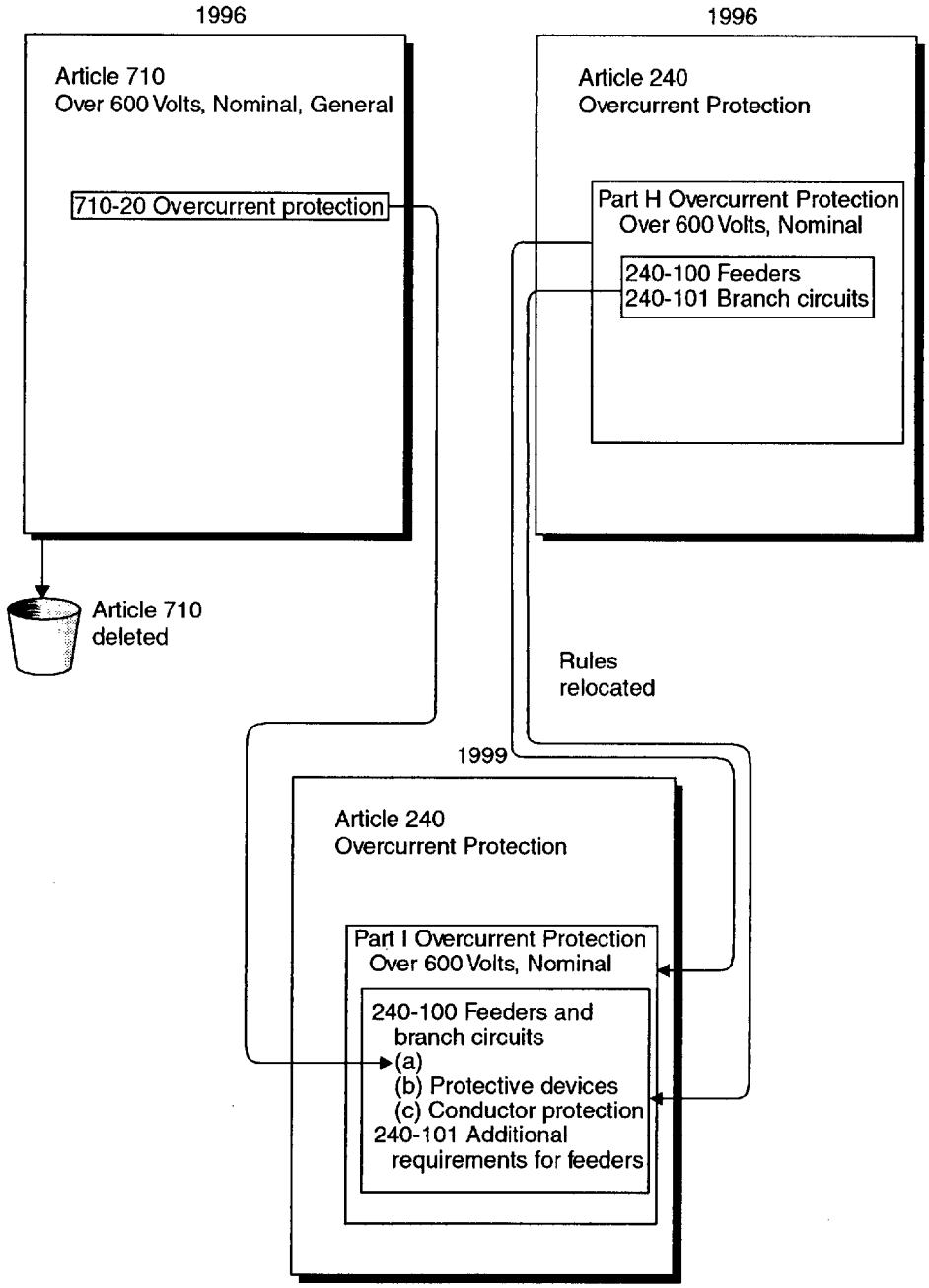
conductor. For fire pumps, conductors shall be permitted to be protected for overcurrent in accordance with Section 695-4(b).

(b) Feeder Taps. Conductors tapped to a feeder shall be permitted to be protected by the feeder overcurrent device where that overcurrent device also protects the tap conductor.

(TCC 13-35)



High Voltage Rules Relocated

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Application

The illustration shows the origin and new location of the relocated and rearranged sections. The rules on overcurrent protection for over 600 volts are now grouped in Sections 240-100 and 240-101. Section 240-100 now requires overcurrent protection to be located either where the conductors receive their supply or at a location determined under engineering supervision.

Background and Explanation

This change was part of the redistribution of Article 710 and the consolidation of requirements for over 600 volts. Part H of Article 240 was changed to Part I. Section 240-100 was combined with Section 240-101 and reorganized to become 240-100(a), (b), and (c) and 240-101(a) and (b). Section 710-20 was moved to Section 240-100(a) because it was concerned with overcurrent protection.

Section 240-100(a) was revised to clarify the location of overcurrent protective devices for feeders and branch circuits over 600 volts. Overload and short-circuit and ground-fault protection are required, but the location of the protective devices may be other than at the source of supply. For circuits over 600 volts, the revised rule permits the location to be determined under engineering supervision. However, without engineering supervision, the location of the overcurrent protection device is now clearly the same as for circuits of 600 volts or less: The overcurrent device(s) must be located where the conductors receive their supply.

A new Part H was added to cover supervised industrial locations. That change is discussed separately.

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NEC pp. 80–103

Article 250 Grounding: Reorganization of Entire Article

Type of Change Revision

BRIEF SUMMARY

All occupancies. Extensive revision has been made of the entire article.

Code Language

See Appendix E table.

Application

The arrangement of Article 250 has been completely revised to enhance the usability of the article. Many of the requirements of previous editions of the code have been relocated into the new part of the article that contains similar subject matter. The format is intended to provide a more logical approach to grounding.

Background and Explanation

There have been many comments from users about the difficulty of using Article 250. Users have indicated that related language was not clearly grouped.

Through joint efforts of the NEC Usability Task Group, Code-Making panel 5, and proposals from users, a major revision was undertaken.

A few significant changes were made and will be discussed here separately. In general, the material in Article 250 has been rearranged for clarity and some exceptions have been revised into the main text of the code. Some duplication of requirements has been eliminated.

A new Appendix E has been added to cross reference old section numbers to new section numbers.

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(ROC 5-37)

Appendix E
Article 250 Cross Reference

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E2. Cross Reference from the 1996 NEC to the 1999 NEC

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NEC pp. 80–82

250-2 & 250-4 Grounding Performance Requirements

Type of Change

Relocation/Revision; Relocation

BRIEF SUMMARY

All installations. Grounding performance information in FPNs was converted to mandatory language and combined with former Section 250-51 as a new Section 250-2. The old Section 250-2 was renumbered as Section 250-4.

Code Language

250-2. General Requirements for Grounding and Bonding. The following general requirements identify what grounding and bonding of electrical systems are required to accomplish. The prescriptive methods contained in Article 250 shall be followed to comply with the performance requirements of this section. (ROC 5-45)

(a) Grounding of Electrical Systems. Electrical systems that are required to be grounded shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges, or unintentional contact with higher voltage lines and that will stabilize the voltage to earth during normal operation. (ROC 5-45)

(b) Grounding of Electrical Equipment. Conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected to earth so as to limit the voltage to ground on these materials. Where the electrical system is required to be grounded, these materials shall be connected together and to the supply system grounded conductor as specified by this article. Where the electrical system is not solidly grounded, these materials shall be connected together in a manner that establishes an effective path for fault current. (ROC 5-45)

(c) Bonding of Electrically Conductive Materials and Other Equipment. Electrically conductive materials, such as metal water piping, metal gas piping, and structural steel members, that are likely to become energized shall be bonded as specified by this article to the supply system grounded conductor or, in the case of an ungrounded electrical system, to the electrical system grounded equipment, in a manner that establishes an effective path for fault current. (ROC 5-45)

(d) Performance of Fault Current Path. The fault current path shall be permanent and electrically continuous, shall be capable of safely carrying the maximum fault likely to be imposed on it, and shall have sufficiently low impedance to facilitate the operation of overcurrent devices under fault conditions. (ROC 5-45)

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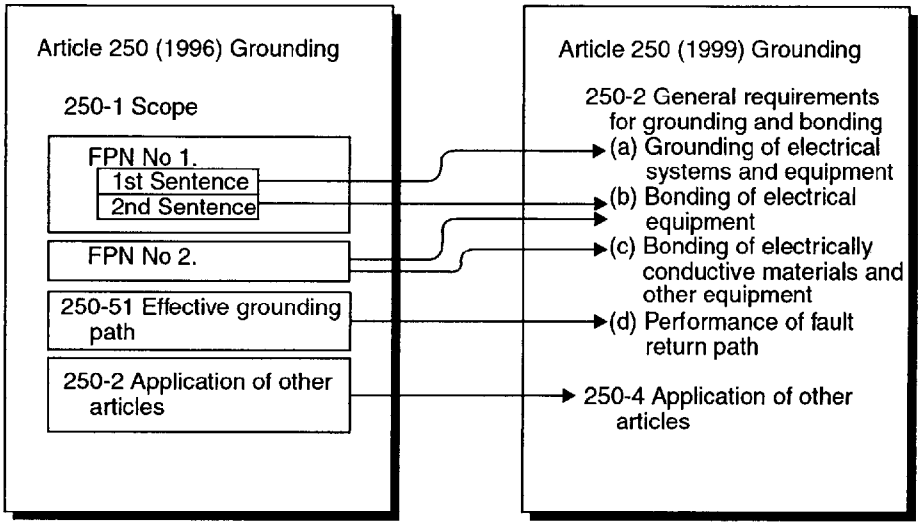
The earth shall not be used as the sole equipment grounding conductor or fault current path.



Grounding Performance Requirements

Application

The FPNs following Section 250-1 have been converted to code requirements and combined with the previous Section 250-51 to form a new Section 250-2 "General Requirements for Grounding and Bonding." The previous Section 250-2 "Application of Other Articles" has been moved to Section 250-4.

The new Section 250-2 provides performance requirements for grounding and bonding. These code rules identify what is required to be accomplished by following the rules of Article 250. The performance requirements do not change the technical requirements of the code. Rather, they explain the reason for the requirements.

Background and Explanation

This change represents a departure from the usual nature of code rules. Most code rules say what to do, but seldom does the code tell us in mandatory language why we are to do something. Most such information is advisory, in the form of FPNs. As stated in the substantiation for this change: "The NEC provides requirements that, when followed, result in a safe electrical installation, but, because it is a prescriptive code, there is no explanation of how these requirements were established or what they are intended to accomplish." The submitter goes on to say: "These performance requirements will still be met by proper compliance with the existing prescriptive rules but installers will have a much better idea of what they are doing and why."

Most of what appears in Section 250-2 was formerly in two FPNs. The FPNs were reworded and recombined to group the subject matter into the new Section 250-2. The last sentences of Section 250-2(a) and (b) were added to explain the reasons for grounding and bonding equipment when the system is not grounded.

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250-30(a) (1) & (2) Separately Derived System Grounding

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. The requirements for grounding separately derived systems apply to all grounded systems, not only those required to be grounded. The bonding jumper and grounding electrode conductor connections to the grounded conductor of a separately derived system must be in the same location.

Code Language

250-30. Grounding Separately Derived Alternating-Current Systems.

(a) Grounded Systems. A separately derived ac system **that is grounded** shall comply with (1) through (4).

Exception: High-impedance grounded neutral system grounding connection requirements shall not be required to comply with (1) and (2) and shall be made as specified in Sections 250-36 and 250-186.

(1) Bonding Jumper. A bonding jumper in compliance with Sections 250-28(a) through (d), that is sized for the derived phase conductors, shall be used to connect the equipment grounding conductors of the separately derived system to the grounded conductor. Except as permitted by Section 250-24(a)(4), this connection shall be made at any point on the separately derived system from the source to the first system disconnecting means or overcurrent device, or it shall be made at the source of a separately derived system that has no disconnecting means or overcurrent devices. **The point of connection shall be the same as the grounding electrode conductor as required in Section 250-30(a)(2).** (TCC 5-65)

Exception No. 1: A bonding jumper at both the source and the first disconnecting means shall be permitted where doing so does not establish a parallel path for the grounded circuit conductor. Where a grounded conductor is used in this manner, it shall not be smaller than the size specified for the bonding jumper but shall not be required to be larger than the ungrounded conductor(s). For the purposes of this exception, connection through the earth is not considered as providing a parallel path.

Exception No. 2: The size of the bonding jumper for a system that supplies a Class 1, Class 2, or Class 3 circuit, and is derived from a transformer rated not more than 1000 volt-amperes, shall not be smaller than the derived phase conductors and shall not be smaller than No. 14 copper or No. 12 aluminum.

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(2) Grounding Electrode Conductor. A grounding electrode conductor, sized in accordance with Section 250-66 for the derived phase conductors, shall be used to connect the grounded conductor of the derived system to the grounding electrode as specified in (3). **Except as permitted by Sections 250-24(a)(3) or (a)(4), this connection shall be made at the same point on the separately derived system where the bonding jumper is installed.**

Exception: A grounding electrode conductor shall not be required for a system that supplies a Class 1, Class 2, or Class 3 circuit and is derived from a transformer rated not more than 1000 volt-amperes, provided the system grounded conductor is bonded to the transformer frame or enclosure by a jumper sized in accordance with Section 250-30(a)(1), Exception No. 2, and the transformer frame or enclosure is grounded by one of the means specified in Section 250-134.

(3) Grounding Electrode. The grounding electrode shall be as near as practicable to and preferably in the same area as the grounding electrode conductor connection to the system. The grounding electrode shall be the nearest one of the following:

(a) An effectively grounded structural metal member of the structure
(b) An effectively grounded metal water pipe **within 5 ft (1.52 m) from the point of entrance into the building**

Exception: In industrial and commercial buildings where conditions of maintenance and supervision ensure that only qualified persons will service the installation and the entire length of the interior metal water pipe that is being used for the grounding electrode is exposed, the connection shall be permitted at any point on the water pipe system.

(c) Other electrodes as specified in Sections 250-50 and 250-52 where the electrodes specified by (a) or (b) are not available

Exception for (a), (b), and (c): Where a separately derived system originates in listed equipment also used as service equipment, the grounding electrode used for the service equipment shall be permitted as the grounding electrode for the separately derived system provided the grounding electrode conductor from the service equipment to the grounding electrode is of sufficient size for the separately derived system. Where the equipment ground bus internal to the service equipment is not smaller than the required grounding electrode conductor, the grounding electrode connection for the separately derived system shall be permitted to be made to the bus.

FPN: See Section 250-104(a)(4) for bonding requirements of interior metal water piping in the area served by separately derived systems.

(4) Grounding Methods. In all other respects, grounding methods shall comply with requirements prescribed in other parts of this *Code*.

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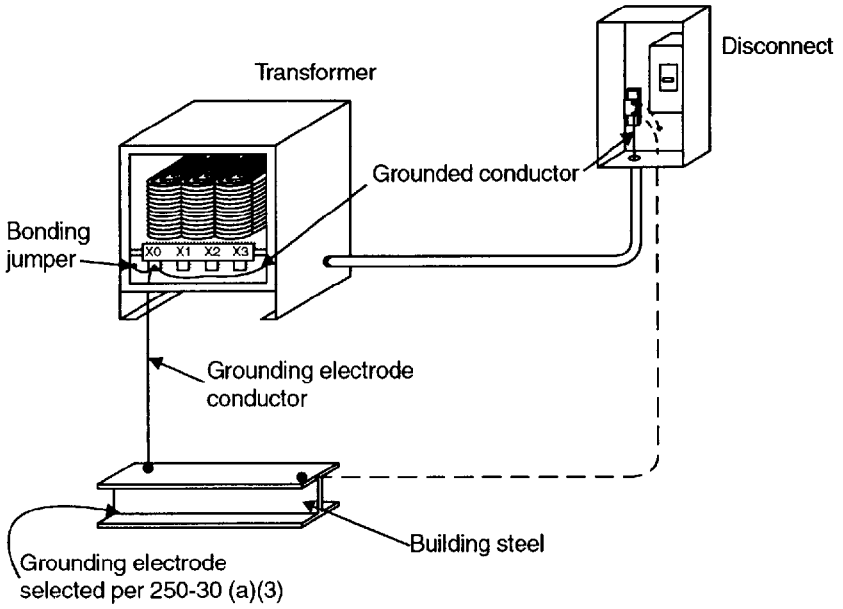

Grounding Separately Derived Systems

Application

The requirements of Section 250-30(a) were extended to cover all grounded separately derived systems, not just those required to be grounded.

As in the 1996 NEC, the location of the bonding jumper and grounding electrode conductor connections to the grounded conductor of a separately derived system may be made at any location from the source to the first disconnecting means. However, under the 1999 NEC both connections must be in the same location. Bonding jumpers may be installed at both the source and the first disconnect if there is no conductive pathway paralleling the grounded conductor between the two bonding jumpers. Such an installation requires the grounded conductor to be at least as large as the size required for the bonding jumpers. Connection through the earth is not considered to be a parallel pathway, but parallel pathways created by metallic raceways, enclosures, building steel, or electrodes such as water piping are prohibited.

The illustration shows both the bonding jumper and grounding electrode connections at the source of a separately derived system. The dashed lines show that both connections could be made at the disconnecting means. According to the main rule, both connections must be made in the same location. Although the code allows the connections to be made at some point between these two locations, other connection points are usually not practical.

Background and Explanation

This is one of a number of changes that address the problem of parallel pathways that may be created by multiple grounding connections to the grounded conductor of a service or separately derived system. Similar changes were made to Section 250-32 for separate buildings.

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Under the 1996 code, the location of the grounding electrode conductor and the bonding jumper connections to the grounded conductor could be selected independently. However, parallel pathways are often created where the two connections are not made at the same point.

Parallel pathways are also created by metallic raceways enclosing the derived system conductors. A parallel path will cause the currents on the grounded conductor to divide between the available pathways. Grounded conductor currents on raceways, bonding or grounding conductors, or through electrodes are considered objectionable currents under Section 250-6. This change clarifies the intent of the code to avoid such parallel paths and objectionable currents. The bonding jumper is intended to connect the grounded conductor to enclosures and equipment grounding conductors. The grounding electrode conductor is intended to connect the grounded conductor to ground reference through a grounding electrode. But the grounding electrode conductor must also be bonded to its enclosures, which, in effect, creates an additional bonding jumper.

Section 250-30(a)(1) Exception No. 1 permits bonding jumpers at both the source and the first disconnect if no parallel pathway is created. When this exception is used, the grounded conductor takes on the function of a bonding jumper. That is, the grounded conductor becomes the fault return path as well as a conductor for normal load currents or unbalanced currents. In such cases, the grounded conductor must be as large as the size required for the bonding jumpers. Parallel pathways would be likely if metallic raceways are used to enclose the derived system conductors. Such pathways would also be created if the enclosures at the source and the disconnect were both connected to building steel, especially where the building steel is used as an electrode.

Section 250-142 still allows the grounded conductor of a separately derived system to be used to ground equipment on the supply side of the disconnecting means, but only where the provisions of Section 250-30(a)(1) do not result in a parallel grounding path.

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250-30(a)(3) Electrodes for Separately Derived Systems

Type of Change

Relocated and Revised

BRIEF SUMMARY

Commercial and industrial. These revisions clarify the selection of the grounding electrode for a separately derived system.

Code Language

250-30. Grounding Separately Derived Alternating-Current Systems.

(a) Grounded Systems. A separately derived ac system that is grounded shall comply with (1) through (4).

(3) Grounding Electrode. The grounding electrode shall be as near as practicable to and preferably in the same area as the grounding electrode conductor connection to the system. The grounding electrode shall be the nearest one of the following:

(a) An effectively grounded structural metal member of the structure

(b) An effectively grounded metal water pipe ***within 5 ft (1.52 m) from the point of entrance into the building***

Exception: In industrial and commercial buildings where conditions of maintenance and supervision ensure that only qualified persons will service the installation and the entire length of the interior metal water pipe that is being used for the grounding electrode is exposed, the connection shall be permitted at any point on the water pipe system.

(c) Other electrodes as specified in Sections 250-50 and 250-52 where the electrodes specified by (a) or (b) are not available

Exception for (a), (b), and (c). Where a separately derived system originates in listed equipment also used as service equipment, the grounding electrode used for the service equipment shall be permitted as the grounding electrode for the separately derived system provided the grounding electrode conductor from the service equipment to the grounding electrode is of sufficient size for the separately derived system. Where the equipment ground bus internal to the service equipment is not smaller than the required grounding electrode conductor, the grounding electrode connection for the separately derived system shall be permitted to be made to the bus.

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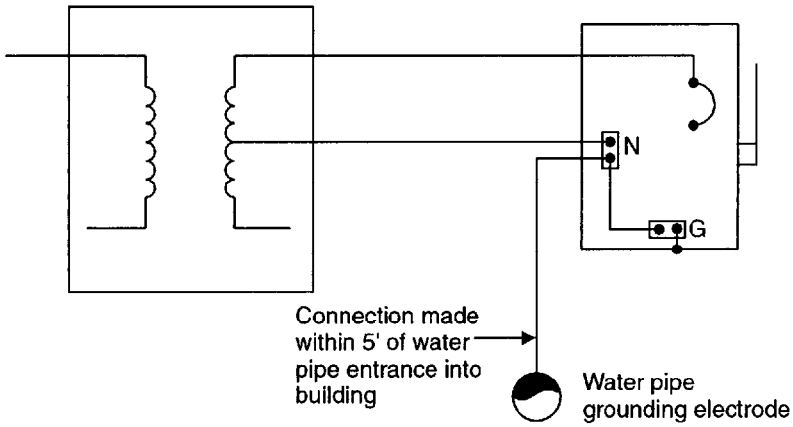
FPN: See Section 250-104(a)(4) for bonding requirements of interior metal water piping in the area served by separately derived systems.



Grounding and Bonding of Separately Derived System

Application

The grounding electrode for a separately derived system must be as near as practicable to the source of the system. The nearest of the first two choices listed in (a) or (b) should be selected. Where the grounded water pipe is nearest, it should be used. Where the grounded structural steel is nearest, it would be used. If grounded water pipe or building steel does not exist, any of the other electrodes listed in Sections 250-50 or 250-52 are used.

For a service supplied system, Section 250-50 requires the connection to the water pipe to be within 5 feet of the point where the water pipe enters the building. This same requirement now also applies to a separately derived system.

Bonding of interior metal piping systems may be required for some installations. The bonding requirements are found in Section 250-104(b).

Background and Explanation

This section was revised to clarify the selection of the electrode and where connections should be made. Water pipe electrodes for separately derived systems are now treated in the same manner as water pipe electrodes for grounding services relative to the connection point being within 5 feet of where the water piping enters the building or structure.

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250-30(b) Ungrounded Separately Derived Systems

Type of Change New

BRIEF SUMMARY

Commercial and industrial. A new subsection provides requirements for ungrounded separately derived systems.

Code Language

250-30. Grounding Separately Derived Alternating-Current Systems.

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(b) Ungrounded Systems. The equipment of an ungrounded separately derived system shall be grounded as specified in (1) through (3).

(1) Grounding Electrode Conductor. A grounding electrode conductor, sized in accordance with Section 250-66 for the derived phase conductors, shall be used to connect the metal enclosures of the derived system to the grounding electrode as specified in (2). This connection shall be made at any point on the separately derived system from the source to the first system disconnecting means.

(2) Grounding Electrode. Except as permitted by Section 250-34 for portable and vehicle mounted generators, the grounding electrode shall comply with Section 250-30(a)(3).

(3) Grounding Methods. In all other respects, grounding methods shall comply with requirements prescribed in other parts of this *Code*. (ROC 5-65) (ROC 5-82)

Application

The illustration shows a generator supplying an ungrounded separately derived system. This system might be a 480-volt delta system or any other system not required to be grounded by Sections 250-20 or 250-162. A grounding electrode conductor is required to connect a grounding electrode to the enclosures of the derived system. The connection to the enclosure may be made at any point from the source of the derived system to the first disconnecting means. The illustration shows the connection made to the generator frame. The dashed lines indicate another acceptable location for the connection. Electrodes are selected using the same criteria as for grounded systems, that is the nearest effectively grounded steel building member or water pipe, or other electrodes if building

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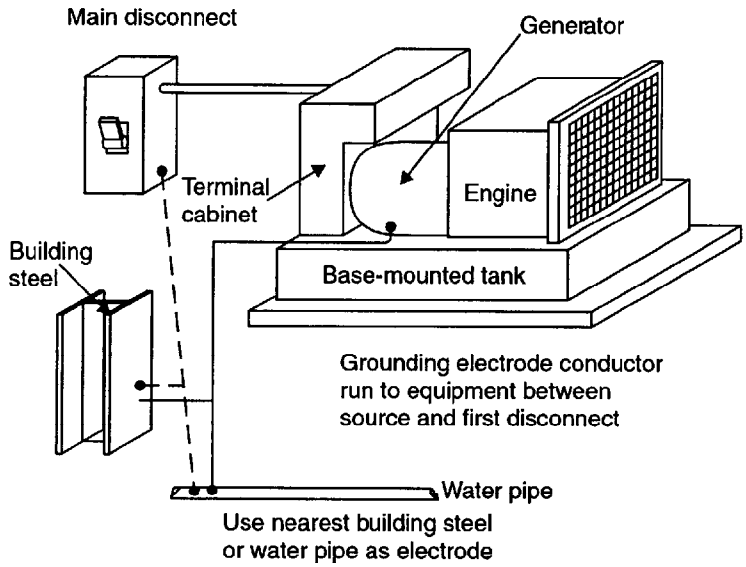
steel and water pipe are not available. No bonding jumper is used because there is no grounded system conductor. Connection to a water pipe electrode must be made within 5 feet of the metal water pipe entrance into a building. There is an exception that permits the connection to be made at any convenient point on the water piping system within commercial and industrial buildings, provided the piping used as an electrode is exposed for its entire length and the installation is serviced by qualified personnel.



Ungrounded Separately Derived Systems

Background and Explanation

This change expands and clarifies the rules on grounding where an ungrounded system is used. Prior editions of the code did not contain specific rules for grounding where an ungrounded separately derived system was installed. These new rules are now consistent with the grounding requirements for service-supplied ungrounded systems.

Although the system itself has no grounded conductor, the enclosures and other noncurrent-carrying metal parts must still be connected to a ground reference and to each other to provide adequate fault paths and reduce shock hazards.

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250-32 (a) & (b) Multiple Building Grounding

Type of Change

Relocated and Revised

BRIEF SUMMARY

All occupancies. This section has been revised to reduce parallel neutral and equipment grounding paths.

Code Language

250-32. Two or More Buildings or Structures Supplied from a Common Service.

(a) Grounding Electrode. Where two or more buildings or structures are supplied from a common ac service **by a feeder(s) or branch circuit(s), the grounding electrode(s) required in Part C of this article at each building or structure shall be connected in the manner specified in (b) or (c). Where there are no existing grounding electrodes, the grounding electrode(s) required in Part C of this article shall be installed.** (TCC 5-82)

Exception: A grounding electrode at separate buildings or structures shall not be required where only one branch circuit ***supplies the*** *building or structure* ***and the branch circuit includes an equipment grounding conductor for grounding the noncurrent-carrying parts of all equipment.***

(b) Grounded Systems. For a grounded system at the separate building or structure, the connection to the grounding electrode and grounding or bonding of equipment, structures, or frames required to be grounded or bonded shall comply with either (1) or (2).

(1) Equipment Grounding Conductor. An equipment grounding conductor as described in Section 250-118 shall be run with the supply conductors and connected to the building or structure disconnecting means and to the grounding electrode(s). The equipment grounding conductor shall be used for grounding or bonding of equipment, structures, or frames required to be grounded or bonded. Any installed grounded conductor shall not be connected to the equipment grounding conductor or to the grounding electrode(s).

(2) Grounded Conductor. Where (1) an equipment grounding conductor is not run with the supply to the building or structure, **and (2) there are no continuous metallic paths bonded to the grounding system in both buildings or structures involved, and (3) ground-fault protection of equipment has not been installed on the common ac service, the grounded circuit conductor run with the supply to the building or structure shall be connected to the building or structure disconnecting means and to the grounding electrode(s) and shall be used for grounding or bonding of equipment, structures, or frames required to be grounded or bonded.**

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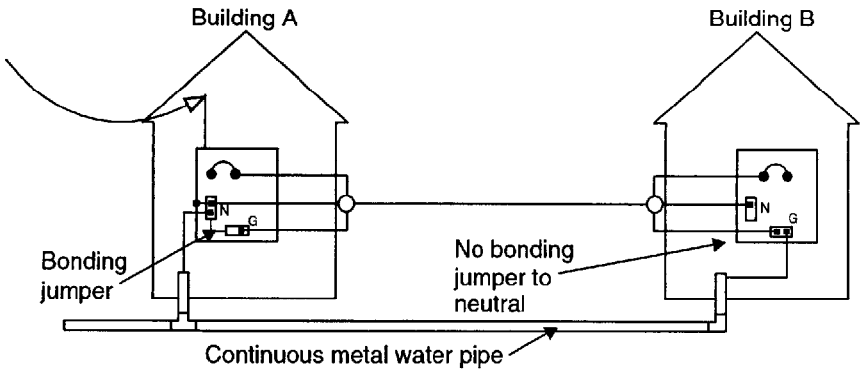

Parallel Neutral Path Between Buildings

Application

As revised, Section 250-32(a) clarifies that either the equipment grounding conductor or the grounded (neutral) conductor (but not both) is required to be connected to a grounding electrode system at a separate building or structure. For grounded systems, Sections 250-32(b)(1) and (2) provide the grounding and bonding requirements for circuits run to a separate building or structure and have been revised to minimize the possibility of parallel ground return paths between buildings. Parallel paths may exist where equipment grounding conductors, metal piping systems, pipe racks, or other continuous metal paths are installed between buildings. In such cases, Sections 250-32(b)(1) and (2) prohibit a bonding connection between the grounded conductor and the equipment grounding conductor at a separate building or structure. In addition, where ground-fault protection of equipment is provided, bonding of the grounded and grounding conductors may result in improper operation of the ground-fault protection system due to the potential for parallel ground-fault current return paths.

Section 250-32(b)(1) requires the installation of at least one of the equipment grounding conductors described in Section 250-118. Where the equipment grounding conductor(s) is bonded to the grounding electrode system of the building or structure supplied, a grounding connection to the grounded conductor is not permitted.

Background and Explanation

This section was revised to eliminate parallel paths for neutral current that are created by multipoint neutral grounding at facilities having common mechanical, piping, or grounding systems or where the circuit conductors are installed in metallic raceways. This revision also assures the proper operation of ground-fault protection systems by providing a single path for fault current.

Where only a grounded (neutral) conductor is installed with the ungrounded conductors, it takes on the dual function of circuit conductor for line-to-neutral loads and as the ground-fault current return path. Therefore, it is necessary to size the conductor adequately for both functions. Section 220-22 provides the sizing rule for feeder neutral conductors based on the maximum unbalance that could occur in the circuit. Section 250-2(d) describes the performance objectives for the conductor that will provide the return path for ground-fault current. Table 250-122 provides the minimum size for equipment grounding conductors that will meet those performance objectives. The grounded conductor should be sized based on whichever section (220-22 or 250-2(d)) requires the largest conductor.

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250-50 Number of Grounding Electrodes Required

Type of Change Revision

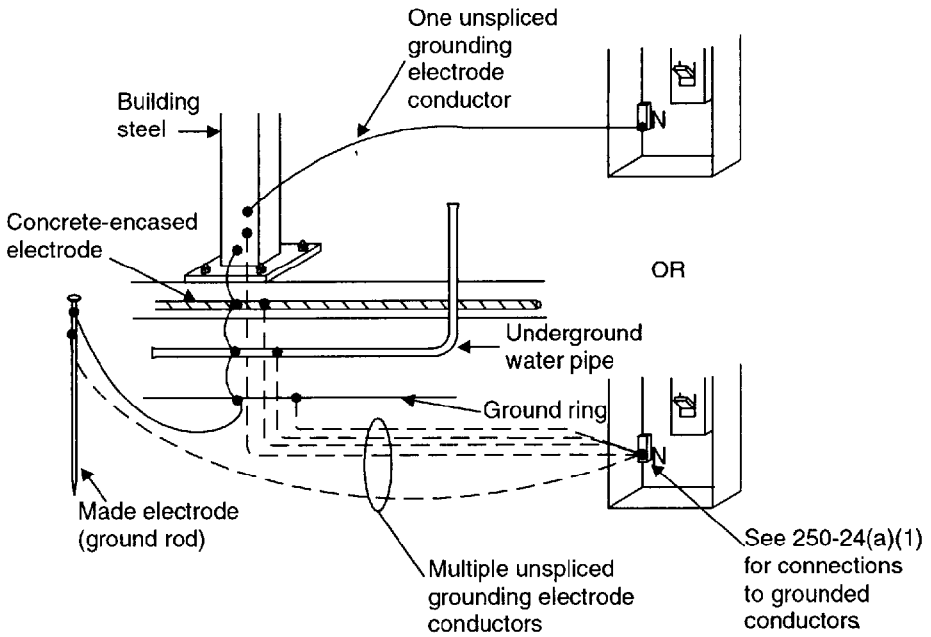
BRIEF SUMMARY

All installations. One or more grounding electrode conductors are permitted.

Code Language

250-50. Grounding Electrode System. If available on the premises at each building or structure served, each item (a) through (d), and any made electrodes in accordance with Sections 250-52(b), (c), and (d), shall be bonded together to form the grounding electrode system. The bonding jumper(s) shall be installed in accordance with Sections 250-64(a), (b), and (e) shall be sized in accordance with Section 250-66, and shall be connected in the manner specified in Section 250-70. (ROP 5-224a, 5-225) (ROC 5-100)

An unspliced grounding electrode conductor shall be permitted to be run to any convenient grounding electrode available in the grounding electrode system **or to one or more grounding electrode(s) individually.** It shall be sized for the largest grounding electrode conductor required among all the electrodes connected to it. (ROP 5-227)



Grounding Electrode Conductors

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Application

The illustration shows a collection of the grounding electrodes listed in Sections 250-50(a) through (d) and 250-52. The solid lines indicate a single unspliced grounding electrode conductor run to one of the electrodes, in this case the building steel. The other electrodes are bonded together to form the grounding electrode system. The single grounding electrode conductor must be full sized according to Section 250-66. The bonding conductors can be sized on the basis of the electrodes they connect to. For instance, the bonding conductor between the ground ring and the ground rod would not have to be larger than No. 6 copper.

The dashed lines in the illustration show an alternative way of running grounding electrode conductors and bonding the electrodes together. Separate grounding electrode conductors may be run to each electrode. In this case, the grounding electrodes are bonded together in the service equipment. The individual conductors may be sized on the basis of the phase conductors and the electrodes they connect to. For example, the conductors to the water pipe and the building steel would have to be sized from Table 250-66, but the conductors to the ground rod, ground ring, and concrete-encased electrode are permitted to be smaller in accordance with Section 250-66(a), (b), or (c).

The illustration shows two extremes: one grounding electrode conductor; or one grounding electrode conductor for each electrode. The electrodes could also be grouped. For example, one conductor could be run to the ground ring and ground rod and sized for the ground ring. Another conductor could be run to the building steel, water pipe, and concrete-encased electrode and sized for the water pipe or building steel.

Background and Explanation

This change is intended to be a clarification. No technical requirement was actually modified by this change. However, some authorities interpreted the previous language (this was in Section 250-81 in the 1996 NEC) to require a single grounding electrode conductor. Others interpreted the previous language to mean that only one grounding electrode conductor had to be unspliced and the others were really just bonding conductors. This change should help to make interpretations more uniform. With this change it should be clear that each grounding electrode conductor must be run unspliced to an electrode, and there can be more than one. Note that the main difference between the alternatives in the illustration is the location of the bonding point between electrodes at the service equipment or at each electrode.

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250-104(a)(3) Sizing of Bonding Conductors

Type of Change New

BRIEF SUMMARY

All occupancies. A new rule clarifies requirements for bonding of water piping systems in separate buildings.

Code Language

250-104. Bonding of Piping Systems and Exposed Structural Steel.

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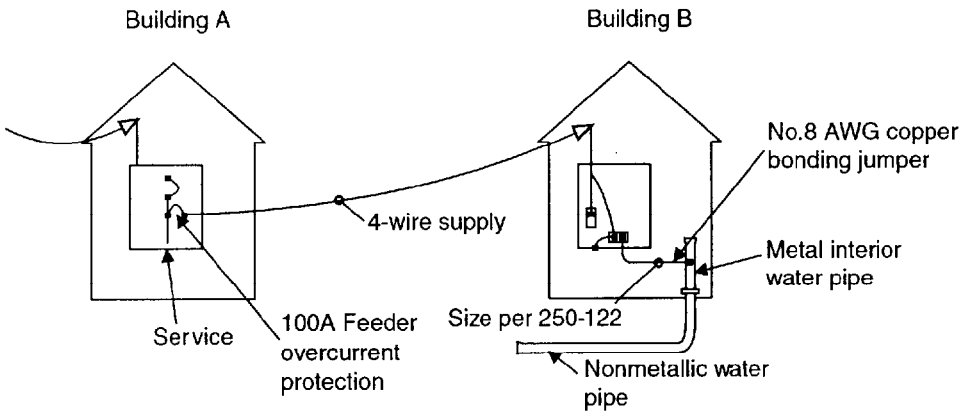
(3) Multiple Buildings or Structures Supplied from a Common Service. The interior metal water piping system shall be bonded to the building or structure disconnecting means enclosure where located at the building or structure, or to the equipment grounding conductor run with the supply conductors, or to the one or more grounding electrodes used. The bonding jumper shall be sized in accordance with Section 250-122 based on the rating or setting of the largest overcurrent device protecting the feeder(s) or branch circuit(s) that supply the building. (ROC 5-158)



Sizing Bonding Jumper at Separate Building

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Application

Section 250-32 (formerly Section 250-24) provides grounding requirements for separate buildings. Section 250-104(a)(3) requires that interior metal water piping systems be bonded.

Section 250-104(a) (formerly Section 250-80(a)) Exception requires the bonding jumper to be sized from Section 250-122 (formerly Section 250-95) based on the size of the overcurrent device in the circuit likely to energize the piping system.

Background and Explanation

The 1996 NEC required bonding of the metal structure and metallic piping systems in a multibuilding electrical distribution arrangement but the 1999 NEC now provides clear guidance for the sizing of this bonding conductor(s).

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250-106 & FPNs Spacing from Lightning Protection Components

Type of Change Revision

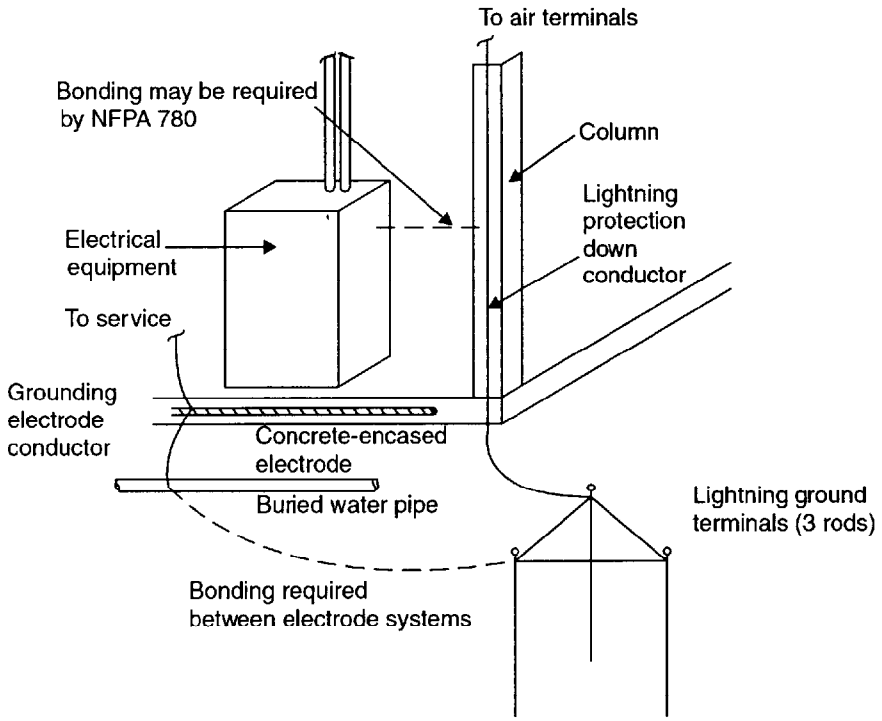
BRIEF SUMMARY

All installations. The ground terminals of a lightning protection system must be bonded to the grounding electrode system of the building or structure.

Code Language

250-106. Lightning Protection Systems. The lightning protection system ground terminals shall be bonded to the building or structure grounding electrode system.

FPN No. 1: See Section 250-60 for use of air terminals. For further information, see *Standard for the Installation of Lightning Protection Systems*, NFPA 780-1997, which contains detailed information on grounding, bonding, and spacing from lightning protection systems.



Lightning Protection Systems

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FPN No. 2: Metal raceways, enclosures, frames, and other noncurrent-carrying metal parts of electric equipment installed on a building equipped with a lightning protection system may require bonding or spacing from the lightning protection conductors in accordance with *Standard for the Installation of Lightning Protection Systems*, NFPA 780-1997. Separation from lightning protection conductors is typically 6 ft (1.83 m) through air or 3 ft (0.92 m) through dense materials such as concrete, brick, or wood. (ROP 5-150a) (ROC 5-241)

Application

Where lightning protection systems are installed, the ground terminals of the lightning protection system must be bonded to the grounding electrode system of the building or structure.

The illustration shows a lightning protection down conductor connected to a ground terminal of a lightning protection system. Also shown are electrical equipment and raceways and grounding electrodes for the building. The ground terminal must be bonded to the grounding electrode system. However, according to Section 250-60, the ground terminal of the lightning protection system may not be used in place of the electrodes for the building.

The revised FPNs refer to NFPA 780 for other bonding requirements. In the illustration, some conductive parts of electrical equipment are in close proximity to the down conductor and must be bonded to the down conductor if determined necessary by calculations performed in accordance with NFPA 780. Types of equipment that must be bonded to down conductors and the spacings required to eliminate bonding are covered by NFPA 780.

Background and Explanation

This change was made to correct language and to state clearly the requirement to bond ground terminals to the grounding electrode system.

The previous wording in this section, formerly Section 250-46, required six-foot spacing or bonding between down conductors and electrical equipment or enclosures. This requirement was not entirely correct and did not completely address the bonding requirements of NFPA 780. In addition, the term "lightning rod," while commonly used and somewhat understood, is not correct terminology. Also, the previous wording did not state the very important requirement for bonding between electrodes and ground terminals.

Lightning protection systems consist of three basic elements: air terminals, ground terminals, and down conductors connecting the air terminals to the ground terminals. The objective is to provide safe and adequate pathways that lightning currents are likely to follow. By providing specific pathways, we can reduce the likelihood of damage due to lightning strikes finding their own pathways through building materials.

In the event of a lightning strike, the large currents in the down conductors cause strong, rapidly changing electromagnetic fields around the down conductors. These magnetic fields can induce voltages in other nearby metal bodies. Because of the extremely high voltages that produce them, lightning currents

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may also jump to other systems that provide alternate pathways to ground. To reduce the hazards, NFPA 780 provides a method to calculate whether it is necessary to provide additional bonding connections between the lightning protection system and metallic components of other systems. The distance depends on the materials surrounding the down conductors, as explained in FPN No. 2.

Technical corrections changing the term "lightning rods" to "air terminals" were also made to the language of Section 250-60 (formerly Section 250-86).

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250-122(f) Use of GFPE with Multiconductor Cables in Parallel

Type of Change New

BRIEF SUMMARY

Industrial. The new subsection provides an alternative method for selecting the size of equipment grounding conductors in multiconductor cables that are installed in parallel.

Code Language

250-122. Size of Equipment Grounding Conductors.

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(f) Conductors in Parallel. Where conductors are run in parallel in multiple raceways or cables as permitted in Section 310-4, the equipment grounding conductors, where used, shall be run in parallel in each raceway or cable. **One of the following methods shall be used to ensure the equipment grounding conductors are protected.**

(1) Each parallel equipment grounding conductor shall be sized on the basis of the ampere rating of the overcurrent device protecting the circuit conductors in the raceway or cable in accordance with Table 250-122.

(2) Where ground-fault protection of equipment is installed, each parallel equipment grounding conductor in a multiconductor cable shall be permitted to be sized in accordance with Table 250-122 on the basis of the trip rating of the ground-fault protection where the following conditions are met.

(1) Conditions of maintenance and supervision ensure that only qualified persons will service the installation.

(2) The ground-fault protection equipment is set to trip at not more than the ampacity of a single ungrounded conductor of one of the cables in parallel.

(3) The ground-fault protection is listed for the purpose.

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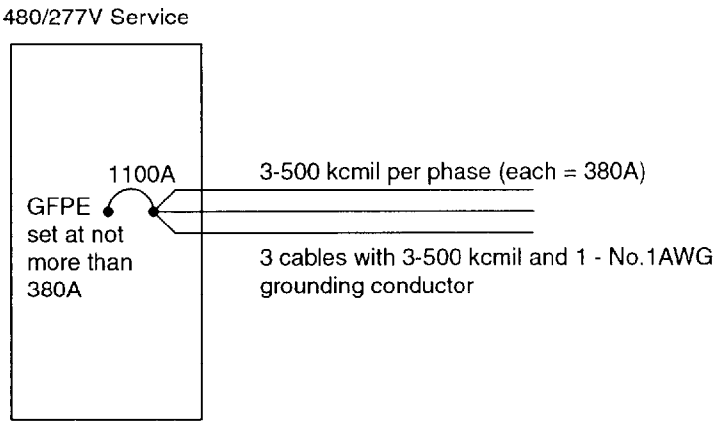

GFPE for Multiconductor Cables in Parallel

Application

In most installations, the equipment grounding conductor for parallel circuits must be based on the rating of the circuit. This requires each parallel raceway or cable to contain a full-sized grounding conductor based on Section 250-122. If a fault occurs in a raceway or cable, the equipment grounding conductor must be capable of carrying enough current to clear the fault.

New Section 250-122(f)(2) allows an alternate method where ground-fault protection for equipment is provided. In this case the setting of the ground-fault protection is to be not more than the ampacity of a single ungrounded conductor. The equipment grounding conductors are permitted to be sized in accordance with Table 250-122 based on the GFPE setting instead of the continuous current rating of the overcurrent device.

Background and Explanation

This allows the use of cables of standard construction and reduces the need for special-order cables, particularly where cables are used for large-capacity parallel circuits. This change will have use where cables are used for parallel circuits installed in cable trays. The use of the GFPE will provide safe levels of ground-fault protection for this type of installation.

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300-1(a) Excs. Relocation/Deletion of Exceptions

Type of Change Deleted or Relocated

BRIEF SUMMARY

All occupancies. Exceptions have been deleted or relocated from Article 300.

Section 300-1

1996 NEC	*1999 NEC*
Exception No. 1	Deleted
Exception No. 2	725-3
Exception No. 3	760-3
Exception No. 4	770-3
Exception No. 5	Deleted
Exception No. 6	Deleted
Exception No. 7	Deleted

Background and Explanation

Section 300-1 contained a series of exceptions indicating that Article 300 does not apply to some installations in Chapters 5, 7, and 8. Section 90-3 indicates that Chapters 5, 6, and 7 modify the general rule in Chapters 1 through 4. Chapter 8 is independent of the other chapters.

Since Section 90-3 allows these other chapters to modify Chapter 3, the exceptions were unnecessary. As shown above, some were deleted, others were relocated.

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300-4(b)(1) Full-Opening Protection with Grommets and Bushings

Type of Change Revision

BRIEF SUMMARY

All installations. Bushings or grommets must cover all metal edges where NM cable is installed through holes in metal framing.

Code Language

300-4. Protection Against Physical Damage.

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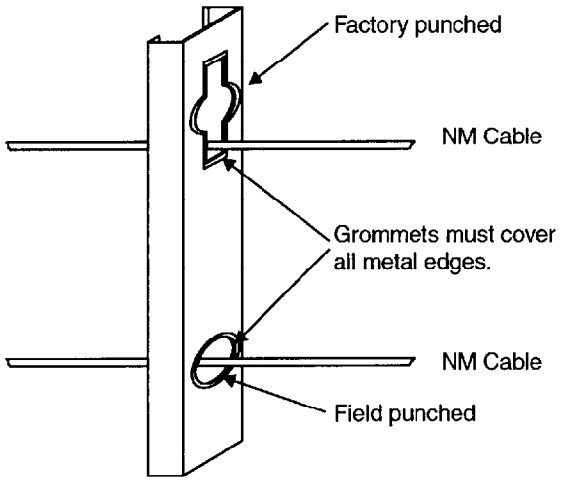
(b)Nonmetallic-Sheathed Cables and Electrical Nonmetallic Tubing Through Metal Framing Members.

(1)Nonmetallic-Sheathed Cable. In both exposed and concealed locations where nonmetallic-sheathed cables pass through either factory or field punched, cut, or drilled slots or holes in metal members, the cable shall be protected by bushings or grommets **covering all metal edges and** securely fastened in the opening prior to installation of the cable. (ROP 3-31)



NM Cable in Metal Framing

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Application

Grommets that are available in U or V shapes and cover only the lower edges of a hole through metal framing are no longer permitted. Grommets must cover all metal edges of holes through which NM cable is installed.

Background and Explanation

Type NM cables are subject to damage during installation as they are pulled through holes in metal framing. The substantiation for this change cited a specific case where a construction worker was shocked by energized metal framing. The framing was energized because the outer sheath and conductor insulation were damaged by the sharp edges of metal framing as the cable was pulled through the holes. The holes were equipped with grommets that covered only the bottom edges, and the cables were damaged by the uncovered edges.

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300-5(d) Marking Tape for Underground Installation

Type of Change Revision

BRIEF SUMMARY

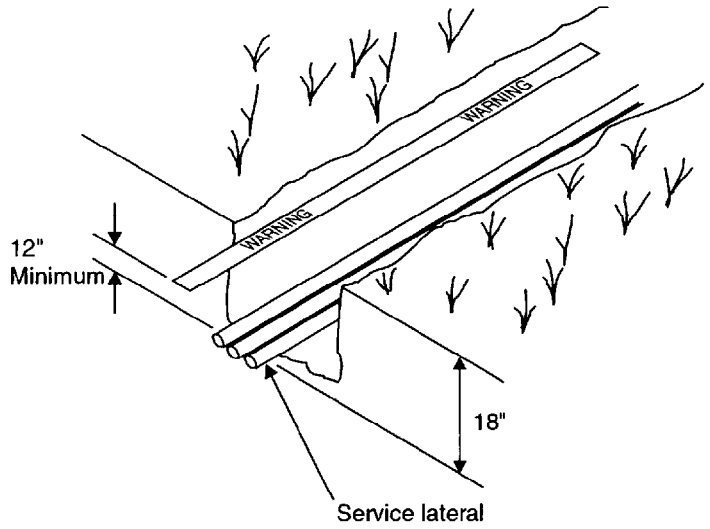
All occupancies. This change requires a warning ribbon above underground service laterals.

Code Language

300-5. Underground Installations.

(d) Protection from Damage. Direct-buried conductors and cables emerging from the ground shall be protected by enclosures or raceways extending from the minimum cover distance required by Section 300-5(a) below grade to a point at least 8 ft (2.44 m) above finished grade. In no case shall the protection be required to exceed 18 in. (457 mm) below finished grade.

Service laterals that are not encased in concrete and that are buried 18 in. (457 mm) or more below grade shall have their location identified by a warning ribbon that is placed in the trench at least 12 in. (305 mm) above the underground installation. (ROC 3-3)



Warning Ribbon for Service Laterals

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Application

Where underground service laterals are not encased in concrete, their location must be marked by a warning tape or ribbon. The marking ribbon should be placed in the trench after at least 12 inches of backfill is in place.

Background and Explanation

The intent is to reduce the shock hazards present when excavation is done near underground service conductors. The warning tape or ribbon is often required by utility company specifications for underground service lateral conductors, but up until now was not required by the NEC.

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300-11(a) Support Wires for Wiring Methods

Type of Change Revision

BRIEF SUMMARY

All installations. Separate support wires may be used as support for wiring methods if they provide secure support. Where used in fire-rated floor-ceiling or roof-ceiling assemblies, the independent support wires must be color-coded or tagged.

Code Language

300-11. Securing and Supporting.

(a) Secured in Place. Raceways, cable assemblies, boxes, cabinets, and fittings shall be securely fastened in place. Support wires that do not provide secure support shall not be permitted as the sole support. **Support wires and associated fittings that provide secure support and that are installed in addition to the ceiling grid support wires, shall be permitted as the sole support. Where independent support wires are used, they shall be secured at both ends.** Cables and raceways shall not be supported by ceiling grids. (ROP 3-64) (ROC 3-55)

(1) Wiring located **within the cavity** of a fire-rated floor-ceiling or roof-ceiling assembly shall not be secured to, or supported by, the ceiling assembly, including the ceiling support wires. An independent means of secure support shall be provided. **Where independent support wires are used, they shall be distinguishable by color, tagging, or other effective means from those that are part of the fire-rated design.** (ROP 3-64) (ROC 3-55)

Exception: The ceiling support system shall be permitted to support wiring and equipment that have been tested as part of the fire-rated assembly.

FPN: One method of determining fire rating is testing in accordance with *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, NFPA 251-1995.

(2) Wiring located **within the cavity** of a nonfire-rated floor-ceiling or roof-ceiling assembly shall not be secured to, or supported by, the ceiling assembly, including the ceiling support wires. An independent means of secure support shall be provided. (ROP 3-64)

Exception: The ceiling support system shall be permitted to support branch-circuit wiring and associated equipment where installed in accordance with the ceiling system manufacturer's instructions.

(ROC 3-55)

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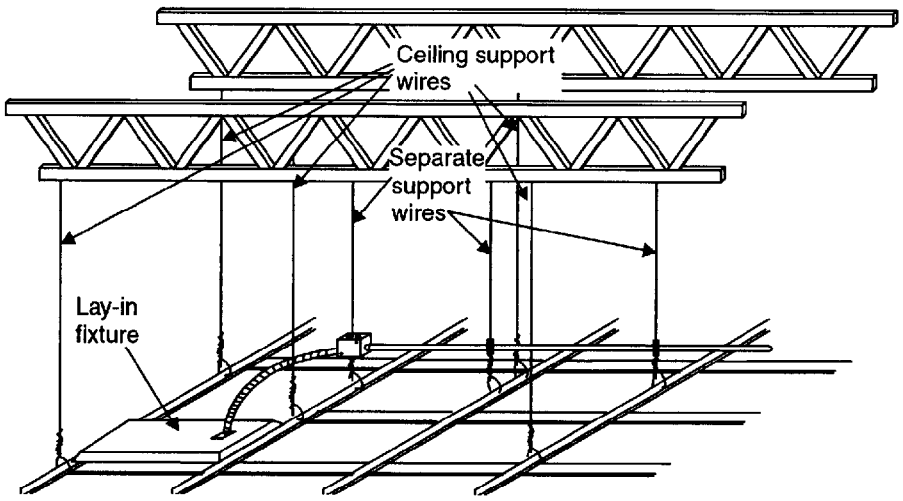

Separate Support Wires for Wiring Methods

Application

Ceiling support wires and ceiling assemblies may not be used for support of electrical wiring methods unless tested for that use. Separate support wires may be installed, but they must be fastened at both ends as shown in the illustration, and they must provide secure support. Separate support wires used with fire-rated floor-ceiling or roof-ceiling assemblies must be tagged or color-coded to distinguish them from the ceiling support wires.

Background and Explanation

This section has been modified during each of the last five code cycles. For at least 20 years prior to the 1987 code, this part of Section 300-11 simply said "Raceways, cable assemblies, boxes, cabinets, and fittings shall be securely fastened in place...." In the 1987 code the following sentence was added: "Support wires that do not provide rigid support shall not be permitted as the sole support." In 1990 the word "rigid" was changed to "secure," and another sentence was added: "Equipment that is located within, supported by, or located below a suspended ceiling shall be permitted to be supplied or controlled by branch-circuit wiring that is supported by the suspended ceiling support wires." This was further modified in 1993 by replacing the third sentence with two new paragraphs: "Branch-circuit wiring associated with equipment that is located within, supported by, or secured to a fire-rated floor or roof-ceiling assembly shall not be secured to the ceiling support wires.

"Branch-circuit wiring associated with equipment that is located within, supported by, or secured to a nonfire-rated floor or roof-ceiling assembly shall be permitted to be supported by the ceiling support wires."

The 1996 NEC reworded the 1993 paragraphs and prohibited wiring to be "secured to, or supported by, the ceiling assembly" whether the floor-ceiling or

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roof-ceiling assembly was fire-rated or not. An additional sentence said "Cables and raceways shall not be permitted to be supported by ceiling grids." This requirement eliminated the possibility of using the grid itself as support for any wiring methods, even though the ceiling was still allowed to support boxes and fixtures, and some fixtures were still required to be secured to the ceiling grid in accordance with Section 410-16(c).

The 1996 requirement made installations in ceilings that were suspended more than a few feet more difficult, as a separate support system had to be constructed for raceway or cable systems in these cavities. It also rendered some wiring methods, such as manufactured wiring systems, impractical in some of the applications where they had previously been installed.

The language in the 1999 NEC is a step back toward previous practice, but new wording is provided to assure that the ceiling assemblies do not have to carry the weight of the wiring methods. The fact that ceiling systems are not tested for the unknown weight of the wiring methods that might be attached to the support wires was the primary substantiation behind the 1996 and 1999 changes.

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300-11(b) Use of Raceways to Support Wiring Methods

Type of Change Revision

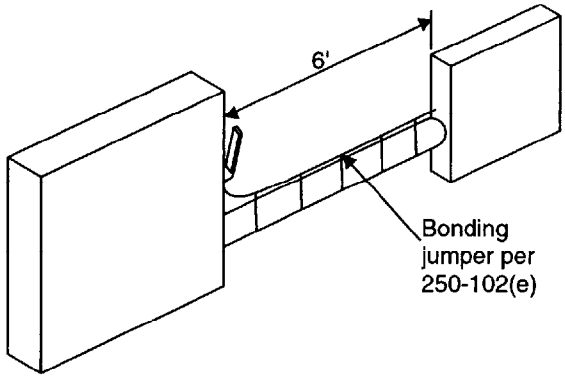
BRIEF SUMMARY

All occupancies. This revision restricts the use of raceways to support other items.

Code Language

300-11. Securing and Supporting.
(b) Raceways Used as Means of Support. Raceways shall ~~not~~ **only** be used as a means of support for other raceways, cables, or nonelectric equipment **under the following conditions:** (ROP 3-82) (ROC 3-59) (TCC 3-59)

(1) Where the raceway or means of support is identified for the purpose; or
(2) Where the raceway contains power supply conductors for electrically controlled equipment and is used to support Class 2 circuit conductors or cables that are solely for the purpose of connection to the equipment control circuits; or
(3) Where the raceway is used to support boxes or conduit bodies in accordance with Section 370-23 or to support fixtures in accordance with Section 410-16(f). (ROC 3-54)



Bonding Jumper Attached to Raceway

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Background and Explanation

The changes to this section are another example of exceptions being converted to positive code text. In addition, the code panel actions on proposals and comments to this section indicate that the common industry practice of installing a bonding jumper on the exterior of a raceway in accordance with Section 250-102(e) and attaching it to that raceway is permitted. To keep the bonding conductor in close proximity to the circuit conductors and to prevent physical damage to the conductor, securing it to the raceway is often necessary.

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300-14 Length of Free Conductor

Type of Change Revision

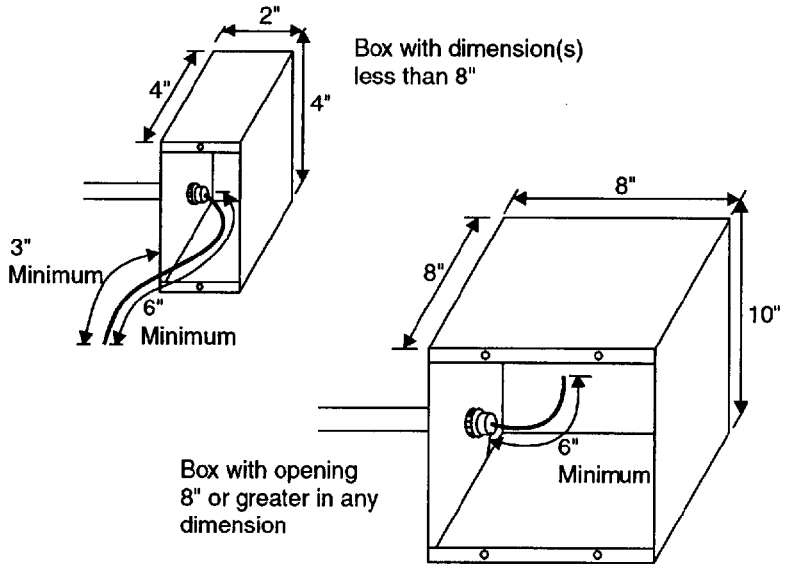
BRIEF SUMMARY

All installations. This section has been revised to clarify how to determine free conductor length and to address the length that extends beyond the enclosure opening.

Code Language

300-14. Length of Free Conductors at Outlets, Junctions, and Switch Points. At least 6 in. (152 mm) of free conductor, **measured from the point in the box where it emerges from its raceway or cable sheath**, shall be left at each outlet, junction, and switch point for splices or the connection of fixtures or devices. **Where the opening to an outlet, junction, or switch point is less than 8 in. (203 mm) in any dimension, each conductor shall be long enough to extend at least 3 in. (76.2 mm) outside the opening.** (ROP 3-103)

Exception: Conductors that are not spliced or terminated at the outlet, junction, or switch point.



Length of Free Conductor

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Application

The illustration shows the two basic conditions for this rule. The box with an opening less than 8 inches in height or width must have at least 6 inches of free conductor measured from where it emerges from the conduit and at least 3 inches of free conductor extending outside the opening. The larger box, where a dimension of the opening is at least 8 inches, is only required to have 6 inches of free conductor measured from where it emerges from the conduit. While these examples show conductors in conduits, the same rules apply for cables, except that the measurement is taken from the point where the conductor emerges from the cable fitting or sheath inside the box or enclosure.

Background and Explanation

The "6-inch free conductor rule" has long been subject to varying interpretations. A number of sometimes conflicting proposals and comments to clarify the requirement were proposed for the 1996 code. A task group was formed to resolve the language, and the result is the revised wording of Section 300-14. This wording clarifies how the measurement should be made. In addition, where box openings are relatively small, three inches of conductor must extend from the box opening for splices or the connection of devices.

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STD·NFPA NEC CHANGES-ENGL 1999 ■ 6474446 0577035 42T ■

300-18(b) Prohibition on Welding Metal Conduits

Type of Change New

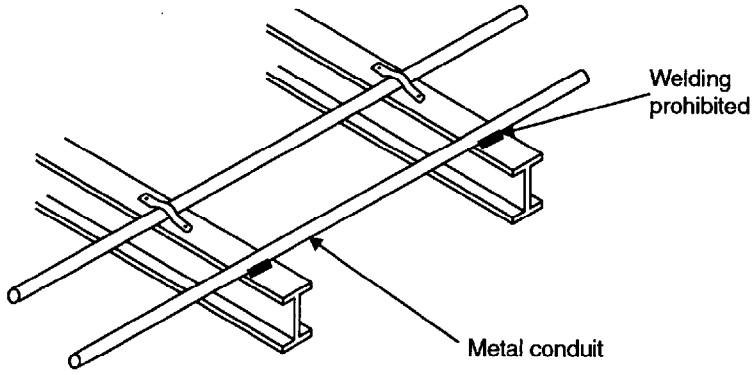
BRIEF SUMMARY

All occupancies. Welding of conduit is prohibited.

Code Language

300-18. Raceway Installations.

(b) Welding. Metal raceways shall not be supported, terminated, or connected by welding to the raceway unless specifically designed to be or otherwise specifically permitted to be in this *Code*. (ROP 3-119) (ROC 3-88, 3-92)



Securing Raceways by Welding Not Permitted

Application

Inspectors have reported cases where welding was used to secure metal conduit and EMT. This section now clearly prohibits this practice.

Background and Explanation

Welding is not a recognized method for the support of conduit and may compromise the integrity of external and internal finishes as well as possibly cause distortion to the interior of the raceway. There was no specific language in the NEC to prohibit this method of support for metal raceways.

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NEC pp. 113–115

Article 300
Part B Relocated Requirements from Article 710

Type of Change Relocation

BRIEF SUMMARY

Commercial and industrial. Existing Article 300, Part B (including Sections 300-31 through 300-37) has been expanded with the rules for wiring methods from the deleted Article 710.

Code Language

Part B. Requirements for Over 600 Volts, Nominal
300-31. Covers Required.
300-32. Conductors of Different Systems.
300-34. Conductor Bending Radius.
300-35. Protection Against Induction Heating.
300-37. Aboveground Wiring Methods.
300-39. Braid-Covered Insulated Conductors—Open Installation.
300-40. Insulation Shielding.
300-42. Moisture or Mechanical Protection for Metal-Sheathed Cables.
300-50. Underground Installations.

Application

The illustration shows the origin and new location of the relocated and rearranged sections.

Background and Explanation

This change was part of the redistribution of Article 710 and the consolidation of requirements for over 600 volts. The previous Sections 300-31 through 300-35 were retained. Section 300-36 on grounding was deleted because it was an unneeded general reference to Article 250. The sections of Article 710 that were applicable to wiring methods were relocated as shown in the diagram.

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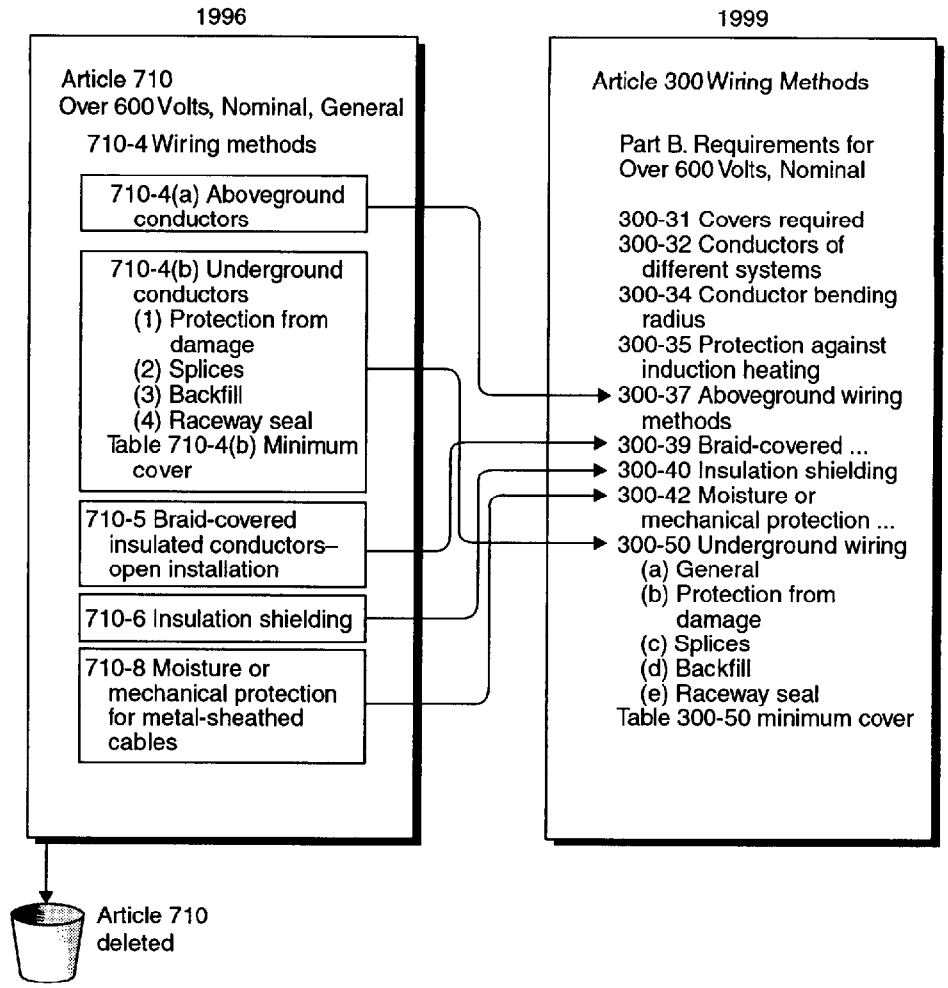

High Voltage Rules Relocated

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300-37 EMT Permitted for Use Over 600 Volts

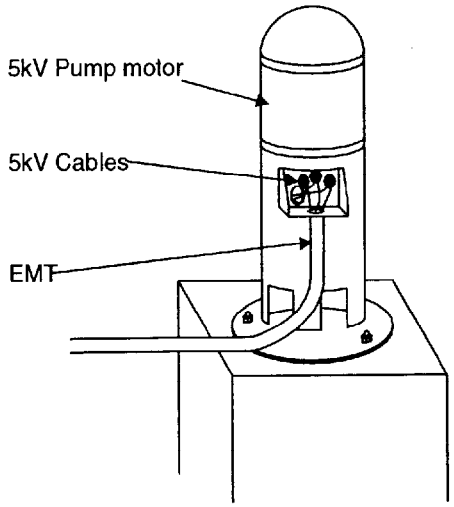
Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Electrical metallic tubing is now included as a suitable wiring method for over 600 volts in aboveground locations.

Code Language

300-37. Aboveground Wiring Methods. Aboveground conductors shall be installed in rigid metal conduit, in intermediate metal conduit, **in electrical metallic tubing,** in rigid nonmetallic conduit, in cable trays, as busways, as cablebus, in other identified raceways, or as open runs of metal-clad cable suitable for the use and purpose. In locations accessible to qualified persons only, open runs of Type MV cables, bare conductors, and bare busbars shall also be permitted. Busbars shall be permitted to be either copper or aluminum. (ROP 13-35, 13-37, 13-38, 3-148)



EMT for Over 600 Volts

Application

Electrical metallic tubing may be used as a wiring method for over 600 volts in aboveground locations. The illustration shows an example of a possible application for EMT in an over-600-volt application.

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Background and Explanation

Section 300-37 in the 1996 NEC was titled "Underground Installations." It provided only a reference to Section 710-4(b). Article 710 has been deleted from the 1999 code and the provisions of Section 710-4 have been moved to Sections 300-37 and 300-50. Section 300-37 now covers wiring methods for over 600 volts for aboveground installations. EMT was added as an acceptable wiring method; some testing laboratories now list EMT as suitable for over 600-volt installations.

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305-4(b) & (c) NM and NMC Cable for Temporary Wiring

Type of Change Revision

BRIEF SUMMARY

All installations. Type NM and NMC cables may be used for temporary feeder and branch-circuit wiring without height restrictions.

Code Language

305-4. General.

(a) Services. Services shall be installed in conformance with Article 230.

(b) Feeders. Feeders shall be protected as provided in Article 240. They shall originate in an approved distribution center. Conductors shall be permitted within cable assemblies, or within cords or cables of a type identified in Table 400-4 for hard usage or extra-hard usage. **For the purpose of this section, Type NM and Type NMC cables shall be permitted to be used in any dwelling, building, or structure without any height limitation.** (ROC 3-137)

Exception: Single insulated conductors shall be permitted where installed for the purpose(s) specified in Section 305-3(c), where accessible only to qualified persons. (ROP 3-157)

(c) Branch Circuits. All branch circuits shall originate in an approved power outlet or panelboard. Conductors shall be permitted within cable assemblies, or within multiconductor cord or cable of a type identified in Table 400-4 for hard usage or extra-hard usage. All conductors shall be protected as provided in Article 240. **For the purposes of this section, Type NM and Type NMC cables shall be permitted to be used in any dwelling, building, or structure without any height limitation.** (ROP 3-161) (ROC 3-138)

Application

As shown in the illustration, NM and NMC cables may be used as feeders or branch circuits for temporary wiring even in structures over three stories high. The cables must be suitable for the conditions and be adequately supported and protected from damage.

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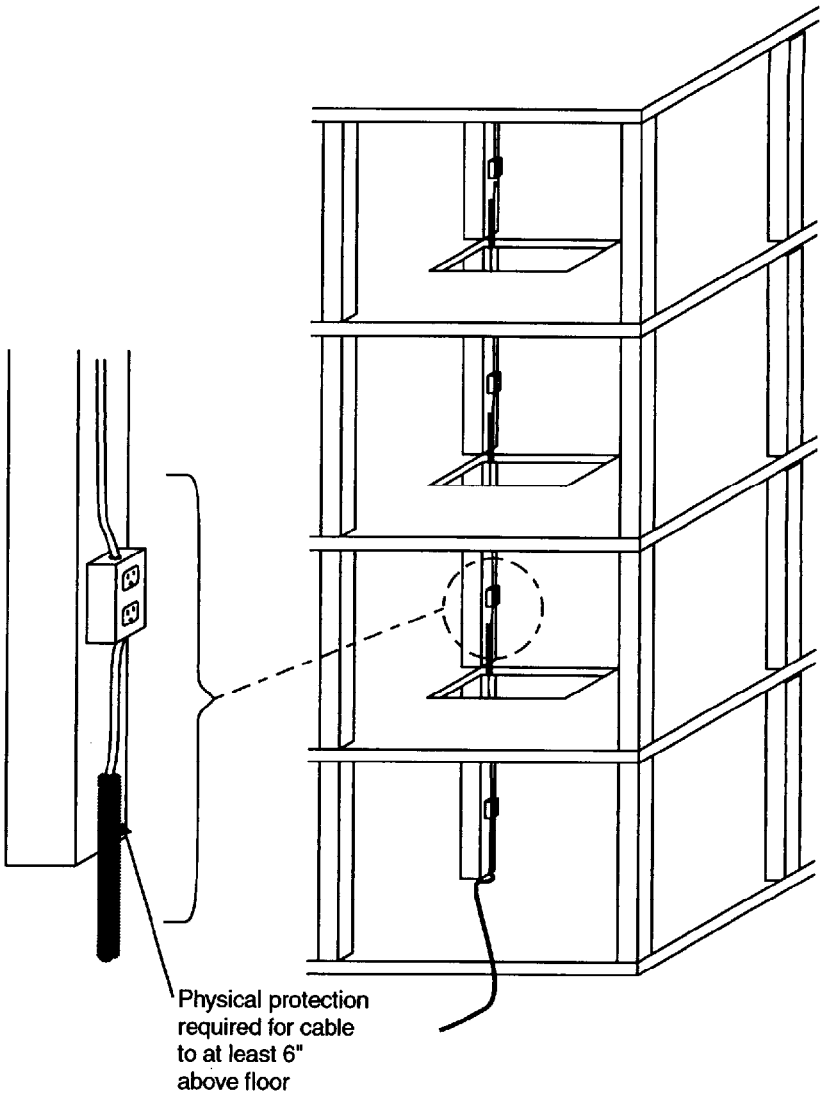

NM and NMC Cable for Temporary Wiring

Background and Explanation

NM or NMC cables are restricted by occupancy in some cases, and restricted by height limitations in some buildings. (See the revisions to Section 336-4.) However, as stated in Section 305-1, temporary wiring methods "... may be of a class less than would be required for permanent installations." This change makes explicit mention of the suitability of NM and NMC cables as temporary wiring methods. It also settles the issue of whether the height restrictions of Article 336 apply to temporary wiring installations. However, the cables should be suitable for the conditions, and NM and NMC cables are not suitable for use in wet locations according to Section 336-4. In addition, Section 336-6(b) requires physical protection for cables subject to physical damage. Otherwise, both NM and NMC are suitable for exposed work, even when permanently installed. NM cable has been successfully used as a temporary wiring method, and this fact is now recognized in Article 305.

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305-4(j) Support Requirements for Temporary Wiring Methods

Type of Change New

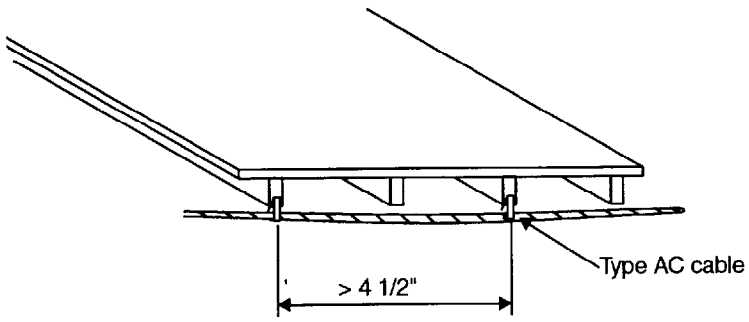
BRIEF SUMMARY

All installations. Adequate support of cables used for temporary wiring is required.

Code Language

305-4. General.

(j) Support. Cable assemblies and flexible cords and cables shall be supported in place at intervals that ensure that they will be protected from physical damage. Support shall be in the form of staples, cable ties, straps, or similar type fittings installed so as not to cause damage. (ROP 3-167) (ROC 3-148)



Adequate Support Intervals for Temporary Wiring

Application

Cables used for temporary wiring must be protected from physical damage. To ensure proper protection, cables and cords must be adequately supported. Distance between supports is not specified and is therefore dependent on the specific jobsite conditions. Installers should check with the authority having jurisdiction for approval of the support intervals. Staples, straps, and cable ties are among the recognized methods.

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Background and Explanation

The submitter of the proposal indicated that the requirements for the support of cables for permanent installations (from the respective Chapter 3 articles) were in most cases overly restrictive for temporary wiring applications. However, it is necessary to provide some support in order to reduce the number of cases where cables are damaged on temporary wiring sites. This new rule allows for a practical approach to cable and cord management depending on the type of cable or cord, and its location, and the specific conditions that will be encountered at the installation site.

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305-6(a) & (b) 30-Ampere, 125-Volt GFCI Protection

Type of Change Revision

BRIEF SUMMARY

All installations. 30-ampere, 125-volt receptacles used for temporary wiring must have GFCI protection.

Code Language

305-6. Ground-Fault Protection for Personnel. Ground-fault protection for personnel for all temporary wiring installations shall be provided to comply with (a) and (b). This section shall apply only to temporary wiring installations used to supply temporary power to equipment used by personnel during construction, remodeling, maintenance, repair, or demolition of buildings, structures, equipment, or similar activities.

(a) Receptacle Outlets. All 125-volt, single-phase, 15-, 20-, and **30-ampere** receptacle outlets that are not a part of the permanent wiring of the building or structure and that are in use by personnel shall have ground-fault circuit interrupter protection for personnel. If a receptacle(s) is installed or exists as part of the permanent wiring of the building or structure and is used for temporary electric power, ground-fault circuit interrupter protection for personnel shall be provided. For the purposes of this section, cord sets or devices incorporating listed ground-fault circuit interrupter protection for personnel **identified for portable** use shall be permitted. (ROC 3-153)

Exception No. 1: Receptacles on a 2-wire, single-phase portable or vehicle-mounted generator rated not more than 5 kW, where the circuit conductors of the generator are insulated from the generator frame and all other grounded surfaces, shall be permitted without ground-fault protection for personnel.

Exception No. 2: In industrial establishments only, where conditions of maintenance and supervision ensure that only qualified personnel are involved, an assured equipment grounding conductor program as specified in Section 305-6(b)(2) shall be permitted to be utilized ***for all receptacle outlets.***

(b) Use of Other Outlets. **Receptacles other than 125-volt, single-phase, 15-, 20-, and 30-ampere receptacles shall have protection in accordance with (1) or the assured equipment grounding conductor program in accordance with (2).** (ROC 3-153)

(1) Ground-fault circuit interrupter protection for personnel.

(2) A written assured equipment grounding conductor program continuously enforced at the site by one or more designated persons to ensure that equipment grounding conductors for all cord sets, receptacles that are

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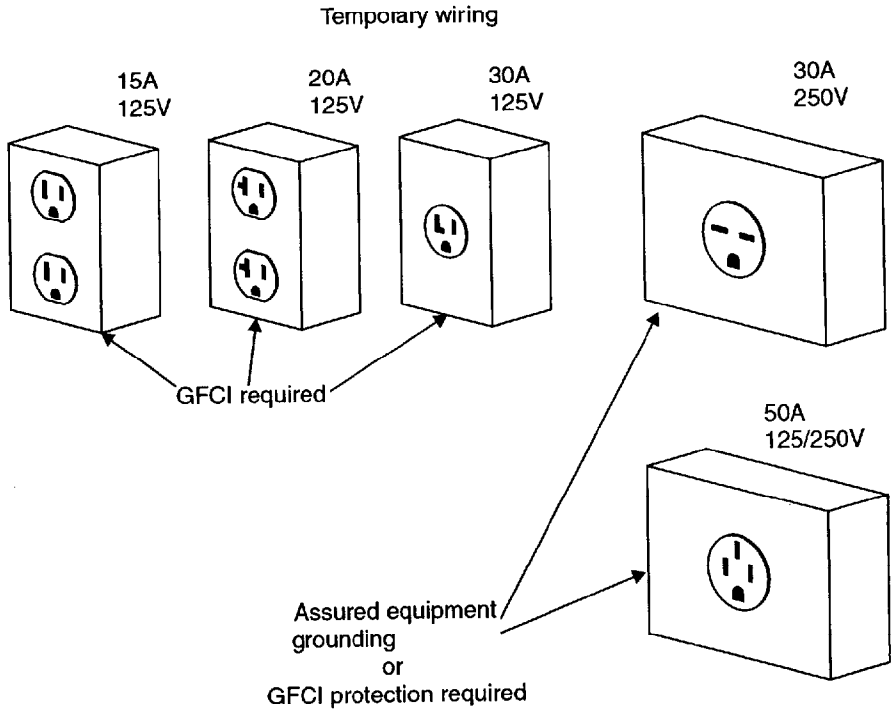
not a part of the permanent wiring of the building or structure, and equipment connected by cord and plug are installed and maintained in accordance with the applicable requirements of Sections 210-7(c), 250-114, 250-138, and 305-4(d).

(a) The following tests shall be performed on all cord sets, receptacles that are not part of the permanent wiring of the building or structure, and cord- and plug-connected equipment required to be grounded.

(1) All equipment grounding conductors shall be tested for continuity and shall be electrically continuous.
(2) Each receptacle and attachment plug shall be tested for correct attachment of the equipment grounding conductor. The equipment grounding conductor shall be connected to its proper terminal.
(3) All required tests shall be performed
  (a) Before first use on ~~construction~~ site (ROC 3-153)
  (b) When there is evidence of damage
  (c) Before equipment is returned to service following any repairs
  (d) At intervals not exceeding 3 months

(b) The tests required in (2)(a) shall be recorded and made available to the authority having jurisdiction. (ROP 3-175)



Receptacles Used for Temporary Power

Application

As shown in the illustration, 125-volt, 15-, 20-, and 30-ampere rated receptacles used for temporary wiring must have GFCI protection. The GFCI protection may be provided by a portable device. Other receptacles used for temporary wiring may be GFCI protected or they shall comply with the requirements of an assured equipment grounding program. Other types of outlets, such as a permanent

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connection to a lift or a welder on a construction site or lighting outlets not wired through receptacles, are not required to be covered by the GFCI or assured equipment grounding requirements.

Background and Explanation

This change involves four wording changes. In the first sentence of Section 305-6 the phrase "shall be provided to comply with (a) or (b) below" was changed to "...(a) and (b) below." Some people were interpreting the "or" to mean that 15- and 20-ampere 125-volt receptacles could still be covered by an assured equipment grounding program. This change was a clarification, with no change in intent.

Another clarification was made by rewording Section 305-6(b) and changing its title to "Use of Other Outlets."

The other two changes modified the technical requirements of the section. These changes were the addition of 30-ampere receptacles in subsection (a) and the addition of the phrases "or devices" and "identified for portable use" in the last sentence of Section 305-6(a) before the exceptions. The first of these changes removed 30-ampere, 125-volt receptacles from the assured equipment grounding option and required GFCI protection for these outlets. The second allows for the use of portable cords or devices provided with GFCI protection. This change also clarifies that industrial facilities are permitted to use the "assured equipment grounding conductor program" for all receptacles, including 15-, 20-, and 30-ampere, single-phase, 125-volt configurations. Section 305-6(b) requires receptacles other than 15,20, and 30 ampere, 125 volt, single phase to be protected by either ground-fault circuit interrupters or the assured equipment-grounding conductor program.

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310-4 Parallel Conductor Requirements

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. The requirement for the installation for parallel conductors has been clarified.

Code Language

310-4. Conductors in Parallel. Aluminum, copper-clad aluminum, or copper conductors of size No. 1/0 and larger, comprising each phase, neutral, or grounded circuit conductor, shall be permitted to be connected in parallel (electrically joined at both ends to form a single conductor).

Exception No. 1: As permitted in Section 620-12(a)(1).

Exception No. 2: Conductors in sizes smaller than No. 1/0 shall be permitted to be run in parallel to supply control power to indicating instruments, contactors, relays, solenoids, and similar control devices provided

(a) They are contained within the same raceway or cable

(b) The ampacity of each individual conductor is sufficient to carry the entire load current shared by the parallel conductors and

(c) The overcurrent protection is such that the ampacity of each individual conductor will not be exceeded if one or more of the parallel conductors become inadvertently disconnected.

Exception No. 3: Conductors in sizes smaller than No. 1/0 shall be permitted to be run in parallel for frequencies of 360 Hz and higher where conditions (a), (b), and (c) of Exception No. 2 are met.

Exception No. 4: Under engineering supervision, grounded neutral conductors in sizes No. 2 and larger shall be permitted to be run in parallel for existing installations.

FPN: Exception No. 4 can be utilized to alleviate overheating of neutral conductors in existing installations due to high content of triplen harmonic currents.

The paralleled conductors in each phase, neutral, or grounded circuit conductor shall:

(1) Be the same length
(2) Have the same conductor material
(3) Be the same size in circular mil area
(4) Have the same insulation type
(5) Be terminated in the same manner

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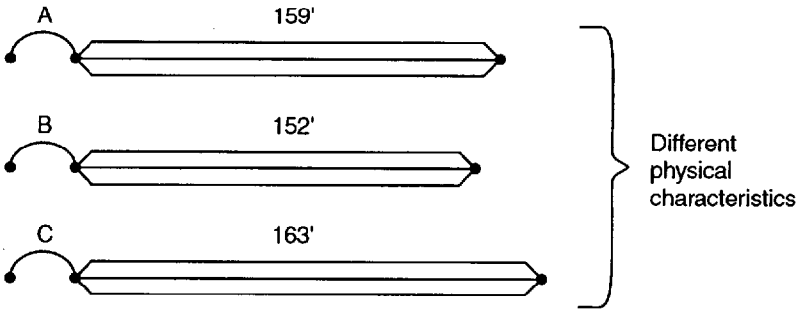
Where run in separate raceways or cables, the raceways or cables shall have the same physical characteristics. **Conductors of one phase, neutral, or grounded circuit conductor shall not be required to have the same physical characteristics as those of another phase, neutral, or grounded circuit conductor to achieve balance.**

FPN: Differences in inductive reactance and unequal division of current can be minimized by choice of materials, methods of construction, and orientation of conductors. (ROP 6-8)

Where equipment grounding conductors are used with conductors in parallel, they shall comply with the requirements of this section except that they shall be sized in accordance with Section 250-122.

Where conductors are used in parallel, space in enclosures shall be given consideration (see Articles 370 and 373).

Conductors installed in parallel shall comply with the provisions of Section 310-15(b)(2)(a).



Rules for Parallel Conductors Apply Individually to Each Phase Group.

Application

Where conductors are installed in parallel, the conductors in each phase must be the same as shown in Section 310-4(1) through (5). It is not necessary for one phase to be the same as another phase. Conductors in each phase must be the same to assure equal division of current within that phase. Load sharing will not occur between the conductors of the different phases. This only becomes a problem within each phase. For example, one phase could be copper and another could be aluminum.

Background and Explanation

This material was changed from a FPN to code text to clarify the rule. The change also makes the provision mandatory code text rather than informational only. It is not intended that all of the ungrounded, grounded, and neutral conductors have the same characteristics, only those conductors in parallel that comprise the same phase, grounded conductor, or neutral. Requiring all of the parallel conductors for all of the phases, grounded conductor, and neutral to be the same length, for example, is unnecessary and can lead to installation problems within enclosures due to excessive amounts of conductor.

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NEC pp. 123–125

310-15 Tables 310-16–310-19, Notes

Type of Change Reorganization

BRIEF SUMMARY

All installations. Section 310-15, the ampacity tables and notes, are reorganized. The table notes are incorporated into Section 310-15.

Code Language

See the table.

Table Showing Moves and Reorganization

1996 NEC Section	*Section Heading or Description*	*1999 NEC Section*
310-15	Ampacities for Conductors Rated 0-2000 Volts	310-15
310-15 (part)	General—Tables or Engineering Supervision	310-15(a)(1)
310-15(FPN)	Tables do not account for voltage drop.	310-15(a)(1)(FPN No. 1)
Tables Note 7 FPN	Type MTW Machine Tool Wire Ampacities	310-15(1)(FPN No. 2)
310-15(c)	General—Selection of Ampacity	310-15(a)(2)
310-15(a) (part)	Tables	310-15(b)
310-15(a)(FPN)	Load based on Article 220—ampacity considerations	310-15(b)(FPN)
Tables Note 1	Tables—General—insulation-type letters	310-15(b)(1)
Tables Note 8(a)	Adjustment Factors and Table	310-15(b)(2)(a)
Tables Note 8(b)	More Than One Conduit, Tube, or Raceway	310-15(b)(2)(b)
Tables Note 5	Bare or Covered Conductors	310-15(b)(3)
Tables Note 10	Neutral Conductor—when counted as current-carrying	310-15(b)(4)
Tables Note 11	Grounding or Bonding Conductor	310-15(b)(5)
Tables Note 3	Dwelling Units—feeder and service conductor ampacities	310-15(b)(6)
Tables Note 6	Mineral-Insulated, Metal-Sheathed Cable	310-15(b)(7)
310-15(b)	Engineering Supervision	310-15(c)
Tables Note 9	Overcurrent Protection	Deleted—Sec 240-3
Obelisk Notes at bottom of Tables 310-16 & 310-17	Limitations on overcurrent protection for small conductors	240-3(d)

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Application

The table shows the old and new locations of the notes to Tables 310-16 through 310-19 and the reorganization of Section 310-15. This change did not change any technical requirements from the 1996 NEC.

Background and Explanation

This change was made to improve the usability of Section 310-15 and the Allowable Ampacity Tables and to place the note on small-conductor overcurrent protection limitation into Section 240-3, which is the basic conductor protection requirement.

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318-2 Securing Cables in Cable Trays

Type of Change Revision

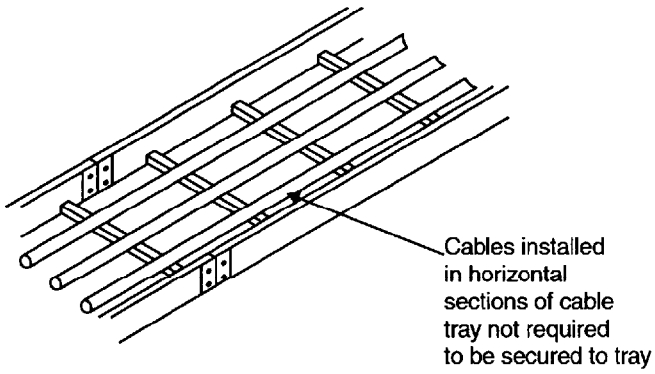
BRIEF SUMMARY

Commercial and industrial. The definition of cable tray systems has been clarified relative to cable supporting and securing.

Code Language

318-2. Definition.

Cable Tray System. A unit or assembly of units or sections and associated fittings forming a ~~rigid~~ structural system used to **securely fasten or** support cables and raceways. (ROP 8-8, 8-10)



A Cable Support System

Application

Cable tray systems may be used to support various types of cables and raceways. The tray system provides the support required by the articles covering the wiring methods used. Article 318 does not require that wiring methods such as cables be securely fastened to the cable tray. In some installations the designer may specify that cables be fastened to the tray with cable ties or other methods. This technique will limit cable movement under fault conditions.

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Background and Explanation

The panel statement for this change indicates the intent is that cables and raceways may be, but are not required to be, securely fastened.

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318-6(j) Outlet Boxes Supported by Cable Trays

Type of Change Revision

BRIEF SUMMARY

Industrial. Outlet boxes have been added to the items that may be supported from cable trays.

Code Language

318-6. Installation.

•
•
•

(j) Raceways, Cables, and Outlet Boxes Supported from Cable Trays. In industrial facilities where conditions of maintenance and supervision ensure only qualified persons will service the installation and where cable trays are designed to support the load, raceways, cables, **and outlet boxes** shall be permitted to be supported from cable trays. For raceway terminating at the tray, a listed cable tray clamp or adapter shall be used and no nearby support, such as a support within 3 ft (914 mm), shall be required.

For raceway or cable running parallel to, but under or beside, a tray, support shall be in accordance with the requirements of the appropriate raceway or cable article.

For outlet boxes located under or beside a tray, support shall be in accordance with the requirements of Article 370. (ROP 8-29, 8-30)

Application

As shown in the illustration, outlet boxes may be supported from cable trays in industrial installations. Boxes mounted under or beside the tray, as in the illustration, must also meet the requirements of Article 370. Specifically, Section 370-23(a) requires the box to be rigidly and securely fastened. The cable tray must be designed to support the load, and servicing of the installation must be by qualified persons only. Raceways and cable may also be supported by cable trays. The illustration shows a receptacle outlet, but other types of outlets may be installed.

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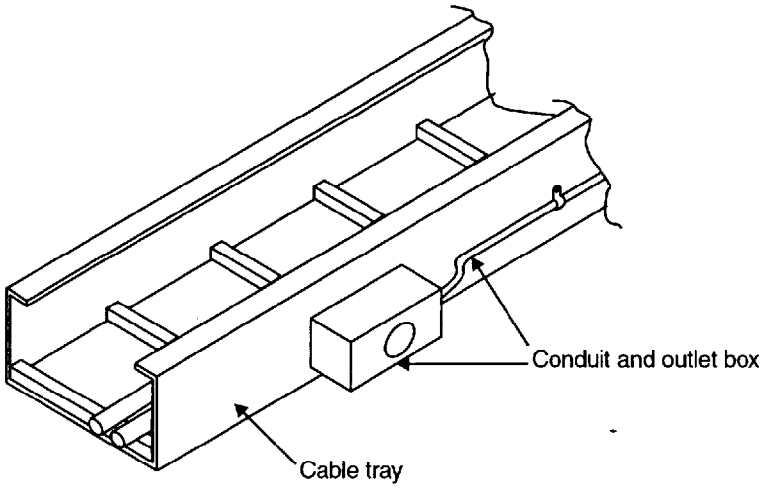

Outlet Boxes on Cable Tray

Background and Explanation

This change was made primarily for the convenience of industrial users. In industrial installations of cable trays, the tray is often the only convenient place to locate an outlet box. The code panel modified the original proposal to ensure that adequate support for raceways and outlet boxes is provided.

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331-3(6) ENT Under Concrete Slabs

Type of Change New

BRIEF SUMMARY

All occupancies. Electrical nonmetallic tubing is permitted under concrete slabs.

Code Language

331-3. Uses Permitted. The use of electrical nonmetallic tubing and fittings shall be permitted in the following:

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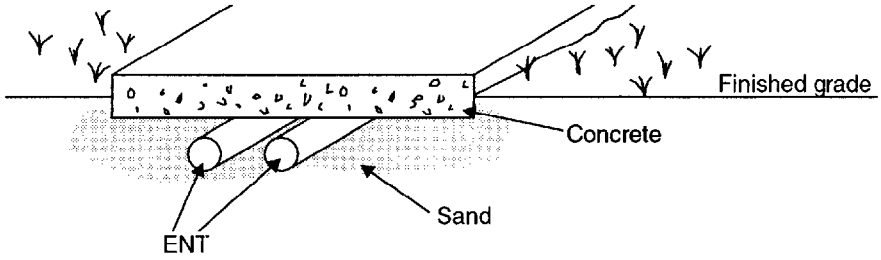
•
•

(6) Encased in poured concrete, **or embedded in a concrete slab on grade where ENT is placed on sand or approved screenings**, provided fittings identified for this purpose are used for conditions (ROC 8-134)



ENT Permitted to Be Located Beneath Slab on Grade

Application

Where ENT is installed below a concrete slab on grade, it must be provided with a bed of sand or other screened material. With proper bedding and care during installation, ENT can be installed below concrete slabs without damage.

Background and Explanation

Electrical metallic tubing has been permitted to be encased in poured concrete in previous editions of the code. This new rule allows for the installation of ENT on a bed of sand or other suitable material prior to the pouring of the concrete slab. It was noted in the proposal that ENT has the same crush requirements as Schedule 40 rigid nonmetallic conduit.

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331-3(8) & 300-18 ENT for Prewired Assemblies

Type of Change New and Revised

BRIEF SUMMARY

All installations. Electrical nonmetallic tubing is permitted to be used in ½-inch through 1-inch sizes for listed prewired assemblies.

Code Language

331-3. Uses Permitted. The use of electrical nonmetallic tubing and fittings shall be permitted in the following:

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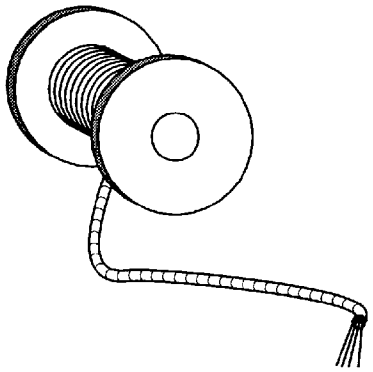
(8) ½ in. through 1 in. as listed manufactured prewired assembly (ROP 8-66)



1/2"–1" Trade sizes
Electrical nonmetallic tubing as a manufactured prewired assembly

Prewired ENT

Application

The illustration shows a reel of ENT with conductors preinstalled. This product can be used in the same locations and under the same conditions as regular ENT. Termination fittings are cemented in place at the time of installation and special tools are available to cut the tubing without damaging the conductors.

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Background and Explanation

This is the third code cycle in which this product has been proposed. Code panel members had several objections and questions about the suitability of this product, but subsequent testing and an Underwriters Laboratories fact-finding report were able to satisfy the concerns of the panel.

This product is similar to NUC (nonmetallic underground conduit with conductors) as covered in Article 343. NUC has a greater range of sizes; however, prewired ENT assemblies can be used aboveground and are more flexible.

The term "manufactured prewired assemblies" is not defined. Other prewired assemblies using flexible metal conduit and flexible metallic tubing are recognized in Sections 350-10(a)(5) and 349-10 Exception No. 2, but these uses are subject to 6-foot length restrictions. There is no length restriction on ENT in manufactured prewired assemblies.

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333-7 Cable Ties for Support of AC Cable

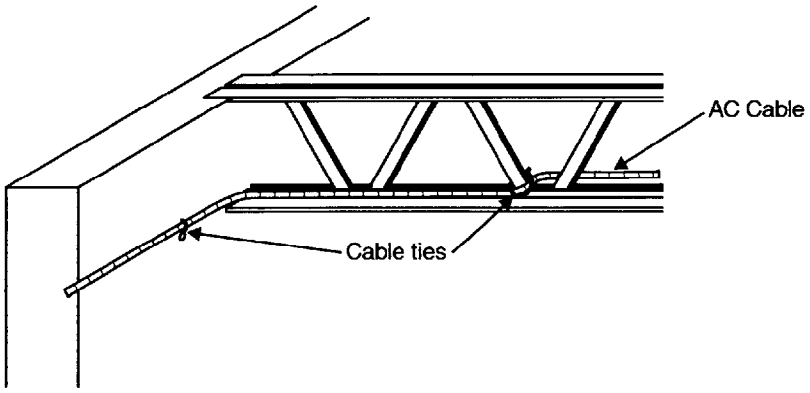
Types of Change Revised

BRIEF SUMMARY

All occupancies. The rule for support of type AC cable has been clarified.

Code Language

333-7. Support. Type AC cable shall be secured by staples, **cable ties,** straps, hangers, or similar fittings designed and installed so as not to damage the cable at intervals not exceeding 4½ ft (1.37 m) and within 12 in. (305 mm) of every outlet box, junction box, cabinet, or fitting. (ROC 7-60) (TCC 7-60)



AC Cable Support

Application

Cable ties may be used to secure type AC cable provided the cable is not damaged by their use. This gives another method to secure cables to bar joist type construction or in areas above suspended ceilings.

Background and Explanation

The use of cable ties has been a common practice in some jurisdictions. No problems have been reported as a result of this support method. Since the 1993 code, Section 336-18 has recognized the use of cable ties as a securing method for nonmetallic sheathed cables without any reported problems.

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STD.NFPA NEC CHANGES-ENGL 1999 ■ 6474446 0577059 963 ■

336-4 and 336-5 Height Restriction for NM, NMC, and NMS Cables

Type of Change Revision

BRIEF SUMMARY

Residential. The three-floor height restriction on the use of NM cable in one- and two-family dwellings was removed.

Code Language

336-4. Uses Permitted. Type NM, Type NMC, and Type NMS cables shall be permitted to be used in the following:

(1) One- and two-family dwellings

(2) Multifamily dwellings and other structures, except as prohibited in Section 336-5

(3) Cable trays, where the cables are identified for the use

(TCC 7-74) (ROC 7-138)

336-5. Uses Not Permitted.

(a) Types NM, NMC, and NMS. Types NM, NMC, and NMS cables shall not be used in the following:

1. In any ~~dwelling~~ **multifamily dwelling or other structure exceeding three floors above grade** (ROC 7-163)

Application

Type NM cable may be used in one- and two-family dwellings of any height. NM cable may not be used in multifamily dwellings and other structures over three floors in height.

Background and Explanation

The three-story height limit originated in the 1975 NEC and was based on concerns over physical damage occurring to the NM cable during construction on large projects where such exposure to damage increased. Although the code panel agreed to remove the height restriction on one- and two-family dwellings,

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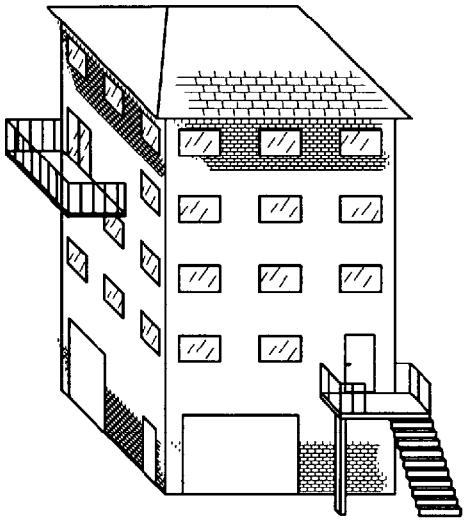
the restriction remains for multifamily dwellings and other structures. Other proposals to place additional limits on the use of NM cable were defeated in the public comment period. Building codes recognize specific methods of vertical fire-rated construction (such as a 2-hour rated firewall) as a delineation that enables the construction on either side to be considered a separate building or structure. This concept does not apply to horizontal fire-rated construction.



One- or two-family dwellings, no height restriction on use of NM cable

NM Cable—Over Three Floors

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336-6(b) NM in Surface Raceway

Type of Change Revision

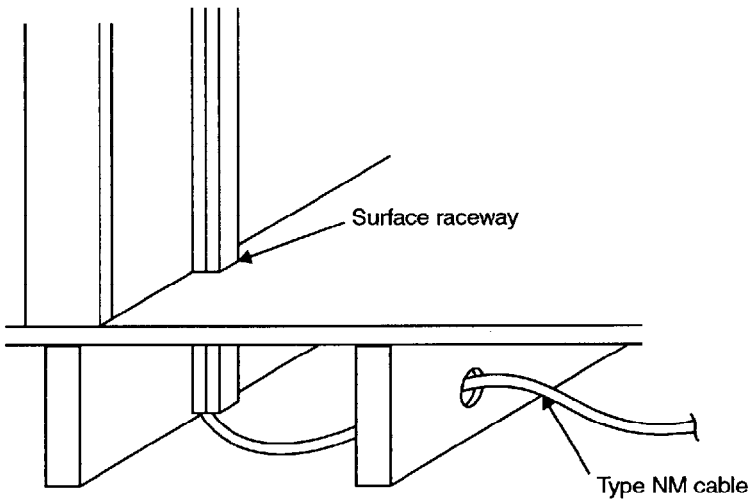
BRIEF SUMMARY

Residential and commercial. Listed surface raceways are included in the acceptable means for protecting NM cable from physical damage.

Code Language

336-6. Exposed Work—General. In exposed work, except as provided in Section 300-11(a), the cable shall be installed as specified in (a) through (d).

(b) Protection from Physical Damage. The cable shall be protected from physical damage where necessary by conduit, electrical metallic tubing, Schedule 80 PVC rigid nonmetallic conduit, pipe, guard strips, listed surface metal or nonmetallic raceway, or other means. Where passing through a floor, the cable shall be enclosed in rigid metal conduit, intermediate metal conduit, electrical metallic tubing, Schedule 80 PVC rigid metallic conduit, **listed surface metal or nonmetallic raceway**, or other metal pipe extending at least 6 in. (152 mm) above the floor.



NM Cable in Surface Raceway

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Application

Listed surface metal or nonmetallic raceway may be used where mechanical protection is needed for NM cable exposed to physical damage or passing through a floor. An example of such an installation is shown in the illustration.

Background and Explanation

The proposed uses for surface raceways were already included as permitted uses in Sections 352-1, 352-5, 352-22, and 352-28. The change to include surface raceways in Section 336-6(b) as a method of protecting NM cable was made to provide a more aesthetic option for protection of NM cables than the options that were previously specified.

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336-18 Use of NM to Connect Fixtures Within Accessible Ceiling

Type of Change Revision

BRIEF SUMMARY

All occupancies. The rules for the support of nonmetallic-sheathed cables have been relaxed.

Code Language

336-18. Supports. Nonmetallic-sheathed cable shall be secured by staples, cable ties, straps, or similar fittings designed and installed so as not to damage the cable. Cable shall be secured in place at intervals not exceeding 4½ ft (1.37 m) and within 12 in. (305 mm) from every cabinet, box, or fitting. **Flat** cables shall not be stapled on edge. Cables run through holes in wood or metal joists, rafters, or studs shall be considered to be supported and secured. (ROP 7-110) (ROC 7-178)

FPN: See Section 370-17(c) for support where nonmetallic boxes are used. (ROC 7-178)

Exception No. 1: For concealed work in finished buildings or finished panels for prefabricated buildings where such supporting is impracticable, it shall be permissible to fish cable between access points. (ROC 7-178)

Exception No. 2: A wiring device identified for the use, without a separate outlet box, incorporating an integral cable clamp shall be permitted where the cable is secured in place at intervals not exceeding 4½ ft (1.37 m) and within 12 in. (305 mm) from the wiring device wall opening, and there shall be at least a 12-in. (305-mm) loop of unbroken cable or 6 in. (152 mm) of a cable end available on the interior side of the finished wall to permit replacement. (ROC 7-178)

Exception No. 3: Lengths not more than 4½ ft (1.37 m) from an outlet for connection within an accessible ceiling to lighting fixture(s) or equipment. (ROP 7-111, 7-117) (ROC 7-181)

Application

Section 300-11 prohibits the use of ceiling grid systems and support wires as support for cables and raceways. In suspended ceiling systems it is difficult to support cables within 12 inches of a lighting fixture. This revision allows Type NM cable to be installed up to 4½ feet from fixtures and equipment without support.

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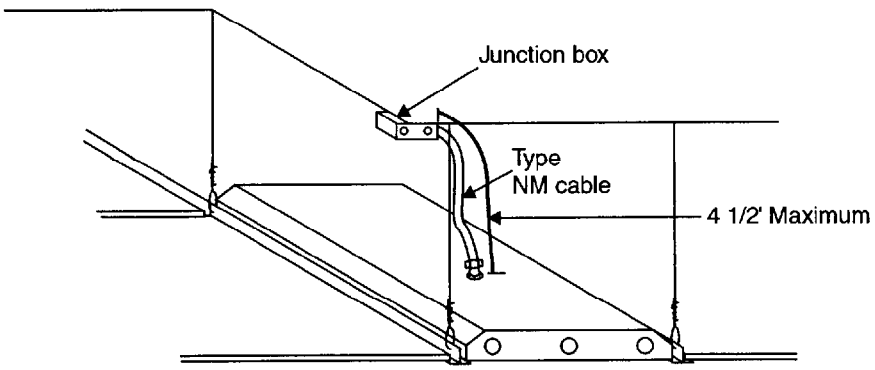

NM Cable for a Wiring of Fixtures in Accessible Ceiling

Background and Explanation

The revision recognizes the use of unsupported short sections (4½ feet) of Type NM cable as a wiring method to supply lighting fixtures or equipment within an accessible ceiling. This exception is similar to exceptions found in other articles permitting short unsupported lengths of cables and flexible or pliable raceways for fixture and equipment connections.

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339-3(b) Physical Protection for UF Cable

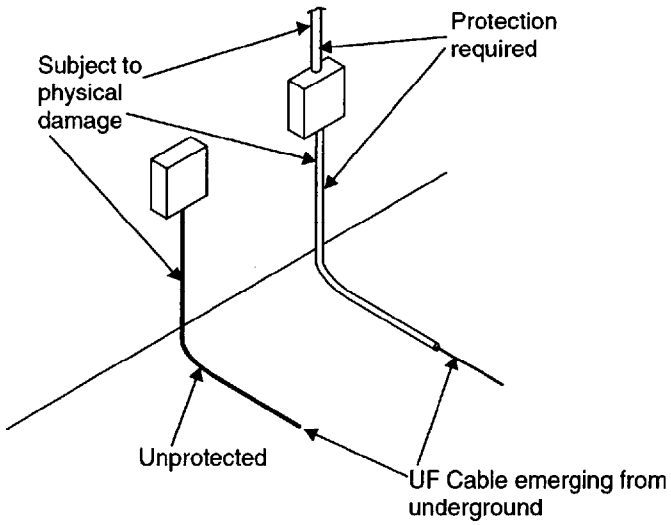
Type of Change Revision

BRIEF SUMMARY

Residential and commercial. Type UF cable may not be installed where it would be subject to physical damage.

Code Language

339-3. Use.
(b) Uses Not Permitted. Type UF cable shall not be used in the following:
•
•
•
(10) Where subject to physical damage



Physical Protection for UF Cable

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Application

The illustration shows Type UF cables emerging from underground at the side of a building. The unenclosed cable is subject to physical damage by such things as lawnmowers and weed trimmers. The unprotected cable would not comply with Sections 339-3(b) and 300-5(d), therefore protection must be provided.

The other cable is protected from physical damage. According to Section 300-5(d), the cable must be protected to its required burial depth or 18 inches, whichever is less. Permitted protection methods are rigid metal conduit, intermediate metal conduit, Schedule 80 rigid nonmetallic conduit, or the equivalent. Similar requirements apply to the cable that is enclosed in a raceway extending up from the junction box.

Background and Explanation

According to the substantiation, this change was meant "to address the problem of exterior installed conductors or cables where Section 300-5 and 336-6 do not apply." Article 300 applies generally unless modified by some specific provision of another section, but it is also specifically referenced in Sections 339-2 and 339-3(a)(3). Section 339-3(a)(2) references Section 336-6 (NM cable) for installation requirements when UF cable is used for interior wiring.

The installation shown in the illustration would appear to be covered by the requirements of Section 300-5. However, if UF cable is used to extend from the top of the box as shown, that cable is not covered by the reference to Section 336-6 because it is not interior wiring, and it is not covered by Section 300-5 because it is not emerging from underground. Although such an installation is not specifically permitted by the code, it is not specifically prohibited either.

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362-6 Dimensions of Wireways Used as Pull Point

Type of Change Revision

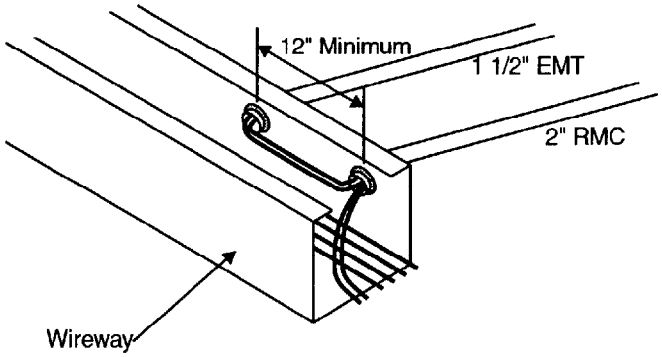
BRIEF SUMMARY

Commercial and industrial. For wireways, the minimum distance between raceway entries enclosing the same conductor is six times the trade size of the largest raceway.

Code Language

362-6. Deflected Insulated Conductors. Where insulated conductors are deflected within a wireway, either at the ends or where conduits, fittings, or other raceways or cables enter or leave the wireway, or where the direction of the wireway is deflected greater than 30 degrees, dimensions corresponding to Section 373-6 shall apply. **Where insulated conductors No. 4 or larger enter a wireway through a raceway or cable, the distance between those raceway and cable entries shall not be less than six times the trade diameter of the larger raceway or cable connector.**

Where insulated conductors No. 4 or larger enter a wireway through a raceway or cable, the distance between raceway and cable entries enclosing the same conductor shall not be less than six times the trade diameter of the larger raceway or cable connector.



Minimum distance between raceways enclosing the same conductor(s) is six times trade diameter of the largest raceway.

Raceway Entries to Wireways

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Application

Where a conductor enters a wireway in one raceway and exits through another raceway, the distance between raceway entries must be at least six times the trade diameter of the largest raceway. In the illustration, two conduits enter a wireway and two conductors enter the wireway in one conduit and leave in the other. Because the larger conduit is 2-inch trade size, the minimum separation between entries is 12 inches (6 × 2 inches).

Background and Explanation

This proposal is intended to ensure that adequate bending space is provided for conductors entering and leaving the wireway. Section 362-6 already had a rule for conductors deflected within a wireway, and that rule covered conductors entering or leaving the wireway, but it did not cover a conductor that both entered and left the wireway. The new wording is based on a similar rule for pull boxes found in Section 370-28(a)(2). Wireways are commonly used as a wire pulling location in addition to their use as raceways. In the illustration, the wireway is being used as both a raceway and a pull box in the same section. With this change, Section 362-6 covers both uses.

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362-8(a) Support at Wireway Ends

Type of Change Revision

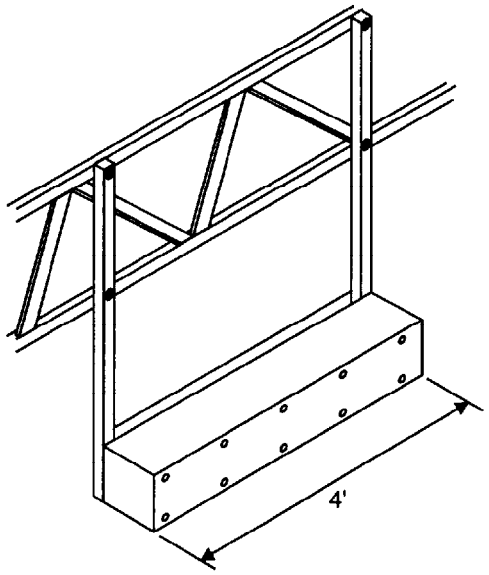
BRIEF SUMMARY

Commercial and industrial. Support requirements for wireways have been clarified.

Code Language

362-8. Supports. Wireways shall be supported in accordance with the following:

(a) Horizontal Support. Wireways shall be supported where run horizontally **at each end and** at intervals not to exceed 5 ft (1.52 m) or for individual lengths longer than 5 ft (1.52 m) at each end or joint, unless listed for other support intervals. The distance between supports shall not exceed 10 ft (3.05 m). (ROP 8-242)



Support of Horizontally Installed Wireway

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Application

All wireways are required to be supported at each end.

Background and Explanation

The 1996 code text could be interpreted as allowing a single support for short sections of wireway. This revision assures proper support for short sections of wireway.

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362-26 Bonding of Raceways Connected to Nonmetallic Wireways

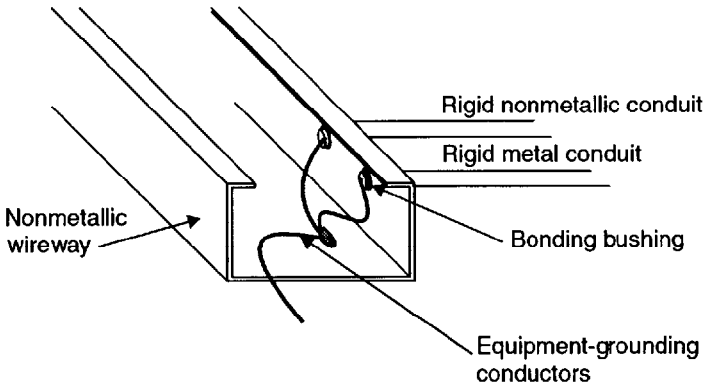
Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Required equipment grounding conductors may be installed in or bonded to metal raceway extensions from nonmetallic wireways.

Code Language

362-26. Extensions from Nonmetallic Wireways. Extensions from nonmetallic wireways shall be made with cord pendants or any wiring method of Chapter 3. A separate equipment grounding conductor shall be installed in, **or an equipment grounding connection shall be made to,** any of the wiring methods used for the extension. (ROP 8-253)



Bonding of Metal Raceways Connected to Nonmetallic Wireways

Application

When an extension is made from a nonmetallic wireway, equipment grounding conductors for the extension must be provided. Generally, equipment grounding conductors are installed in a cord pendant, a cable, or a raceway as shown in the rigid nonmetallic conduit in the illustration. However, if the raceway itself is suitable as an equipment grounding conductor, an equipment grounding connection may be made to the raceway as shown for the rigid metal conduit in the illustration.

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Background and Explanation

This change was made to clarify that equipment grounding conductors need not be installed in conduit extensions from nonmetallic wireways if the conduit is suitable as an equipment grounding conductor. Conduit that is suitable for equipment grounding need only be bonded to an equipment grounding conductor in the wireway. Even if an equipment grounding conductor were installed in the rigid metal conduit in the illustration, the conduit would still have to be connected to the equipment grounding conductor at one end or the other to comply with Sections 250-86 and 250-96(a).

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364-6(b) Curbs for Protection of Busway

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Curbing of floor penetrations for busways is required.

Code Language

364-6. Through Walls and Floors.

(a) Walls. Unbroken lengths of busway shall be permitted to be extended through dry walls.

(b) Floors. Floor penetrations shall comply with (1) and (2).

(1) Busways shall be permitted to be extended vertically through dry floors if totally enclosed (unventilated) where passing through and for a minimum distance of 6 ft (1.83 m) above the floor to provide adequate protection from physical damage.

(2) In other than industrial establishments, where a vertical riser penetrates two or more dry floors, a minimum 4-in. (102-mm) high curb shall be installed around all floor openings for riser busways to prevent liquids from entering the opening. The curb shall be installed within 12 in. (304.8 mm) of the floor opening. Electrical equipment shall be located so that it will not be damaged by liquids that are retained by the curb.

Application

Where busways penetrate two or more dry floors, a curb at least 4 inches high is required to prevent the entry of liquids. This requirement does not apply within industrial buildings.

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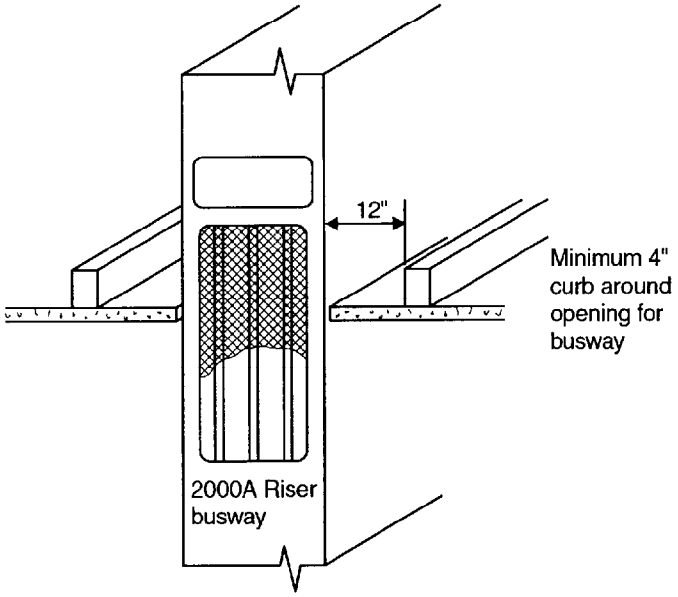

Protection of Busway at Floor Penetration

Background and Explanation

Where busways penetrate dry floors, piping system failures may occur. In the event of a piping system failure, liquids can flow through the floor openings and enter the busway system. Curbing of the openings will help to eliminate this problem. It was cited that often busways are installed in areas that have toilets or janitor's closets with sinks that are occasionally subjected to overflows or spills.

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370-16(b) (1) Exc. Box/Fixture Canopy Conductor Support

Type of Change Revision

BRIEF SUMMARY

Residential and commercial. The first four fixture wires smaller than No. 14 and an equipment ground wire entering a box from a domed canopy may be omitted from box fill calculations.

Code Language

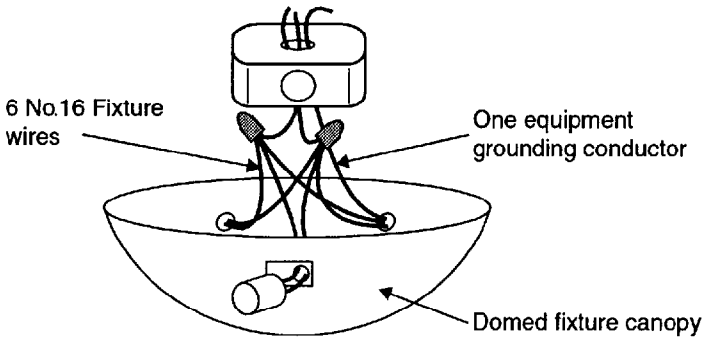
370-16. Number of Conductors in Outlet, Device and Junction Boxes, and Conduit Bodies.

•
•
•

(b) Box Fill Calculations.

(1) Conductor Fill. Each conductor that originates outside the box and terminates or is spliced within the box shall be counted once, and each conductor that passes through the box without splice or termination shall be counted once. The conductor fill, in cubic inches, shall be computed using Table 370-16(b). A conductor, no part of which leaves the box, shall not be counted.

Exception: An equipment grounding conductor ***or conductors*** *or not over four fixture wires smaller than No. 14, or both,* ***shall be permitted to be omitted from the calculations where they enter a box from a domed fixture or similar canopy and terminate within that box.*** (ROP 9-18, 9-21) (ROC 9-4)(ROP 9-18)



Fixture Wires in Domed Canopies

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Application

The illustration shows a domed fixture canopy with six No. 16 fixture wires and an equipment ground in a conductor. Only two of the No. 16 fixture wires, plus the branch-circuit conductors, must be included in the box-fill calculation.

Background and Explanation

This change is intended to clarify that up to four fixture wires and an equipment ground wire may be omitted entirely from box-fill calculations. The previous wording was sometimes interpreted to require counting all six No. 16 conductors in the illustration because there are more than four. The change also clarifies that multiple equipment grounding conductors located within the box and/or canopy are to be counted as a single conductor.

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370-23 Box Support Requirements Revised and Clarified

Type of Change Revision

BRIEF SUMMARY

All occupancies. The support requirements for boxes and enclosures covered by Article 370 have been clarified.

Code Language

370-23. Supports. Enclosures within the scope of this article shall be supported in accordance with one or more of the provisions in (a) through (h):

•
•
•

(d) Suspended Ceilings. An enclosure mounted to structural or supporting elements of a suspended ceiling shall be not more than 100 in.^{3} (1640 cm^3) in size and shall be securely fastened in place in one of the following ways:

(1) Framing Members. An enclosure shall be fastened to the framing members by mechanical means such as bolts, screws, or rivets, or by the use of **clips or other securing means identified for use with the type of ceiling framing member(s) and enclosure(s) employed.** The framing members shall be adequately supported and securely fastened to each other and to the building structure.

(2) Support Wires. The installation shall comply with the provisions of Section 300-11(a). The enclosure shall be secured, using methods identified for the purpose, to ceiling support wires, including any additional support wires installed for that purpose. Support wires used for enclosure support shall be fastened at each end so as to be taut within the ceiling cavity. (ROC 9-12)

(e) Raceway Supported Enclosure, Without Devices or Fixtures. An enclosure that does not contain a device(s) or support a fixture(s) or other equipment, and is supported by entering raceways shall not exceed 100 in.^{3} (1640 cm^3) in size. It shall have threaded entries or have hubs identified for the purpose. It shall be supported by two or more conduits threaded wrenchtight into the enclosure or hubs. **Each conduit shall be secured within 3 ft (914 mm) of the enclosure, or within 18 in. (457 mm) of the enclosure if all entries are on the same side.** (ROC 9-16)

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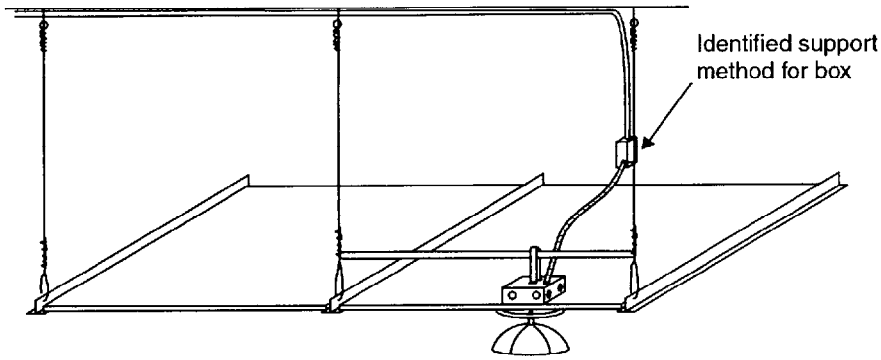
Exception: Rigid metal, intermediate metal, or rigid nonmetallic conduit or electrical metallic tubing shall be permitted to support a conduit body ***of any size, including a conduit body constructed with only one conduit entry,*** *provided the conduit body is not larger that the largest trade size of the conduit or electrical metallic tubing.*



Box Support in Suspended Ceilings

Application

This section has been revised to provide more guidance for supporting boxes and enclosures 100 cubic inches and less within and to fire-rated and nonfire-rated suspended ceiling systems in accordance with Section 300-11(a)(2) Exception. The requirements are similar to those found in Section 300-11 for wiring. Paragraph (e) now recognizes raceway supported enclosures without devices or fixtures to be supported by two or more conduits on the same side of the box.

Background and Explanation

This section has undergone an editorial rewrite to make it more usable. Various support methods have been separated into logical groups. Information on suspended ceilings has been added and correlated with Section 300-11.

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370-27(a) Use of Device Boxes to Support Fixtures

Type of Change Revision

BRIEF SUMMARY

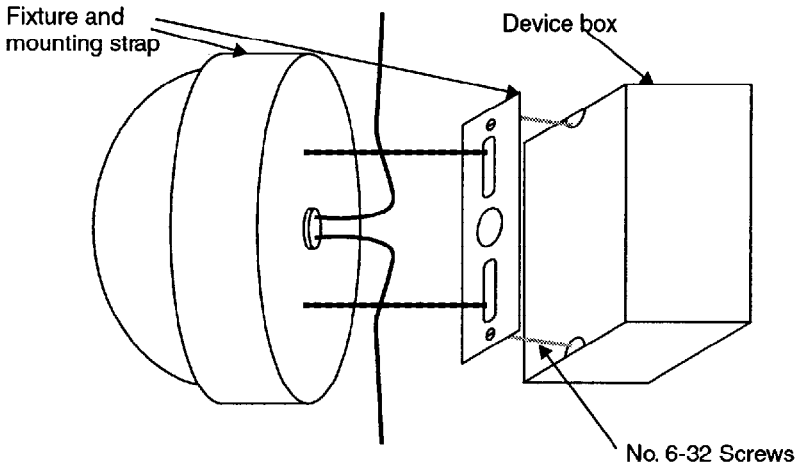
Residential and commercial. Device boxes may be used as lighting outlet boxes to support some small wall-mounted fixtures.

Code Language

370-27. Outlet Boxes.

(a) Boxes at Lighting Fixture Outlets. Boxes used at lighting fixture outlets shall be designed for the purpose. At every outlet used exclusively for lighting, the box shall be designed or installed so that a lighting fixture may be attached.

Exception: A wall-mounted fixture weighing not more than 6 lb (2.72 kg) and not exceeding 16 in. (406 mm) in any dimension shall be permitted to be supported on other boxes, provided the fixture or its supporting yoke is secured to the box with no fewer than two No. 6 or larger screws. (ROP 9-54) (ROC 9-19a)



Device Box as Support for Wall-Mounted Fixture

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Application

Boxes other than those designed for use as lighting fixture outlet boxes may be used to support small wall-mounted fixtures. The fixtures must be not more than 16 inches in any dimension and must weigh no more than six pounds. The fixture or its supporting yoke must be attached by no fewer than two screws and the screws must be size No. 6 or larger. The illustration shows a small fixture and a suitable box. This method of installation is useful for small wall fixtures where the fixture base does not cover a standard ceiling box.

Background and Explanation

This change was made to recognize a common application that has been accepted by many authorities having jurisdiction. The size and weight limits are derived from Section 410-15(a), which allows similar fixtures to be supported by the screw shell of a lampholder. The wall-mounted fixture is partially a shear load, and not entirely a tension load, as is the case with a ceiling mounted fixture.

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370-27(b) Exc. Boxes and Receptacle Assemblies in Show Windows

Type of Change Revision

BRIEF SUMMARY

Commercial. The type of outlet box and receptacle assembly allowed in show windows has been clarified.

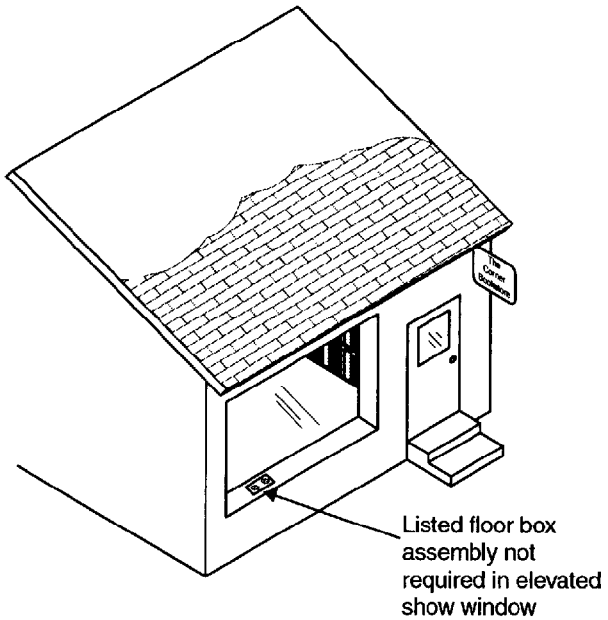
Code Language

370-27. Outlet Boxes.

•
•
•

(b) Floor Boxes. Boxes listed specifically for this application shall be used for receptacles located in the floor.

Exception: Where the authority having jurisdiction judges them free from likely exposure to physical damage, moisture, and dirt, boxes located in elevated floors of show windows and similar locations shall be permitted to be other than those listed for floor applications. ***Receptacles and covers shall be listed as an assembly for this type of location.*** (ROP 9-56)



Show Window Receptacles

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Application

Many show windows have elevated floors not subject to foot traffic or scrub water. In show windows of this type, listed floor boxes are not required. The receptacle and cover are listed as an assembly for this kind of use. Receptacles of the type required by this section are listed as "display receptacles."

Application of the exception is subject to the authority having jurisdiction's determing that the location is free from damage. Installers would be prudent to discuss an installation of this type with the authority having jurisdiction prior to starting the job.

Background and Explanation

Elevated floors in show windows are not subjected to the same traffic or floor washing conditions as general floor areas. This revision recognizes the difference and allows the use of listed device and cover assemblies but does not require that the box, device, and cover be listed together as a floor box assembly.

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370-27(c) Paddle Fan Support

Type of Change Revision

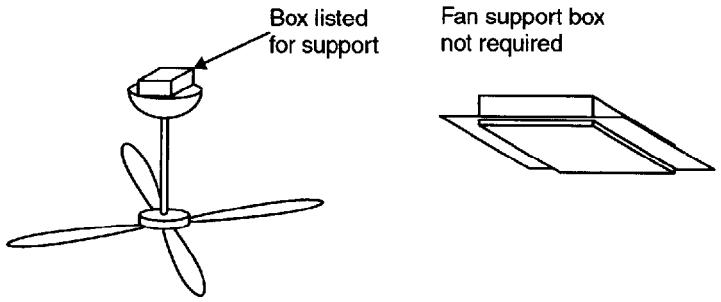
BRIEF SUMMARY

Residential and commercial. The title of this section was changed to "Boxes at Ceiling-Suspended (Paddle) Fan Outlets."

Code Language

370-27. Outlet Boxes.

(c) Boxes at Ceiling-Suspended **(Paddle)** Fan Outlets. Outlet boxes shall not be used as the sole support for ceiling-suspended **(paddle)** fans. (ROP 9-57)



Support Requirements

Application

There was no change in the technical requirements. Paddle fans require special support. Outlet boxes may not be used as the sole support for such fans unless the outlet boxes are specifically listed for the application.

Background and Explanation

The title of this section was changed for clarity. Similar wording changes were made in a number of other sections to more clearly differentiate ceiling-suspended paddle fans from other fans that may be installed in or on a ceiling.

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NEC pp. 197–199

Article 370
Part D Enclosures Intended for Personnel Entry

Type of Change New

BRIEF SUMMARY

Commercial and industrial. Requirements for manholes and other large enclosures are provided.

Code Language

Requirements for enclosures large enough to allow entry of personnel are provided.

D. Manholes and Other Electric Enclosures Intended for Personnel Entry.
Section 370-50 gives the general requirements for adequate workspace.
Section 370-51 requires design under qualified engineering supervision to ensure adequate strength.
Section 370-52 lists the specific requirements for cabling workspace.
Section 370-53 requires adequate workspace around equipment in the manhole or vault likely to be serviced while energized.
Section 370-54 provides the requirement for adequate cable bending space.
Section 370-55 provides the requirement to ensure safe access into the enclosures.
Section 370-56 lists additional rules on entry and locking arrangements to ensure safe entry into vaults and tunnels.
Section 370-57 lists ventilation requirements.
Section 370-58 requires guarding to protect against personnel contact and prevent damage by falling objects.
Section 370-59 covers corrosion resistant ladders.

Application

This new part expands on existing rules in the NEC for subsurface enclosures and integrates requirements from Section 323 of the National Electrical Safety Code, ANSI C2.

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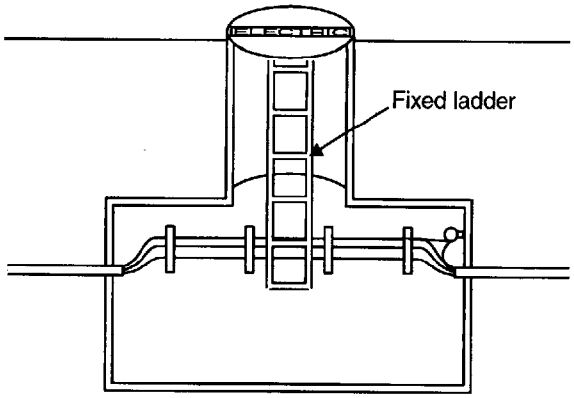

Manholes in Premises Wiring System

Background and Explanation

Many large facilities have their own electric distribution systems. Manholes and vaults are frequently used in these installations. It was also noted that as electric utility deregulation increases, the number of these types of installations that are part of a premises wiring system will increase. Some of these new requirements include existing NEC rules. The remainder of this part is derived from the National Electrical Safety Code.

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373-5(c) Exc. & FPN Sleeves for Cables Entering Cabinets

Type of Change New

BRIEF SUMMARY

Residential and commercial. NM cables may enter a panelboard through a conduit sleeve instead of being individually secured to the panelboard.

Code Language

373-5. Cabinets, Cutout Boxes, and Meter Socket Enclosures.

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•
•

(c) Cables.Where cable is used, each cable shall be secured to the cabinet, cutout box, or meter socket enclosure. (ROP 9-70)

Exception: Cables with entirely nonmetallic sheaths shall be permitted to enter the top of a surface-mounted enclosure through one or more nonflexible raceways not less than 18 in. (457 mm) or more than 10 ft (3.05 m) in length, provided all the following conditions are met.

(a) Each cable is fastened within 12 in. (305 mm), measured along the sheath, of the outer end of the raceway.

(b) The raceway extends directly above the enclosure and does not penetrate a structural ceiling.

(c) A fitting is provided on each end of the raceway to protect the cable(s) from abrasion and the fittings remain accessible after installation.

(d) The raceway is sealed or plugged at the outer end using approved means so as to prevent access to the enclosure through the raceway.

(e) The cable sheath is continuous through the raceway and extends into the enclosure beyond the fitting not less than 1/4 in. (6.35 mm).

(f) The raceway is fastened at its outer end and at other points in accordance with the applicable article.

(g) Where installed as conduit or tubing, the allowable cable fill does not exceed that permitted for complete conduit or tubing systems by Table 1 of Chapter 9 of this Code, and all applicable notes thereto. (ROC 9-44)

FPN: See Table 1 in Chapter 9, including Note 9, for allowable cable fill in circular raceways. See Section 310-15(b)(2)(a) for required ampacity reductions for multiple cables installed in a common raceway. (ROP 9-75) (ROC 9-44)

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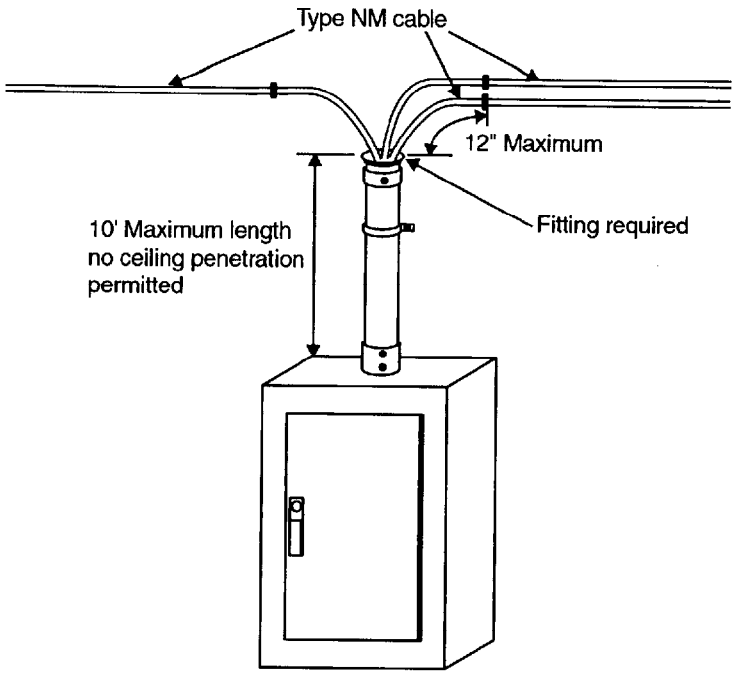

NM Cable and Panelboards

Application

Rather than each cable being secured to the cabinet of a panelboard, cables with a totally nonmetallic sheath may be installed in a nonflexible raceway that is not less than 18 inches long and that meets the five conditions shown in the illustration. The means of plugging the conduit end should be discussed with the authority having jurisdiction. A product like electrical putty or "duct seal" should be suitable to plug the raceway end. The conduit fill rules of Chapter 9 apply. Derating factors given in Section 310-15(b)(2)(a) also apply if the raceway is more than 24 inches long. (See Section 310-15(b)(2)(a) Exception No. 3.) If the NM cables have an elliptical cross-section, as many do, Note 9 to Table 1 in Chapter 9 requires the fill calculation to be based on using the major diameter of the ellipse as a circle diameter. The new exception still does not allow the common practice of extending a raceway through a structural ceiling or floor. However, the raceway could extend through a suspended ceiling.

Background and Explanation

The new exception recognizes a common practice that has been allowed in many jurisdictions but has been a violation of the requirement to secure each cable to a cabinet. This type of installation provides for a neat and workmanlike way of getting multiple NM cables into a panelboard. This section applies to panelboards because panelboards are, according to the definition in Article 100, assemblies designed to be placed in cabinets or cutout boxes.

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As noted in "Application" above, derating factors may apply, and conduit fill rules do apply. Chapter 9, Table 1, Note 4 permits short pieces of raceway (nipples) not more than 24 inches long to be filled to 60 percent of their cross-sectional area. However, the wording applies this permission to nipples "installed between" enclosures. Thus, a strict reading of Note 4 would not allow its use for the raceway described in the above new exception unless approved by the authority having jurisdiction.

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380-9 & 380-12 Grounding of Snap Switches and Faceplates for Switches

Type of Change Revision

BRIEF SUMMARY

All occupancies. Grounding of all snap switches is required, and the grounding requirements for metal faceplates are clarified.

Code Language

380-9. Provisions for Snap Switch Faceplates. (ROP 9-93)

(b) Grounding. Snap switches, including dimmer switches, shall be effectively grounded and shall provide a means to ground metal faceplates, whether or not a metal faceplate is installed. Snap switches shall be considered effectively grounded if either of the following conditions are met.

(1) The switch is mounted with metal screws to a metal box or to a nonmetallic box with integral means for grounding devices.

(2) An equipment grounding conductor or equipment bonding jumper is connected to an equipment grounding termination of the snap switch.

Exception to (b): Where no grounding means exists within the snap-switch enclosure or where the wiring method does not include or provide an equipment ground, a snap switch without a grounding connection shall be permitted for replacement purposes only. A snap switch wired under the provisions of this exception and located within reach of conducting floors or other conducting surfaces shall be provided with a faceplate of nonconducting, noncombustible material.

380-12. Grounding of Enclosures. Metal enclosures for switches or circuit breakers shall be grounded as specified in Article 250. Where nonmetallic enclosures are used with metal raceways or metal-armored cables, provisions shall be made for grounding continuity.

Metal boxes for switches shall be effectively grounded. **Nonmetallic boxes for switches shall be installed with a wiring method that provides or includes an equipment ground.** (ROP 9-95, 9-97)

Application

All snap switches and dimmers must be properly grounded. Grounding may be accomplished by several methods. If installed in a grounded metal box or a nonmetallic box with integral grounding means, the switch is considered to be

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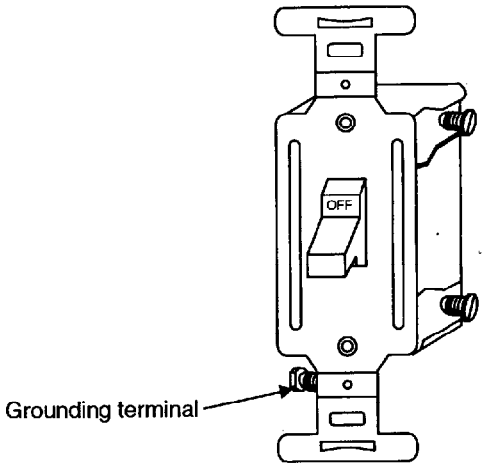
grounded through its mounting strap and screws. The alternate method is to connect an equipment grounding conductor or bonding jumper to a terminal provided on the switch.

Metal faceplates installed on properly grounded switches will be properly grounded provided metal screws are used to secure the faceplate.

The new exception allows ungrounded switches as replacements only if there is no grounding means available. In this case a nonmetallic plate is required and nonmetallic screws should be used to eliminate potential shock hazards.



Grounding of Snap Switches and Faceplates

Background and Explanation

Section 380-9 was revised to reduce potential shock hazards. It is not uncommon for users to replace nonmetallic faceplates with metal faceplates, resulting in ungrounded and hazardous exposed metal parts if the switch has not been grounded.

The grounding requirement for metal faceplates was removed from Section 380-12. Grounding of faceplates is accomplished through the attachment of the plate to the mounting yoke of the switch and is now covered by Section 380-9.

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384-3(a) Barriers in Service Switchboard

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. The purpose of barriers in service switchboards is clarified.

Code Language

384-3. Support and Arrangement of Busbars and Conductors.

(a) Conductors and Busbars on a Switchboard or Panelboard. Conductors and busbars on a switchboard or panelboard shall **comply with (1), (2), and (3)** as applicable.

(1) Location. Conductors and busbars shall be located so as to be free from physical damage and shall be held firmly in place.

(2) Service Switchboards. Barriers shall be placed in all service switchboards **such that no uninsulated, ungrounded service busbar or service terminal will be exposed to inadvertent contact by persons or maintenance equipment while servicing load terminations.**

(3) Same Vertical Section. Other than the required interconnections and control wiring, only those conductors that are intended for termination in a vertical section of a switchboard shall be located in that section.

Exception: Conductors shall be permitted to travel horizontally through vertical sections of switchboards where such conductors are isolated from busbars by a barrier. (ROP 9-103)

Application

Service busbars and terminals must be provided with barriers to prevent personnel from making accidental contact with energized parts while performing maintenance on energized equipment. Where barriers are removed during installation they must be replaced before the switchboard is energized.

Background and Explanation

The wording in the 1996 NEC did not clearly reflect the purpose of barriers. Manufacturers install barriers in accordance with UL standards. Due to the unclear wording, some jurisdictions have required switchboards to have barriers that exceeded the intent of this section. The requirements of this section apply only to service terminals and busbars that could be contacted by personnel working on the service load terminations.

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384-14 Definitions of Power and Lighting and Appliance Panelboards

Type of Change Revision

BRIEF SUMMARY

All installations. The definition of a lighting and appliance branch-circuit panelboard has been revised. A new definition and overcurrent protection requirements have been provided for power panelboards.

Code Language

384-14. Classification of Panelboards. Panelboards shall be classified for the purposes of this article as either lighting and appliance branch-circuit panelboards or power panelboards.

(a) Lighting and Appliance Branch-Circuit Panelboard. A lighting and appliance branch-circuit panelboard is one having more than 10 percent of its overcurrent devices protecting lighting and appliance branch circuits. A lighting and appliance branch circuit is a branch circuit that has a connection to the neutral of the panelboard and that has overcurrent protection of 30 amperes or less in one or more conductors. (ROP 9-120)

(b) Power Panelboard. A power panelboard is one having 10 percent or fewer of its overcurrent devices protecting lighting and appliance branch circuits. (ROP 9-120)

Application

The definition of a lighting and appliance branch circuit is illustrated in the accompanying diagram. A lighting and appliance branch circuit is a circuit rated 30 amperes or less, with one or more ungrounded conductors and a conductor connected to the neutral.

The definitions of lighting and appliance branch-circuit panelboards and power panelboards are also provided and it is important to note the differences. Lighting and appliance branch-circuit panelboards are panelboards with more than 10 percent of their overcurrent devices protecting lighting and appliance branch circuits. Those panelboards that have 10 percent or fewer of their overcurrent devices protecting lighting and appliance branch circuits are defined as power panelboards.

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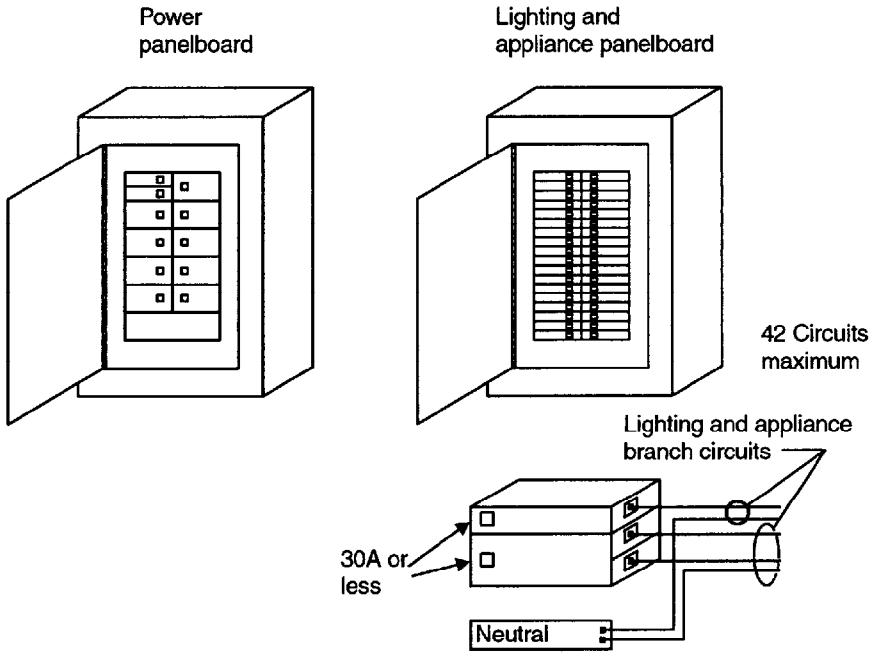
There are two primary differences between the way lighting and appliance and power panelboards are used. The first difference is in the number of overcurrent devices allowed. Lighting and appliance branch-circuit panelboards are limited to 42 overcurrent devices in any one cabinet by Section 384-15. Power panelboards are not limited in the number of overcurrent devices.

The second difference is in the way overcurrent protection is provided. Lighting and appliance branch-circuit panelboards must be protected by not more than two main overcurrent devices that will limit the load to the rating of the panelboard. Power panelboards generally are required to have a rating adequate for the load as outlined in Section 384-13, but they are not required to be protected at their ratings. However, power panelboards must be protected by a single main overcurrent device with a rating not greater than that of the panelboard where the panelboard is supplied by a set of conductors that includes a neutral conductor and more than 10 percent of the overcurrent devices are rated 30 amperes or less.



Panelboard Definitions

Background and Explanation

In the "Application" above a distinction is made between the overcurrent protection requirements for different classes of panelboards. Section 384-16(b) states that "... a power panelboard with neutral connections available and more than 10 percent of its overcurrent devices protecting branch circuits rated 30 amperes or less shall be protected on the supply side by an overcurrent device having a rating not greater than that of the panelboard." This statement must be examined carefully. Note that if the 30-ampere or lower-rated overcurrent devices were protecting circuits that included neutral conductors, those circuits would be lighting and appliance branch circuits, and the panelboards

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would be lighting and appliance branch-circuit panelboards. A distinction is made here between panelboards with circuits that *use* neutral connections and panelboards where neutral connections are *available*. Panelboards that are supplied by a set of conductors that does not include a neutral conductor are power panelboards by definition. But power panelboards supplied by a set of conductors that includes a neutral conductor can be modified to become lighting and appliance branch-circuit panelboards simply by adding a few small appliance branch circuits. Of course panelboards that supply only feeders are also power panelboards by definition.

These changes were inspired by a long-standing controversy over the proper interpretation of the definition of lighting and appliance branch-circuit panelboards. The definition of lighting and appliance branch-circuit panelboard in the 1993 (and 1996) code said "a lighting and appliance branch-circuit panelboard is one having more than 10 percent of its overcurrent devices rated 30 amperes or less, for which neutral connections are provided." A proposal for the 1996 code suggested that the varying interpretations of this rule could be resolved by replacing the phrase "for which neutral connections are provided" by either "and installed in circuits containing a grounded conductor" or "for which branch-circuit grounded conductor connections are provided, whether or not utilized." This highlighted the issue raised above, that is, the distinction between neutral connections used and neutral connections available. It also highlighted another issue: Is there a reason to continue to distinguish between different classes of panelboards? These issues were assigned to a task group to study during the 1999 code cycle.

The task group decided to recommend that the distinction between different classes of panelboards be retained. The original distinction seems to have been based on limiting the number of overcurrent devices in a panelboard to limit the "volume of combustible rubber-insulated wire that might otherwise end up in a panelboard." The reason given by the task group for continuing to make the distinction is that "panelboards with appreciable numbers of small branch circuits and neutral connections present (whether or not utilized) appear to be the ones that are most likely to have additional circuits and loads added from time to time, and under the least rigorous supervision or likelihood of inspection." For this reason, it was determined that such panelboards should continue to have overcurrent protection provided to limit the load to the capacity of the panelboard busing.

Based on these findings, the definition of lighting and appliance branch-circuit panelboards was modified, and the decision was made to define the rest of the panelboards as power panelboards. This retained the old limitations on lighting and appliance branch-circuit panelboards. In addition, those power panelboards that were likely to be used or modified to become lighting and appliance branch-circuit panelboards are also required to have main overcurrent protection to limit the load to the rating of the panel.

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384-16(b) Overcurrent Protection of Power Panelboards

Type of Change New

BRIEF SUMMARY

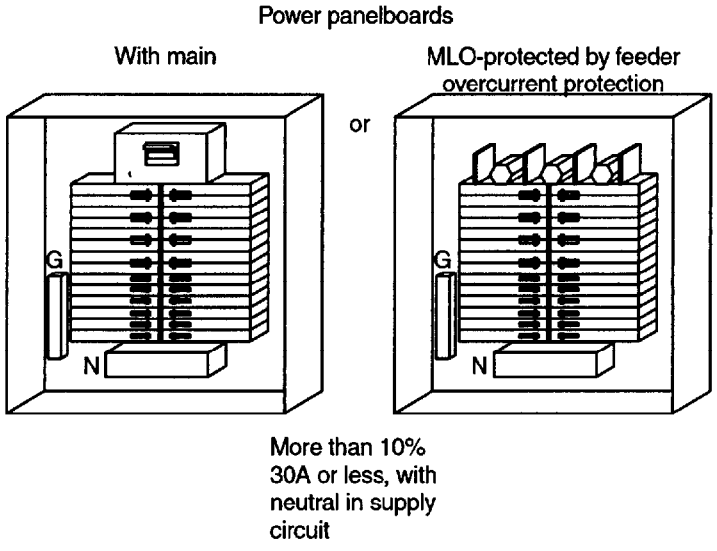
Commercial and industrial. A requirement for the protection of power panelboards has been added.

Code Language

384-16. Overcurrent Protection.

(b) Power Panelboard Protection. In addition to the requirements of Section 384-13, a power panelboard with supply conductors that include a neutral and having more than 10 percent of its overcurrent devices protecting branch circuits rated 30 amperes or less shall be protected on the supply side by an overcurrent protective device having a rating not greater than that of the panelboard. (ROP 9-120) (ROC 9-79)

Exception: This individual protection shall not be required for a power panelboard used as service equipment with multiple disconnecting means in accordance with Section 230-71. (ROP 9-120)



Power Panelboard Overcurrent Protection

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Application

The new description of a power panelboard in Section 384-14(b) is a panelboard with not more than 10 percent of the overcurrent devices in lighting and appliance circuits. Lighting and appliance circuits are rated 30 amperes or less and supply line to neutral loads.

New Section 384-16(b) requires power panelboards that contain a neutral bus and more than 10 percent of the circuits rated 30 amperes or less to be protected by an overcurrent device not larger than the panelboard rating. This protection is required even if none of the circuits are connected line to neutral. The conditions in the rule are based on the presence of a neutral bus, a neutral conductor, and the rating of the circuits. The new exception allows the overcurrent protection to be omitted where the panelboard is service equipment with multiple disconnects.

Background and Explanation

The changes in Sections 384-14 and 384-16 were made as a result of the task group study of proposals and comments held over from the 1996 NEC. As a result of the work done by the task group, Section 384-14 was revised to clearly define two types of panelboards. Section 384-16 was revised, providing rules for the protection of both types of panelboard.

A power panelboard provided with a neutral bus can easily be changed to a lighting and appliance panelboard by increasing the number of lighting and appliance branch circuits supplied. The addition of Section 384-16(b) is intended to provide adequate protection for this type of equipment.

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384-16(e) Panelboards Protected by Transformer Primary Overcurrent Device

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Panelboards supplied through a delta-delta transformer may be protected by the transformer primary overcurrent device.

Code Language

384-16. Overcurrent Protection.

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(e) Supplied Through a Transformer. Where a panelboard is supplied through a transformer, the overcurrent protection in (a), (b), and (c) shall be located on the secondary side of the transformer. (ROP 9-120)

Exception: A panelboard supplied by the secondary side of a transformer ~~having a 2-wire (single voltage) secondary~~ shall be considered as protected by the overcurrent protection provided on the primary side of the transformer ***where that protection is in accordance with Section 240-21(c)(1)***. (ROP 9-121) (ROC 9-81a)

Application

The illustration shows a typical application of this rule. The rated primary current of the 30kVA transformer is 36 amperes. According to Section 450-3(b), this transformer can be protected at 125 percent of the primary current rating. 125% × 36 amperes = 45 amperes, so the transformer can be protected by a 45-ampere overcurrent device, in this case, a fuse. This fuse also protects the No. 6 THWN primary conductors because the conductor ampacity is 55 amperes.

Now, according to Section 240-3(f) and 240-21(c), the secondary conductors can be protected by the primary overcurrent device if the primary device protects the transformer (determined above) and the rating of the primary overcurrent device does not exceed the product of the secondary conductor ampacity and the secondary to primary voltage ratio. The ampacity of the No. 2 THWN secondary conductor is 95 amperes, selected from the 60 column in accordance with Section 110-14(c). The secondary to primary voltage ratio is 240/480 = 0.5. The maximum primary fuse that could protect the secondary

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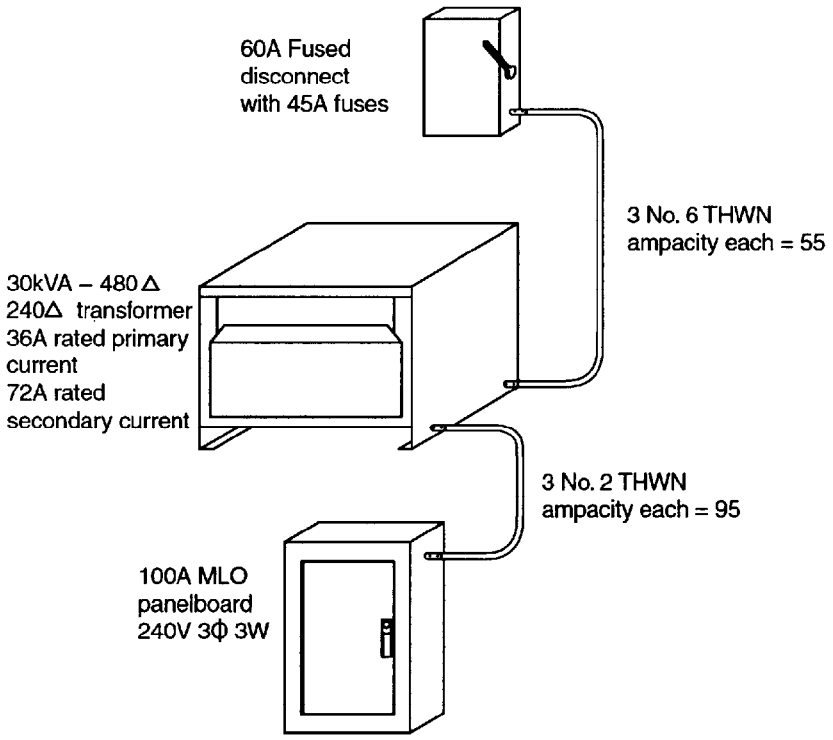
conductors is 95 amperes × 0.5 = 47.5 amperes, so the secondary conductors are protected by the 45-ampere primary fuse. Only single-phase, 2-wire to 2-wire or three-phase, delta-delta, 3-wire secondary transformers can be protected in this manner.

Finally, the panelboard can be protected in a manner similar to that for the secondary conductors. The transformer is already protected. The rating of the panelboard is 100 amperes. The maximum primary fuse rating that will also protect the panelboard is 100 × 0.5 = 50 amperes, so the panelboard is also protected by the 45-ampere fuses. This method of protecting a panel or secondary conductors can only be used when the transformer has a 2-wire single-voltage secondary or is a 3-phase delta-delta transformer with a 3-wire single-voltage secondary.



Primary Protection and Panelboards

Background and Explanation

The use of a primary device to protect the secondary conductors of a delta-delta transformer was first recognized in Section 240-3(i) in the 1996 NEC. This change simply extends that protective technique to panelboards.

Notice that the 3-phase, 3-wire panelboard in the example can only be a power panelboard because a lighting and appliance branch-circuit panelboard must include a neutral by definition, and, in this case, the delta secondary has no neutral. Similarly a 2-wire secondary has a grounded conductor that is not a neutral.

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Table 400-4 New Type Portable Power Cable (G-GC)

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Type G-GC cable has been added to the table.

Code Language

See accompanying table.

Background and Explanation

Type G-GC cable is similar to Type G, but it also contains an insulated ground check (GC) conductor. This cable has been in common use in industrial occupancies for quite some time. The addition of Type G-GC recognizes the use of the product. The ground-check conductor is used on a low-voltage system to monitor equipment-grounding continuity. Where continuity is not maintained, the circuit is automatically de-energized.

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Type G-CC Cable in Table 400-4

Trade Name	*Type Letter*	*Size AWG*	*No. of Conductors*	*Insulation*	*Nominal Insulation Thickness* AWG*	*Mils*	*Braid on Each Conductor*	*Outer Covering*	*Use*		
Lamp Cord	C	18-10	2 or More	Thermoset or Thermoplastic	18-16 14-10	30 45	Cotton	None	Pendant or Portable	Dry Locations	Not Hard Usage
Elevator Cable	E See Note 5.							Three Cotton, Outer One Flame-Retardant & Moisture-Resistant See Note 3.	Elevator Lighting and Control	Nonhazardous Locations	
	See Note 9.				20-16 14-12 12-10	20 30 45	Cotton				
	See Note 10.	20-2	2 or More	Thermoset	8-2 20-16 14-12 12-10 8-2	60 20 30 45 60	Flexible Nylon Jacket				
Elevator Cable	EO See Note 5.	20-2	2 or More	Thermoset	20-16 14-12 12-10	20 30 45	Cotton	Three Cotton, Outer One Flame-Retardant & Moisture-Resistant See Note 3.		Nonhazardous Locations	
	See Note 10.				8-2	60					
								One Cotton and a Neoprene Jacket See Note 3.	Elevator Lighting and Control	Hazardous (Classified) Locations	
Elevator Cable	ET See Note 5. See Note 10.	20-2	2 or More	Thermoplastic	20-16 14-12 12-10 8-2	20 30 45 60	Rayon	Three Cotton or equivalent, Outer one Flame-Retardant & Moisture-Resistant See Note 3.	Nonhazardous Locations		
	ETLB See Note 5. See Note 10.						None				
	ETP See Note 5. See Note 10.			Thermoplastic			Rayon	Thermoplastic	Hazardous (Classified) Locations		
	ETT See Note 5. See Note 10.			Thermoplastic			None	One Cotton or equivalent and a Thermoplastic Jacket	Hazardous (Classified) Locations		
Portable Power Cable	G	8-500 kcmil	2-6 plus Grounding Conductor(s)	Thermoset	8-2 1-4/0 250 kcmil 500 kcmil	60 80 95		Oil-Resistant Thermoset	Portable and Extra Hard Usage		
Portable Power Cable	**G-CC**	**8-500 kcmil**	**3 plus 2 grounding Conductors and 1 ground check conductor**	**Thermoset**	**8-2 1-4/0 250 kcmil 500 kcmil**	**60 80 95**		**Oil-Resistant Thermoset**	**Portable and Extra Hard Usage**		
Heater Cord	HPD	18-12	2, 3, or 4	Thermoset	Thermoset 18-16 14-12	 15 30	None	Cotton or Rayon	Portable Heaters	Dry Locations	Not Hard Usage
Parallel Heater Cord	HPN See Note 6.	18-12	2 or 3	Oil-Resistant Thermoset	18-16 14 12	45 60 95	None	Oil-Resistant Thermoset	Portable	Damp Locations	Not Hard Usage

See Notes 1 through 12. *See Note 8

400-7 Use of Cords with Portable and Mobile Signs

Type of Change Revision

BRIEF SUMMARY

Commercial. Portable and mobile signs may be wired with flexible cords and attachment plugs.

Code Language

400-7. Uses Permitted.
(a) Uses. Flexible cords and cables shall be used only for the following:
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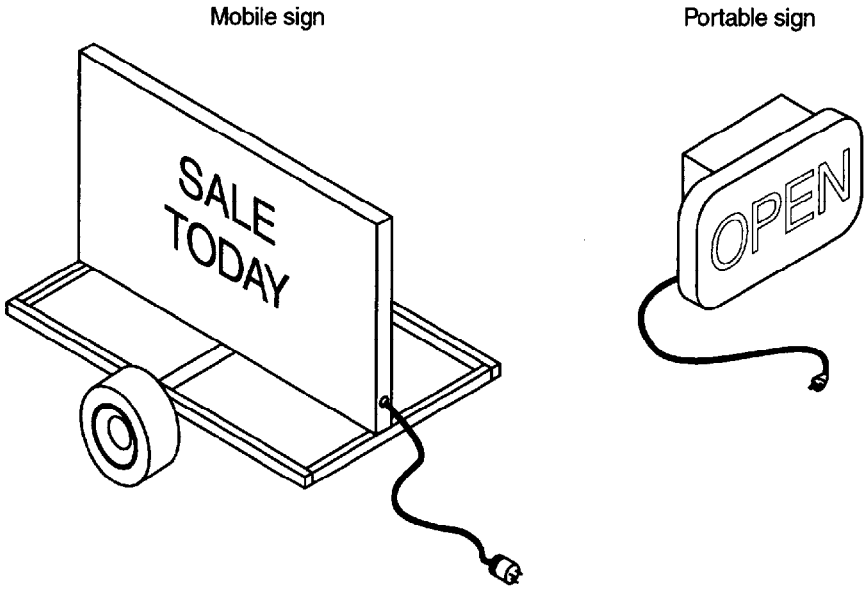
•
(3) Connection of portable lamps, **portable and mobile signs**, or appliances



Use of Cords for Signs

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Application

The illustration shows examples of portable and mobile signs with flexible cords and attachment plugs. The new language in Section 400-7(a)(3) allows the use of cords for these purposes, and the existing language of Section 400-7(b) requires attachment plugs for these cords.

Background and Explanation

These changes were made to correlate with Article 600 and UL 48, both of which allow cords on signs of this type. Portable signs are distinguished from mobile signs by the standard definitions of the terms. A portable sign is capable of being carried, and a mobile sign is movable, not fixed or stationary.

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400-8(2) Cords Not Permitted Through Holes in Suspended Ceilings

Type of Change Revision

BRIEF SUMMARY

All occupancies. Uses not permitted for flexible cord are clarified.

Code Language

400-8. Uses Not Permitted. Unless specifically permitted in Section 400-7, flexible cords and cables shall not be used for the following:

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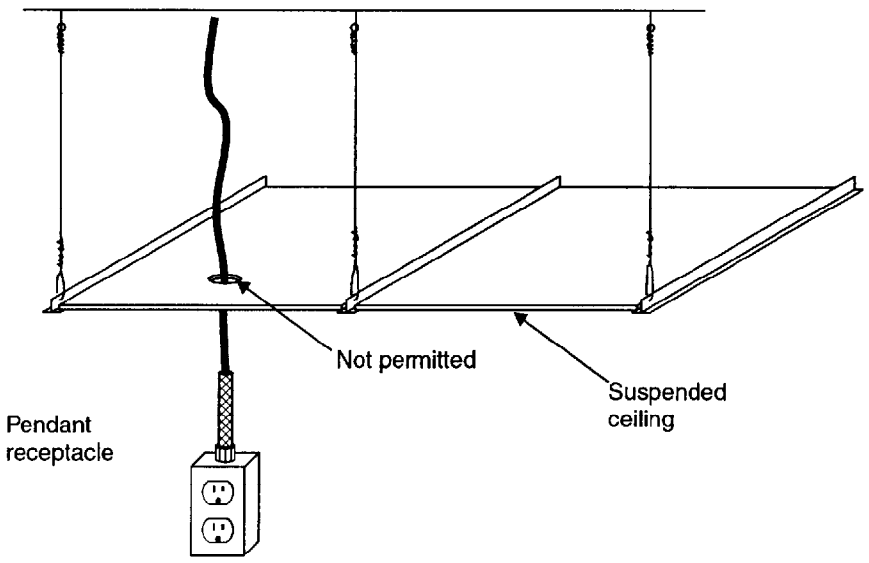
(2) Where run through holes in walls, **structural** ceilings, **suspended ceilings, dropped ceilings**, or floors (ROP 6-128) (ROC 6-75)



Cords Through Hole in Ceiling Not Permitted

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Application

Flexible cords and cables are not permitted to be run through holes in any type of ceiling including suspended or dropped ceilings. Another change to this section prohibits cords and cables from being concealed in the space above a suspended ceiling.

Background and Explanation

The 1996 NEC only used the term "ceilings" and some confusion existed as to whether it encompassed dropped and suspended ceilings. This revision clarifies that the rule applies to suspended or dropped ceilings as well as structural ceilings. If a cord is damaged above a suspended ceiling, the damage is not likely to be detected. The use of cords through holes in metal ceiling assemblies was cited as an area in which cords could be damaged.

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410-4(a) & (d) Bathroom Paddle Fan Installation

Type of Change Revision

BRIEF SUMMARY

All locations. Descriptions of damp and wet locations were removed, and provisions for equipment above and around tubs were clarified and extended to include shower stalls.

Code Language

410-4. Fixtures in Specific Locations.

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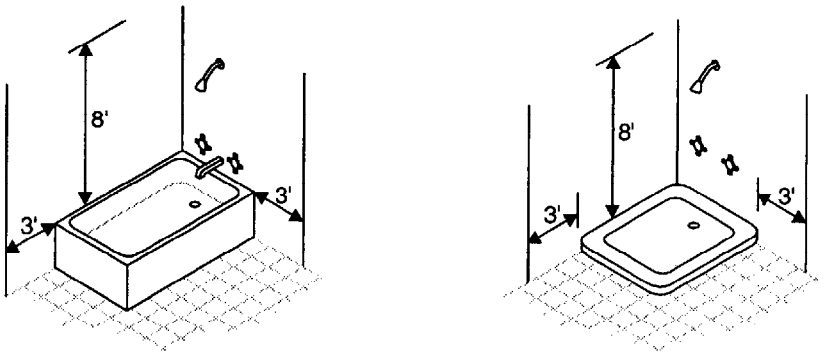
(d) Bathtub and **Shower** Areas. No parts of cord-connected fixtures, hanging fixtures, lighting track, pendants, or ceiling-**suspended (paddle)** fans shall be located within a zone measured 3 ft (914 mm) horizontally and 8 ft (2.44 m) vertically from the top of the bathtub rim or **shower stall threshold.** This zone is all encompassing and includes the zone directly over the tub **or shower stall.** (ROP 18-13)



Bathtub zone Shower zone

Restricted Spaces at Tubs and Showers

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Application

The restricted areas around a tub or shower are shown in the illustration. Equipment is excluded from these areas unless suitable for the location and not otherwise prohibited. Equipment prohibited includes cord-connected fixtures, hanging fixtures, lighting track, pendants, and ceiling-suspended (paddle) fans. Equipment that may be installed in the restricted area include recessed fixtures, recessed exhaust fans, and surface-mounted fixtures. Of course, permitted equipment must be marked as suitable for the damp or wet location.

Background and Explanation

A proposal to define the area up to eight feet above a shower or tub as a damp location was not accepted. In addition, the definitions of "damp" and "wet" locations that appeared in the second and third paragraphs of Section 410-4(a) in the 1996 code were deleted because the terms are defined in Article 100. The language in Section 410-4(d) for bathtub or shower areas was also changed to clarify that the restrictions on fans within eight feet vertically and three feet horizontally apply to ceiling-suspended (paddle) fans, not to recessed exhaust fans. The heading and wording of Section 410-4(d) were changed to include shower stalls as well as bathtubs.

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410-4(c) Lighting Fixtures in Commercial Cooking Hoods

Type of Change Revision

BRIEF SUMMARY

All locations. The requirements for lighting fixtures installed in commercial cooking hoods in all occupancies have been clarified.

Code Language

410-4. Fixtures in Specific Locations.

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(c) In Ducts or Hoods. Fixtures shall be permitted to be installed in **commercial** cooking hoods ~~of nonresidential occupancies~~ where all of the following conditions are met.

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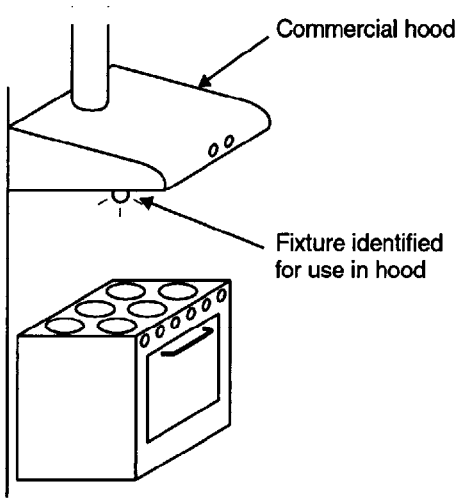
(ROP 18-6)



Lighting Fixtures in Commercial Cooking Hoods

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Application

Commercial cooking hoods and other commercial kitchen appliances typically used in restaurants are installed in some custom kitchens in residential occupancies. Where hoods are installed in any occupancy type, lighting fixtures may be installed in the hood. The requirements of Section 410-4(c)(1) through (4) must be satisfied.

Background and Explanation

The wording in the 1996 NEC seemed to imply that lighting was not allowed in commercial hoods installed in a dwelling. The revised wording clearly reflects that the code does not prohibit such installations provided all of the requirements for the type and construction of the fixture(s) and location of the supply wiring are complied with.

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410-11 & FPN Through-Wiring in Recessed Fixture Junction Boxes

Type of Change Revision

BRIEF SUMMARY

All occupancies. Clarification is provided of when boxes integral to recessed fixtures can be used for through-wiring.

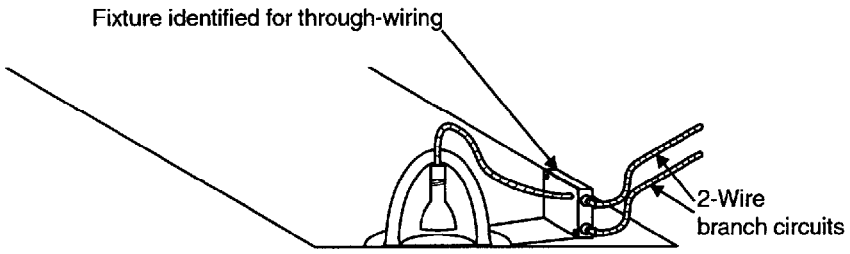
Code Language

410-11. Temperature Limit of Conductors in Outlet Boxes. Fixtures shall be of such construction or installed so that the conductors in outlet boxes shall not be subjected to temperatures greater than that for which the conductors are rated.

Branch-circuit wiring, **other than 2-wire or multiwire branch-circuits supplying power to fixtures connected together**, shall not be passed through an outlet box that is an integral part of a ~~an incandescent~~ fixture unless the fixture is identified for through-wiring. (ROP 18-25)

FPN: See Section 410-31, Exceptions No. 2 and 3 for circuits supplying power to fixtures connected together. (ROC 18-9)

(ROP 18-25)



Through-Wiring of Fixtures

Application

A junction box integral to a recessed fixture can be used to interconnect groups of fixtures. A 2-wire circuit or a multiwire circuit may pass through the box to supply groups of fixtures. In this case the fixture is not required to be identified for through-wiring. Other circuits may pass through a box only if the fixture is identified as suitable.

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Background and Explanation

The revised wording clarifies the rule. The term "incandescent" was deleted. Electric discharge fixtures are available with integral boxes listed for through-wiring. This change clarifies that listed fixtures (electric discharge and incandescent) with an integral junction box are permitted to be wired "fixture to fixture." Note that markings on a fixture may restrict the number and size of the supply conductors and in addition may specify the permitted wiring method.

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410-15(b) Metal Lighting Poles as Raceways

Type of Change Reorganization

BRIEF SUMMARY

All installations. Requirements for metal poles enclosing conductors were reorganized and clarified.

Code Language

410-15. Supports

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(b) Metal Poles Supporting Lighting Fixtures. Metal poles shall be permitted to be used to support lighting fixtures and **as a raceway** to enclose supply conductors, provided the following conditions are met. (ROC 18-11)

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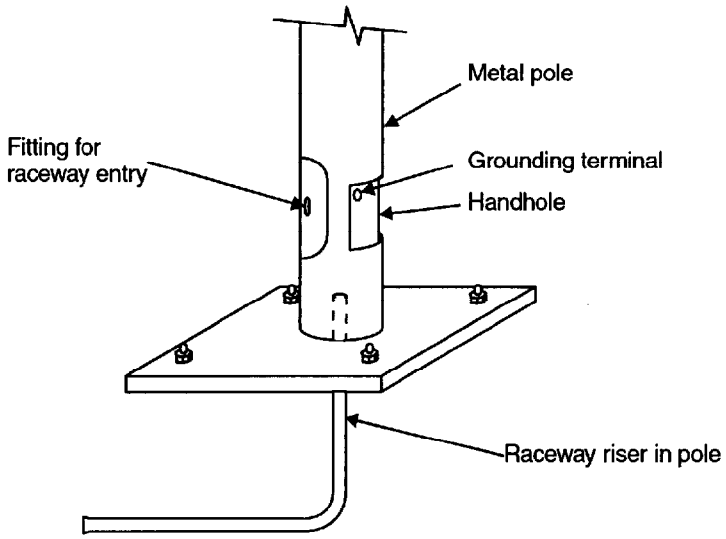

Metal Lighting Poles

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Application

The parts of a metal pole are shown in the illustration. The requirements for metal poles are summarized in the following outline:

410-15(b) Metal Poles Supporting Light Fixtures—Requirements

(1) Handhole with raintight cover required

Exception No. 1: ***Handhole not required for poles 8 feet or less in height.***

Exception No. 2: ***Handhole not required for poles 20 feet or less with hinged bases.***

(2) Fitting opposite handhole required if raceway or cable risers are not in pole.

(3) Grounding terminal required in pole.

a. Grounding terminal must be accessible from handhole when handhole required.

b. Grounding terminal must be accessible from base when base is hinged.

Exception: ***Grounding terminal not required for poles less than 8 feet under certain conditions.***

(4) Base must be bonded to pole when pole has a hinged base.

(5) Equipment grounding conductors must be bonded to pole.

(6) Conductors in poles must be supported per Section 300-19.

Background and Explanation

This change is primarily editorial, with the added clarification that metal poles, though not listed as raceways, may be used as raceways to enclose conductors. Because the pole is being treated as a raceway, the separation requirements between power conductors and the conductors covered by Articles 640, 725, 760, 800, and 820 are applicable.

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410-16(a) Boxes Listed for Support of Fixtures Over 50 Pounds

Type of Change Revision

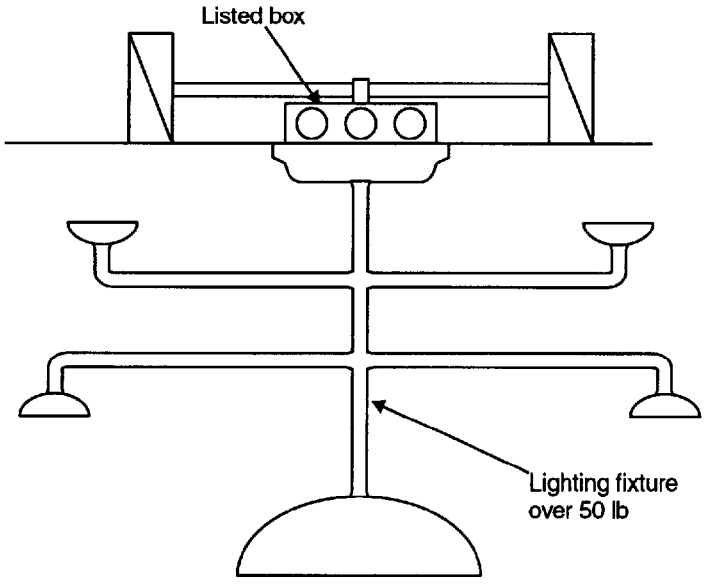
BRIEF OF SUMMARY

All occupancies. Boxes are available that are listed for support of fixtures in excess of 50 lb.

Code Language

410-16. Means of Support.

(a) Outlet Boxes. Outlet boxes or fittings installed as required by Section 370-23 shall be permitted to support fixtures weighing 50 lb (22.7 kg) or less. A fixture that weighs more than 50 lb (22.7 kg) shall be supported independent of the outlet box **unless the outlet box is listed for the weight to be supported.** (ROP 18-31)



Support of Fixtures Over 50 Pounds

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Background and Explanation

For many years outlet boxes have not been available listed for support of fixtures in excess of 50 lb. This section, therefore, required independent support for fixtures in excess of 50 lb. Listed boxes are now available for heavier fixtures. These boxes may be used, without independent support, up to their weight limit. Many large chandeliers weigh in excess of 50 lb.

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410-16(c) Listing of Fixtures Clips Used in Suspended Ceilings

Type of Change Revision

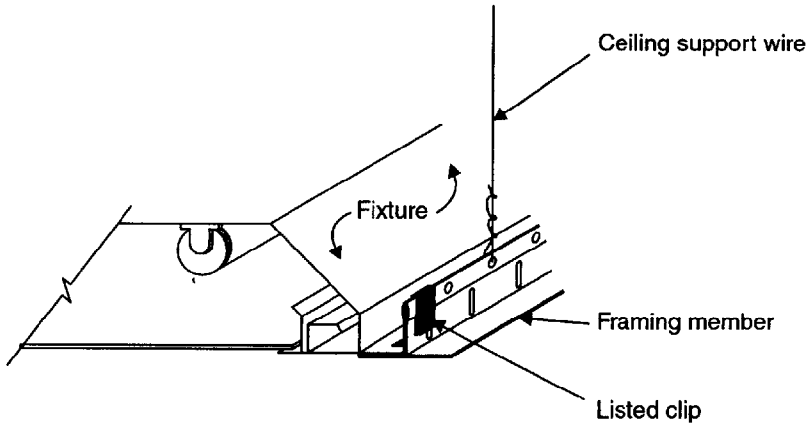
BRIEF SUMMARY

Commercial and residential. Clips used to attach fixtures to ceiling framing members must be listed for compatibility with the fixture and the framing members.

Code Language

410-16. Means of Support.

(c) Suspended Ceilings. Framing members of suspended ceiling systems used to support fixtures shall be securely fastened to each other and shall be securely attached to the building structure at appropriate intervals. Fixtures shall be securely fastened to the ceiling framing member by mechanical means such as bolts, screws, or rivets. **Listed** clips identified for use with the type of ceiling framing member(s) and fixture(s) shall also be permitted. (ROP 18-38)



Attaching Fixtures to Ceiling Framing Member

Application

Where clips are used to attach fixtures to suspended ceiling framing members, the clips must be listed for use with both the type of fixture and the type of ceiling framing. Listed fixtures supplied with integral clips must identify the type of ceiling framing member with which they are intended to be used. The illustration shows a typical lay-in-type fixture installation with a clip of the type covered by the revised rule.

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Background and Explanation

Many clips for attaching fixtures to ceiling grids are identified but not listed. This change will require listed clips. Clips that are a part of a listed fixture should be considered as meeting the listing requirement for the clips if the ceiling types are also identified in the fixture installation instructions.

Clips are not required to be used where other methods of attachment are used. Building code requirements for "slack wires" or "seismic support wires" are in addition to the NEC requirement for attaching fixtures to ceiling grids, where the grid is used as the means of support for the lighting fixtures.

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410-56(c) Grounding of Metal Faceplates Used with IG Receptacles

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. The grounding requirement for isolated ground receptacles has been clarified.

Code Language

410-56. Rating and Type.

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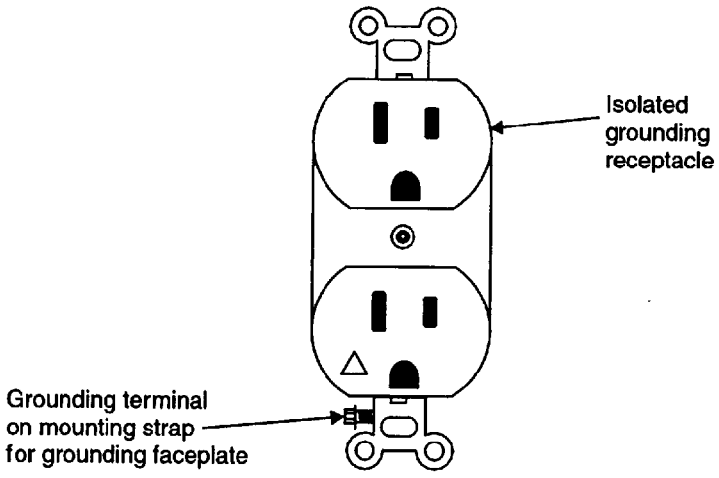
(c) Isolated Ground Receptacles. Receptacles intended for the reduction of electrical noise (electromagnetic interference) as permitted in Section **250-146(d)** shall be identified by an orange triangle located on the face of the receptacle. Receptacles so identified shall be used only with grounding conductors that are isolated in accordance with Section **250-146(d)**. Isolated ground receptacles installed in nonmetallic boxes shall be covered with a nonmetallic faceplate. (ROP 18-59)(ROC 18-47)

Exception: Where an isolated ground receptacle is installed in a nonmetallic box, a metal faceplate shall be permitted if the box contains a feature or accessory that permits the effective grounding of the faceplate. (ROC 18-47)



Faceplate Grounding with Isolated Ground Receptacles

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Application

Section 410-56(d) requires grounding of metal faceplates. Grounding of the faceplate is usually accomplished through the screws securing the plate to the device. With an isolated ground receptacle the mounting yoke of the device is usually grounded through the screws securing the device to a grounded box.

Where an isolated ground device is installed in a nonmetallic box, the device yoke remains ungrounded, depending on the isolated ground receptacle design. A metal faceplate would also be ungrounded. The 1996 NEC required a nonmetallic faceplate in this application. Revision of this section allows the use of a nonmetallic plate or an effectively grounded metal faceplate.

Background and Explanation

Some nonmetallic boxes contain provision for the grounding of device yokes. As revised, this rule recognizes the installation of an isolated ground receptacle in this type of box. The box design provides for the grounding of the receptacle mounting strap and the metal faceplate.

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410-56 (f)(3) Mounting Requirements for Cover-Mounted Receptacles

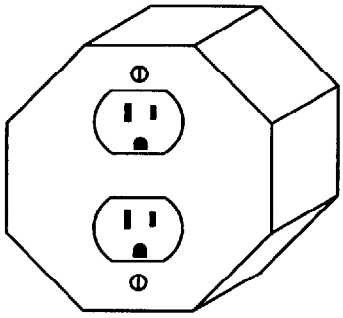
Type of Change Revision

BRIEF SUMMARY

All occupancies. Requirements for mounting of receptacles secured to covers have been clarified.

Code Language

410-56. Rating and Type.
(f) Receptacle Mounting.
(3) Receptacles Mounted on Covers. Receptacles mounted to and supported by a cover shall be secured by more than one screw or shall be a device assembly or box cover listed and identified for securing by a single screw. (ROP 18-62, 18-63a) (ROC 18-53)



Receptacle to be mounted with not fewer than two screws

Cover-Mounted Receptacles

Application

When receptacles are secured and supported by a box cover, the general rule requires more than one screw. Receptacle attached to covers with a single No.6-32 screw have been found to become loose with use. To eliminate this problem more than one screw is required. There are listed multiple receptacle assemblies designed to be plugged into an existing receptacle outlet. These are listed for use with a single supporting screw that attaches the assembly to the cover-mounting hole of the receptacle.

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Background and Explanation

The 1996 NEC only addressed raised covers, which are referred to as industrial covers. Covers used on octagonal boxes are flat covers. The problem of loose receptacles occurs with both raised and flat covers. The revised wording of the 1999 code includes both types of covers.

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410-56(g) Live Exposed Parts of Cord Cap Prohibited

Type of Change Revision

BRIEF SUMMARY

All installations. Power may not be supplied by the exposed energized blades of an attachment plug.

Code Language

410-56. Rating and Type.

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(g) Attachment Plugs. All 15- and 20-ampere attachment plugs and connectors shall be constructed so that there are no exposed current-carrying parts except the prongs, blades, or pins. The cover for wire terminations shall be a part, which is essential for the operation of an attachment plug or connector (dead-front construction). **Attachment plugs shall be installed so that their prongs, blades, or pins are not energized unless inserted into an energized receptacle. No receptacle shall be installed so as to require an energized attachment plug as its source of supply.** (ROP 18-62, 18-63a)

Application

Where power is supplied from a portable power source through a cord and plug connection, the blades of an attachment plug may not be energized except when inserted in the mating receptacle or connector body. The illustration shows cords supplying power from a generator. The cord on the left has an attachment plug with exposed blades that are energized while the generator is running, even while the plug is not connected. The other cord has a connector body that guards the energized parts from contact. The exposed blades of the flanged mating plug remain de-energized until the connector body supplied by the generator is attached. If the powered system as shown in the illustration has another source of supply, a transfer switch must be employed to keep the exposed blades of the flanged plug from being energized while exposed and not in use.

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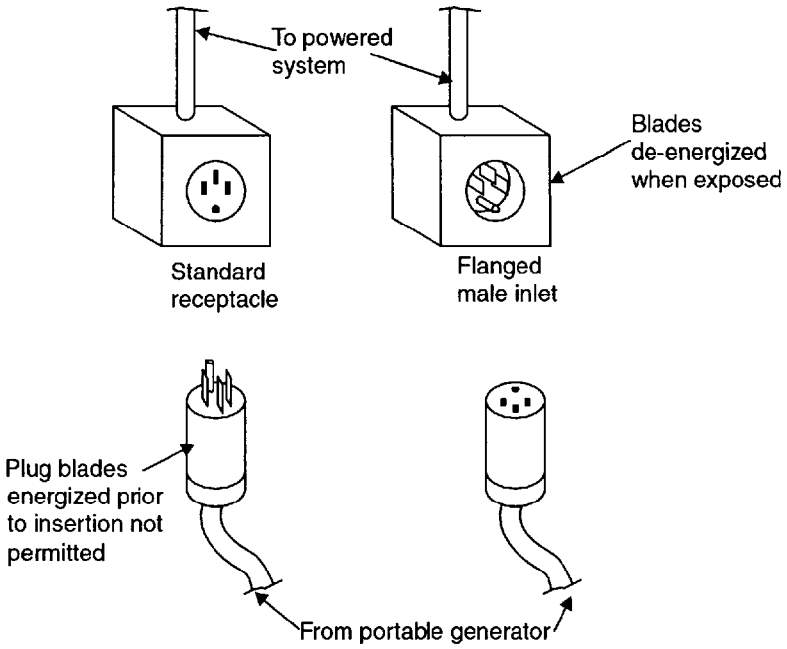

Exposed Energized Plug Blades Prohibited

Background and Explanation

A similar rule that covers recreational vehicles was previously provided in Section 551-47(p)(4). This new rule applies generally to other applications where power sources or supplied equipment are portable. Many residential, commercial and industrial facilities have provisions to connect the premises wiring system to a portable generator. The illustration given matches the substantiation for this change, where the powered system is fixed and the power source is portable. An optional standby system for fixed equipment might use such a connection scheme. The illustration might also apply to a cabin or other structure that has no permanent power source and is supplied by a portable generator.

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410-58(a) Self-Restoring Ground Pin on Portable GFCIs

Type of Change Revision

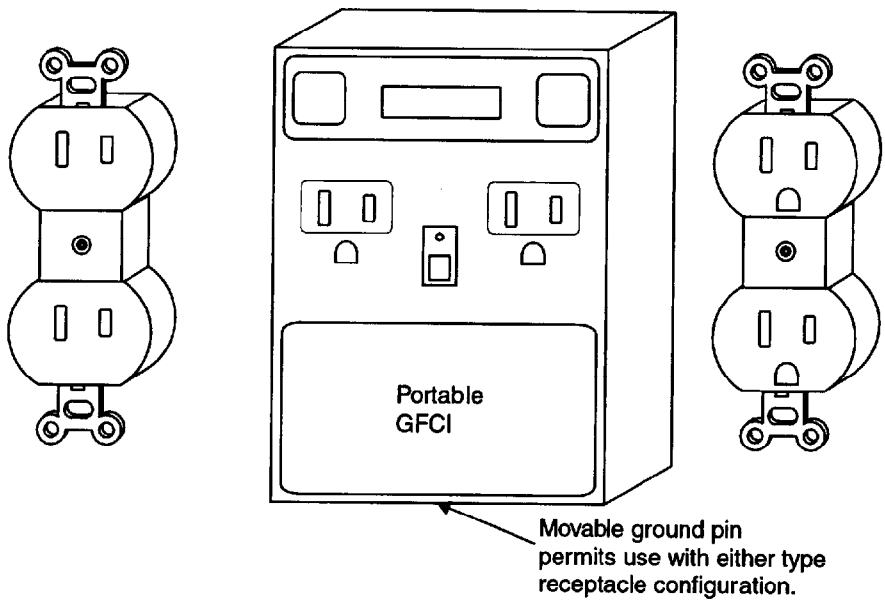
BRIEF SUMMARY

All installations. Movable, self-restoring grounding contacts are permitted on some plug-in-type GFCI devices.

Code Language

410-58. Grounding-type Receptacles, Adapters, Cord Connectors, and Attachment Plugs.

(a) Grounding Poles. Grounding-type receptacles, cord connectors, and attachment plugs shall be provided with one fixed grounding pole in addition to the circuit poles. **The grounding contacting pole of grounding-type plug-in ground-fault circuit interrupters shall be permitted to be of the movable, self-restoring type on circuits operating at not over 150 volts between and to conductors nor over 150 volts between any conductor and ground.** (ROP 18-74)



Self-Restoring Ground on Portable GFCI

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Application

The device referred to in this change is a portable 3-wire GFCI protective device that can be plugged into either a 2-wire or 3-wire receptacle. The ground prong can be moved out of the way to insert into a 2-wire receptacle but restores itself for the next use.

Background and Explanation

The 1993 and earlier codes contained an exception to Section 410-58(a) that permitted the use of a movable self-restoring grounding contact on portable hand tools. That exception was deleted from the 1996 code on the grounds that "such products are no longer available." This change restores the permission to use a similar type of attachment plug on portable GFCI devices. Such portable GFCI devices can be easily applied with both grounding and nongrounding type receptacles without having to make field modifications.

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410-67(c) Reduction of Minimum Length for Fixture Tap Conductor

Type of Change Revision

BRIEF SUMMARY

All occupancies. The minimum length of fixture tap conductors has been reduced.

Code Language

410-67. Wiring.

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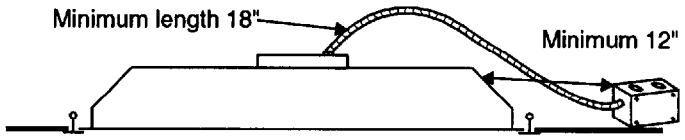
(c) Tap Conductors. Tap conductors of a type suitable for the temperature encountered shall be permitted to run from the fixture terminal connection to an outlet box placed at least 1 ft (305 mm) from the fixture. Such tap conductors shall be in suitable raceway or Type AC or MC cable of at least ~~4 ft.(1.22m)~~ **18 in.** (450 mm) but not more than 6 ft (1.83 m) in length. (ROP 18-78)



Minimum Tap Conductor Length

Application

The code permits unsupported raceways and certain cable assemblies in lengths not less than 18 inches and not more than 6 feet to contain tap conductors run from an outlet to the fixture connection point. This set of rules applies to fixture tap conductors installed from the outlet to the fixture. Conductors that are the same size as the branch-circuit conductors are not covered by this requirement.

Background and Explanation

The 1996 NEC permittted the tap to be run to a box at least 1 foot from the fixture. The minimum length for the tap conductor raceway was 4 feet.

Where a box is one foot from the fixture, the 1996 requirement for a minimum length of 4 feet results in an excessive amount of raceway and conductor. The extra raceway and conductor could possibly come in contact with the hot fixture surfaces and result in conductor damage.

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NEC pp. 236–241

Article 422 Reorganization of Entire Article

Type of Change Reorganization

BRIEF SUMMARY

All installations. Article 422 has been reorganized and renumbered.

Code Language

See accompanying table.

Application

Article 422 covers electric appliances used in any occupancy. The old and new locations and numbers of the various sections of Article 422 are given in the table. The new Section 422-15, "Central Vacuum Outlet Assemblies," is covered separately in this book. Otherwise, the reorganization does not significantly alter the requirements for appliances.

Background and Explanation

This change was intended to be primarily editorial. Sections 422-6 and 422-22(d) were deleted. Section 422-22(d) was more properly covered in Section 410-56; and Section 422-6 (1996 NEC), requiring all appliances to be installed in an approved manner, was redundant. The reorganization groups sections by subject matter more accurately. Although Article 422 contained similar parts under the 1996 code, the sections were not as well grouped within the parts as they are in the 1999 version.

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Reorganization of Article 422

1996 NEC Section	*Section Heading or Description*	*1999 NEC Section*
	Part A. General	
422-1	Scope	422-1
422-3	Other Articles	422-3
422-2	Live Parts	422-4
	Part B. Installation (Previously Parts B. and C.)	
422-4	Branch-Circuit Rating	422-10
422-28	Overcurrent Protection	422-11
422-5	Branch-Circuit Overcurrent Protection	422-11(a)
422-7	Central Heating Equipment	422-12
422-14(b)	Storage-Type Water Heaters	422-13
422-15(c)	Infrared Lamp Industrial Heating Appliances	422-14
New	Central Vacuum Outlet Assemblies	422-15
422-8(c)&(d)	Flexible Cords (Other Appliances, Specific Appliances)	422-16
422-17	Specific Appliances (Wall-mounted ovens . . .)	422-16(b)(3)
422-10	Protection of Combustible Material	422-17
422-18	Support of Ceiling Fans	422-18
422-16	Grounding	422-19
422-19	Other Installation Methods	422-20
	Part C. Disconnecting Means (Previously Part D.)	
422-20	General (Disconnecting Means)	422-30
422-21	Disconnection of Permanently Connected Appliances	422-31
422-22	Disconnection of Cord- and Plug-Connected Appliances	422-32
422-25	Unit Switch(es) as Disconnecting Means	422-33
422-26	Switch and Circuit Breaker to Be Indicating	422-34
422-27	Disconnecting Means for Motor-Driven Appliances	422-35
	Part D. Construction (New Part)	
422-23	Polarity in Cord- and Plug-Connected Appliances	422-40
422-24	Cord- and Plug-Connected Appliances Subject to Immersion	422-41
422-12	Signals for Heated Appliances	422-42
422-8(a)&(b)	Flexible Cords (Heater Cords, Other Heating Appliances)	422-43
422-9	Cord- and Plug-Connected Immersion Heaters	422-44
422-11	Stands for Cord- and Plug-Connected Appliances	422-45
422-13	Flatirons	422-46
422-14(a)	Water Heaters	422-47
422-15(a)&(b)	Infrared Lamp Industrial Heating Appliances	422-48
422-8(d)(3)	High Pressure Spray Washers	422-49
422-29	Cord- and Plug-Connected Pipe Heating	422-50
	Part E. Marking	
422-30	Nameplate	422-60
422-31	Marking of Heating Elements	422-61
422-32	Appliances Consisting of Motors and Other Loads	422-62
422-6	General	Deleted
422-22(d)	Requirements for Attachment Plugs and Connectors	Deleted

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422-15 Central Vacuum Cleaner Outlets

Type of Change New

BRIEF SUMMARY

Residential. New requirements for central vacuum outlet assemblies have been provided.

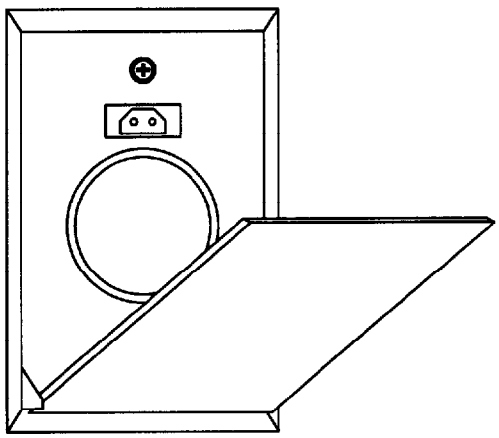
Code Language

422-15. Central Vacuum Outlet Assemblies.

(a) Listed central vacuum outlet assemblies shall be permitted to be connected to a branch circuit in accordance with Section 210-23(a).

(b) The ampacity of the connecting conductors shall not be less than the ampacity of the branch-circuit conductors to which they are connected.

(c) An equipment grounding conductor shall be used where the central vacuum outlet assembly has accessible noncurrent-carrying metal parts. (ROP 20-51)



Central vacuum outlet with 120-volt power for attachments

Centeral Vacuum Outlet Assembly

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Application

Some central vacuum systems use an outlet that includes a receptacle to provide power to a power head. Power to the vacuum system power head is supplied through a cord connection at the vacuum outlet by a molded multipin polarized cord cap or through conductors that are integral with the hose. A separate receptacle outlet at the suction outlet is not necessary with this new type of power outlet. These outlets contain a wiring compartment for the connection of the power supply conductors.

Background and Explanation

This new section allows devices of this type to be connected to 15- or 20-ampere general purpose branch circuits that are located in the area where the vacuum outlet is to be installed. The control circuit that initiates the operation of the central vacuum unit is typically a Class 2 circuit supplied by the unit.

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422-16 (b)(1) & (2) Cords Identified by Installation Instructions for Specific Appliances

Type of Change Revision

BRIEF SUMMARY

Residential and commercial. Restrictions have been added and clarified on the use of cords with dishwashers, compactors, and waste disposers.

Code Language

422-16. Flexible Cords.

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(b) Specific Appliances.

(1) Electrically operated kitchen waste disposers shall be permitted to be cord- and plug-connected with a flexible cord identified **as suitable for the purpose in the installation instructions of the appliance manufacturer**, where all of the following conditions are met.

(a) The flexible cord shall be terminated with a grounding type attachment plug.

Exception: A listed kitchen disposer distinctly marked to identify it as protected by a system of double insulation, or its equivalent, shall not be required to be ***terminated with a grounding-type attachment plug.*** (ROC 20-14)

(b) The length of the cord shall not be less than 18 in. (457 mm) and not over 36 in. (914 mm).

(c) Receptacles shall be located to avoid physical damage to the flexible cord.

(d) The receptacle shall be accessible.

(2) Built-in dishwashers and trash compactors shall be permitted to be cord- and plug-connected with a flexible cord identified **as suitable for the purpose in the installation instructions of the appliance manufacturer** where all of the following conditions are met.

(a) The flexible cord shall be terminated with a grounding-type attachment plug.

Exception: A listed dishwasher or trash compactor distinctly marked to identify it as protected by a system of double insulation, or its equivalent, shall not be required to be ***terminated with a grounding-type attachment plug.*** (ROC 20-14)

(b) The length of the cord shall be 3 ft to 4 ft (0.914 m to 1.22 m) **measured from the face of the attachment plug to the plane of the rear of the appliance.**

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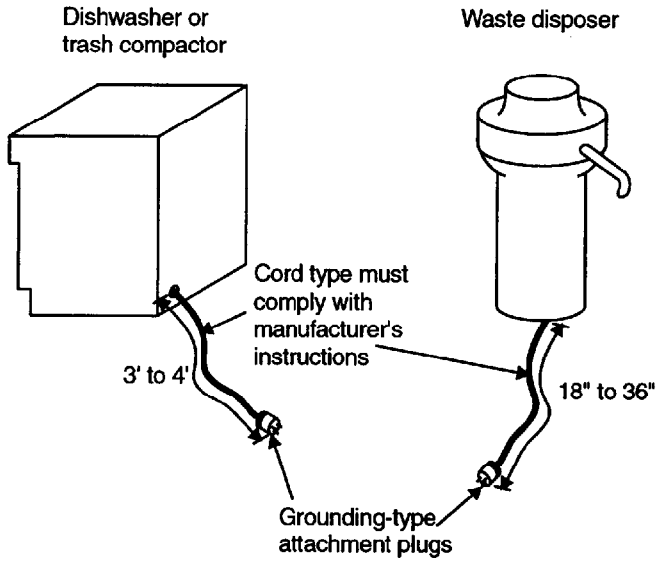
(c) Receptacles shall be located to avoid physical damage to the flexible cord.

(d) The receptacle shall be located in the space occupied by the appliance or adjacent thereto.

(e) The receptacle shall be accessible.



Cords on Kitchen Appliances

Application

Three changes were made that restrict or clarify the use of flexible cords with dishwashers, trash compactors, or waste disposers: (1) Cords must be identified as suitable for the purpose in the manufacturers instructions, (2) Cords must have a grounding-type attachment plug unless the appliance is double insulated; and (3) The cord length for a dishwasher or compactor is measured from the plane of the rear of the appliance to the face of the attachment plug.

Background and Explanation

This change was meant to clarify the existing requirements and deletes some of the exceptions by rewriting them into positive code language. It also clarifies that the identification of suitable cords is to be done by consulting the manufacturer's literature, not by looking for some mention of the appliance type on the cords. In addition, the change specifies the points of measurement for cords for dishwashers and compactors. This specification allows for only the part of the cord external to the appliance to be counted. Thus, somewhat longer cords may be used to get to the necessary connection points within the appliances.

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424-44(g) GFCI Protection for Embedded Floor Heating Elements

Type of Change New

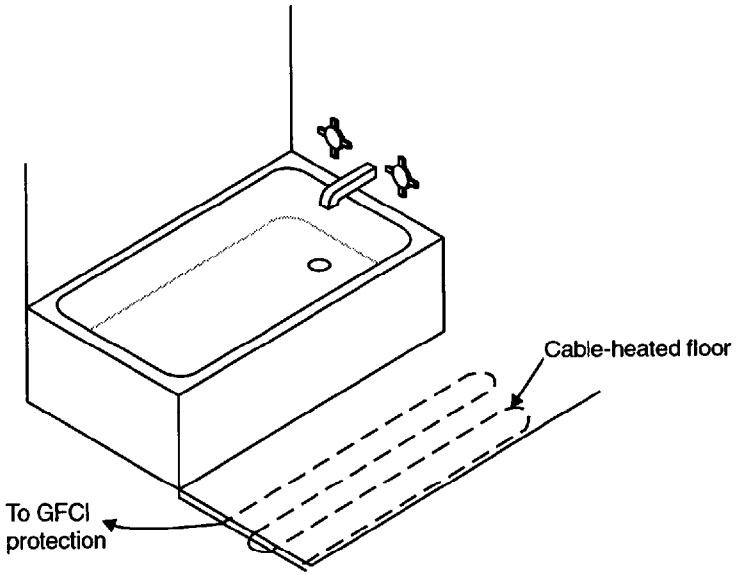
BRIEF SUMMARY

Residential and commercial. GFCI protection is required for some electrically heated floors.

Code Language

424-44. Installation of Cables in Concrete or Poured Masonry Floors.

(g) Ground-Fault Circuit-Interrupter Protection for Conductive Heated Floors of Bathrooms, Hydromassage Bathtub, Spa, and Hot Tub Locations. Ground-fault circuit-interrupter protection for personnel shall be provided for electrically heated floors in bathrooms, hydromassage bathtub, spa, and hot tub locations. This shall apply to all systems used with conductive floor coverings, whether cable, panel, or other approved types. (ROP 20-69) (ROC 20-74, 20-80, 20-82)



GFCI Protection for Bathroom Floor Heating

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Application

Electric floor heating cable systems are installed in some bathrooms. These systems may also be installed where spas, hot tubs, or hydromassage bathtubs are installed in locations not defined as bathrooms. Where such heating systems are installed, ground-fault circuit-interrupter protection must be provided. This will reduce the shock hazard that may exist for someone stepping out of the tub onto the conductive floor.

Background and Explanation

As the floor structure ages, cracks may develop due to flexing of the floor. This flexing and cracking may cause damage in the heating cable system that results in leakage current. The use of the GFCI protection will serve to reduce shock hazards to persons with bare feet in these areas.

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426-28 GFPE for Snow-Melting Equipment

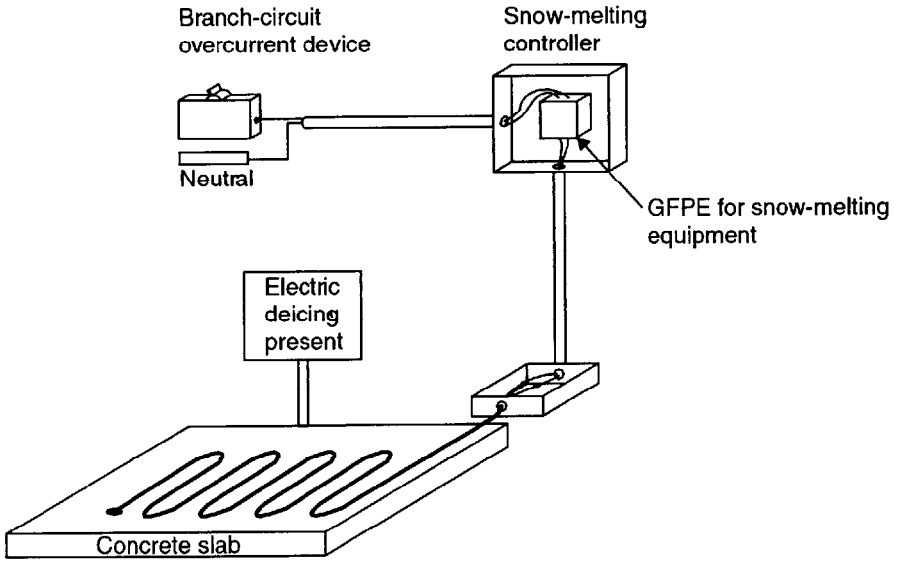
Type of Change Revision

BRIEF SUMMARY

All installations. Ground-fault protection for fixed outdoor electric deicing and snow-melting equipment must protect the equipment but need not protect the entire branch circuit. Some embedded mineral-insulated cables are exempted.

Code Language

426-28. Equipment Protection. Ground-fault protection of equipment shall be provided for **fixed outdoor electric deicing and snow-melting equipment, except for equipment that employs mineral-insulated, metal-sheathed cable in a noncombustible medium.** (ROP 12-7, 12-8) (ROC 12-3)



GFPE for Deicing and Snow-Melting

Application

The illustration shows an installation of embedded electric deicing equipment with ground-fault protection for equipment (GFPE) provided. A separate ground-fault equipment protection circuit-interrupter (GFEPCI) device is shown. The entire branch circuit is not required to be protected, so an ordinary circuit breaker is shown as the branch-circuit overcurrent device. Ground-fault

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equipment protection is required for all fixed outdoor electric deicing and snow-melting equipment except for equipment that employs mineral-insulated metal-sheathed cables installed in a noncombustible medium.

Background and Explanation

Not all manufacturers make circuit breakers with GFPE in all ampere and voltage ratings. Supplementary devices may be necessary to avoid changing the branch-circuit distribution panels. This change makes it clear that the GFPE requirement is for the equipment and not for the branch circuit. There are electric deicing and snow-melting units that have an integral GFPE as part of the listed assembly. Such units will comply with the revised wording of this section. GFEPCI devices are designed for equipment protection at leakage current levels between 6mA and 50mA.

New wording also provides an exemption for mineral-insulated metal-sheathed cable used for deicing or snow-melting if it is embedded in a noncombustible medium such as the concrete slab in the illustration. Such cable is much less susceptible to the arcing ground faults that have occurred with other cable types.

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427-22 GFPE for Heat Tracing and Heating Panels

Type of Change Revision

BRIEF SUMMARY

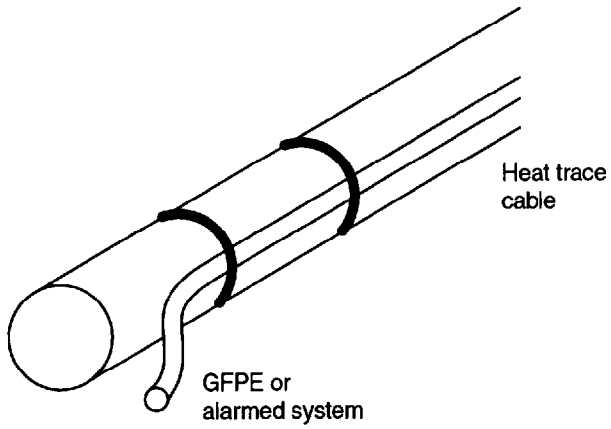
Industrial. The requirements for ground-fault protection of equipment has been clarified.

Code Language

427-22. Equipment Protection. Ground-fault protection of equipment shall be provided for ~~each branch circuit supplying electric heating equipment~~ **electric heat tracing and heating panels.** This requirement shall not apply in industrial establishments where there is alarm indication of ground faults and (ROC 12-10)

(1) Conditions of maintenance and supervision ensure that only qualified persons will service the installed systems.

(2) Continued circuit operation is necessary for safe operation of equipment or processes. (ROP 12-25, 12-26)(ROC 12-9)



Protection for Heat Tracing and Heating Panels

Application

As revised, this section requires GFPE for heat tracing and heating panels only and not for the branch circuit supplying the equipment. Such protection is not required in industrial establishments where alarms are installed to indicate a ground-fault condition and the conditions specified in (1) and (2) are met.

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Background and Explanation

The 1996 code required protection of the branch circuit and the heating equipment. The intent was to protect the equipment, not the entire circuit. This revision clarifies that intent. In addition, the 1996 code required ground-fault protection for all equipment related to resistance heating elements for pipelines and vessels. The revision to the 1999 code also makes it clear that heat tracing and heating panels are the only types of equipment requiring GFPE. The exception for industrial facilities has been integrated as part of the main rule.

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430-6(a)(1) Exc. No. 3 HP and Motor-Operated Appliances

Type of Change Revision

BRIEF SUMMARY

All installations. The ampere rating on the nameplate of an appliance shall be used instead of a marked horsepower rating for sizing conductors and other circuit components.

Code Language

430-6. Ampacity and Motor Rating Determination.

(a) General Motor Applications. For general motor applications, current ratings shall be determined based on (1) and (2).

(1) Table Values. The values given in Tables 430-147, 430-148, 430-149, and 430-150, including notes, shall be used to determine the ampacity of conductors or ampere ratings of switches, branch-circuit short-circuit and ground-fault protection, instead of the actual current rating marked on the motor nameplate. Where a motor is marked in amperes, but not horsepower, the horsepower rating shall be assumed to be that corresponding to the value given in Tables 430-147, 430-148, 430-149, and 430-150, interpolated if necessary.

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Exception No. 3: For a listed motor-operated appliance that is marked with both motor horsepower and full-load current, the motor full-load current marked on the nameplate of the appliance shall be used instead of the horsepower rating on the appliance nameplate to determine the ampacity or rating of the disconnecting means, the branch-circuit conductors, the controller, the branch-circuit short-circuit and ground-fault protection, and any separate overload protection. (ROP 11-10) (ROC 11-8)

Application

Some appliances have both horsepower and current ratings on their nameplates. When applying the provisions of Article 430 for sizing conductors, disconnecting means, controllers, and so on, the current rating of the appliance shall be used rather than the horsepower rating. For example, the illustration is based on an ac-

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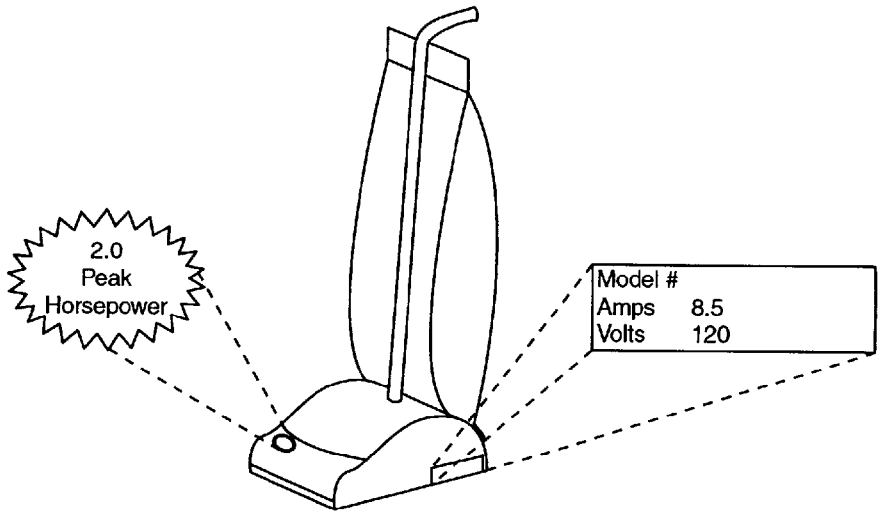
tual appliance. The current rating is approximately equivalent to a ½ HP motor and is equipped with an 18/2 cord with a 15-ampere-rated attachment plug. Based on the nameplate current rating of 8.5 amps, the appliance can be connected to a 15- or 20-ampere branch circuit. This meets the requirements of Sections 210-23(a), 430-22, 430-32(b), 430-53(a), and 430-109(f), as well as the applicable provisions of Article 422.



Use of Appliance Horsepower Markings

Background and Explanation

This change was meant to resolve the confusion that results when motor-operated appliances are labeled with horsepower as well as ampere ratings. In the example given in the illustration, if the 2 HP rating were an actual horsepower rating, the appliance would require a 30-ampere-rated circuit (based on the full load current of 24 amperes for a 115-volt, 2HP motor from Table 430-148) with No. 12 or No. 10 wire, and it could not be supplied from a 15- or 20-ampere-rated circuit. The current rating of the appliance is more meaningful and accurate in such cases and is subject to closer scrutiny by the testing laboratories than the marked horsepower rating.

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430-40 Exc. Protection of Overload Devices

Type of Change Revision

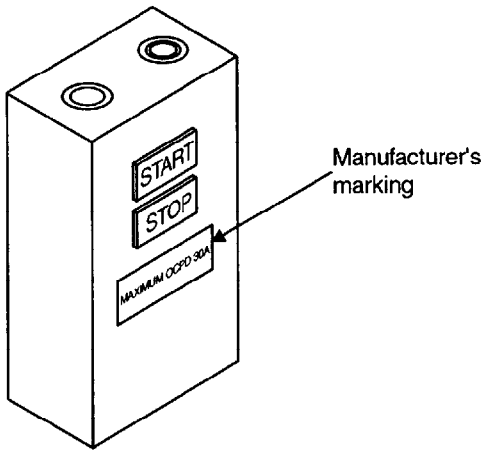
BRIEF SUMMARY

All occupancies. Overload relays are permitted to be protected in accordance with their markings.

Code Language

430-40. Overload Relays. Overload relays and other devices for motor overload protection that are not capable of opening short circuits shall be protected by fuses or circuit breakers with ratings or settings in accordance with Section 430-52 or by a motor short-circuit protector in accordance with Section 430-52.

Exception: Where approved for group installation and marked to indicate the maximum size of fuse or inverse time circuit breaker by which they must be protected, ***the overload devices shall be protected in accordance with this marking.*** (ROP 11-43)(ROC 11-20)



Overload Relays Protected per Manufacturer's Marking

Application

Overload relays may be marked to indicate a maximum overcurrent protection rating. If marked, the relay must be protected by overcurrent devices not in excess of the marked rating.

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Background and Explanation

The new wording in the exception clarifies that overloads for multiple-motor (group installation) type equipment are to be protected by a short-circuit device sized in accordance with the value marked on the equipment by the manufacturer.

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430-52(c)(6) Self-Protected Combination Controllers

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Listed self-protected combination starters may be used to provide short-circuit and ground-fault protection in motor circuits.

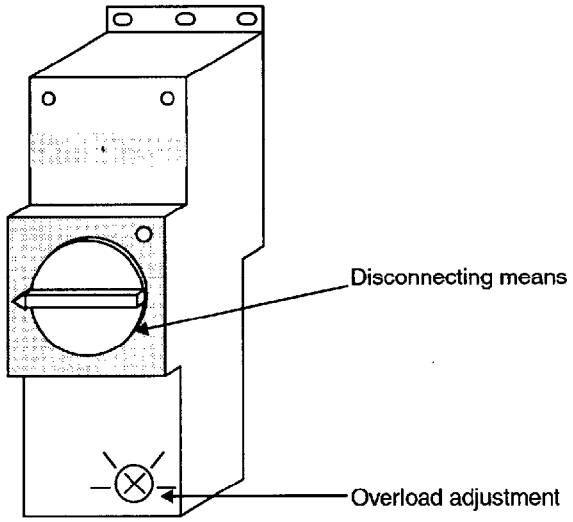
Code Language

430-52. Rating or Setting for Individual Motor Circuit.

(a) General. The motor branch-circuit short-circuit and ground-fault protective device shall comply with (b) and either (c) or (d), as applicable.

(c) Rating or Setting.

(6) A listed self-protected combination controller shall be permitted in lieu of the devices specified in Table 430-152. Adjustable instantaneous-trip settings shall not exceed 1300 percent of full-load motor current for other than Design E motors or Design B energy efficient motors and not more than 1700 percent of full-load motor current for Design E motors or Design B energy efficient motors. (ROP 11-55) (ROC 11-35)



Listed combination controller with integral SCGF protection

Self-Protected Combination Controllers

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Application

Self-protected combination controllers can combine the functions of a disconnect, short-circuit, ground-fault protection device, an overload relay, and a contactor into a single device. The illustration shows a self-protected controller. This device uses replaceable modules. The modules have separate protection components. One adjustment provides overload protection. A separate adjustable magnetic trip unit provides short-circuit and ground-fault protection. A set of contacts functions as a controller. In fact, in this case, a single set of contacts functions as controller, circuit breaker, and disconnect. The same set of contacts are controlled by the magnetic trip unit, the overload trip unit, external control devices, and by the manual operating knob. The operating knob is capable of being locked in the off position for maintenance.

Background and Explanation

Although self-protected combination starters have been available as products listed under a special category of UL508, only the overload and controller functions have been recognized by the language of previous codes. The list of devices suitable for short-circuit and ground-fault protection has previously included only fuses, circuit breakers, and motor circuit protectors. This change recognizes the use of self-protected controllers as short-circuit and ground-fault protective devices. Section 430-52(c)(6) provides maximum settings for the adjustable instantaneous trip settings. A separate proposal was accepted to modify Section 430-109 (see Section 430-109(a)(5)) to recognize these devices as disconnecting means.

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430-52(c) (6) & (7) High Efficiency Design B Motors

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. The selection of motor short-circuit and ground-fault protective devices has been clarified.

Code Language

430-52. Rating or Setting for Individual Motor Circuit.

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(c) Rating or Setting.

(6) A listed self-protected combination controller shall be permitted in lieu of the devices specified in Table 430-152. Adjustable instantaneous-trip settings shall not exceed 1300 percent of full-load motor current for other than Design E motors or Design B energy efficient motors and not more than 1700 percent of full-load motor current for Design E motors or Design B energy efficient motors. (ROP 11-55) (ROC 11-35)

(7) A motor short-circuit protector shall be permitted in lieu of devices listed in Table 430-152 if the motor short-circuit protector is part of a listed combination motor controller having coordinated motor overload protection and short-circuit and ground-fault protection in each conductor and it will open the circuit at currents exceeding 1300 percent of motor full-load current for other than Design E motors or Design B energy efficient motors and 1700 percent of motor full-load motor current for Design E motors or Design B energy efficient motors.

(ROP 11-54) (ROC 11-36)(TCC 11-53)

Application

Sections 430-52(c)(6) and (7) now treat energy efficient design B motors the same as Design E motors relative to maximum settings of short-circuit, ground-fault protection devices.

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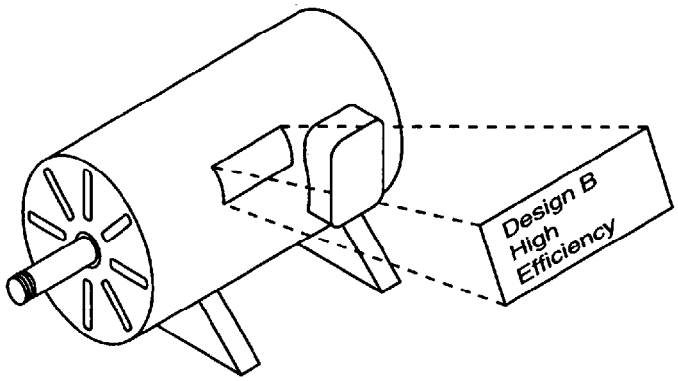
Section 430-52(c)(7) was relocated from Section 430-52(c)(3) to separate the requirements for motor short-circuit protectors from those for instantaneous-trip circuit breakers.

Section 430-52(c)(3) requires an instantaneous-trip breaker to be selected based on Table 430-152. The exception allows the size to be increased only if the need has been demonstrated. Sections 430-52(c)(6) and(c)(7) do not require the use of Table 430-152 and do not require the demonstration of need when the size is selected.



Energy Efficient Design B Motor Protection

Background and Explanation

Instantaneous-trip circuit breakers and motor short-circuit protectors are not interchangeable terms and are separate types of protective devices that have maximum settings unique to each type of device. The changes to these two sections recognize that energy efficient Design B motors have locked rotor currents equivalent to Design E motors.

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430-102(a) & Exc. No. 2 Controller Provided with Individual Disconnect

Type of Change Revision

BRIEF SUMMARY

All occupancies. The requirements for disconnects at motor controllers have been clarified.

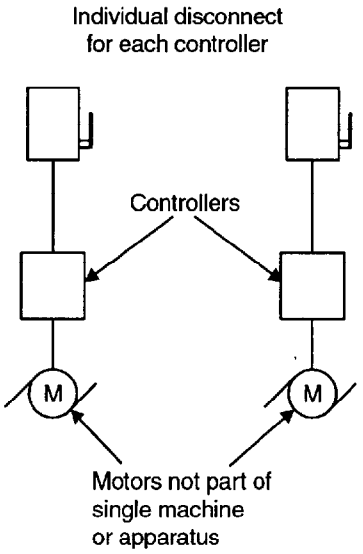
Code Language

430-102. Location.

(a) Controller. An **individual** disconnecting means shall be **provided for each controller** and shall disconnect the controller. The disconnecting means shall be located in sight from the controller location. (ROP 8-81, 8-82) (ROC 11-52)

Exception No. 1: For motor circuits over 600 volts, nominal, a controller disconnecting means capable of being locked in the open position shall be permitted to be out of sight of the controller, provided the controller is marked with a warning label giving the location of the disconnecting means.

Exception No. 2: A single disconnecting means shall be permitted for a group of coordinated controllers ***that drive several parts of a single machine or piece of apparatus. The disconnecting means and the controllers shall be located in sight from the machine or apparatus.*** (ROP 11-82)



Individual Disconnecting Means for Each Controller

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Application

In motor applications an individual disconnect is required to be installed within sight of each motor controller. Exception No. 2 allows the use of a single disconnect for a group of coordinated controllers that drive a single machine or apparatus.

Background and Explanation

The revised wording is intended to clarify to what type of machine the exception applies. The requirement for individual disconnects was not clear in the 1996 NEC. Exception No. 2 applied to a multimotor continuous process machine. There were many different interpretations of the meaning of "continuous process machine." These words were replaced with "a single machine or piece of apparatus" to clarify that it does not apply only to a continuous process machine.

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430-102(b) Exc. Disconnect at Motor Not Required

Type of Change Revision

BRIEF SUMMARY

All installations. The rule that allows the omission of a disconnect at a motor when the disconnect at the controller is lockable has been clarified.

Code Language

430-102. Location.

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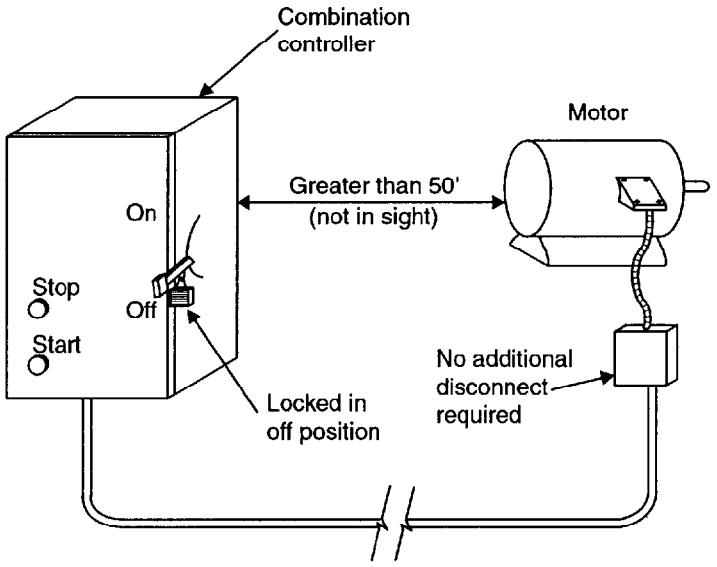
(b) Motor. A separate disconnecting means shall be located in sight from the motor location and the driven machinery location.

Exception: A disconnecting means, ***in addition to the controller disconnecting means as required*** *in accordance with Section 430-102(a),* ***shall not be required for the motor*** *where the disconnecting means* ***for the controller*** *is individually capable of being locked in the open position.* (ROP 11-92) (ROC 11-61)



Disconnects for Motors

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Application

Where the controller for a motor has a disconnect located in sight from the controller and the controller disconnect is capable of being locked in the off position, no additional disconnect is required at the motor or between the controller and the motor. The illustration shows an example of a lockable disconnect at the controller with no additional disconnect for the motor. "In sight from" means visible and not more than 50 feet away, according to the definition in Article 100.

Background and Explanation

This change is intended as a clarification. The intent of the rule was not changed.

The basic rule of Section 430-102 requires disconnects in sight from both a motor and controller. Section 430-102 does not require two separate disconnects if one disconnect can be located in sight of both the controller and motor. A controller and disconnect mounted adjacent to each other and within sight (as defined in Article 100) of the controlled motor comply with the requirements of both Sections 430-102(a) and (b). For example, if the controller in the illustration were located in sight from the motor, the disconnect for the controller could also serve as the disconnect for the motor, even if the disconnect were not lockable. The NEC does not require lockable disconnects as required under OSHA regulations.

Interpretations of the previous wording of this exception varied widely. Some interpretations allowed the motor disconnect to be out of sight of the motor but still required it to be located somewhere between the controller and motor in the circuit. Another interpretation incorporated Exception No. 1 under Section 430-102(a) into the rule and allowed the motor disconnect to be remote from the motor only when the motor was rated over 600 volts. The revised wording makes the rule clear in allowing the omission of the disconnect at the motor when the disconnect at the controller can be locked in the open (off) position.

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430-109(a)(6) & (c)(3) Marked Manual Motor Starter as Disconnecting Means

Type of Change Revision

BRIEF SUMMARY

All occupancies. Some manual motor controllers are permitted to be used as both the controller and disconnect.

Code Language

430-109. Type. The disconnecting means shall be a type specified in (a), unless otherwise permitted in (b) through (g), under the conditions specified. (ROP 11-98) (ROC 11-64)

(a) General.

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(6) Listed manual motor controllers additionally marked "Suitable as Motor Disconnect" shall be permitted as a disconnecting means where installed between the final motor branch-circuit short-circuit and ground-fault protective device and the motor. (ROP 11-98, 11-100)

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(c) Stationary Motors of 2 Horsepower or Less. For stationary motors rated at 2 hp or less and 300 volts or less, the disconnecting means shall be permitted to be one of the devices specified in (1), or (2), or (3).

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(3) A listed manual motor controller having a horsepower rating not less than the rating of the motor and marked "Suitable as Motor Disconnect." (ROC 11-63)

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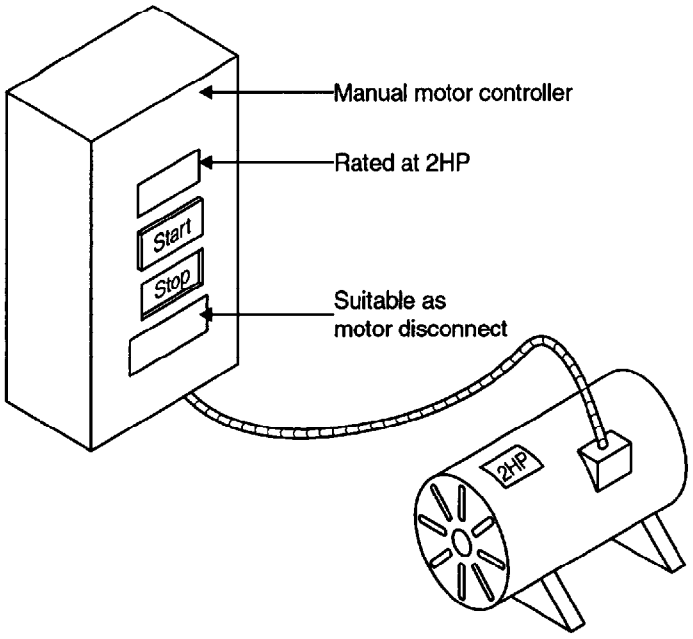

Manual Motor Controller Permitted as Motor Disconnect

Application

For general motor installations, Section 430-109(a)(6) allows manual motor controllers to serve as the disconnect. The controller must be marked as suitable for the use and be located between the short-circuit, ground-fault device and the motor.

For motors 2 HP or less rated 300 volts or less, Section 430-109(c)(3) allows the use of a manual motor controller as the disconnect. In this case the disconnect must also be marked as suitable for the use.

Background and Explanation

The entire section was totally revised to change the exceptions into positive code language. The recognition of manual motor controllers marked as "suitable as motor disconnect" was also added. There are manual motor controllers that are not provided with this marking and thus are not permitted to be used as a motor disconnecting means.

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Section 430-110(a) Exc. Nonfused Motor Disconnects

Type of Change New

BRIEF SUMMARY

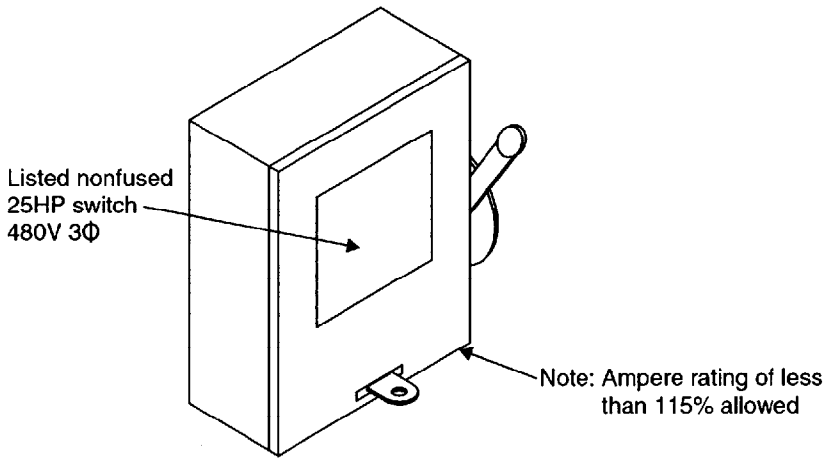
All occupancies. The requirement for selection of nonfused disconnects for use in motor circuits has been revised.

Code Language

430-110. Ampere Rating and Interrupting Capacity.

(a) General. The disconnecting means for motor circuits rated 600 volts, nominal, or less, shall have an ampere rating of at least 115 percent of the full-load current rating of the motor.

Exception: A listed nonfused motor-circuit switch having a horsepower rating equal to or greater than the motor horsepower shall be permitted to have an ampere rating less than 115 percent of the full-load current rating of the motor. (ROP 11-109)(ROC 11-70)



Listed Nonfused Switch with HP Rating

Application

It is common practice to install a nonfused disconnect in sight from a motor to comply with Section 430-102(b). In applications of this type, the nonfused switch may be selected based on the HP rating marked on the listed switch. It is not necessary to verify compliance with the 115 percent sizing requirement contained in the main rule of Section 430-110(a).

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Background and Explanation

An HP-rated nonfused switch may not have an ampere rating of 115 percent of the full load current rating of the motor. However, switches of this type have undergone temperature testing at 115 percent of the motor full load currents from Tables 430-148 through 430-150 and are now permitted to serve as a motor-circuit disconnecting means. This revision is intended to eliminate enforcement problems where a nonfused HP-rated switch is used in a motor circuit.

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NEC pp. 291–292

450-3 Transformer Overcurrent Protection Rules

Type of Change Revision

BRIEF SUMMARY

All installations. The rules for overcurrent protection of transformers have been rearranged into tables with notes.

Code Language

450-3. Overcurrent Protection. Overcurrent protection of transformers shall comply with (a), (b), or (c). As used in this section, the word *transformer* shall mean a transformer or polyphase bank of two or more single-phase transformers operating as a unit.

FPN No. 1: See Sections 240-3, 240-21, 240-100, and 240-101 for overcurrent protection of conductors.

FPN No. 2: Nonlinear loads can increase heat in a transformer without operating its overcurrent protective device.

(a) Transformers Over 600 Volts, Nominal. Overcurrent protection shall be provided in accordance with Table 450-3(a).

(b) Transformers 600 Volts, Nominal, or Less. Overcurrent protection shall be provided in accordance with Table 450-3(b).

Exception: Where the transformer is installed as a motor-control circuit transformer in accordance with Sections 430-72(c)(1) through (5).

(c) Voltage Transformers. Voltage transformers installed indoors or enclosed shall be protected with primary fuses.

FPN: For protection of instrument circuits including voltage transformers, see Section 384-32. (ROP 13-8)

Application

As shown on the next two pages, Tables 450-3(a) and (b) provide requirements for overcurrent protection of transformers. The following procedure can be used with the new tables:

First, select the appropriate table based on the voltage rating of a transformer. For voltages over 600 volts, use Table 450-3(a). Use Table 450-3(b) for transformers rated 600 volts or less.

Second, select the conditions of use or characteristics of the transformer. Table 450-3(a) is based on the rated voltage of the transformer primary and secondary, the impedance of the transformer, and the type of location (supervised

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or not). Table 450-3(b) is based on the current rating of the transformer and whether only primary protection or both primary and secondary protection is provided

Third, choose a percentage multiplier from the appropriate table. Table 450-3(a) provides different percentages for circuit breakers and fuses. Use the selected percentage and the rated transformer primary and secondary currents to calculate the appropriate maximum ratings of overcurrent protective devices for the transformers.

Use the table notes at the bottom of the table to provide clarification and additional information, such as when the next standard size overcurrent device may be used.

Table 450-3(a). Maximum Rating or Setting of Overcurrent Protection for Transformers over 600 Volts (as a Percentage of Transformer-Rated Current)

		Primary Protection		*Secondary Protection (see Note 2)*		
		Over 600 Volts		*Over 600 Volts*		*600 Volts or Below*
Location Limitations	*Transformer Rated Impedance*	*Circuit Breaker (see Note 4)*	*Fuse Rating*	*Circuit Breaker (see Note 4)*	*Fuse Rating*	*Circuit Breaker or Fuse Rating*
Any location	Not more than 6%	600% (see Note 1)	300% (see Note 1)	300% (see Note 1)	250% (see Note 1)	125% (see Note 1)
	More than 6% and not more than 10%	400% (see Note 1)	300% (see Note 1)	250% (see Note 1)	225% (see Note 1)	125% (see Note 1)
Supervised locations only (see Note 3)	Any	300% (see Note 1)	250% (see Note 1)	Not required	Not required	Not required
	Not more than 6%	600%	300%	300% (see Note 5)	250% (see Note 5)	250% (see Note 5)
	More than 6% and not more than 10%	400%	300%	250% (see Note 5)	225% (see Note 5)	250% (see Note 5)

Note 1: Where the required fuse rating or circuit breaker setting does not correspond to a standard rating or setting, the next higher standard rating or setting shall be permitted.

Note 2: Where secondary overcurrent protection is required, the secondary overcurrent device shall be permitted to consist of not more than six circuit breakers or six sets of fuses grouped in one location. Where multiple overcurrent devices are utilized, the total of all the device ratings shall not exceed the allowed value of a single overcurrent device. If both breakers and fuses are utilized as the overcurrent device, the total of the device ratings shall not exceed that allowed for fuses.

Note 3: A supervised location is a location where conditions of maintenance and supervision ensure that only qualified persons will monitor and service the transformer installation.

Note 4: Electronically actuated fuses that may be set to open at a specific current shall be set in accordance with settings for circuit breakers. (ROP 13-8)

Note 5: A transformer equipped with a coordinated thermal overload protection by the manufacturer shall be permitted to have separate secondary protection omitted. (ROC 13-3)

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Table 450-3(b). Maximum Rating or Setting of Overcurrent Protection for Transformers 600 Volts and Less (as a Percentage of Transformer-Rated Current)

	Primary Protection			*Secondary Protection (see Note 2)*	
Protection Method	*Currents of 9 Amperes or more*	*Currents less than 9 Amperes*	*Currents less than 2 Amperes*	*Currents of 9 Amperes or more*	*Currents less than 9 Amperes*
Primary only protection	125% (see Note 1)	167%	300%	Not required	Not required
Primary and secondary protection	250% (see Note 3)	250% (see Note 3)	250% (see Note 3)	125% (see Note 1)	167%

Note 1: Where 125 percent of this current does not correspond to a standard rating of a fuse or nonadjustable circuit breaker, the next higher standard rating described in Section 240-6 shall be permitted.

Note 2: Where secondary overcurrent protection is required, the secondary overcurrent device shall be permitted to consist of not more than six circuit breakers or six sets of fuses grouped in one location. Where multiple overcurrent devices are utilized, the total of all the device ratings shall not exceed that allowed value of a single overcurrent device. If both breakers and fuses are utilized as the overcurrent device, the total of the device ratings shall not exceed that allowed for fuses.

Note 3: A transformer equipped with coordinated thermal overload protection by the manufacturer and arranged to interrupt the primary current, shall be permitted to have primary overcurrent protection rated or set at a current value that is not more than six times the rated current of the transformer for transformers having not more than 6 percent impedance, and not more than four times the rated current of the transformer for transformers having more than 6 percent but not more than 10 percent impedance.

Background and Explanation

The requirements of this section have not been changed from the 1996 code. This change was intended to make the selection of overcurrent protection for transformers easier by grouping all of the requirements into two tables with simplified notes.

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450-13(b) Transformers in Hollow Spaces of Buildings

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Transformers up to 50kVA can be installed in an accessible hollow space.

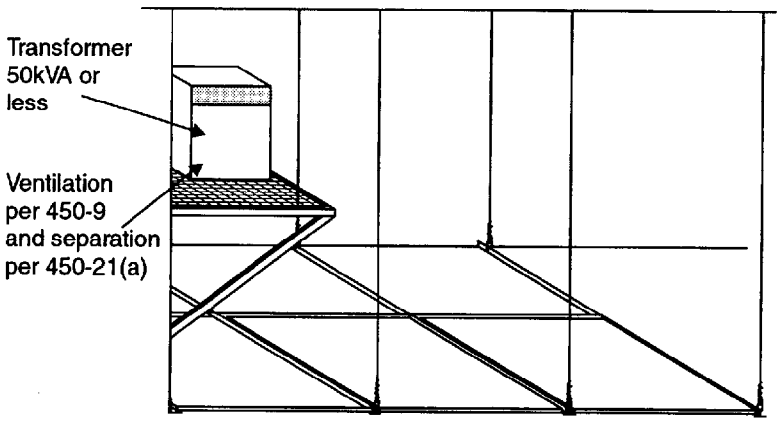
Code Language

450-13. Accessibility. All transformers and transformer vaults shall be readily accessible to qualified personnel for inspection and maintenance, or meet the requirements of (a) or (b).

(a) Open Installations. Dry-type transformers 600 volts, nominal, or less, located in the open on walls, columns, or structures, shall not be required to be readily accessible.

(b) Hollow Space Installations. Dry-type transformers 600 volts, nominal, or less and not exceeding 50kVA shall be permitted in ~~fire-resistant~~ hollow spaces of buildings not permanently closed in by structure, and provided they meet the ventilation requirements of Section 450-9 **and separation from combustible materials requirements of Section 450-21(a).** Transformers so installed shall not be required to be readily accessible.

(ROP 13-17)(ROC 13-10, 13-11)



Transformer in Accessible Hollow Space Above Ceiling

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Application

Transformers up to 50kVA can be installed in hollow spaces of buildings such as the accessible space above a suspended ceiling. Adequate ventilation in accordance with Section 430-9 must be provided and separation from combustible material is required. Section 110-26 also requires adequate workspace for all electrical equipment and would apply to an installation of this type.

Background and Explanation

The 1996 NEC required hollow spaces to have a 1-hour fire rating. Individual hollow spaces are not fire rated. Even with a fire-rated floor-ceiling assembly the entire assembly was rated but not the hollow space alone.

This revision provides a practical approach to locating dry-type transformers rated 50kVA or less within the hollow spaces of a building.

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480-8(c) Working Clearances in Battery Rooms

Type of Change New

BRIEF SUMMARY

Commercial and industrial. Clearances in battery rooms must comply with Section 110-26.

Code Language

480-8. Battery Locations.

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(c) Working Space. Working space about the battery systems shall comply with Section 110-26. Working clearance shall be measured from the edge of the battery rack. (ROP 15-17)(ROC 15-14a) (TCC 15-14a)

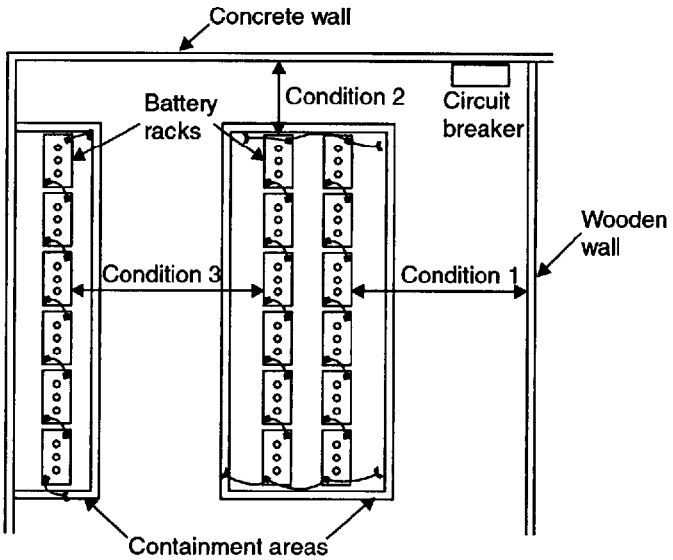

Table 110-26(a) clearances required

Battery Room Clearances

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Application

The illustration shows a plan view of a battery room layout. Clearances must be maintained in accordance with Section 110-26. The output voltage of the battery system shall be used in selecting the appropriate clearances from Table 110-26(a). Measurements are to be taken from the battery racks as shown. The illustration shows the three conditions from Table 110-26(a) applied to a storage battery installation. The specific distances will be determined based on the system voltage to ground.

Background and Explanation

Battery installations usually require routine maintenance. Clearances have not been specifically mentioned in Article 480 in previous codes. Although some authorities would have required the clearances of Section 110-26 anyway, others have argued that batteries don't fall under the general category of electrical equipment. This change clarifies the applicability of the work space requirements by making a specific reference to Section 110-26.

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STD.NFPA NEC CHANGES-ENGL 1999 ■ 6474446 0577161 4T2 ■

Article 490 Equipment Over 600 Volts

Type of Change New

BRIEF SUMMARY

Commercial and industrial. A new Article 490 covers the general requirements for equipment operating at over 600 volts.

Code Language

A. General

490-1. Scope. This article covers the general requirements for equipment operating at more than 600 volts, nominal.

FPN: See *Standard for Electrical Safety Requirements for Employee Workplaces,* NFPA 70E-1995, for electrical safety requirements for employee workplaces.

490-2. Definition. For the purposes of this article, *high voltage* shall be defined as more than 600 volts, nominal.

Application

This new article includes much of the material in the deleted Article 710 of the 1996 NEC. The origin and destination of the sections making up the new Article 490 are shown in the accompanying diagram.

Background and Explanation

Article 710 was an article covering systems of over 600 volts that combined rules on equipment, installation, wiring methods, and overcurrent protection. Since equipment over 600 volts is common, particulary in the industrial environment, the location of these requirements in Chapter 7 ("Special Conditions") was not appropriate. The new Article 490 is located in Chapter 4, "Equipment for General Use." The rules applicable to the equipment itself were relocated to the new Article 490. Other rules were relocated to Articles 110, 240, and 300. Those changes are covered separately.

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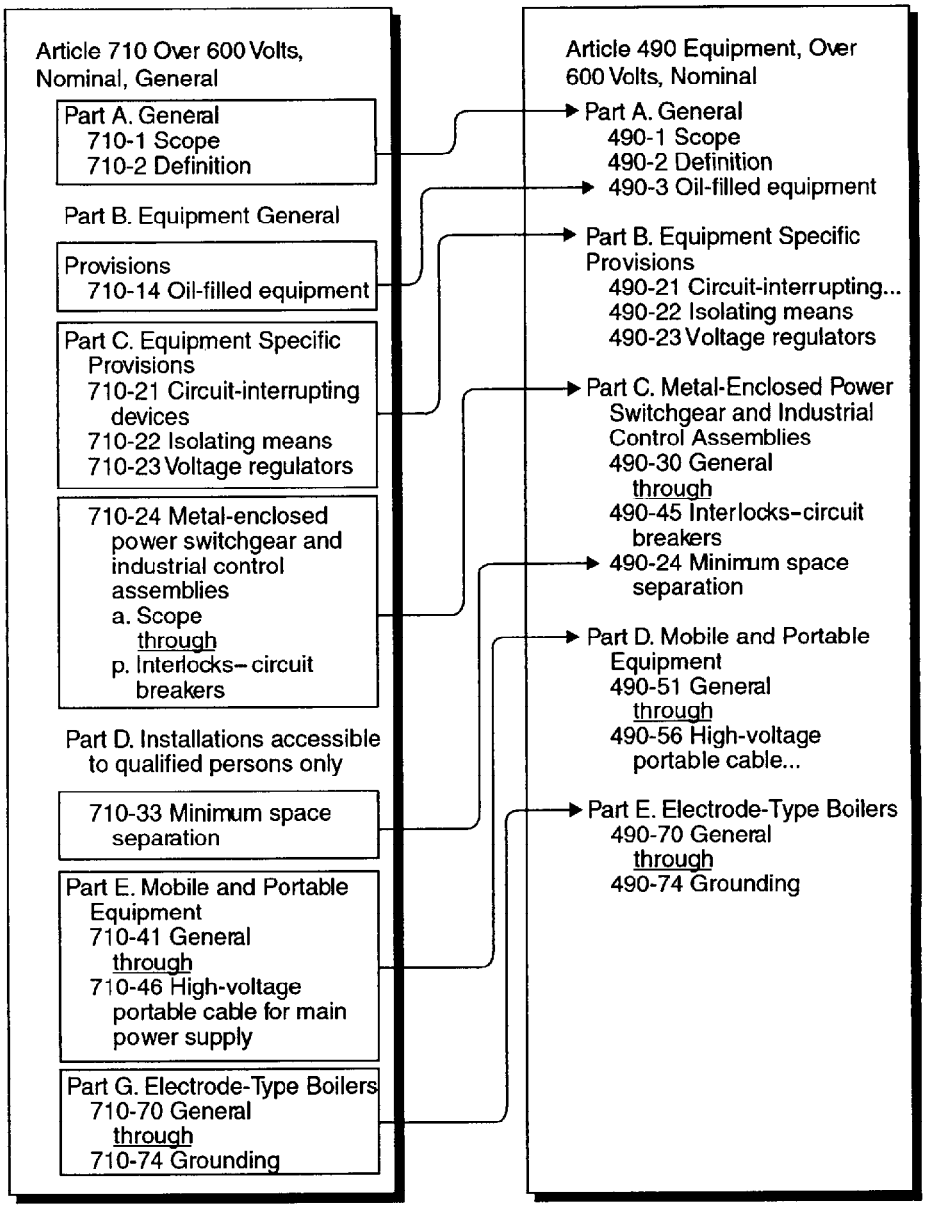

High Voltage Rules Moved to New Article 490

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500-3(b) Documentation of Area Classification Scheme

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Hazardous areas must be documented and the documentation available to those responsible for design, maintenance, installation, inspection, or operation of equipment in the areas.

Code Language

500-3. General.

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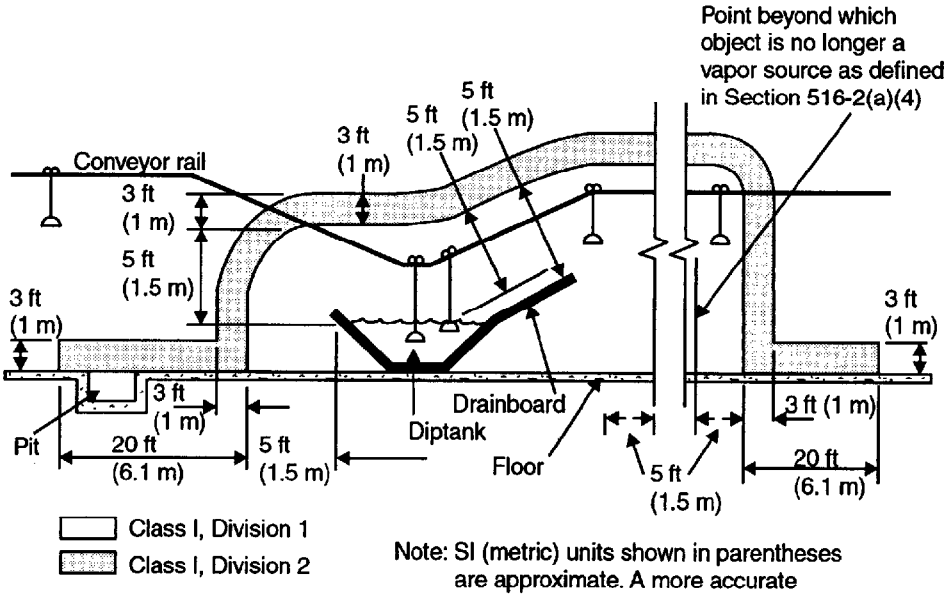
(b) Documentation. All areas designated as hazardous (classified) locations shall be properly documented. This documentation shall be available to those authorized to design, install, inspect, maintain, or operate electrical equipment at the location. (ROP 14-8, 14-15)



Area Classification Drawing

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Background and Application

Hazardous (classified) areas must be defined as to the type and extent of the hazardous areas. Documentation is usually in the form of an area classification drawing like the one in the illustration or an area classification map for a large facility. Such documentation must be available to properly design, install, inspect, maintain, test, or operate electrical equipment in the hazardous areas. Class, division, and group information, as well as details of the locations and extent of the areas, are necessary for proper installation.

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500-4(i) Listed Alternative Protection Techniques

Type of Change New

BRIEF SUMMARY

Industrial. The development of new products for use in hazardous locations is permitted as a protection method.

Code Language

500-4. Protection Techniques. The following shall be acceptable protection techniques for electrical and electronic equipment in hazardous (classified) locations. (ROP 14-8)

•
•
•

(i) Other Protection Techniques. Other protection techniques used in equipment listed for use in hazardous (classified) locations. (ROP 14-19)

Background and Explanation

Section 500-4 (formerly Section 500-2(a)) provides a list of the various protection techniques permitted for use in hazardous (classified) locations covered by Articles 500 through 504. The addition of new paragraph (i) "Other Protection Techniques." to this list allows the industry to develop new products for use in hazardous locations and recognizes methods already available, such as encapsulation, within listed equipment.

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STD.NFPA NEC CHANGES-ENGL 1999 ■ 6474446 0577166 T84 ■

501-4(a) Exc. No. 1 Rigid Nonmetallic Conduit in Class I Locations

Type of Change Revision

BRIEF SUMMARY

Industrial. The conditions for the installation of underground nonmetallic conduit have been clarified.

Code Language

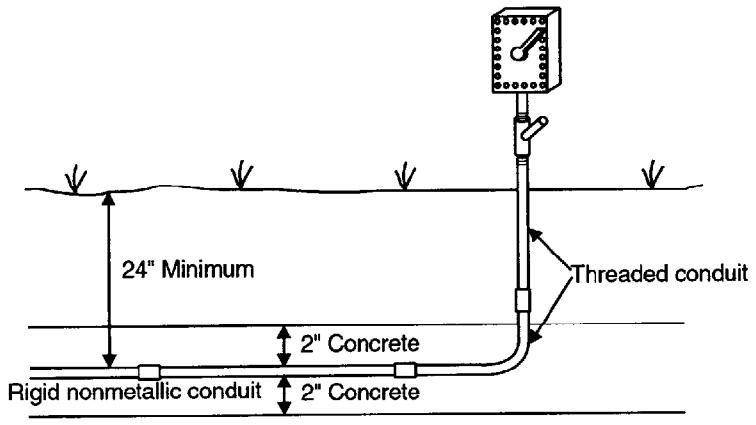
501-4. Wiring Methods. Wiring methods shall comply with (a) and (b).

(a) Class I, Division 1.

(1) Fixed Wiring.

Exception No. 1: Rigid nonmetallic conduit complying with Article 347 shall be permitted where encased in a concrete envelope a minimum of 2 in. (50.8 mm) thick and ~~*buried below the surface under not less than 2 ft (610mm) of earth*~~ ***provided with not less than 24 in. (610 mm) of cover measured from the top of the conduit to grade. The concrete encasement shall be permitted to be omitted where subject to the provisions of Section 511-4, Exception; Section 514-8, Exception No. 2; and Section 515-5(a).***

Where rigid nonmetallic conduit is used, threaded rigid metal conduit or threaded steel intermediate metal conduit shall be used for the last 24 in. (610 mm) of the underground run to emergence or to the point of connection to the aboveground raceway. An equipment grounding conductor shall be included to provide for electrical continuity of the raceway system and for grounding of noncurrent-carrying metal parts. (ROP 14-97)



Rigid Nonmetallic Conduit in Class I, Division 1 Location

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Application

Where rigid nonmetallic conduit is used underground in a Class I, Division 1 area, the conduit must have 24 inches of cover. The conduit must emerge from underground in one of the acceptable metal conduits and the change to metal conduit must also have 24 inches of cover. This exception also requires the nonmetallic conduit to be encased in at least 2 inches of concrete. However, the concrete envelope is not required in similar rules in Articles 511, 514, and 515.

Background and Explanation

The 1996 NEC required cover by 24 inches of earth. Some enforcers interpreted this to mean that conduit under a paved area needed 24 inches of soil plus the pavement plus 2 inches of concrete. The change to 24 inches of cover clarifies the intent. References to Articles 511, 514, and 515 were added to clarify that similar exceptions for underground installations contained in those specific articles do not require concrete encasement.

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501-4(a)(1) Exc. No. 3 ITC Cable in Class I, Division 1

Type of Change New

BRIEF SUMMARY

Industrial. Some Type ITC cable may be used in certain industrial Class I, Division 1 locations.

Code Language

501-4. Wiring Methods.
(a) Class I, Division 1.
(1) Fixed Wiring.
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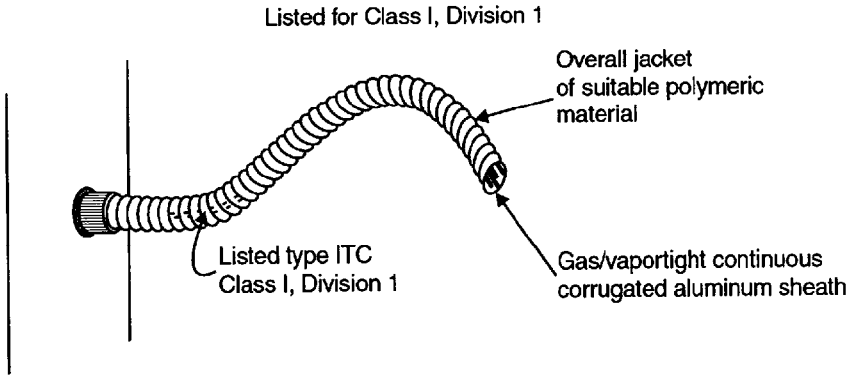
•

Exception No. 3: In industrial establishments with restricted public access, where the conditions of maintenance and supervision ensure that only qualified persons will service the installation, Type ITC cable, listed for use in Class I, Division 1 locations, with a gas/vaportight continuous corrugated aluminum sheath, an overall jacket of suitable polymeric material and provided with termination fittings listed for the application shall be permitted. (ROP 14-105) (ROC 14-47)



ITC Cable in Class I, Division 1 Locations

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Application

Type ITC cable (Instrumentation Tray Cable) is permitted in hazardous (classified) locations in industrial facilities if there is restricted public access and the installation is serviced only by qualified persons. Article 727 covers the general requirements for Type ITC cable and not all such cables are allowed in hazardous locations. The cable construction, listing, and fittings must meet the conditions shown in the illustration.

Background and Explanation

The cable described in this new exception is nearly identical to the MC cable allowed by Exception No. 2 in this same section except that the insulation is rated at 300 volts for the ITC cable and 600 volts for the MC cable. ITC cable is limited to installations where the circuit operates at not greater than 150 volts by Section 727-3(b). Also, except for some small sizes, Type MC cable usually includes a separate equipment grounding conductor. The continuous corrugated sheath of the variety of ITC cable permitted by this new exception provides an adequate grounding path without a separate equipment grounding conductor.

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NEC pp. 317–320

501-5(a) & (b) Sealing Requirements Reorganized

Type of Change Reorganization

BRIEF SUMMARY

Commercial and industrial. Section 501-5 was rewritten and reorganized to clarify the rules for conduit seals. Seals in conduits crossing Class I, Division 2 boundaries must be within 10 feet of the boundary.

Code Language

The following outlines of the 1996 and 1999 NEC illustrate the reorganization.

Outlines Illustrating Reorganization

1996 NEC

501-5. Sealing and Drainage.
501-5(a) Conduit Seals, Class I, Division 1
501-5(a)(1) In each conduit entering enclosures with arcs, sparks, high temps
Exception: Hermetically sealed, oil-immersed contacts, factory seals
(FPN): Factory-sealed enclosures do not serve to seal other enclosures.
501-5(a)(2) In each conduit 2 in. or larger with terminals, splices, or taps
501-5(a)(3) Single seal for two or more enclosures
501-5(a)(4) In each conduit leaving the Class I, Division 1 area
Exception: Conduits passing through area without fittings
501-5(b) Conduit Seals, Class I, Division 2
501-5(b)(1) For explosion-proof enclosures, same as (a)(1), (a)(2), and (a)(3)
501-5(b)(2) In each conduit leaving the Class I, Division 2 area
Exceptions 1, 2, 3, 4

1999 NEC Reorganization with New Material Boldfaced

501-5 Sealing and Drainage
501-5(a) Conduit Seals, Class I, Division 1
501-5(a)(1) (a) Conduit entries to enclosures with arcs, sparks, high temps
(b) Conduit entries 2" or larger with terminals, splices, or taps
For the purposes of this section, high temperatures shall be considered to be any temperature exceeding 80 percent of the autoignition temperature
•
•
•
Exception: Hermetically sealed, oil-immersed contact, factory seals
Factory-sealed enclosures shall not be considered to serve as a seal for another adjacent explosionproof enclosure.

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501-5(a)(2) Conduit entries to pressurized enclosures . . . within 18 in.
(FPN No. 1): Seal location reduces problems in purging conduit.
(FPN No. 2): See NFPA 496-1998.
501-5(a)(3) Single seal for two or more enclosures
501-5(a)(4) In each conduit leaving the Class I, Division 1 area
Exception: Conduits passing through area without fittings
501-5(b) Conduit Seals, Class I, Division 2
501-5(b)(1) For explosion-proof enclosures, same as (a)(1)(a), and (a)(3)
501-5(b)(2) In each conduit leaving Class I, Division 2 area **within 10 ft of boundary**
Exceptions 1, 2, 3, 4

Application

The outlines show the reorganization of Section 501-5(a) and (b) for sealing in Class I, Division 1 and 2 areas. The new last sentence of Section 501-5(a)(1) explains that a "high temperature" is a temperature in excess of 80 percent of the auto ignition temperature of the combustible material producing the classified area. A revision to Section 501-5(b)(2) clarifies the requirement that seals be within 10 feet of the boundary when a conduit crosses a Class I, Division 2 boundary similar to the requirement for a seal within 10 feet of a Class I, Division 1 boundary specified in the 1996 code.

Background and Explanation

The reorganization of Section 501-5(a) and (b) was done to improve usability and accuracy in application. The new text was added to explain what was meant by "high temperatures" in the context of this section.

Section 501-5(b)(2) was changed to clarify that a seal at the boundary of a Class I, Division 2 area must be within 10 feet of the boundary. The previous code said that seals could be on either side of the boundary with no distance restriction. The 10-foot restriction matches the requirement of Section 501-5(a)(4) for Division 1 boundaries.

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501-5(a)(2) Sealing Requirements

Type of Change New

BRIEF SUMMARY

Commercial/industrial. A new rule provides requirements for installation of conduit seals around pressurized enclosures.

Code Language

501-5 Sealing and Drainage.

(a) Conduit Seals, Class I, Division 1. In Class I, Division 1 locations, conduit seals shall be located as follows.

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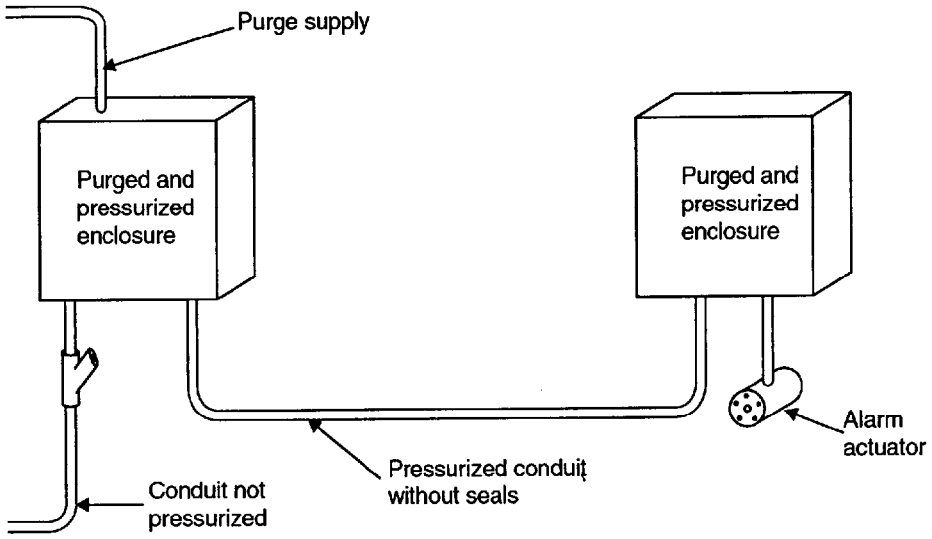
•

(2) In each conduit entry into a pressurized enclosure where the conduit is not pressurized as part of the protection system. Conduit seals shall be installed within 18 in. (457 mm) from the pressurized enclosure.

FPN No. 1: Installing the seal as close as possible to the enclosure will reduce problems with purging the dead airspace in the pressurized conduit.

FPN No. 2: For further information, see *Standard for Purged and Pressurized Enclosures for Electrical Equipment,* NFPA 496-1998.



Sealing Purged and Pressurized Enclosures

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Application

The illustration portrays the new requirement in Section 501-5(a)(2). Seals are required in conduits leaving pressurized enclosures if the pressurization system is not intended also to pressurize the conduit system. Such seals must be located within 18 inches of the pressurized enclosure, as shown in the illustration. This rule would most likely apply to Type X purged and pressurized enclosures, although it could also apply to Type Y. Two new FPNs explain that such seals are needed because of the difficulty of purging the dead air space formed by a sealed conduit.

Background and Explanation

NFPA 496 provides requirements for the installation of purged and pressurized enclosures and describes the classification obtained within the enclosure depending on the type of purging and pressurization used. Type X purging and pressurization changes the interior of an enclosure or room from Class I, Division 1 to unclassified. Type Y purging and pressurization changes the interior of an enclosure from Class I, Division 1 to Class I, Division 2. An enclosure is purged of all gases and vapors that might have entered and then pressurized with clean air or nonflammable gas to exclude gases and vapors from entering the enclosure or room. This allows equipment to be installed in a non-explosion-proof enclosure in a hazardous location where the enclosure and the contained equipment would not ordinarily be allowed. The classification of the area surrounding the enclosure is not changed.

In some cases, a purging system can be designed to purge connecting conduits and perhaps more than one enclosure. However, often the conduits leaving the purged enclosure extend to equipment that is required to be explosion-proof. Such conduits are required to be sealed at the explosion-proof enclosures. A conduit connected to a purged enclosure is, in effect, an extension of the purged enclosure and is susceptible to the entry of flammable gases and vapors. Long lengths of conduit that are not part of the purged system, especially conduits that are sealed at one end, are difficult to purge, so the length of such conduits is limited to 18 inches before a seal must be installed.

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501-5(c) (3) & (6) Thickness of Sealing Compound and Revised Conductor Fill in Seal Fitting

Type of Change Revision

BRIEF SUMMARY

Industrial. The thickness of sealing compound and conductor fill in conduit sealing fittings has been clarified.

Code Language

501-5. Sealing and Drainage.

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(c) Class I, Divisions 1 and 2. Where required, seals in Class I, Division 1 and 2 locations shall comply with the following.

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(3) Thickness of Compounds. In a completed seal, the minimum thickness of the sealing compound shall not be less than the trade size of the **sealing fitting** and in no case less than ⅝ in. (16 mm). (ROP 14-135)

Exception: Listed cable sealing fittings shall not be required to have a minimum thickness equal to the trade size of the fitting.

(6) Conductor Fill. The cross-sectional area of the conductors permitted in a seal shall not exceed 25 percent of the cross-sectional area of a **rigid metal** conduit of the same trade size unless it is specifically approved for a higher percentage of fill. (ROP 14-138)

Application

Some conduit seals are listed for 25 percent conductor fill while a conduit of the same trade size may be filled to 40 percent. Section 501-5(c)(6) requires the 25 percent fill requirement to be based on the internal area of a rigid metal conduit that is the same trade size as the conduit seal. Some seals are listed for more than 25 percent fill. In this case, higher fill percentages are allowed.

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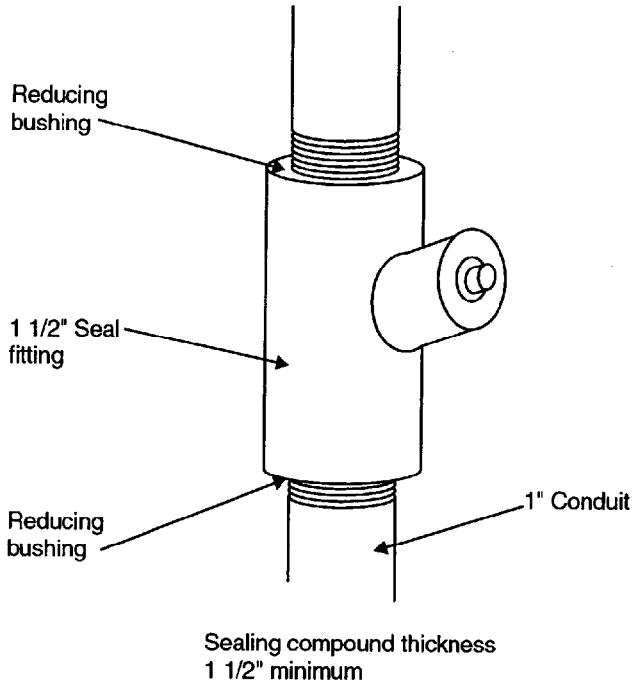
The minimum thickness for sealing compound is specified in Section 501-5(c)(3). Sealing compound must be at least ⅝ inches thick and not less than the trade diameter of the conduit sealing fitting. When conduit is filled to 40 percent and seals listed for only 25 percent are used, it is necessary to install seals of at least one trade size larger than the conduit. In this case, compound thickness is to be based on the trade size of the sealing fitting rather than conduit size.



Sealing Compound Requirements

Background and Explanation

Section 501-5(c)(3) was revised to clarify that sealing is based on fitting size rather than conduit size. Section 501-5(c)(6) was revised to clarify that conductor fill in sealing fittings is based on rigid metal conduit rather than some other type. The internal diameter of intermediate metal conduit is larger than that of rigid metal conduit. If IMC is installed, the fitting fill is to be calculated based on the cross-sectional area of rigid metal conduit of the same trade size.

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NEC pp. 319 & 320

501-5(d)(1) Exc. (e)(1) Exc. No. 2 Sealing Shielded Cables

Type of Change New

BRIEF SUMMARY

Commercial and industrial. Shielded cables and twisted pair cables need not have the shield removed or the twisted pairs separated where the cables are sealed.

Code Language

501-5. Sealing and Drainage.

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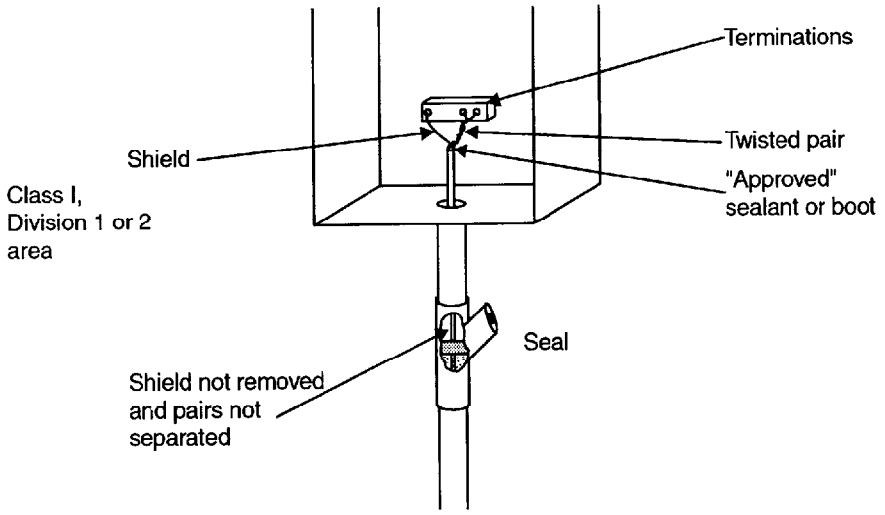
(d) Cable Seals, Class I, Division 1

(e) Cable Seals, Class I, Division 2

Exception: Shielded cables and twisted pair cables shall not require the removal of the shielding material or separation of the twisted pairs provided the termination is by an approved means to minimize the entrance of gases or vapors and prevent propagation of flame into the cable core. (ROP 14-139)



Sealing Shielded Cable

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Application

The figure shows a shielded twisted-pair cable in a Class I, Division 1 or 2 location. The cable shield is not required to be removed and the twisted pairs are not required to be separated in the sealing fitting if the cable is "sealed" at the termination in an approved manner. This rule is provided in Section 501-5(d)(1) Exception for Division 1 locations and by Section 501-5(e)(1) Exception No. 2 for Division 2 locations.

Background and Explanation

Removal of shields or separation of twisted pairs may prevent the proper operation of instrumentation circuits and similar circuits that rely upon shielding or twisting of pairs as part of their operation. This change permits such cables to be left intact at seals as long as an approved means of sealing the cable from the entry or passage of gases or vapors is provided at terminations.

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501-5(e) Exc. No. 1 Cable Ceiling with Type Z Pressurization

Type of Change New

BRIEF SUMMARY

Commercial and industrial. Cables passing from a Type Z purged and pressurized enclosure to the surrounding Class I, Division 2 area are not required to be sealed at the boundary.

Code Language

501-5(e). Cable Seals, Class I, Division 2.

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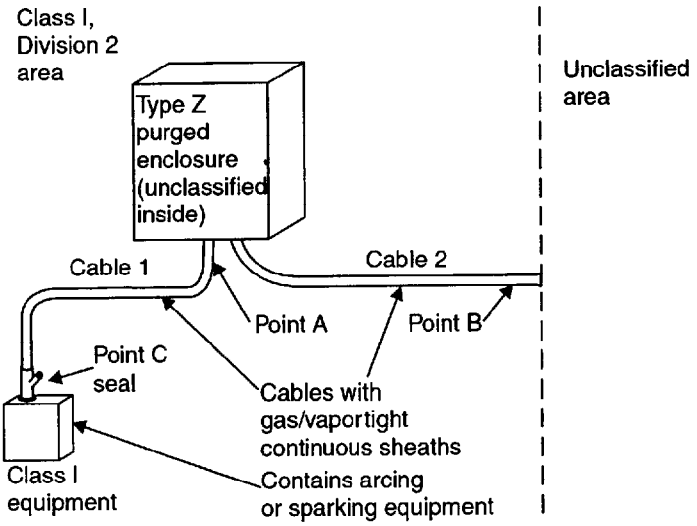
Exception No. 1: Cables passing from an enclosure or room that is unclassified as a result of Type Z pressurization into a Class I, Division 2 location shall not require a seal at the boundary. (ROP 14-143)



Sealing Type Z Pressurized Enclosures

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Application

The illustration shows two cables leaving a Type Z purged and pressurized enclosure. The interior of the enclosure (or area) is unclassified due to the purging and pressurization of the enclosure or room. The surrounding area is Class I, Division 2. Cable 1 in the illustration is not required to be sealed where it passes into the Class I, Division 2 area at Point A according to Section 501-5(e)(1), Exception No. 1. The cable labeled Cable 2 is shown leaving the enclosure and passing unbroken into the unclassified area at Point B. Cable 2 is not required to be sealed according to Section 501-5(e)(3). However, Cable 1 is required to be sealed at Point C in accordance with Section 501-5(e) because it enters an enclosure that is required to be approved for Class I locations.

Background and Explanation

This new exception applies to cables, but is similar in purpose and effect to Section 501-5(b)(2), Exception No. 3, which applies to conduit. An enclosure located in a Class I, Division 2 area may be made unclassified on the inside through the use of Type Z purging and pressurization. Since the enclosure is unclassified on the inside, cables or conduits connected to the enclosure will not be exposed to the entry of flammable gases or vapors from the enclosure. The risk of having gases or vapors enter the cable or conduit from the surrounding classified area is small because it is a Division 2 area, that is, an area where gases and vapors are not normally present. Even if gases or vapors did enter the cable or conduit from the surrounding area, the pressurization of the system would keep the gases and vapors from migrating to the unclassified area inside the enclosure. Thus, the purpose of seals is fulfilled without a requirement to install seals.

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NEC pp. 335–342

Article 505 Zone Classification Requirements

Type of Change Revision

BRIEF SUMMARY

Industrial. The entire article has been extensively revised.

Code Language

Complete revision of the article.

505-10. Listing, Marking, and Documentation.

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(b) Marking

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FPN: No. 2: An explanation of the marking that is required follows.

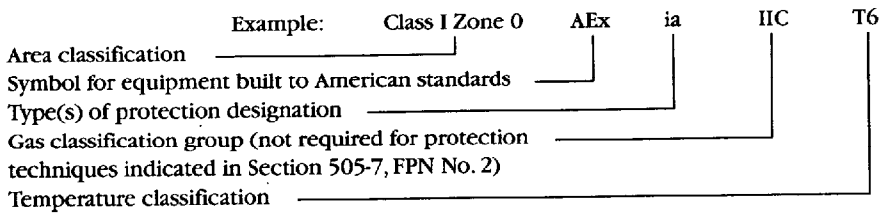

Figure 505-10(b)(1).

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Table 505-10(b)(1). Types of Protection Designation

Designation	*Technique*	*Zone 1**
d	Flameproof enclosure	1
e	Increased safety	1
ia	Intrinsic safety	0
ib	Intrinsic safety	1
[ia]	Intrinsically safe associated apparatus	Nonhazardous
[ib]	Intrinsically safe associated apparatus	Nonhazardous
m	Encapsulation	1
nA	Nonsparking equipment	2
nC	Sparking equipment in which the contacts are suitably protected other than by restricted breathing enclosure	2
nR	Restricted breathing enclosure	2
o	Oil immersion	1
p	Purged and pressurized	1 or 2
q	Powder filled	1

* Does not address use where a combination of techniques is used.

Application

Users of this article will find expanded requirements for the use of the zone system for area classification. The requirement for a "qualified registered professional engineer" to oversee the implementation of this system has been relocated from Section 500-3 to Section 505-6(a). The use of increased safety "e" motors and generators that are listed for Class I, Zone 1 locations is now specifically referenced in the revised article.

Background and Explanation

The Class I, Zone 0, 1, and 2 classification system is the NEC version of the system used by the International Electrotechnical Commission (IEC). Information on the IEC system can be found in various publications in the IEC 79 series.

Part of the work done in Article 505 is the result of proposals requesting that the IEC marking system be included in the NEC. The IEC marking information is summarized on new Table 505-10(b)(1). More detailed information on acceptable protection techniques has been placed in Section 505-4. Section 505-10(b)(2) adds an additional marking for NEC applications. The symbol "AEx" is used to indicate that equipment is zone equipment that is also built and tested to American standards.

Section 505-6(b) was added to allow both the class/division and class/zone systems to be used in the same facility. Areas classified using different systems shall not overlap or abut.

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505-6(b) & (c) Dual Area Classification

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Areas classified under division and zone classification rules may not overlap, and some may not abut each other, but reclassification is permitted.

Code Language

505-6. Special Precautions.

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(b) Dual Classification. In instances of areas within the same facility classified separately, Class I, Zone 2 locations shall be permitted to abut, but not overlap, Class I, Division 2 locations. Class I, Zone 0 or Zone 1 locations shall not abut Class I, Division 1 or Division 2 locations.

(c) Reclassification Permitted. A Class I, Division 1 or Division 2 location shall be permitted to be reclassified as a Class I, Zone 0, Zone 1, or Zone 2 location provided all of the space that is classified because of a single flammable gas or vapor source is reclassified under the requirements of this article. (ROP 14-281)

Application

The illustration shows a simplified area classification drawing. The classified areas are bounded by walls on three sides. Half of the total area is classified under the zone classification system and half is classified under the division classification system. The two classification systems are permitted to coexist with restrictions. The Class I, Zone 2 area is permitted to adjoin the Class I, Division 2 area at the top of the drawing. However, the Class I, Zone 0 and Zone 1 areas may not adjoin the Class I, Division 1 and Division 2 areas. The illustration shows a heavy line at the boundaries of the areas that are not permitted to be adjacent to each other.

Reclassification is permitted under certain conditions. As long as the entire area classified because of any single flammable source is reclassified, the change from division to zone classification is permitted. For example, the area identified in the drawing as Class I, Division 1 might be reclassified as Class I, Zone 1. The surrounding Division 2 area could then be reclassified as Zone 2, and the violations in the original layout would be resolved. A portion of the Division 2 area that abuts

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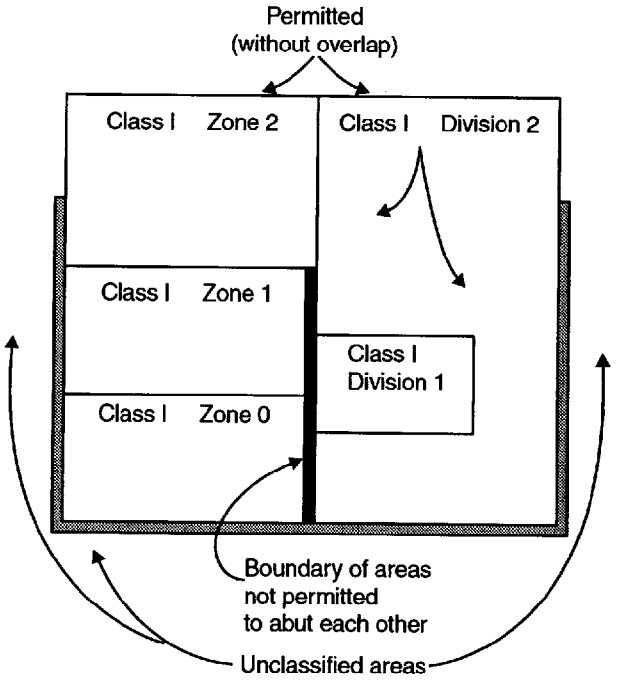
the Zone 0 area might also have to be reclassified as Zone 1 to meet the requirements of Section 505-9(b)(4). The remaining portion of the Class I, Division 2 area could retain its division classification as long as it was not classified due to a flammable gas or vapor source that existed in the reclassified areas.



Classification by Zone and Division

Background and Explanation

As the use of the zone classification system becomes more common, personnel in many facilities will find themselves with adjoining areas that are classified under different systems. This change clarifies what areas are permitted to abut each other and allows reclassification to resolve conflicts.

One basic concept in both the division and zone classification systems is that areas adjoining a higher risk area often are classified as the next lower risk area. Thus, areas abutting Zone 0 areas are generally Zone 1 areas, and areas adjoining Division 1 areas are generally Division 2 areas. Division 2 and Zone 2 areas are classified based on essentially the same level and type of risk, so it makes sense that they could lie next to each other. On the other hand, Division 1 is not quite the same as Zone 0 or Zone 1, so rather than allow such areas to abut each other, they must be reexamined and reclassified for consistency. The practical effect of this rule is to require a sort of buffer zone of Division 2 and Zone 2 or unclassified areas between higher risk areas.

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513-1 Aircraft Hangar Scope

Type of Change Revision

BRIEF SUMMARY

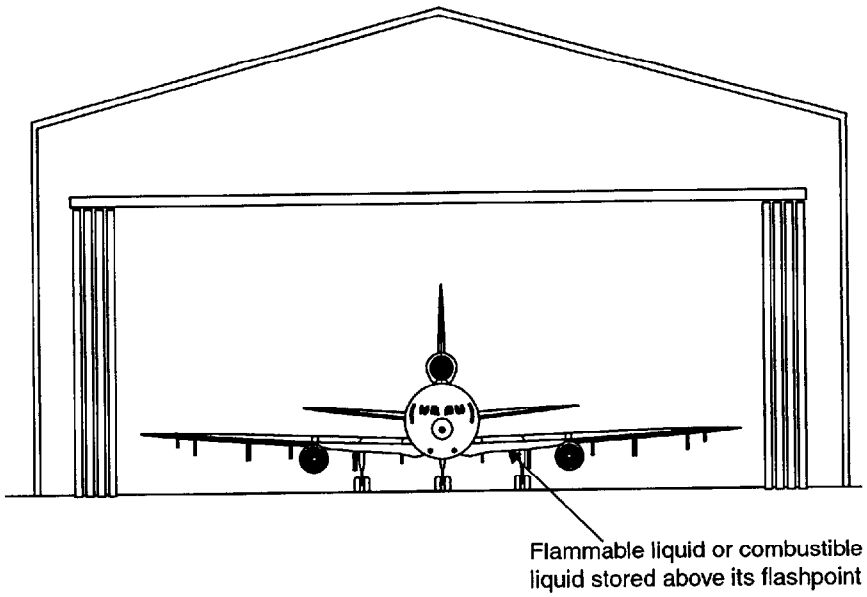
Aircraft hangars. The types of buildings covered by Article 513 have been clarified.

Code Language

513-1. Scope. **This article shall apply to buildings or structures inside any part of which aircraft containing Class I (flammable) liquids or Class II (combustible) liquids whose temperatures are above their flash points are housed or stored and in which aircraft might undergo service, repairs, or alterations.** It shall not apply to locations used exclusively for aircraft that have never contained ~~such liquids or gases~~ fuel or ~~aircraft drained and properly purged~~ unfueled aircraft.

FPN No. 1: For definitions of aircraft hangar and unfueled aircraft, see *Standard on Aircraft Hangars,* NFPA 409-1995.

FPN No. 2: For further information on fuel classification, see *Flammable and Combustible Liquids Code,* NFPA 30-1996, and *Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids,* NFPA 325-1994. (ROP 14-331)



Applicability of Article 513 Depends on Fuel Type.

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Application

The revised scope statement recognizes that it is not necessary to classify areas in which the aircraft fuel is a Class II (combustible liquid) unless it will be handled or stored above its flashpoint.

Background and Explanation

In the 1996 NEC, Article 513 covered buildings where the aircraft contained flammable fuels or any jet fuel. A flammable fuel is a liquid with a flash point of less than 100°F. Liquids with a flash point above 100°F are classified as combustible. Jet-A fuel has a flash point of over 100°F and is a combustible liquid. In general, combustible liquids do not require area classification. Based on 1996 code requirements, the storage areas and areas where fuel trucks are filled would not be classified but the hangar would be. The revised wording clarifies the intent that Jet-A fuel is only of concern if it is heated above its flash point.

Purging of fuel tanks is not possible to achieve by formal definition. NFPA 409, standard for aircraft hangars, defines "unfueled" as the lowest level technically possible (½ percent). The term "purged" has been replaced with "unfueled." The revision eliminates these conflicts and brings Section 513-1 into agreement with the definition in NFPA 409.

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513-4 Mechanical Systems in Pits and Vaults

Type of Change Revision

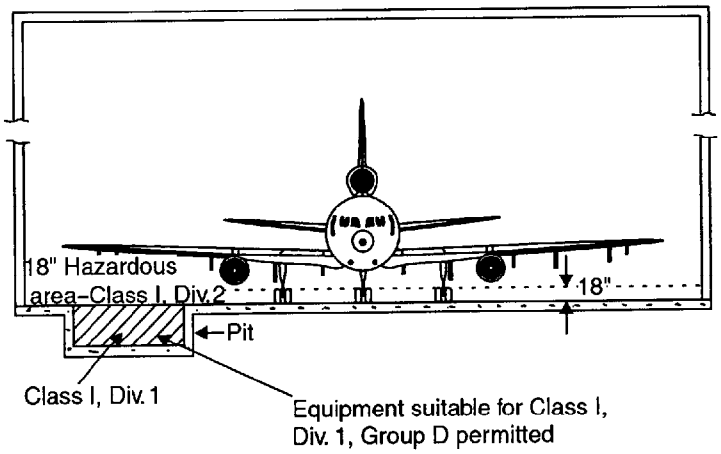
BRIEF SUMMARY

Commercial. The restriction on "other services" in vaults, pits, and ducts in aircraft hangars has been removed.

Code Language

513-4. Wiring and Equipment in Class I Locations. All wiring and equipment that is or may be installed or operated within any of the Class I locations defined in Section 513-3 shall comply with the applicable provisions of Article 501. All wiring installed in or under the hangar floor shall comply with the requirements for Class I, Division 1 locations. Where such wiring is located in vaults, pits, or ducts, adequate drainage shall be provided. ~~and the wiring shall not be placed within the same compartment with any other service other than compressed air~~

Attachment plugs and receptacles in Class I locations shall be approved for Class I locations or shall be designed so that they cannot be energized while the connections are being made or broken. (ROP 14-332, 14-334, 14-335)



Equipment in Aircraft Hangar Pit

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Application

The removal of the restriction on other services will allow services other than compressed air piping to occupy vaults, pits, and ducts in aircraft hangars with wiring. Presumably such other services might include lubrication piping, water lines, or other fluid supplies that are utilized for the servicing of aircraft within landing gear pits.

Background and Explanation

The change to this section reflects the permission to install Class I, Division I, Group D electrical equipment in landing gear pits, ducts, and tunnels. This permission is found in Section 2-9.2 of NFPA 409-1995 *Standard on Aircraft Hangars*. This does not permit the introduction of electrical wiring within ducts used for ventilating the pit, since Section 300-22(a) prohibits wiring systems in a duct used to transport flammable vapors.

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514-6 Dispenser Disconnects to Prevent Feedback

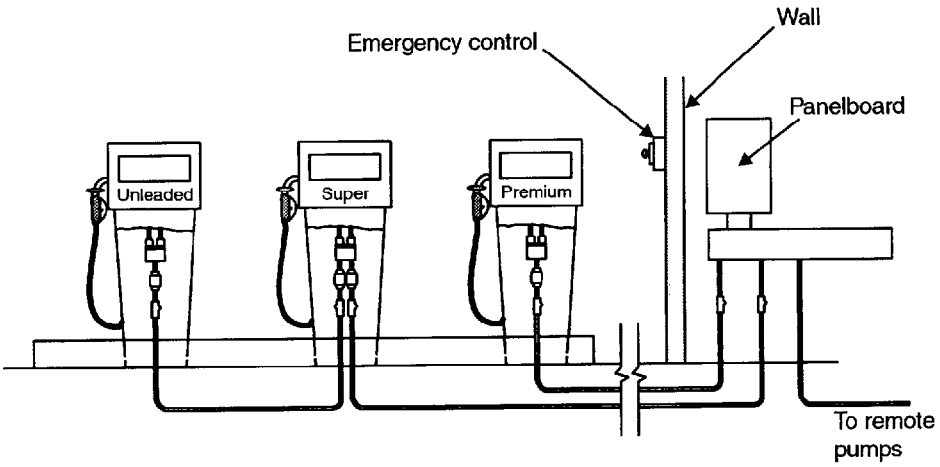
Type of Change New

BRIEF SUMMARY

Gasoline service stations. This section provides improved electrical safety during maintenance of dispensers.

Code Language

514-6. Provisions for Maintenance and Service of Dispensing Equipment. Each dispensing device shall be provided with a means to remove all external voltage sources, including feedback, during periods of maintenance and service of the dispensing equipment. (ROC 14-127)



Isolation required for dispenser control circuits to prevent feedback

Isolation of Dispensing Equipment

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Application

Provisions must be made to disconnect all sources of power, including parallel wiring that could allow possible feedback, from dispensing devices. Some systems now in use may allow pump circuits to backfeed power to a dispenser from remote control circuits when the circuit to the dispenser is disconnected. To eliminate shock hazards to personnel servicing dispensing and related equipment, positive disconnection is required for all possible power sources in the equipment.

Background and Explanation

This change was made based on reports from the field that indicate some control systems now in use allow dangerous feedback into equipment that has been de-energized for servicing due to the use of parallel control circuits. This revision is intended to provide additional safety for personnel servicing dispensing equipment by isolating the equipment.

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515-7 Dispensing of Volatile Flammable Liquids

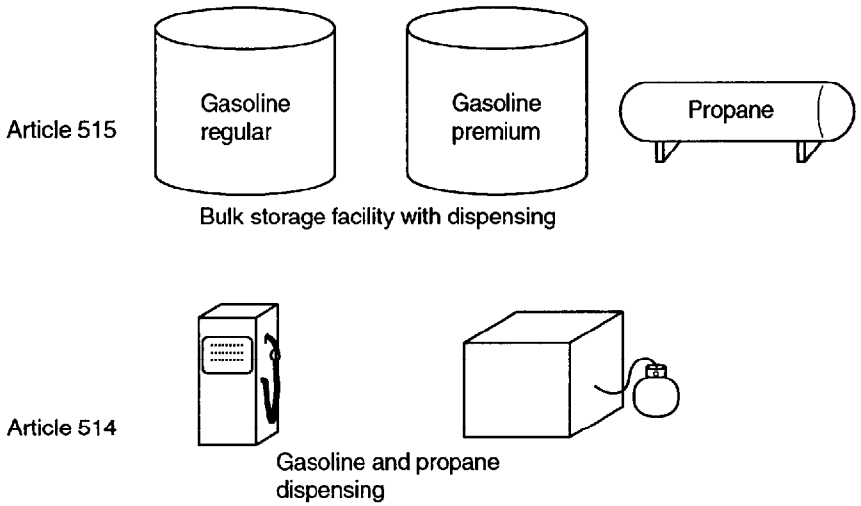
Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Article 514 applies to areas of bulk storage facilities that are used for dispensing any flammable liquids or gases, not just gasoline.

Code Language

515-7. Gasoline Dispensing. Where gasoline **or other volatile flammable liquids or liquefied flammable gases are dispensed at bulk stations,** the applicable provisions of Article 514 shall apply. (ROP 14-383)



Bulk Storage with Dispensing

Application

If a bulk storage facility includes dispensing operations, the dispensing operations fall under the scope of Article 514 and are required to comply with that article. Although the title of Article 514 is "Gasoline Dispensing and Service Stations," the article also applies to the dispensing of flammable liquids and liquefied flammable gases other than gasoline. A bulk storage location containing a dispensing area is shown in the illustration.

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Background and Explanation

The definition of "gasoline dispensing and service stations" is found in Section 514-1, and not in Article 100 or Article 515. For this reason, some code users applied the provisions of Article 514 to dispensing areas in bulk storage facilities only when the dispensed product was gasoline, because only gasoline was mentioned in Section 515-7. This change clarifies that Article 514 also applies to areas of bulk storage facilities where flammable products other than gasoline are dispensed.

Article 515 covers storage and transfer of flammable liquids in bulk, such as from or to pipelines, tank cars, and tank vessels. Article 514 covers the transfer of flammable liquids to fuel tanks of self-propelled vehicles or other relatively small containers. Many facilities have areas that are covered by one or both articles. For example, both Article 514 and Article 515 provide identical dimensions for classified areas around the fill openings of underground tanks, but aboveground tanks are covered only by Article 515. In the absence of specific rules for aboveground tanks in Article 514, Article 515 could also apply. Both articles apply to a bulk storage plant with dispensing areas.

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517-3 Definition of Emergency Systems

Type of Change Revision

BRIEF SUMMARY

Hospitals. Article 517 contains emergency system requirements beyond the general requirements in Article 700.

Code Language

517-3. Definitions.

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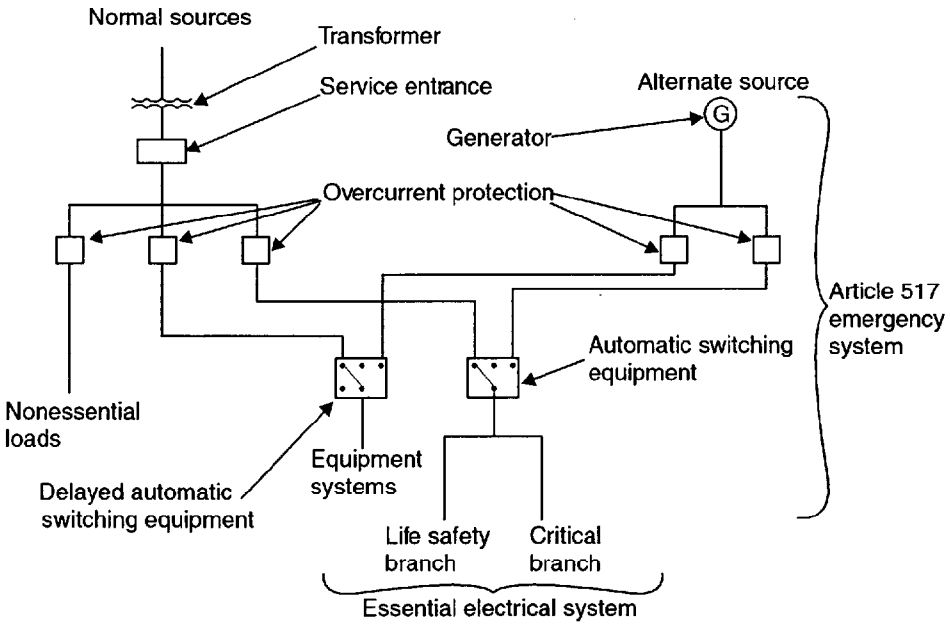
Emergency System. A system of feeders and branch circuits meeting the requirements of Article 700, **except as amended by Article 517,** and intended to supply alternate power to a limited number of prescribed functions vital to the protection of life and patient safety, with automatic restoration of electrical power within 10 seconds of power interruption. (ROP 17-7)



Hospital Emergency System

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Application

Where the emergency system requirements in Article 517 differ from those in Article 700, Article 517 requirements are to be used in health-care facilities. Additional requirements such as those for the subdivision of the emergency system are unique to health-care facilities and are contained in Article 517.

Background and Explanation

Some enforcers and installers have had problems determining when to use Article 517 and when to follow Article 700. The revision to the definition clarifies that the requirements of Article 517 concerning the arrangement and installation of the health-care facility emergency system expand on the requirements of Article 700.

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517-13(a) Exc. No. 3 Redundant Grounding

Type of Change Revision

BRIEF SUMMARY

Hospitals. Switches located outside the patient vicinity are not required to be grounded by an insulated equipment grounding conductor.

Code Language

517-13(a). Patient Care Areas.

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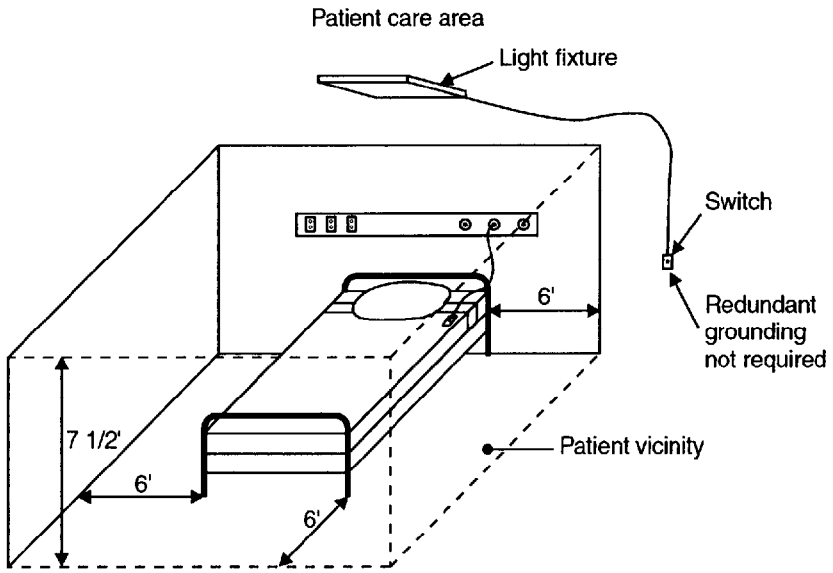
Exception No. 3: Light fixtures more than 7½ ft (2.2 m) above the floor ***and switches located outside of the patient vicinity*** *shall not be required to be grounded by an insulated grounding conductor.* (ROP 17-12) (ROC 17-9)



Grounding Outside Patient Vicinity

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Application

Metal parts of switches, light fixtures, and similar equipment are required to be grounded by a metal raceway or suitable cable armor or sheath as well as by an insulated equipment grounding conductor if the equipment is located in a "patient vicinity." A patient vicinity is defined in Section 517-3 and depicted in the illustration. The redundant grounding requirement applies to electrical equipment within the patient vicinity. The illustration shows a fixture and switch that are not required to have redundant grounding because they are outside the patient vicinity.

Metal parts of switches and metal faceplates are required to be grounded in accordance with Section 380-9 by a metal mounting screw or screws connected to the grounded metal yoke of a switch or other device whether they are located in a patient vicinity or not.

Background and Explanation

Equipment in patient vicinities requires redundant grounding. This requirement is achieved by installing an insulated equipment grounding conductor in a metal raceway or in a metal cable that is constructed with a sheath or armor that is an acceptable grounding return path. Section 517-13(a) Exception No. 3 of the 1996 NEC exempted light fixtures more than 7½ feet above the floor from the redundant grounding requirement because such fixtures are outside the patient vicinity. This code change is intended as clarification that the redundant grounding requirement does not cover switch yokes where the switches are located outside the patient vicinity. A change in Section 380-9 of the 1999 NEC requires all switch yokes to be grounded in accordance with Article 250 whether or not metal faceplates are used.

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517-18(c) Listed Tamper Resistant Covers in Pediatric Areas

Type of Change Revision

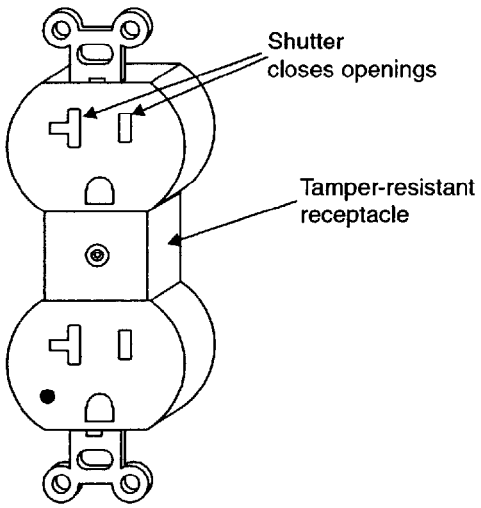
BRIEF SUMMARY

Hospitals. Receptacles and covers allowed in pediatric areas must be listed as tamper resistant.

Code Language

517-18. General Care Areas.

(c) Pediatric Locations. Fifteen- and 20-ampere, 125-volt receptacles intended to supply patient care areas of pediatric wards, rooms, or areas shall be **listed** tamper resistant **or shall employ a listed tamper resistant cover.** (ROC 17-22)



Protection in Pediatric Areas

Application

Due to the presence of children in pediatric care areas the NEC restricts the type of receptacles that may be used. Pediatric care areas, wards, or rooms are the areas where small children are most likely to have access to receptacles. Tamper resistant features limit the possibility of a conductive object being inserted into the receptacle slots. In these areas, only listed tamper resistant receptacles or listed tamper resistant covers are permitted as a safety feature to limit access to live parts.

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Background and Explanation

An exception to this section in the 1996 NEC allowed covers that would limit improper access. Faceplates with lift-up caps or domed covers were used in some installations that were not listed tamper resistant and did not provide the same level of protection as listed tamper resistant receptacles. The panel accepted the inclusion of listed tamper resistant covers as an acceptable method of limiting access to the energized parts of the receptacle.

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517-30(c)(3) Exc. No. 5 Flexible Wiring Methods in Listed Office Furnishings

NEC p. 366

Type of Change Revision

BRIEF SUMMARY

Hospitals. Listed office furnishings containing emergency system branch circuits may be wired by flexible metal raceways and cable assemblies.

Code Language

517-30(c). Wiring Requirements.

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(3) Mechanical Protection of the Emergency System.

The wiring of the emergency system of a hospital shall be mechanically protected by installation in nonflexible metal raceways, **or shall be wired with Type MI cable. Where installed as branch circuit conductors serving patient care areas, the installation shall comply with the requirements of Section 517-13.**

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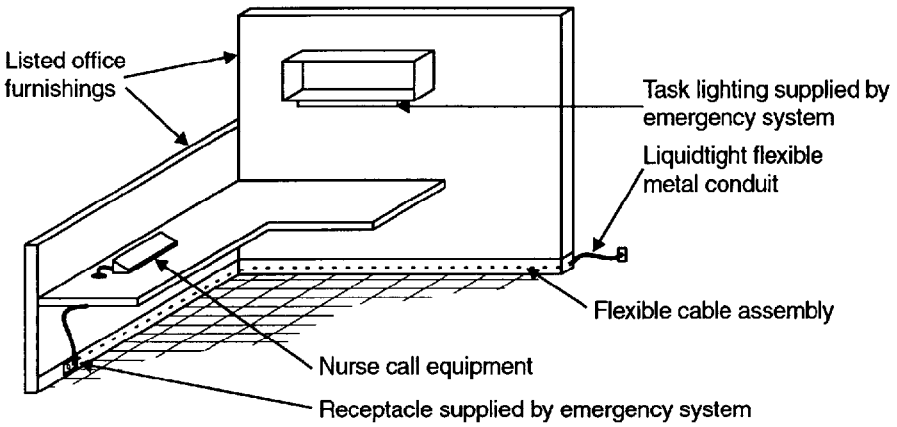
*Exception No. 5: Flexible metal raceways and cable assemblies shall be permitted to be used in listed prefabricated medical headwalls, **listed office furnishings,** or where necessary for flexible connection to equipment.*



Listed Office Furnishings and Emergency Power

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Application

The illustration shows a nurses' station with equipment, task lighting, and receptacles required by Section 517-33(a)(3) and (5) to be on the critical branch of an emergency system. Because the nurses' station is constructed with listed office furnishings, liquidtight flexible metal conduit furnished as part of the office furnishings is allowed to be used to contain the emergency circuits. Similarly, the wiring internal to the office furnishings is also allowed to be in flexible metal raceways and cable assemblies.

Background and Explanation

The main rule of Section 517-30(c)(3) for wiring of the emergency system branch circuits requires mechanical protection of the emergency circuits by nonflexible metal raceways. Former Exception No. 6 in the 1996 code allowed flexible metal raceways or cable assemblies in prefabricated metal headwalls and where required for flexibility for equipment connections. The old Exception No. 5 was reworded into positive language in the main rule of Section 517-30(c) to allow the use of MI cable. Former Exception No. 6 then became Exception No. 5 and "listed office furnishings" was added. The word "listed' was also added to prefabricated metal headwalls.

Although the revised wording says "in" listed headwalls and listed office furnishings, the substantiation for the change said such wiring methods were needed for "connection, interconnection, and reconfiguration" of the office furnishings. The panel statement also referred to a reliance on the listing process, so all such raceways furnished as part of the listed office furnishings should be considered to be included in the exception.

Since the new wording says that flexible methods may be used in listed headwalls and office furnishings, this is more of a product standard than a code rule for field use, since the internal wiring of listed equipment need not be inspected in the field.

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517-33[x](c) Identification of Critical Branch Receptacles

Type of Change New

BRIEF SUMMARY

Hospitals. Receptacles on critical branch circuits must be identified.

Code Language

[x]517-33. Critical Branch.

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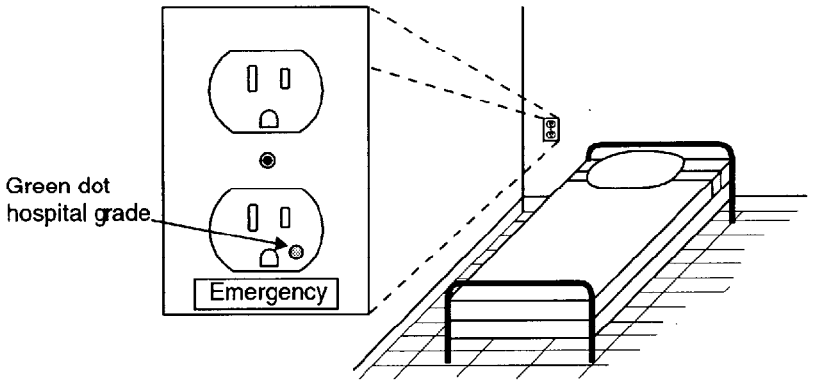
[x] **(c) Receptacle Identification. The receptacles or the faceplates for receptacles supplied by the critical branch shall have a distinctive color or marking so as to be readily recognizable.** (ROP 17-40)



Critical Branch Identification

Application

All receptacles on the critical branch must be identified. This new requirement does not specify the type of identification that must be used. Receptacles, faceplates, or both may be identified by color. While red is usually the color of choice in installations of this kind, red is not specifically required. Any color may be used, provided that the color for the critical branch receptacles or faceplates are different from the normal system. Other methods, such as marking with tags or engraved plates, are also acceptable.

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Background and Explanation

This material is extracted text from the *Standard for Health-Care Facilities, NFPA 99* and covers all receptacles installed on the critical branch. This expands the identification requirement beyond the scope of Section 517-19(a) identification requirement for receptacles installed on the emergency system at patient bed locations in a critical-care area. The receptacles installed at the critical-care patient bed locations have additional marking requirements specified by Section 517-19(a).

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517-160 (a)(5) Use of Identified Grounded Terminal

Type of Change Revision

BRIEF SUMMARY

Hospitals. On isolated power systems, the orange conductor is to be connected to terminals identified for connection to a grounded conductor.

Code Language

517-160. Isolated Power Systems.
(a) Installations.
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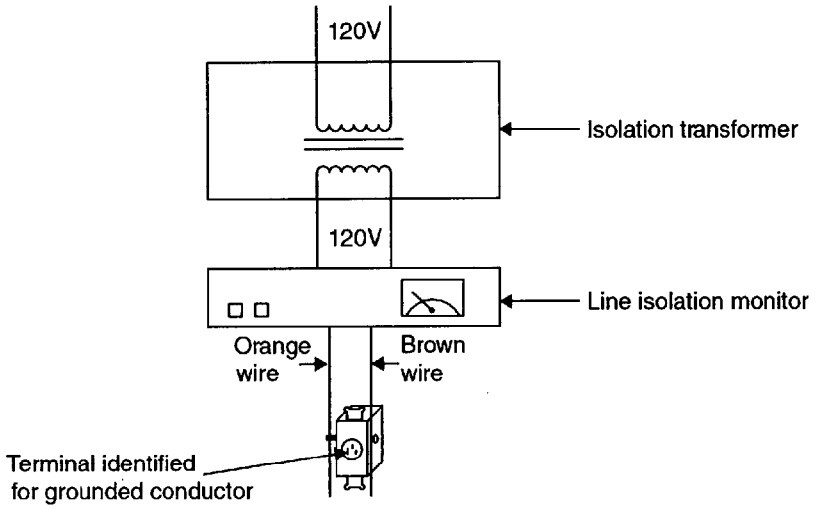
(5) The isolated circuit conductors shall be identified as follows:

Isolated Conductor No. 1—Orange

Isolated Conductor No. 2—Brown

For 3-phase systems, the third conductor shall be identified as yellow. **Where isolated circuit conductors supply 125-volt, single-phase, 15- and 20-ampere receptacles, the orange conductor(s) shall be connected to the terminal(s) on the receptacles that are identified in accordance with Section 200-10(b) for connection to the grounded circuit conductor.** (ROP 17-49)



Use of Wiring Devices with Isolated Power System Conductors

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Application

The illustration shows a typical 125-volt, 15-ampere rated receptacle connected to an isolated power system. The conductors are required to be orange, brown, or yellow for the third conductor of a 3-phase system. The orange conductor must be connected to the terminals marked for connection to grounded conductors. Terminals for grounded conductors are identified by white-colored metal, the word "white," or the letter "W," in accordance with Section 200-10(b).

Background and Explanation

This change was meant to clarify how isolated power systems are to be polarized when there is no grounded conductor. The choice of orange for the conductor connected to the white terminal of a receptacle correlates with the Canadian Electrical Code.

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518-4(a) AC Cable in Places of Assembly

Type of Change Revision

BRIEF SUMMARY

Places of assembly. Some use of Type AC cable in places of assembly is allowed.

Code Language

518-4. Wiring Methods.

(a) General. The fixed wiring methods shall be metal raceways, **flexible metal raceways,** nonmetallic raceways encased in not less than 2 in. (50.8 mm) of concrete, Type MI, MC, **or AC cable containing an insulated equipment grounding conductor sized in accordance with Table 250-122.** (ROP 15-22) (ROC 15-19a)

Application

Type AC cable with an insulated equipment grounding conductor is allowed as a wiring method in areas covered by Article 518. In previous editions of the NEC, Type AC cable was only permitted to be used in places of assembly that were not required to be fire-rated. Where used in a building that is not required to be fire-rated, Type AC cable is permitted and is not required to have an insulated equipment grounding conductor.

Background and Explanation

The armor of Type AC cable is permitted to serve as the equipment grounding conductor. This revision allows the use of Type AC cable in fire-rated construction only where an insulated equipment grounding conductor is provided in the cable construction. Therefore this wiring method provides redundant grounding where used in a place of assembly that is required to be fire-rated. The change also clarifies that flexible metal conduits such as liquidtight flexible metal conduit and flexible metal conduit are permitted wiring methods.

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518-4(c) FPN Description of Finish Rating

Type of Change New

BRIEF SUMMARY

Commercial. A new FPN was added to explain the meaning of the term "finish rating."

Code Language

518-4. Wiring Methods.

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(c) Spaces with Finish Rating.

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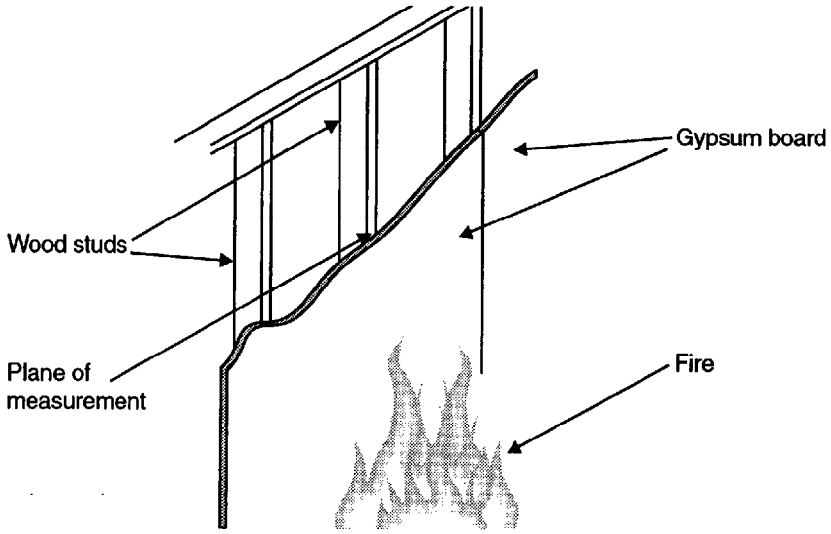
FPN: A finish rating is established for assemblies containing combustible (wood) supports. The finish rating is defined as the time at which the wood stud or wood joist reaches an average temperature rise of 121°C (250°F) or an individual temperature rise of 163°C (325°F) as measured on the plane of the wood nearest the fire. A finish rating is not intended to represent a rating for a membrane ceiling. (ROP 15-23)



Finish Ratings

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Application

Section 518-4(c) allows electrical nonmetallic tubing (ENT) or rigid nonmetallic conduit (RNC) in several specifically identified places of assembly where the ENT or RNC is concealed behind a thermal barrier with at least a 15-minute finish rating. A new FPN describes this finish rating. The illustration shows how such a finish rating is established.

Background and Explanation

An FPN was added to Section 331-3(2) in the 1996 code to explain the term "finish rating" as it applies to the use of ENT in buildings of over three floors above grade. The same wording was used in this new FPN.

Both FPNs provide information to show that finish ratings differ from fire-resistance ratings. Although finish ratings are determined by testing an assembly of wood supports, the finish rating belongs to the thermal barrier material, such as the gypsum board in the illustration, and not to the complete assembly. Fire-resistance ratings, on the other hand, apply to complete assemblies. Finish ratings are concerned with the temperature inside a wall, behind a thermal barrier. Fire-resistance ratings are concerned with the temperature on the side of an assembly opposite a fire. Thus, the gypsum board could be installed on steel studs and still retain its finish rating, even though the fire resistance rating of the steel stud assembly might change. Notice also that ENT and RNC are not restricted to wood construction, but they must remain concealed behind the thermal barrier in places of assembly. Penetrations of the thermal barrier must be made with other wiring methods.

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520-25(d) Listed Dimmers Over 150 Volts Between Conductors

Type of Change Revision

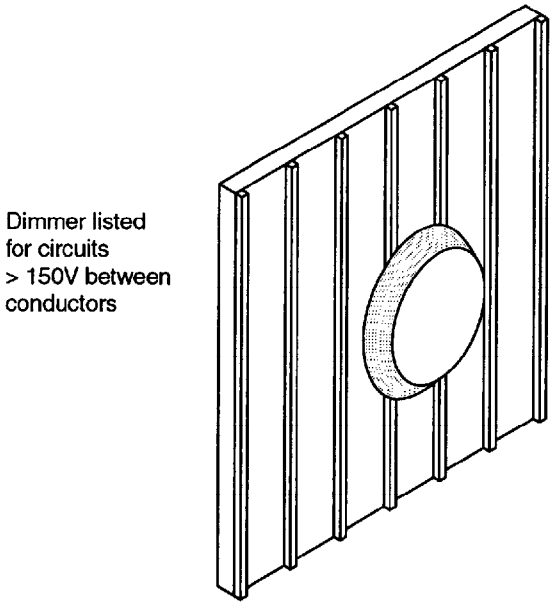
BRIEF SUMMARY

Theaters. Requires listing of solid-state dimmers operating at over 150 volts between conductors.

Code Language

520-25. Dimmers. Dimmers shall comply with (a) through (d).

(d) Solid-State-Type Dimmers. The circuit supplying a solid-state dimmer shall not exceed 150 volts between conductors unless the dimmer is **listed** specifically for higher voltage operation. Where a grounded conductor supplies a dimmer, it shall be common to the input and output circuits. Dimmer chassis shall be connected to the equipment grounding conductor.



Dimmer for Circuits Over 150 Volt Between Conductors

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Application

Solid-state dimmers used in theaters in circuits of over 150 volts between conductors are required to be listed.

Background and Explanation

This revision was made to ensure that solid-state dimmers over 150 volts between conductors are constructed to a recognized product standard. Prior to the 1999 NEC, the only requirement for this type of device was the approval of the authority having jurisdiction.

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520-73 Switched Receptacles in Dressing Rooms

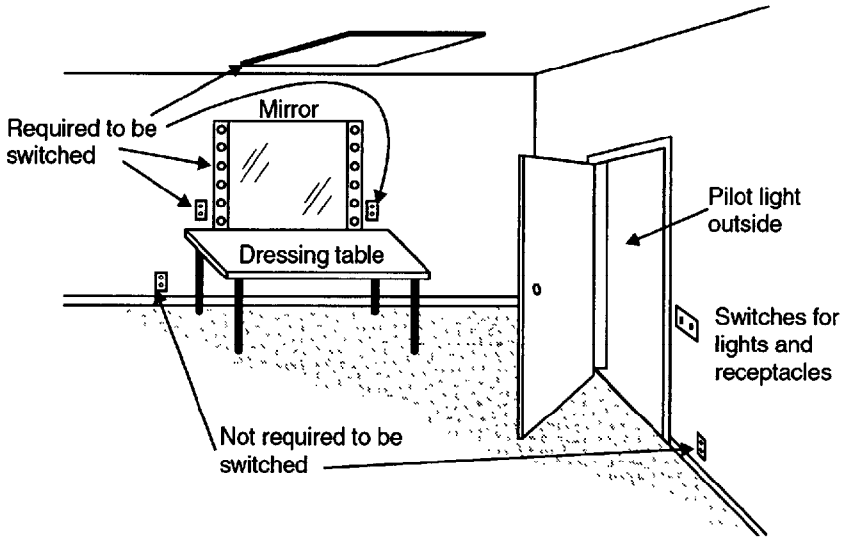
Type of Change Revision

BRIEF SUMMARY

Theaters. Receptacles not located at a dressing table in a dressing room may be unswitched. The required pilot light must be located outside the dressing room, adjacent to the door.

Code Language

520-73. Switches Required. All lights **and any receptacles adjacent to the mirror(s) and above the dressing table counter(s) installed in dressing rooms shall be controlled by wall switches installed** in the dressing room(s). Each switch controlling receptacles **adjacent to the mirror(s) and above the dressing table counter(s)** shall be provided with a pilot light **located outside the dressing room, adjacent to the door** to indicate when the receptacles are energized. **Other outlets installed in the dressing room shall not be required to be switched.** (ROP 15-49)



Switched Receptacles in Dressing Rooms

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Application

Switches must be provided to control lights and receptacles in dressing rooms. This change now requires only receptacles located adjacent to mirrors or above dressing tables to be switched. A pilot light must be provided to indicate that the switch is on. The pilot light must be located outside the dressing room. The illustration shows switches controlling receptacles and lights in a dressing room. A separate pilot light for monitoring the switched receptacles must be installed outside the dressing room. Receptacles not at the dressing table are not required to be switched.

Background and Explanation

Receptacles are often provided in dressing rooms for refrigerators, computers, and similar appliances. Such appliances are not required to be controlled by wall switches. Those receptacles that are likely to be used for hair dryers and similar devices that might present a hazard if left on are required to be controlled by switches. This change also requires that the pilot lights for such switched receptacles be located outside the room. The switches are required to be installed inside the dressing room.

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525-12(a) & 13(g) Conductors Inside Tents; Protection for Lamps Inside Tents

Type of Change Revision; New

BRIEF SUMMARY

Carnivals circuses, fairs, and similar events. The vertical clearances of Section 225-18 apply only to wiring outside tents. Wiring inside of tents must be protected from physical damage, and guards must be provided for lamps.

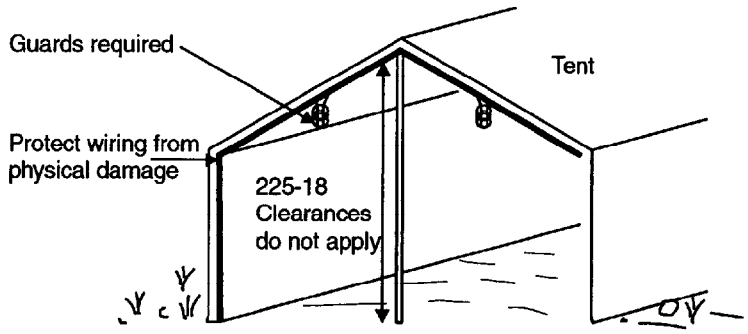
Code Language

525-12. Overhead Conductor Clearances.

(a) Vertical Clearances. Conductors shall have a vertical clearance to ground in accordance with Section 225-18. **These clearances shall apply only to wiring installed outside of tents and concessions.** (ROP 15-54)

525-13. Wiring Methods.

(g) Inside Tents and Concessions. Electrical wiring for temporary lighting, where installed inside of tents and concessions, shall be securely installed, and where subject to physical damage, shall be provided with mechanical protection. All temporary lamps for general illumination shall be protected from accidental breakage by a suitable fixture or lampholder with a guard. (ROP 15-55)



Wiring Inside Tents

Application

The illustration shows a small tent used at a carnival or fair. As shown in the illustration, the vertical clearances of Section 225-18 do not apply to wiring inside of tents. The wiring inside of a tent must be protected from physical damage and lamps used for temporary lighting must be provided with guards.

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Background and Explanation

Many small tents do not have adequate height to maintain the heights required by Section 225-18 for outside wiring, so the wiring inside such tents is exempted by this change. However, the wiring and lamps must be protected against physical damage.

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525-18 GFCI Requirements for Carnivals, Circuses, and Fairs

Type of Change Revision

BRIEF SUMMARY

Carnivals and similar events. GFCI protection is required for some 125-volt, 15- and 20-ampere receptacles.

Code Language

525-18. Ground-Fault Circuit-Interrupter Protection for Personnel.

(a) General-Use 15- and 20-Ampere, 125-Volt Receptacles. All 125-volt, single-phase, 15- and 20-ampere receptacle outlets that are in use by personnel shall have listed ground-fault circuit-interrupter protection for personnel. The ground-fault circuit interrupter shall be permitted to be an integral part of the attachment plug or located in the power-supply cord, within 12 in. (305 mm) of the attachment plug. For the purposes of this section, listed cord sets incorporating ground-fault circuit-interrupter protection for personnel shall be permitted. Egress lighting shall not be connected to the load side terminals of a ground-fault circuit-interrupter receptacle.

(b) Appliance Receptacles. Receptacles supplying items, such as cooking and refrigeration equipment, which are incompatible with ground-fault circuit-interrupter devices shall not be required to have ground-fault circuit-interrupter protection. (ROC 15-53) (TCC 15-52, 15-53)

(c) Other Receptacles. Other receptacle outlets not covered in (a) or (b) shall be permitted to have ground-fault circuit-interrupter protection for personnel, or a written procedure shall be continuously enforced at the site by one or more designated persons to ensure the safety of equipment grounding conductors for all cord sets and receptacles, as described in Section 305-6(b)(2). (ROP 15-68)(ROC 15-53) (TCC 15-52)

Application

GFCI protection for 125-volt, 15- and 20-ampere receptacles may be provided by several methods. As in any other location, the required protection can be achieved through a GFCI circuit breaker or GFCI-type device. Section 525-18(a) recognizes GFCI devices that are an integral part of the cord.

Some older cooking or refrigeration equipment may not be compatible with Class A GFCI devices (those designed to operate at 5mA). In these situations, Section 525-18(b) permits the omission of the GFCI protection.

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GFCI Protection for Receptacles at Carnivals, Circuses, and Fairs

Background and Explanation

Carnival set-up and tear-down is frequently done in bad weather. Due to the presence of moisture and wear and tear to cords due to frequent moves, additional levels of protection are needed. This revision provides for protection similar to Article 305 for temporary wiring yet also provides for some special needs such as the use of older refrigeration and cooking equipment that may have higher levels of leakage currents than newer appliances.

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NEC pp. 397–398

547-8 Disconnects and Grounding at Agricultural Buildings

Type of Change New

BRIEF SUMMARY

Agricultural buildings. The term "distribution point" was defined. Three arrangements of service and feeder disconnects and overcurrent protection were created. The previous requirements of Section 547-8 on bonding and creation of an equipotential plane were revised and relocated to Section 547-9.

Code Language

547-8. Service Equipment, Separately Derived Systems, Feeders, Disconnecting Means, and Grounding. Where one or more agricultural buildings are supplied from a distribution point, the disconnecting means and grounding of services and feeders shall comply with (a), (b), or (c).

(a) Disconnecting Means and Overcurrent Protection at a Building(s). Where the disconnecting means and overcurrent protection are located at the load end of the service conductors, service equipment grounding shall meet the requirements of Section 250-24. A disconnecting means shall also be installed at the distribution point when two or more buildings are supplied from that distribution point.

(b) Disconnecting Means and Overcurrent Protection at Distribution Point. Where the disconnecting means and overcurrent protection are located at the distribution point, feeders to buildings shall meet the requirements of Section 250-32 and Article 225, Part B. (TCC 19-8)

(c) Disconnecting Means Without Overcurrent Protection at the Distribution Point. Where the disconnecting means without overcurrent protection is located at the distribution point and a disconnecting means and overcurrent protection is located at the building(s), the grounded circuit conductor connection to the grounding electrode shall not be permitted at the building disconnecting means at each building and all of the following conditions shall be met.

(1) All buildings and premises wiring are under single management.

(2) Disconnecting means suitable for use as service equipment is provided at the distribution point.

(3) An equipment grounding conductor is run with the supply conductors and is of the same size as the largest supply conductor, if of the same material, or is adjusted in size in accordance with the equivalent size columns of Table 250-122 if of different materials.

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(4) The equipment grounding conductor is bonded to the grounded circuit conductor at the distribution point or at the source of a separately derived system.

(5) A grounding electrode system is provided and connected to the equipment grounding conductor at the building disconnecting means.

Distribution Point. A centrally located electrical supply structure from which services or feeders to agricultural buildings and other buildings, including the associated farm dwelling, are normally supplied. (ROC 19-7, 19-8)

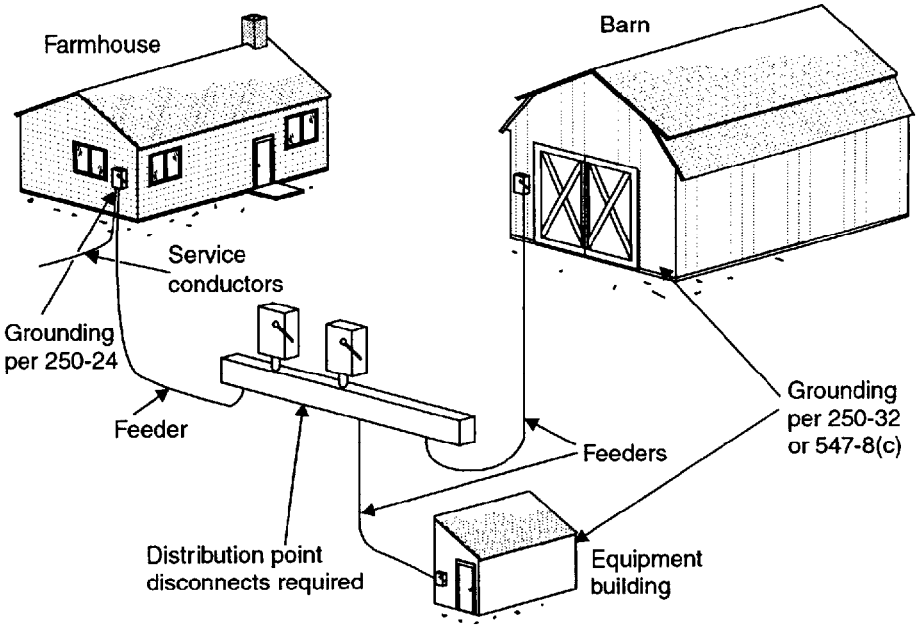

Figure 1. Distribution Point on Load Side of Service

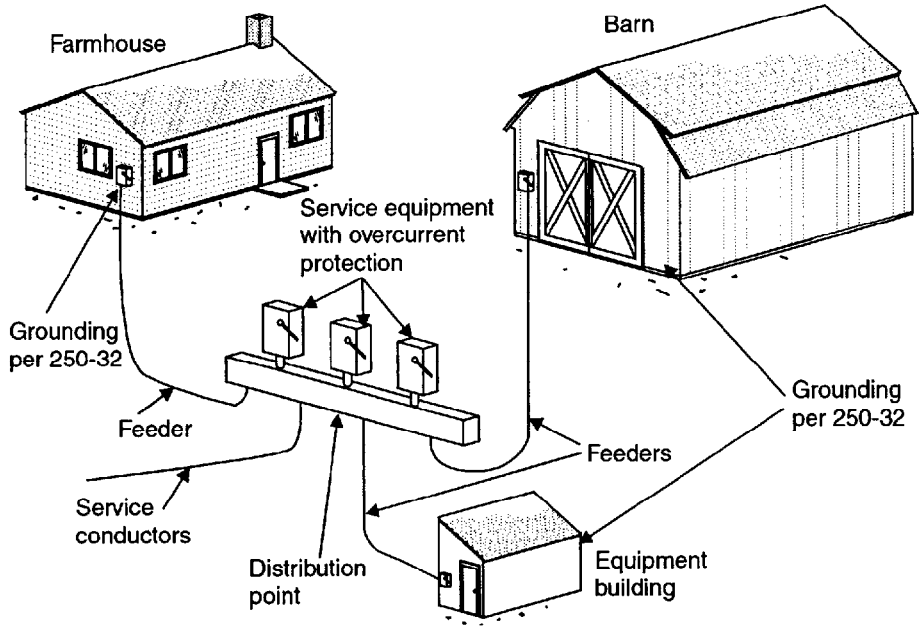

Figure 2. Service Disconnects and Overcurrent Protection at Distribution Point

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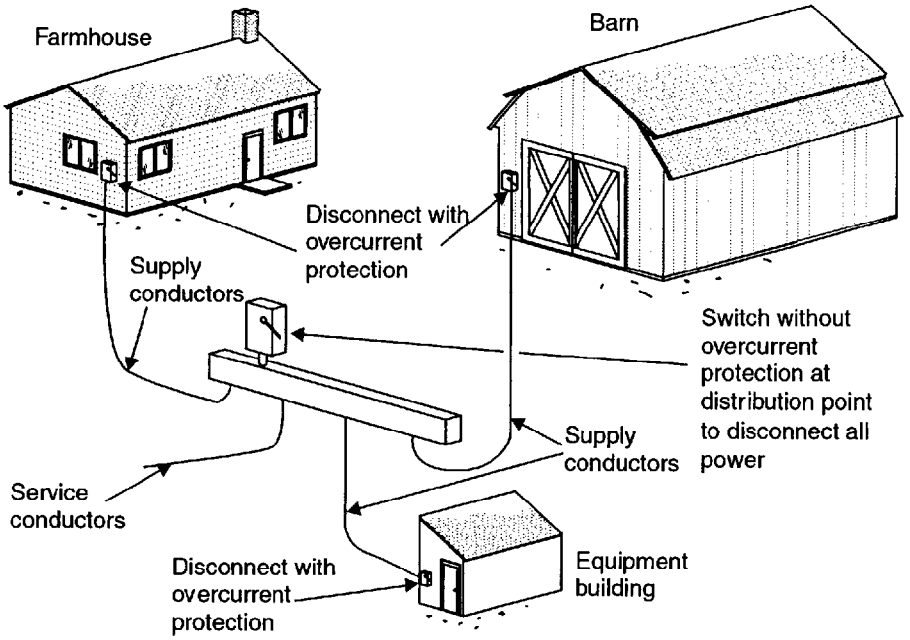

Figure 3. Disconnecting Means at Distribution Point. Note: All grounding to comply with 547-8(c)

Application

Three basic arrangements for distribution of power to groups of agricultural buildings from a distribution point are recognized in Section 547-8. The three arrangements are shown in the three illustrations. These arrangements are intended to provide a common disconnecting point for this type of multibuilding complex and to address the grounding concerns inherent to multiple grounding points.

Figure 1 corresponds to Section 547-8(a). In this case, the service disconnect and service overcurrent devices are located at one of the buildings. A feeder is extended from the service to a distribution point. The distribution point in turn feeds two additional buildings. An additional disconnecting means is required at the distribution point for each of the buildings that is fed from that location. A disconnecting means may be one or more disconnects. Grounding of the service equipment at the farmhouse must meet the regular requirements of Section 250-24.

Figure 2 corresponds to Section 547-8(b). While this example shows the service disconnecting means and overcurrent device(s) located at the distribution point. Feeders extend from the distribution point to the individual buildings. Separate disconnects are then provided at each building in accordance with Section 225-31, and grounding at the separate buildings is in accordance with 250-32.

Figure 3 corresponds to Section 547-8(c). While the first two arrangements discussed above fall under established rules in the code, the third arrangement represents a new rule. (This new rule is similar to 547-8(a) Exception No. 1 in the 1996 NEC but is different in a few respects. See the discussion under Background and Explanation.) In this case, a main disconnect suitable for use as service equipment is installed without overcurrent protection at the distribution point. A disconnecting means with overcurrent protection is installed at each building. Bonding jumpers may not be installed between the grounding electrodes and the grounded conductors at the separate buildings. In addition, five other requirements must be met:

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1. All buildings and premises wiring must be under single management.
2. The disconnecting means must be suitable for use as service equipment even though it does not include overcurrent devices.
3. An equipment grounding conductor must be run with the supply conductors to each building, and the size of each equipment grounding conductor must be equivalent to the largest supply conductor to each building or is adjusted in size according to Table 250-122 where constructed of a different material than the supply conductors.
4. The equipment grounding conductor must be bonded to the grounded conductor at the distribution point.
5. A grounding electrode system must be provided at each building and must be bonded to the equipment grounding conductor at each building disconnect.

Background and Explanation

The first two arrangements outlined in this new rule are not new at all. They both fall under existing rules of the code. Although much of what is now in Section 547-8(c) was previously in Section 547-8(a), Exception No. 1, significant changes were made in this third arrangement. The changes in language have created some important differences from the previous rules of the code and some variations from common practices.

One significant difference can be seen by attempting to label the conductors in Figure 3 using defined terms for conductors. Service conductors end at a "service disconnect" by definition. However, according to the definitions of feeders and service equipment, feeders are those conductors between the "service equipment" and the branch-circuit overcurrent devices, and service equipment normally includes overcurrent devices in the form of circuit breakers or fuses. The switch at the distribution point described in this section is considered to be a premises supply disconnecting means, but overcurrent protection is not required at this location, therefore it is not considered to be the service disconnecting means. The conductors between the distribution point and the building disconnects are not service conductors, and they don't quite match the usual definition of feeders either. However, these supply conductors do fit the description of "outside taps of unlimited length" as described in Section 240-21(b)(5).

Another issue is in the variations in equipment requirements. Although the distribution point disconnect must be suitable for use as service equipment, it is not required to provide overcurrent protection. Section 230-91 requires the service overcurrent protection to be a part of the service disconnect or located immediately adjacent to it. Also, a common practice has been to use pole-top switches as the distribution point disconnecting means, but such switches are not listed as being "suitable for use as service equipment."

According to Section 90-3, Article 547 may modify the requirements of Chapters 1 through 4. However, the new rules of Section 547-8(c) are unique to agricultural buildings, so they should be carefully reviewed with the authority having jurisdiction to ensure compliance with local interpretations.

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547-9(a) & (b) Equipotential Plane

Type of Change Revision

BRIEF SUMMARY

Agricultural buildings. Requirements for equipotential planes have been clarified.

Code Language

547-9. **Bonding and Equipotential Plane.**

(a) Definition of Equipotential Plane. An area accessible to livestock where a wire mesh or other conductive elements are embedded in concrete, are bonded to **all metal structures and fixed nonelectrical metal equipment that may become energized** and are connected to the electrical grounding system to prevent a difference in voltage from developing within the plane. **For this section, livestock does not include poultry.**

(b) General. Wire mesh or other conductive elements shall be installed in the concrete floor of livestock confinement areas and be bonded to the building grounding electrode system to provide an equipotential plane that ~~has a~~ **may have** voltage gradient **ramps** at entrances and exits **that are traversed daily by the same livestock.** The bonding conductor shall be copper, insulated, covered or bare, and not smaller than No. 8. The means of bonding to wire mesh or conductive elements shall be by pressure connectors or clamps of brass, copper, copper alloy, or an equally substantial approved means.

Exception No. 1: An equipotential plane shall not be required where there is no electric service to the building nor metal equipment accessible to livestock that is likely to become energized.

Exception No. 2: Slatted floors that are supported by structures that are a part of an equipotential plane shall not be required to be bonded.

FPN No. 1: A natural voltage gradient exists at the edge of an equipotential plane. Typically, voltage gradients exceeding 1 volt per foot at the edge of the equipotential plane will require a voltage gradient ramp.

FPN No. 2: Methods to establish equipotential planes and voltage gradient ramps are described in *Equipotential Planes in Animal Containment Areas,* American Society of Agricultural Engineers (ASAE) EP473-1997.

FPN No. 3: Low grounding electrode system resistances may reduce potential differences in livestock facilities.

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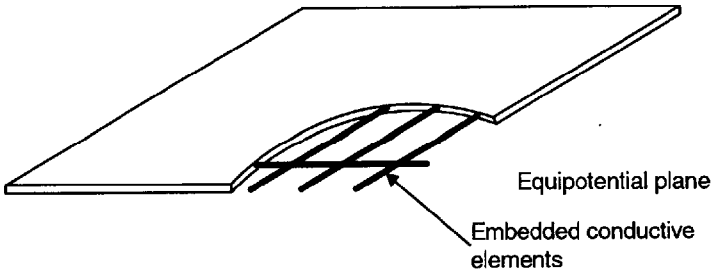

Equipotential Plane in Agricultural Buildings with Livestock

Application

New Exception No. 1 clarifies that equipotential planes are not necessary if stray voltage cannot be encountered. New Exception No. 2 clarifies that slatted floors that are supported by the equipotential plane do not require additional bonding. Three new FPNs were added to provide information on equipotential planes.

Background and Explanation

This revision is intended to clarify where equipotential planes are required and how they should be installed. One of the concerns expressed to the panel addressed livestock buildings in which the livestock are born and raised in the same building (but do not leave) and are not exposed to gradient ramps or entrances and exits. Generally these buildings have steel embedded in the concrete (many are slatted floor construction) and making field connections to the reinforcing steel through the concrete exposes the steel to the severe corrosive environment common to this type of building.

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547-9(c) GFCI Protection in Equipotential Plane Areas

Type of Change Revision

BRIEF SUMMARY

Agricultural buildings. GFCI protection is required for receptacles in equipotential plane areas.

Code Language

547-9. Bonding and Equipotential Plane.

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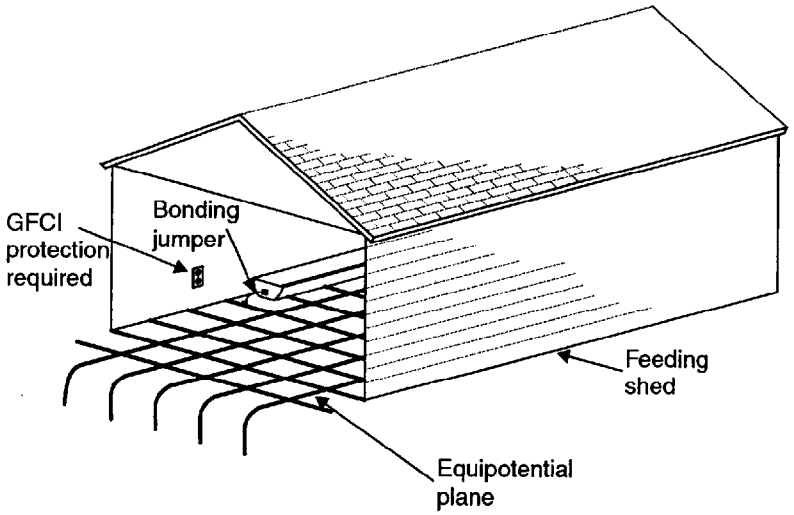
(c) Receptacles. All 125-volt, single-phase, 15- and 20- ampere general purpose receptacles in areas having an equipotential plane shall have ground-fault circuit-interrupter protection for personnel. (ROC 19-15)



Receptacles in Equipotential Plane Areas

Application

The illustration shows an agricultural building with an equipotential plane and metal equipment bonded to the equipotential plane. The 15- or 20-ampere, 125-volt receptacle installed in the area of the equipotential plane must be GFCI protected.

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Background and Explanation

The conditions in livestock buildings are much like those in other locations where GFCI protection is required by the code for 15- and 20-ampere, 125-volt receptacles. The livestock area is likely to be wet or damp, and, because of the equipotential plane, personnel are likely to be in contact with grounded objects or surfaces when using portable electric tools or appliances. The substantiation for this new requirement cited several electric shock incidents that have occurred in these areas.

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550-2 & 550-23(a) & (b) Revised Definition of Manufactured Home; Requirements for Mobile and Manufactured Homes

NEC pp. 399 & 406

Type of Change Revision

BRIEF SUMMARY

Mobile and manufactured homes. The definition of "manufactured home" is clarified. Service location requirements have been modified.

Code Language

550-2. Definitions.

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Manufactured Home. A factory-assembled structure or structures **that bears a label identifying it as a manufactured home that is transportable** in one or more sections, that is built on a permanent chassis and designed to be used as a dwelling with or without a permanent foundation ~~acceptable to the authority having jurisdiction~~ where connected to the required utilities, and that includes the plumbing, heating, air-conditioning, and electrical systems contained therein. (ROP 19-47) (ROC 19-16)

FPN No. 1: See the applicable building code for definition of the term *permanent foundation.*

FPN No. 2: See Part 3280, *Manufactured Home Construction and Safety Standards,* of the federal Department of Housing and Urban Development for additional information on the definition.

For the purpose of this *Code* and unless otherwise indicated, the term *mobile home* includes manufactured homes. (ROP 19-47)

550-23. Service Equipment.

(a) Mobile Home Service Equipment. The mobile home service equipment shall be located adjacent to the mobile home and not mounted in or on the mobile home. The service equipment shall be located in sight from and not more than 30 ft (9.14 m) from the exterior wall of the mobile home it serves. The service equipment shall be permitted to be located elsewhere on the premises, provided that a disconnecting means suitable for service equipment is located in sight from and not more than 30 ft (9.14 m) from the exterior wall of the mobile home it serves. Grounding at the disconnecting means shall be in accordance with Section 250-32.

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(b) Manufactured Home Service Equipment. The manufactured home service equipment shall be permitted to be installed in or on a manufactured home, provided that all of the following conditions are met.

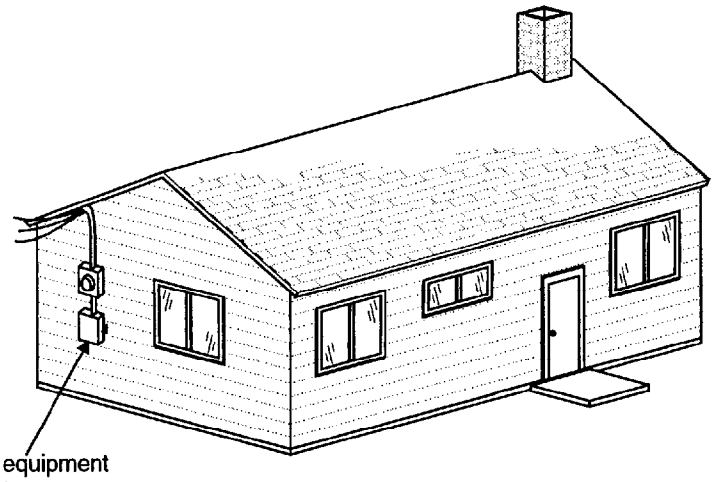
(1) The manufactured home is secured to a permanent foundation that complies with applicable building codes.

(2) The service equipment is installed in a manner acceptable to the authority having jurisdiction.

(3) The installation of the service equipment complies with Article 230.

(4) Means are provided for the connection of a grounding electrode conductor to the service equipment and routing it outside the structure.

(ROP 19-68a)



Manufactured Home Services

Application

Mobile homes and manufactured homes are similar in appearance. The revised definition makes it clear that a manufactured home bears a label identifying it as a manufactured home. Section 550-23(a) prohibits the mounting of a service on a mobile home. Section 550-23(b) allows the service to a manufactured home to be mounted on the home in controlled situations.

Background and Explanation

The definition was revised for clarity. The new definition helps the user to distinguish between the service rules in Sections 550-23(a) and (b). By specifically addressing each type of construction, the code has delineated where it is permitted to attach the service equipment to the structure and where it is necessary to provide a pedestal (or similar supply structure) detached and within 30 feet.

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NEC pp. 402 & 423

550-8(g) & 552-41(d) Circuit Requirements for Heat Tape GFCI Protection

Type of Change Revision

BRIEF SUMMARY

Residential. Outlets for "heat tape" on mobile homes and park trailers must be connected to an interior GFCI protected circuit.

Code Language

550-8. Receptacle Outlets.

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(g) Pipe Heating Cable Outlet. Where a pipe heating cable outlet is installed, the outlet shall be as follows:

(1) Located within 2 ft (610 mm) of the cold water inlet

(2) Connected to an interior branch circuit, other than a small appliance branch circuit. It shall be permitted to utilize a bathroom receptacle circuit for this purpose (ROP 19-57) (ROC 19-19a)

(3) On a circuit where all of the outlets are on the load side of the ground-fault circuit-interrupter protection for personnel (ROP 19-57)

(4) Mounted on the underside of the mobile home and shall not be considered to be the outdoor receptacle outlet required in Section 550-8(e).

552-41. Receptacle Outlets Required.

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(d) Pipe Heating Cable Outlet. Where a pipe heating cable outlet is installed, the outlet shall be as follows:

(1) Located within 2 ft (610 mm) of the cold water inlet

(2) Connected to an interior branch circuit, other than a small appliance branch circuit

(3) On a circuit where all of the outlets are on the load side of the ground-fault circuit-interrupter protection for personnel

(4) Mounted on the underside of the park trailer and **shall not be considered to be the outdoor receptacle outlet required in Section 552-41(e)**

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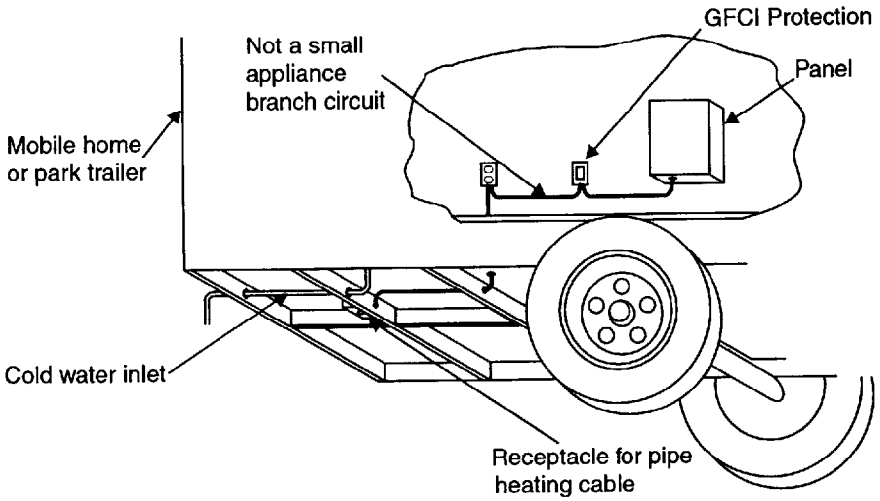

Pipe Heating Cable Outlets

Application

Outlets for pipe heating cable on mobile homes and park trailers must be GFCI protected and the outlet must be connected to an interior branch circuit that is protected by a GFCI device. All outlets on the circuit must be GFCI protected. A GFCI-type circuit breaker or a GFCI device installed in the first outlet on the circuit could be used to protect all outlets. The circuit used may not be a small appliance branch circuit. However, Section 210-11(c)(3), which requires dedicated circuits for bathroom receptacles, is not applicable to park trailers (not a permanent dwelling unit) or to mobile homes (Section 550-8(g)(2) specifically permits connection to the bathroom circuit). Therefore the branch circuit supplying bathroom receptacles is permitted to supply the outlet for pipe heating cable. The "heat tape" outlet must be located within 2 feet of the cold water inlet to the park trailer or mobile home. The illustration shows a typical installation meeting the requirements of this rule.

Background and Explanation

These rules are more restrictive than the rule of Section 427-22 that requires ground-fault protection for equipment. GFCI protection was determined to be acceptable protection for pipe heating cable in mobile homes according to a study by the U.S. Consumer Product Safety Commission and Underwriters Laboratories. The length of heating cable involved in such installations is relatively short and the load relatively small, so overloading of circuits or nuisance tripping of GFCI devices is unlikely. The requirement that the outlet be on an interior circuit on which all other outlets are protected was added to increase the likelihood that a tripped GFCI device would be noticed by the occupant. Mobile homes and park trailers are similar to each other and different from recreational vehicles because both mobile homes and park trailers are likely to be "permanently" installed with connections to water piping. The term "pipe heating cable" was substituted for the less accurate term "heat tape."

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551-41(c)(2) Exc. No. 3 Retractable Walls and GFCI Protection

Type of Change Revision; New Exception

BRIEF SUMMARY

Residential. De-energized receptacles that are within 6 feet of a sink only while retracted into travel mode need not be GFCI protected.

Code Language

551-41. Receptacle Outlets Required.

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(c) Ground-Fault Circuit-Interrupter Protection. Where provided, each 125-volt, single-phase, 15- or 20-ampere receptacle outlet shall have ground-fault circuit-interrupter protection for personnel in the following locations:

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(2) Where the receptacles are installed to serve the countertop surfaces, and are within 6 ft (1.83 m) of any lavatory or sink (ROP 19-101)

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Exception No. 3: De-energized receptacles that are within 6 ft (18.3 m) of any sink or lavatory due to the retraction of the expandable room section. (ROP 19-100)

Application

Some recreational vehicles have sections that retract into a compact configuration for travel. Interior walls with receptacles may be retracted into a position that puts the receptacles within 6 feet of a sink while in the travel mode. Such de-energized receptacles are not required to have GFCI protection.

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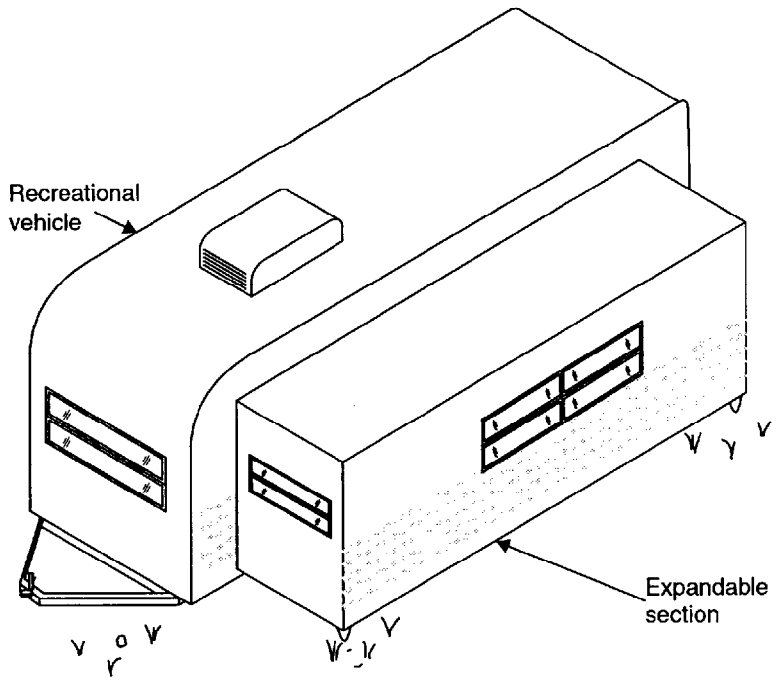

Recreational Vehicle with Retractable Wall Section

Background and Explanation

Although the substantiation stated that receptacles could be energized while in the retracted position, the panel action exempts such receptacles only if they are de-energized. Thus, a receptacle that is energized and within 6 feet of a sink while in the retracted position is not exempted from the GFCI requirement.

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551-60(b) Testing of Low-Voltage Wiring Systems

Type of Change Revision

BRIEF SUMMARY

Recreational vehicles. Factory testing requirements have been revised.

Code Language

551-60. Factory Tests (Electrical). Each recreational vehicle shall be subjected to the following tests.

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(b) Low-Voltage Circuits. An operational test of all low-voltage circuits shall be conducted to demonstrate that all equipment is connected and in electrical working order. **This test shall be performed in the final stages of production after all** ~~The test shall be permitted on running light circuits before the lights are installed provided the vehicle's~~ outer coverings and cabinetry have been secured. (ROP 19-117) (ROC 19-32a) (TCC 19-32a)

Background and Explanation

Section 551-60(b) has been revised based on the testing requirements found in Section 550-12(b)(2) for mobile homes. Specific parameters for duration and voltage level of the testing was removed based on a substatiation that the materials (90°C and 125°C) insulation used for the low-voltage wiring systems in today's recreational vehicles are much safer than wiring systems used in older models. The only test required is a functional test.

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551-72 Three-Phase Distribution Systems in RV Parks

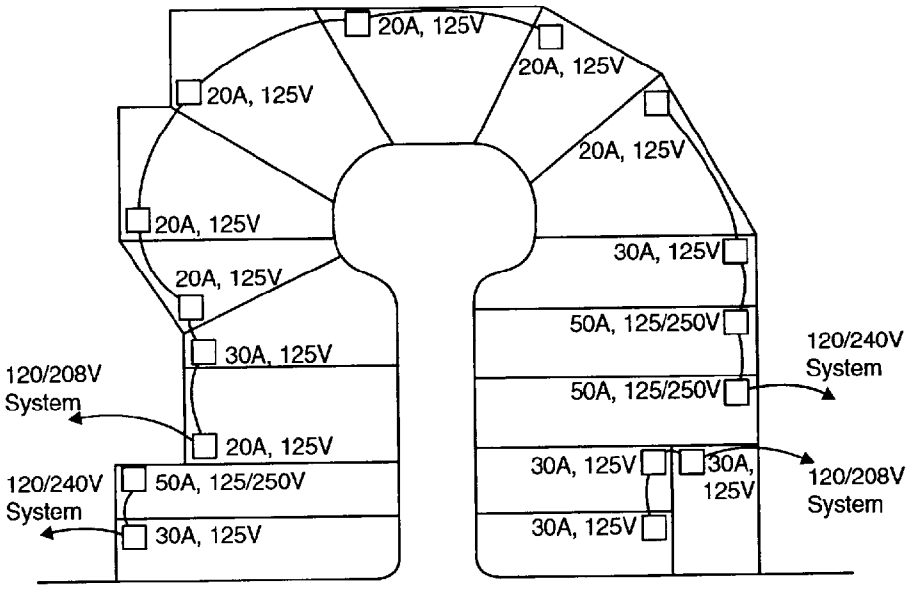
Type of Change Revision

BRIEF SUMMARY

Recreational vehicles. RV sites with 20- and 30-ampere, 120-volt receptacles are not required to be supplied by only 120/240-volt, single-phase systems.

Code Language

551-72. Distribution System. The recreational vehicle park secondary electrical distribution system to 50-ampere recreational vehicle sites shall be derived from a single-phase, 120/240-volt, 3-wire system. **Other recreational vehicle sites with 125-volt, 20- and 30-ampere receptacles may be derived from any grounded distribution system that supplies 120-volt single-phase power.** The neutral conductors shall not be reduced in size below the size of the ungrounded conductors for the site distribution. The neutral conductors shall be permitted to be reduced in size below the minimum required size of the ungrounded conductors for 240-volt, line-to-line, permanently connected loads only. (ROP 19-123)



RV Park Power Distribution

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Application

The illustration shows a portion of a recreational vehicle park. Those sites served by 50-ampere receptacles are required to be derived from a 120/240-volt, single-phase system. Other sites with 20- or 30-ampere receptacles may be derived from other grounded systems that supply 120-volt power.

Background and Explanation

According to Section 551-71, the receptacles used at recreational vehicle sites are to be 20 or 30 ampere, 125 volt, or 50 ampere, 125/250 volt. Thus, the 20- or 30-ampere sites can be supplied by any system that delivers 120-volt grounded circuits and 120/208-volt, single- or 3-phase systems can be used to meet the requirements of the 20- and 30-ampere sites. On the other hand, only 120/240-volt systems can be used to supply the proper voltages for the 50-ampere sites. The 50-ampere circuits supply equipment, such as air conditioners that are designed to operate at 240 volts. A 208-volt supply will not permit the equipment to operate properly.

This change would allow an entire site to be served by a 120/208-volt 3-phase system. Separately derived systems could be used to supply the 120/240-volt power to the 50-ampere sites. This permits a significant degree of design flexibility in supplying power to the RV sites as well as the other buildings and facilities that are sometimes included in RV parks. According to the substantiation for this proposal, 3-phase systems have sometimes been denied for entire parks based on the previous wording of this rule.

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NEC pp. 420 & 424

551-80(b) & 552-43(c) Liquidtight Flexible Nonmetallic Conduit

Type of Change Revision

BRIEF SUMMARY

Recreational vehicles and park trailers. Additional wiring methods for supplying RVs and park trailers are allowed.

Code Language

551-80. Underground Service, Feeder, Branch-Circuit, and Recreational Vehicle Site Feeder-Circuit Conductors.

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(b) Protection Against Physical Damage. Direct-buried conductors and cables entering or leaving a trench shall be protected by rigid metal conduit, intermediate metal conduit, electrical metallic tubing with supplementary corrosion protection, rigid nonmetallic conduit, **liquidtight flexible nonmetallic conduit, liquidtight flexible metal conduit,** or other approved raceways or enclosures. Where subject to physical damage, the conductors or cables shall be protected by rigid metal conduit, intermediate metal conduit, or Schedule 80 rigid nonmetallic conduit. All such protection shall extend at least 18 in. (457 mm) into the trench from finished grade. (ROP 19-128) (ROC 19-36)

552-43. Power Supply.

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(c) Mast Weatherhead or Raceway. Where the calculated load exceeds 50 amperes or where a permanent feeder is used, the supply shall be by means of one of the following:

(1) One mast weatherhead installation, installed in accordance with Article 230, containing four continuous, insulated, color-coded feeder conductors, one of which shall be an equipment grounding conductor; or

(2) A metal raceway, rigid nonmetallic conduit, **or liquidtight flexible nonmetallic conduit** from the disconnecting means in the park trailer to the underside of the park trailer, with provisions for the attachment to a suitable junction box or fitting to the raceway on the underside of the park trailer [with or without conductors as in Section 550-5(i)(1)] (ROP 19-142, 19-144)

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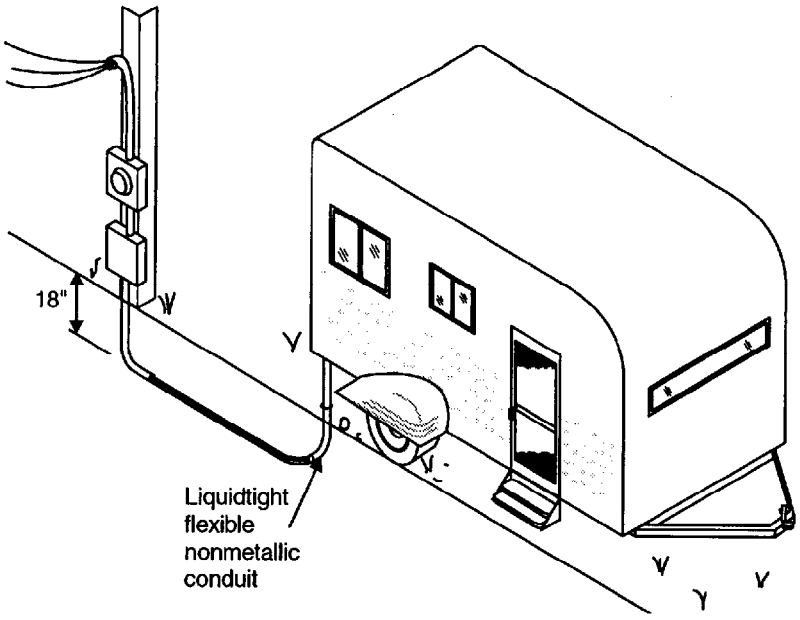

LFNMC for Supply to Park Trailer

Application

Section 551-80(b) now permits the use of liquidtight flexible nonmetallic conduit or liquidtight flexible metal conduit for protection of supply conductors to recreational vehicle sites. This protection is required where direct-buried conductors are brought above ground to supply electrical equipment at recreational vehicle sites. These methods are permitted where the conductors are not subject to physical damage.

Section 552-43(c)(2) has been revised to allow the use of liquidtight flexible nonmetallic conduit as a wiring method from the interior disconnecting means to the underside of the park trailer. A transition method using either a box or fitting is required at the underside of the unit for the connection to the supply wiring system.

Background and Explanation

These two sections have been expanded to permit additional wiring methods that will provide protection for conductors and allow some degree of flexibility.

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552-43(a) Field-Installed Cord Caps

Type of Change Revision

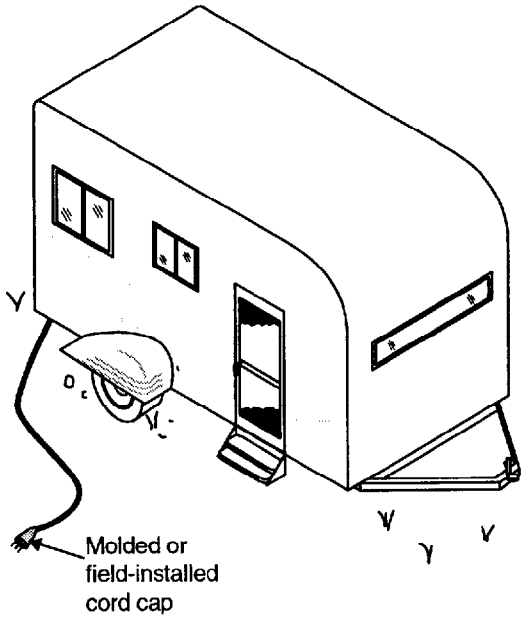
BREIF SUMMARY

Park trailers. Field-installed cord caps on power supply cords are allowed.

Code Language

552-43. Power Supply.

(a) Feeder. The power supply to the park trailer shall be a feeder assembly consisting of not more than one listed 30-ampere or 50-ampere park trailer power-supply cord with an integrally molded **or securely attached cap,** or a permanently installed feeder. (ROP 19-140)



Park Trailer Power Supply Cord

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Application

The power-supply cord for a park trailer may be equipped with a factory-installed or field-installed cord cap. Supply cords are usually furnished with a factory-installed molded cord cap. This revision provides for field-installed cord caps for new installations and replacement of damaged cord caps at existing installations.

Background and Explanation

This section for park trailer installations is now the same as the requirements in Section 550-5(a) for mobile home power cords.

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555-4 Disconnecting Means for Shore Power to Boats

Type of Change New

BRIEF SUMMARY

Marinas. A circuit breaker or switch must be provided to disconnect a boat from its shore power supply.

Code Language

555-4. Disconnecting Means. A readily accessible disconnecting means shall be provided by which each boat can be isolated from its supply circuit. The disconnecting means shall consist of a circuit breaker or switch, or both, and shall be located within sight of the shore power connection and is intended to constitute the means of cutoff of the supply to the boat. (ROC 19-49)

Application

Disconnects in the form of circuit breakers or switches must be included in the shore power supplies for boats in marinas and boatyards. The disconnects are required to be readily accessible and within sight of the shore power connection to the boat. Each boat must be provided with such a disconnecting means. These disconnects are in addition to any disconnects provided in the form of a cord-and-plug connection.

Background and Explanation

This change reinforces the similar requirement in Section 3-15.2 of NFPA 303-1995 *Fire Protection Standard for Marinas and Boatyards*. Even though a receptacle may provide the shore power connection, the cord-and-plug connection may present a hazard to a person attempting to unplug the power supply cord in the wet environment of a marina or boatyard. A partially withdrawn attachment plug may expose a user to live parts. A switch or circuit breaker reduces the exposure of the user to live parts. Since users may be unfamiliar with the specific marina, the disconnect must be in sight of the power connection.

This rule was inserted as a new requirement. The previous Sections 555-4 through 555-10 have been renumbered as Sections 555-5 through 555-11.

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600-6 Disconnecting Requirements for Signs

Type of Change Revision

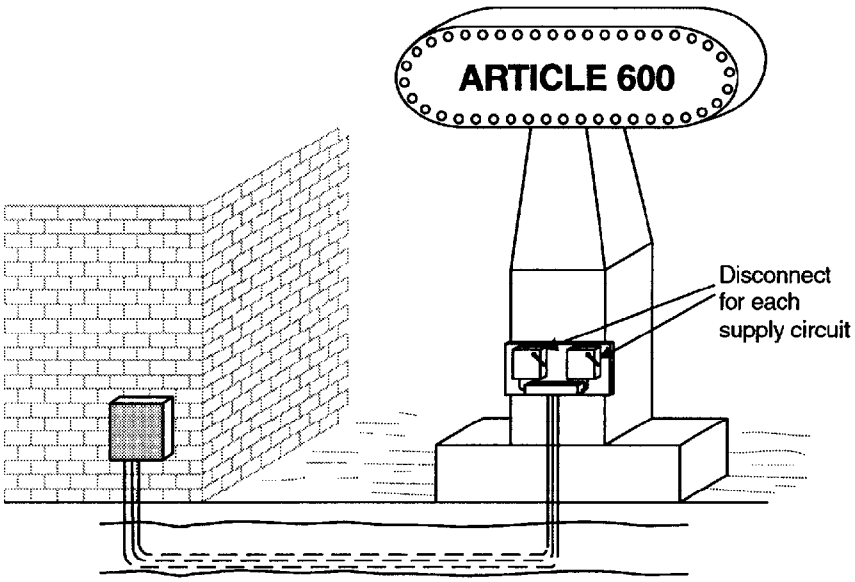
BRIEF SUMMARY

Signs. The requirement for disconnecting means at signs has been clarified.

Code Language

600-6. Disconnects. Each sign and outline lighting system, **or feeder circuit or branch circuit supplying a sign or outline lighting system,** shall be controlled by an externally operable switch or circuit breaker that will open all ungrounded conductors. **Signs and outline lighting systems located within fountains shall have the disconnect located in accordance with Section 680-12.**

(ROP 18-98, 18-101)(ROC 18-82a)



Disconnecting Means for Sign Circuits

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Application

Each feeder or branch circuit supplying a sign must be provided with a disconnect to disconnect all the ungrounded conductors. This disconnect must be within sight of the sign or it is permitted to be located not within sight of the sign provided that it is capable of being locked in the open position.

Background and Explanation

The 1996 NEC required a disconnect for each sign. Some signs are supplied by several circuits and some consist of several sign sections. This revision clarifies that the disconnect must disconnect the power supply and that a separate switch is permitted but not required for each section of a sign.

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600-7 Sign Grounding Requirements

Type of Change Revision

BRIEF SUMMARY

Commercial. Grounding and bonding requirements for signs have been extensively revised.

Code Language

600-7. Grounding. Signs and metal equipment of outline lighting systems shall be grounded. Listed flexible metal conduit or listed liquidtight flexible metal conduit that encloses the secondary wiring of a transformer or power supply for use with electric discharge tubing shall be permitted as a **bonding means in lengths not exceeding 100 ft (30.5 m). Small metal parts not exceeding 2 in. (50.8 mm) in any dimension, not likely to be energized, and spaced at least ¾ in. (19 mm) from neon tubing shall not require bonding.** Where **listed** ~~flexible~~ nonmetallic conduit ~~or tubing~~ is used to enclose the secondary wiring of a transformer or power supply and a bonding conductor is required, the bonding conductor shall be **installed separate and remote from the nonmetallic conduit and be spaced at least 1½ in. (38 mm) from the conduit when the circuit is operated at 100 Hz or 1¾ in. (44.45 mm) when the circuit is operated at over 100 Hz. Bonding conductors shall be copper and not smaller than No. 14. Metal parts of a building shall not be permitted as a grounded or equipment grounding conductor.** (ROP 18-103) (ROC 18-89)

FPN: Refer to Section 600-32(j) for additional restrictions on length of high-voltage secondary conductors. (ROP 18-103) (ROC 18-89)

Application

The illustration depicts the changes made in this section. Up to 100 feet of liquidtight flexible metal conduit (LFMC) or flexible metal conduit (FMC) that contains the secondary wiring of a transformer or power supply may be used for bonding metal parts of signs that employ electric discharge tubing. Listed nonmetallic conduit (rigid nonmetallic conduit or liquidtight flexible nonmetallic conduit) may be used to enclose secondary wiring, but separate conductors must be used for parts requiring bonding. The separate bonding conductors must be copper and not smaller than No.14 AWG. Bonding conductors must be installed separately with spacings from nonmetallic conduits. The spacing must be at least 1½ inches when the frequency of the circuit is not over 100 hertz, and at least 1¾ inches when the frequency is over

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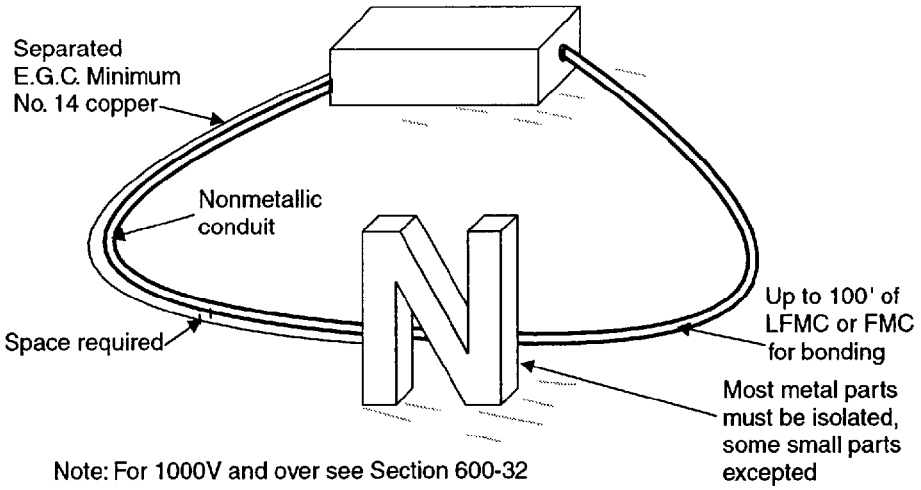
100 hertz. Metal parts of a building may not be used as grounded or grounding conductors. Isolated small metal parts less than 2 inches in any dimension and spaced ¾ inch or more from neon tubing are not required to be bonded.



Sign Wiring

Background and Explanation

Nine changes were made in this section:

1. Liquidtight flexible metal conduit was added as a bonding means.
2. FMC and LFMC up to 100 feet permitted for bonding.
3. "Grounding" changed to "bonding" for the use of flex.
4. Language about the suitability of flexible conduit connectors was deleted.
5. Bonding conductors must be copper and minimum size No.14.
6. Some small metal parts are excluded from bonding requirements.
7. Bonding conductors used with flexible nonmetallic conduit or tubing must be separated and spaced, with the spacing distance depending on frequency.
8. Metal parts of a building may not be used as grounded or grounding conductors.
9. An FPN calls attention to additional restrictions on the length of conductors and permitted wiring methods for secondaries over 1000 volts.

The 100-foot rule and the inclusion of LFMC as a bonding means are based on test data submitted for the 1993 NEC. Bonding is a more accurate and general term with regard to metal parts on the secondary of a sign transformer or power supply. The language about suitability of connectors was redundant, as the general rules of Chapters 1 through 4 already cover this issue. The rule about copper bonding conductors is intended to make it clear that aluminum is not suitable for this use. The language about small metal parts was restored after being inadvertently deleted from the 1993 code, and the specific 2-inch dimension of the parts was added for clarity. Where nonmetallic conduits are used, the required spacing of bonding conductors from the conduit is needed to reduce the deteriorating effects of corona and ozone on the nonmetallic conduit. No specific substantiation for the rule about buildings being used as conductors was provided, but the statement is almost self-evident and also appears in Section 600-32. Section 600-32 limits high-voltage secondary conductor lengths between power supplies and other sign parts to 20 feet in metallic conduits or tubing.

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600-23(f) Marking of Supplies with Secondary Fault Protection

Type of Change New

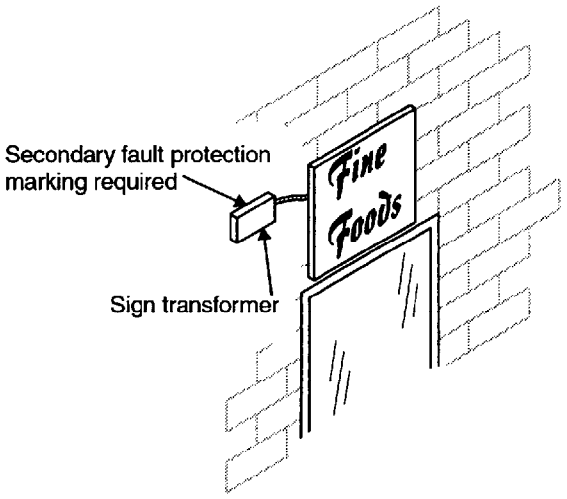
BRIEF SUMMARY

Signs. Secondary fault protection must be marked on sign transformers and power supplies.

Code Language

600-23. Transformers and Electronic Power Supplies.

(f) Marking. A transformer or power supply shall be marked to indicate that it has secondary fault protection. (ROP 18-118)



Marking of Transformers and Power Supplies

Application

Some sign transformers or electronic power supplies are provided with secondary fault protection. Marking of the transformer or power supply is required if the protection is supplied.

Background and Explanation

This marking will assist the inspector in determining that the power supply is code compliant.

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600-32(a) Wiring Methods for Conductors Over 1000 Volts

Type of Change Revision

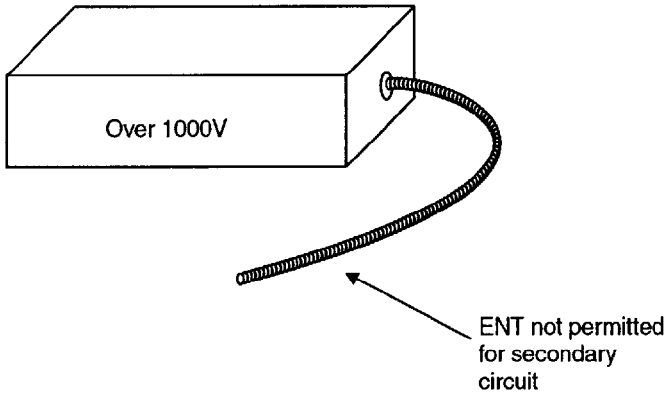
BRIEF SUMMARY

Commercial. Electrical nonmetallic tubing has been eliminated as a wiring method for secondary conductors over 1000V. Nonmetallic conduits are required to have spacing from grounded or bonded parts.

Code Language

600-32. Neon Secondary Circuit Conductors, Over 1000 Volts, Nominal.

(a) Wiring Method. Conductors shall be installed on insulators, in rigid metal conduit, intermediate metal conduit, rigid nonmetallic conduit, liquidtight flexible nonmetallic conduit, flexible metal conduit, liquidtight flexible metal conduit, electrical metallic tubing, ~~electrical nonmetallic tubing~~, metal enclosures, or other equipment listed for the purpose. **Wiring methods shall be installed in accordance with the requirements of Chapter 3.** Only one conductor shall be installed per length of conduit or tubing. **Nonmetallic conduit or flexible nonmetallic conduit, when operated at 100 Hz or less, shall be spaced at least 1½ in. (38 mm) from grounded or bonded parts; and, when operated at over 100 Hz, shall be spaced at least 1¾ in. (44.45 mm) from grounded or bonded parts.** Metal parts of a building shall not be used as a grounded or equipment grounding conductor. (ROP 18-122, 18-124)



Signs with Discharge Lighting Over 1000 Volts

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Application

As shown in the illustration, electrical nonmetallic tubing (ENT) is no longer permitted as a wiring method to enclose secondary conductors of discharge lighting systems over 1000 volts. In addition, where nonmetallic methods are used, they must be spaced from grounded or bonded metal parts. The required spacings are the same as for other nonmetallic conduits containing secondary conductors as outlined in Section 600-7. Conduits of any type are allowed to contain only one conductor.

Background and Explanation

Because conduits are allowed to contain only one conductor, when rigid nonmetallic conduit or liquidtight flexible nonmetallic conduit are used and any sign parts are required to be bonded, the bonding conductor(s) must be run outside of and be separated from the nonmetallic conduit. To quote from the code panel: "The problem encountered with nonmetallic conduit is the inability of the insulation on GTO cable to withstand the electromagnetic stresses created when it comes in close proximity to a grounded surface. The new spacing requirements are considered by CMP 18 as an interim solution to allow time for development of suitable GTO cable and related product safety standards. ENT was deleted because experience has shown that it is too flexible to be able to maintain the specified spacing between itself and a grounded plane."

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604-6(a)(1) & (2) Exc. No. 3 Flexible Cord for Equipment Transitions

Type of Change New

BRIEF SUMMARY

Commercial. Flexible cord is permitted for transitions to equipment from manufactured wiring systems.

Code Language

604-6. Construction.
(a) Cable or Conduit Types.
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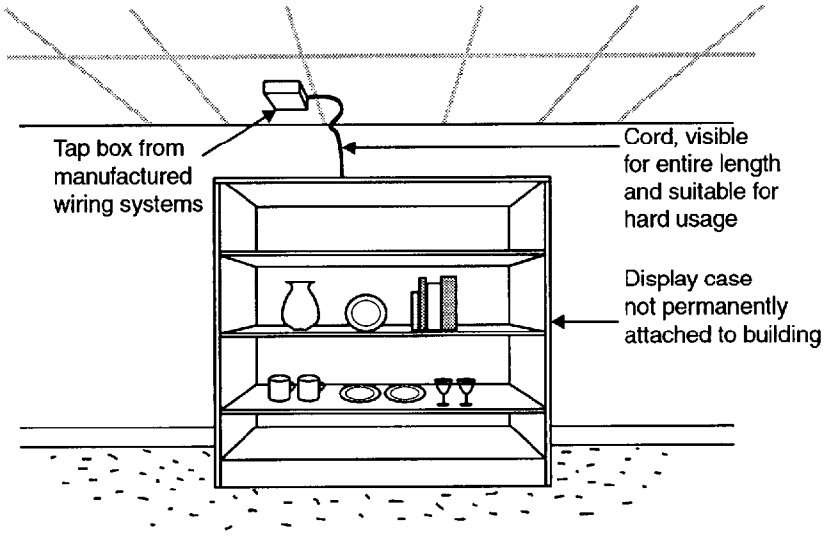
Exception No. 3 to (1) and (2): Flexible cord suitable for hard usage, with minimum No. 12 conductors, shall be permitted as part of a listed factory-made assembly not exceeding 6 ft (1.83 m) in length when making a transition between components of a manufactured wiring system and utilization equipment, not permanently secured to the building structure. The cord shall be visible for its entire length and shall not be subject to strain or physical damage. (ROP 19-177) (ROC 19-167)



Flexible Cords and Manufactured Wiring Systems

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Application

The illustration shows an example of an application of this new exception. Nine conditions must be met for this exception to apply:

1. The conductor size must be No.12 or larger.
2. The cord must be suitable for hard usage.
3. The cord must be part of a listed factory assembly.
4. The cord must not exceed 6 feet in length.
5. The cord must be visible for its entire length.
6. The cord may not be subject to strain or physical damage.
7. The cord is used to make a transition between a manufactured wiring system and utilization equipment.
8. The cord may not supply receptacles. (Receptacles are not utilization equipment.)
9. The utilization equipment supplied must not be permanently secured to the building structure.

Background and Explanation

The substantiation for this proposal listed display cases, merchandise racks, and temporary work stations as intended uses of the new exception. Of the conditions listed above, the code panel added conditions 2, 3, 4, 8, and 9 to the original proposal. The additional conditions were added to protect the cords and prevent their use as a substitute for fixed wiring.

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610-13(d) Crane and Hoist Control Circuit Conductors

Type of Change Revision

BRIEF SUMMARY

Industrial. Control circuit conductors for cranes and hoists may be selected from Article 725.

Code Language

610-13. Types of Conductors. Conductors shall comply with Table 310-13 **unless otherwise permitted in (a) through (d).**

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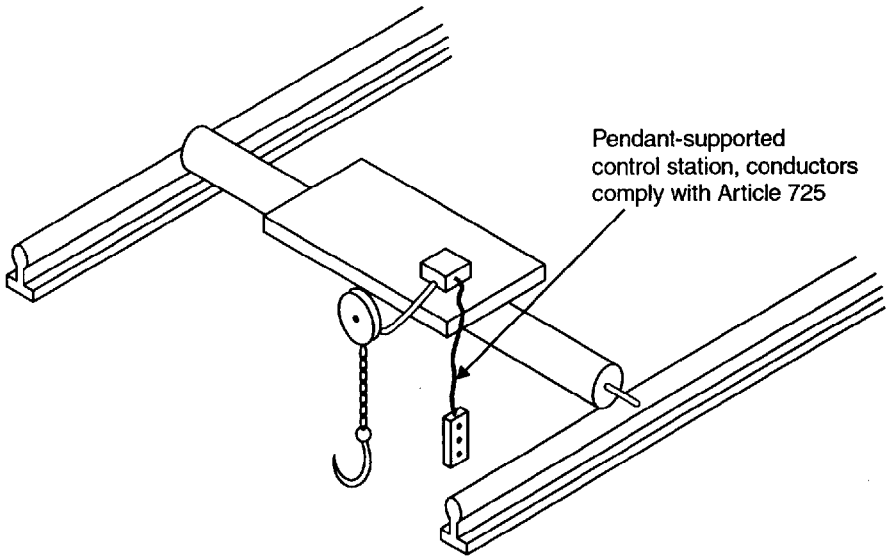
(d) Conductors for Class 1, Class 2, and Class 3 remote-control, signaling, and power-limited circuits, installed in accordance with Article 725, shall be permitted. (ROP 12-39)



Control Circuit Wiring Methods

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Application

Section 610-13 was revised to eliminate three exceptions by changing them to positive code text. Section 610-13(d) was added, allowing the use of Article 725 for conductors in Class 1, Class 2, and Class 3 control circuits.

Background and Explanation

Conductor types permitted by Article 725, particularly Section 725-27(b), are not identified in Table 310-13. This change permits the use of any of the wiring methods from Article 725 to be used with Class 1, Class 2, and Class 3 circuits that are associated with cranes and hoists.

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620-22(a) & (b) Elevator Car Lighting Overcurrent Device

Type of Change Revision

BRIEF SUMMARY

All elevators. The branch-circuit overcurrent devices for lighting, heating, and air-conditioning equipment on each car must be located in the elevator machine room or machinery space.

Code Language

620-22. Branch Circuits for Car Lighting, Receptacle(s), Ventilation, Heating, and Air Conditioning.

(a) Car Light Source. A separate branch circuit shall supply the car lights, receptacle(s), auxiliary lighting power source, and ventilation on each elevator car. **The overcurrent device protecting the branch circuit shall be located in the elevator machine room/machinery space.** (ROP 12-64)

(b) Air-Conditioning and Heating Source. A dedicated branch circuit shall supply the air-conditioning and heating units on each elevator car. **The overcurrent device protecting the branch circuit shall be located in the elevator machine room/machinery space.** (ROP 12-65)

Application

The illustration depicts an elevator equipment room with an elevator controller and two fused disconnects. One disconnect is for the elevator controller and drive motors, and the other is for the elevator car lighting, receptacles, ventilation, and heating and air conditioning. The fused disconnect for car lighting, etc. also serves as the branch circuit overcurrent devices for the same loads. Two dedicated branch circuits are required: one for car lighting, receptacles, and ventilation, and one for car heating and air conditioning. Branch-circuit overcurrent devices must be located in the machine room or machine space. Disconnects must be within sight of the equipment they serve and marked to indicate their use. Where two or more disconnects provide power to the same device, as shown in the illustration, warning signs must be provided in accordance with Section 620-52(b).

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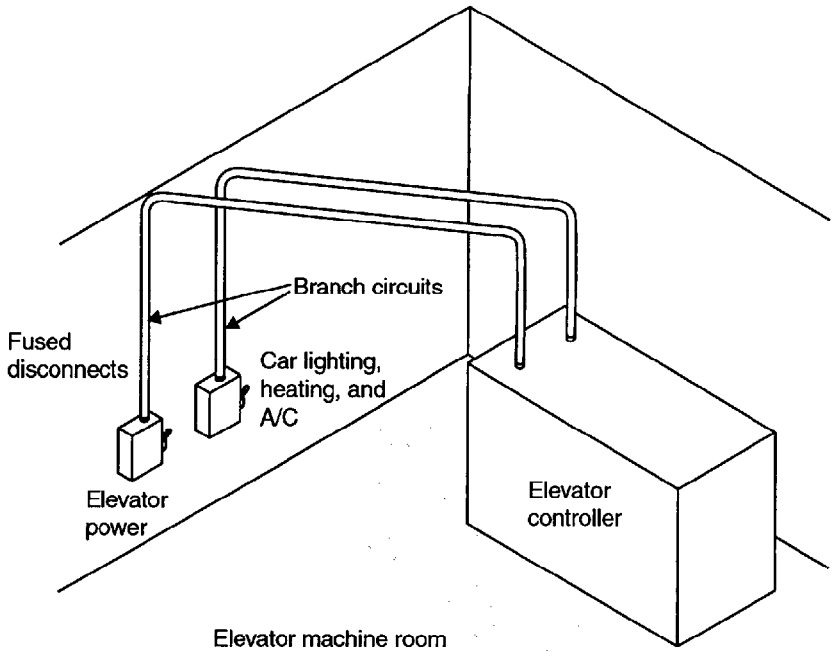

Elevator Overcurrent Devices

Background and Explanation

Negative comments on this change claimed that the requirement to locate branch-circuit overcurrent devices in machine rooms would require distribution panels in the machine rooms or spaces. However, as shown in the illustration, fusible disconnects could serve as the branch-circuit overcurrent devices for the two dedicated circuits required. Circuit breakers are also suitable as the disconnecting means.

Sections 620-53 and 620-54 require a single means of disconnecting the car lighting, receptacles, and ventilation, and a single disconnecting means for the car heating and air conditioning. Nothing requires the two single disconnecting means to be separate disconnecting means, so one multipole fusible switch could serve as both required branch-circuit overcurrent devices and both required disconnects. A single disconnect is also required by Section 620-51 for the main power supply conductors. These new requirements for disconnecting means location harmonize with the Canadian Electrical Code, CAN-CSA C22.1-1994, Rule 38-012(3).

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620-36 Fire Alarm Circuits in Elevator Traveling Cable

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Fire alarm conductors may be installed in a raceway or traveling cable with conductors of other types.

Code Language

620-36. Different Systems in One Raceway or Traveling Cable. Optical fiber cables and conductors for operating devices, operation and motion control, power, signaling, **fire alarm,** lighting, heating, and air-conditioning circuits of 600 volts or less shall be permitted to be run in the same traveling cable or raceway system if all conductors are insulated for the maximum voltage applied to any conductor within the cables or raceway system and if all live parts of the equipment are insulated from ground for this maximum voltage. Such a traveling cable or raceway shall also be permitted to include shielded conductors and/or one or more coaxial cables, if such conductors are insulated for the maximum voltage applied to any conductor within the cable or raceway system. Conductors shall be permitted to be covered with suitable shielding for telephone, audio, video, or higher frequency communications circuits. (ROP 12-68)

Application

This revision clarifies that power-limited and nonpower-limited fire alarm conductors are permitted in the same raceway or traveling cable as power and other types of signaling conductors for elevators. All power conductors, signaling conductors, and fire alarm conductors shall be insulated for the maximum voltage applied to any conductor in the raceway or cable. This permits all conductors associated with an elevator car to be contained within one raceway or traveling cable, instead of a group of raceways or cables. A single raceway or cable facilitates connection of the various systems that are necessary for elevator car operation.

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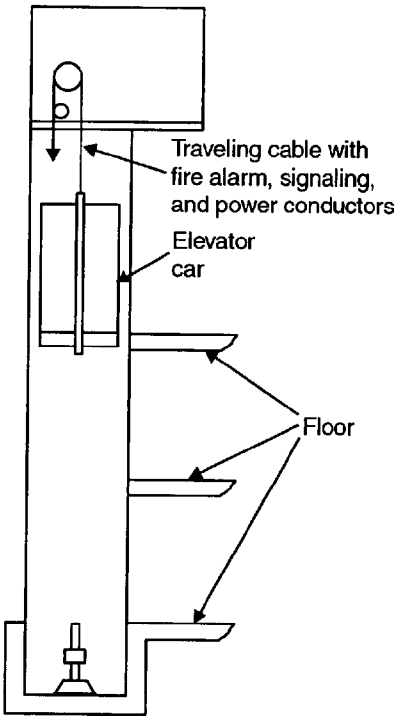

Fire Alarm Circuits in Traveling Cables

Background and Explanation

The 1993 NEC allowed signaling conductors to be with other conductors in a raceway or traveling cable. The 1993 title for Article 760 was "Fire Alarm Signaling Systems." In this case, both remote control signaling from Article 725 and fire alarm signaling from Article 760 could be mixed with other circuits.

In the 1996 NEC the title of Article 760 was changed to "Fire Alarms." By the addition of "Fire Alarm" to Section 620-36 in the 1999 NEC, it again becomes clear that the intent is to allow these conductors to be mixed with others in elevator installations.

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625-22 Personnel Protection Systems at Vehicle Charging Stations

Type of Change New

BRIEF SUMMARY

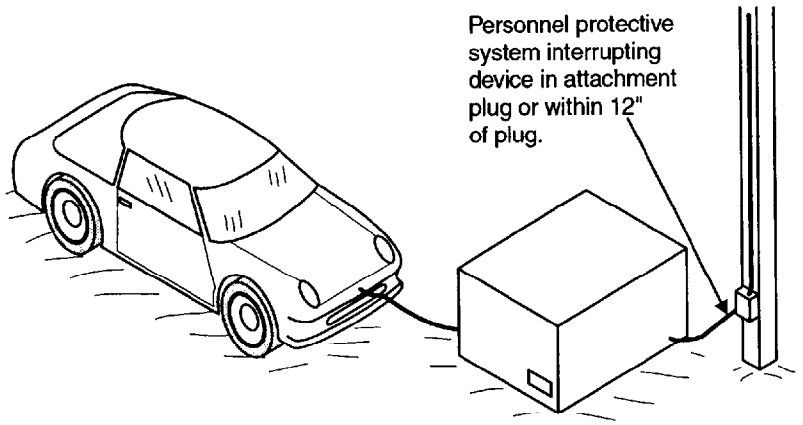
Residential and commercial. Personnel protection systems for electric vehicle charging systems replace GFCI devices for protection from shock.

Code Language

625-2. Definitions.

Personnel Protection System. A system of personnel protection devices and constructional features that when used together provide protection against electric shock of personnel. (ROC 12-42)

625-22. Personnel Protection System. The electric vehicle supply equipment shall have a listed system of protection against electric shock of personnel. **The personnel protection system shall be composed of listed personnel protection devices and constructional features. Where cord- and plug-connected electric vehicle supply equipment is used, the interrupting device of a listed personnel protection system shall be provided and shall be an integral part of the attachment plug or shall be located in the power supply cable not more than 12 in. (305 mm) from the attachment plug.** (ROP 12-90) (ROC 12-48)



Electric Vehicle Charger with Personnel Protective System

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Application

The illustration shows a vehicle charging system equipped with a personnel protective system. These systems are now required to replace what was called "ground-fault protection for personnel" in the 1996 NEC. These systems will provide protection equivalent to GFCI protection.

Background and Explanation

GFCI devices do not provide the range of options needed for the various types of charging systems being developed. Personnel protection systems are constructed of listed devices that provide protection from shock hazards. The devices used for these systems will vary somewhat, based on the voltages of the system. Devices or methods which may be used include basic insulation, double insulation, reinforced insulation, grounding monitors or insulation monitors with interrupters, charging circuit interrupting devices which monitor current differentials between charging circuit conductors, measurement indication units which measure leakage current, and centrally grounded systems with or without impedance limitation. Many combinations and variations of the above devices can be used to provide the personnel protection required. The product requirements for the listed systems are found in UL2331.

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625-29(d)(3) Ventilation of Indoor Charging Locations

Type of Change New

BRIEF SUMMARY

Electric vehicles. This section provides an alternate method for determining ventilation levels.

Code Language

625-29. Indoor Sites. Indoor sites shall include, but not be limited to, integral, attached, and detached residential garages; enclosed and underground parking structures; repair and nonrepair commercial garages; and agricultural buildings.

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(d) Ventilation Required. Where the electric vehicle supply equipment is listed or labeled as suitable for charging electric vehicles that require ventilation for indoor charging and marked in accordance with Section 625-15(c), mechanical ventilation, such as a fan, shall be provided. The ventilation shall include both supply and exhaust equipment and shall be permanently installed and located to intake from, and vent directly to, the outdoors. **Positive pressure ventilation systems shall only be permitted in buildings or areas that have been specifically designed and approved for that application.** Mechanical ventilation requirements shall be determined by one of the following methods. (ROP 12-93) (ROC 12-51) (TCC 12-51)

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(3) For an electric vehicle supply equipment ventilation system designed by a person qualified to perform such calculations as an integral part of a building's total ventilation system, the minimum ventilation requirements shall be permitted to be determined per calculations specified in the engineering study. (ROP 12-93) (ROC 12-50, 12-51)

The supply circuit to the mechanical ventilation equipment shall be electrically interlocked with the electric vehicle supply equipment **and shall remain energized** during the entire electric vehicle charging cycle. Electric vehicle supply equipment, ~~receptacles and power outlets~~ shall be ~~clearly~~ marked **in accordance with Section 625-15. Electric vehicle supply equipment receptacles rated at 125 volts, single phase, 15 and 20 amperes shall be marked in**

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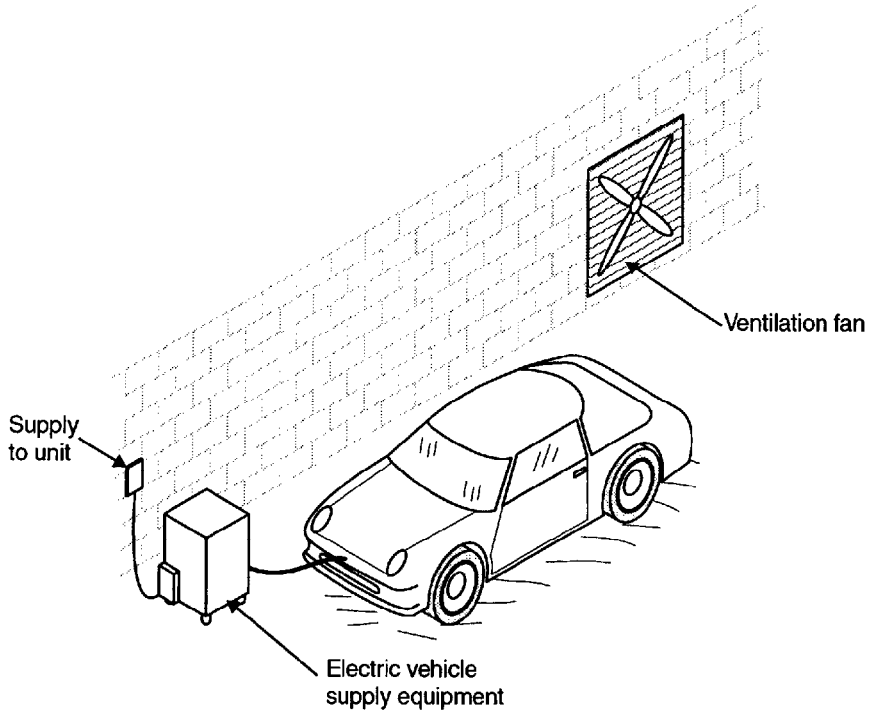
accordance with Section 625-15(c) and shall be switched and the mechanical ventilation system shall be electrically interlocked through the switch supply power to the receptacle. (ROP 12-93) (ROC 12-51)

For receptacles at each electric vehicle charging space identified "For Use with Electric Vehicles," and rated 125 volts, single phase, 15 and 20 amperes, such receptacles shall be switched, and mechanical ventilation shall be electrically interlocked through the switch supply power to the receptacle. (ROP 12-92)



Ventilation System for Charging Area

Application

The electric vehicle charging area is permitted to be ventilated by the building ventilation system. The ventilation system and the charging system must be interlocked to prevent charging if the ventilation is not operating. Where calculation of the ventilation requirements is performed, it must be done by a qualified person.

Background and Explanation

This change recognizes that interlocking of the charging and ventilation systems will prevent excessive buildup of hydrogen gas. Calculation by a qualified person helps to assure that adequate ventilation is provided.

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Article 630 Part B & 630-11, 12 Welder Overcurrent Protection Requirements; Overcurrent Protection Device Calculation

NEC pp. 455–457

Type of Change Deletion and Revision

BRIEF SUMMARY

All Installations. Part C was deleted so that all arc welders are covered by Part B. Other Parts of Article 630 were relettered. Marking requirements were revised and overcurrent calculations were clarified.

Code Language

Part B. Arc Welders. (ROP 12-101)

630-11. Ampacity of Supply Conductors. The ampacity of conductors for ac transformer and dc rectifier arc welders shall be as follows. (ROP 12-95)

(a) Individual Welders. The ampacity of the supply conductors shall not be less than the I_{1eff} **value on the rating plate. Alternatively, if the** I_{1eff} **is not given,** the ampacity of the supply conductors shall not be less than the current value determined by multiplying the rated primary current in amperes given on the welder **rating plate** and the following factor based on the duty cycle of the welder. (ROP 12-95)

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630-12. Overcurrent Protection. Overcurrent protection for arc welders shall be as provided in (a) and (b). Where the values as determined by this section do not correspond with the standard ampere ratings provided in Section 240-6 or the rating or setting specified results in unnecessary opening of the overcurrent device, the next higher standard rating or setting shall be permitted.

(a) For Welders. Each welder shall have overcurrent protection rated or set at not more than 200 percent **of** I_{1max}. **Alternatively, if the** I_{1max} **is not given, the overcurrent protection shall be rated or set at not more than 200 percent of the rated primary current of the welder.**

An overcurrent device shall not be required for a welder that has supply conductors protected by an overcurrent device rated or set at not more than 200 percent of I_{1max} **or the rated primary current of the welder.**

If the supply conductors for a welder are protected by an overcurrent device rated or set at not more than 200 percent of I_{max} **or rated primary current of the welder, a separate overcurrent device shall not be required.**

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(b) For Conductors. Conductors that supply one or more welders shall be protected by an overcurrent device rated or set at not more than 200 percent of the conductor rating.

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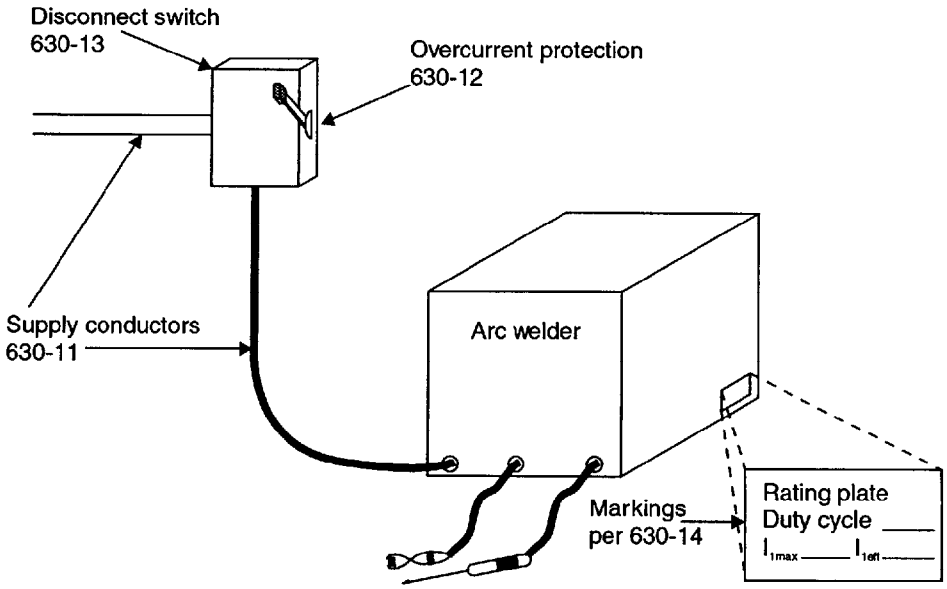
FPN: I_{1max} is the maximum value of the rated supply current at maximum rated output.

I_{1eff} is the maximum value of the effective supply current, calculated from the rated supply current (I_1), the corresponding duty cycle (duty factor) (X), and the supply current at no-load (I_0) by the following formula. (ROP 12-96)

$$I_{1eff} = \sqrt{I_1^2 X + I_0^2(1-X)}$$



Arc Welders

Application

The illustration lists Section 630-11 as the reference for sizing conductors for welders. According to Section 630-11, the ampacity of conductors supplying welders is based on the I_{1eff} rating on the welder rating plate. If the I_{1eff} rating is not available, the size of supply conductors to welders may be calculated. The calculation is done by selecting the appropriate factor from Section 630-12(a) based on the type of welder and the duty cycle of the welder. The selected factor is then multiplied by the primary current rating from the welder rating plate to determine the minimum ampacity of the supply conductors.

Section 630-12 is listed in the illustration as the reference for overcurrent protection of welders and conductors supplying welders. The maximum overcurrent device rating to protect the welder is 200 percent of I_{1max} if I_{1max} is listed on the rating plate. Otherwise, the maximum overcurrent device rating for welder protection is 200 percent of the primary current rating of the welder. The maximum overcurrent protection rating for supply conductors is 200 percent of the ampacity of the

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conductors. If the maximum value calculated for either welders or conductors is not equal to a standard size device listed in Section 240-6, the next higher standard rating may be used. A single overcurrent device may be used for both welder and conductor protection if the device protecting the conductors does not exceed the value required to protect the welder.

Background and Explanation

In order to consolidate the requirements for all arc welders, the table of factors in Section 630-11 includes a new line of multipliers for motor-generator arc welders. This additional line was taken from Section 630-21 in the 1996 code.

Obsolete terms and ratings such as "nameplate" and "1-hour duty cycle" were removed from Section 630-12, and the marking requirements in Section 630-14 have been revised to recognize current practice. The terms I_{1eff} and I_{max} have been added to the marking requirements. A new FPN includes a formula for I_{1eff}, which represents the effective heating value of the welder current. The value of I_{1eff} is preferred over the value derived from using the factors in Section 630-11, although the calculated value is still allowed. I_{max} is basically the same as the rated primary current.

The permission to increase the overcurrent device sizes in Section 630-12 has been changed. It is now based only on the calculation not producing a standard overcurrent device rating, not on whether the nearest standard rating is more or less than the calculated value. The requirement for disconnecting means in Section 630-13 has not changed significantly from the 1996 NEC.

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NEC pp. 458–463

Article 640 Audio Equipment Requirements

Type of Change Revision

BRIEF SUMMARY

All occupancies. Extensive revisions have been made to clarify requirements and update the article for current industry equipment and practices.

Code Language

This article has been extensively revised. Refer to outline.

Article 640 — Audio Signal Processing, Amplification, and Reproduction Equipment

Part A. General
640-1. Scope.
640-2. Definitions.
640-3. Locations and Other Articles.
640-4. Protection of Electrical Equipment.
640-5. Access to Electrical Equipment Behind Panels Designed to Allow Access.
640-6. Mechanical Execution of Work.
640-7. Grounding.
640-8. Grouping of Conductors.
640-9. Wiring Methods.
640-10. Audio Systems Near Bodies of Water.

Part B. Permanent Audio System Installations
640-21. Use of Flexible Cords and Cables.
640-22. Wiring of Equipment Racks.
640-23. Conduit or Tubing.
640-24. Wireways, Gutters, and Auxiliary Gutters.
640-25. Loudspeaker Installation in Fire Resistance Rated Partitions, Walls, and Ceilings.

Part C. Portable and Temporary Audio System Installations
640-41. Multipole Branch-Circuit Cable Connectors.
640-42. Use of Flexible Cords and Cables.
640-43. Wiring of Equipment Racks.
640-44. Environmental Protection of Equipment.
640-45. Protection of Wiring.
640-46. Equipment Access.

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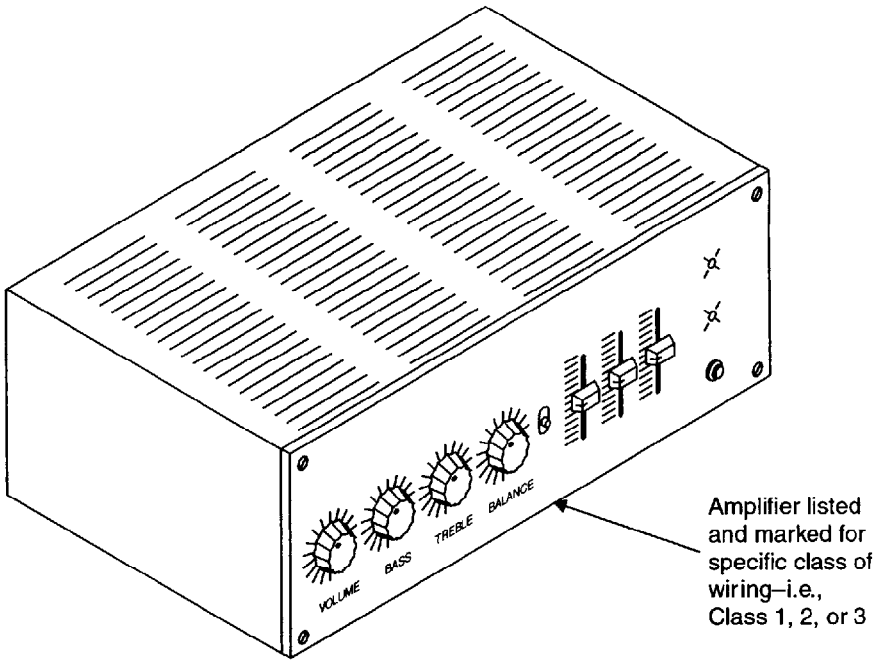

Audio System Equipment

Background and Explanation

Users of this article should thoroughly review the revisions. Out-of-date practices have been removed and new technology has been added to reflect current industry practices. The use of Class 1, Class 2, and Class 3 wiring methods with listed amplifiers that are marked for the specific class of wiring is permitted. The article also specifies separation requirements for audio circuits using different class wiring systems. New parts of the article cover temporary and permanent audio system installations.

More detailed coverage has been introduced to cover the variety of environments where equipment is used. Provisions have been made for safe grounding while reducing audible hum in system outputs.

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NEC pp. 478–479

680-8 Overhead Conductor Clearances

Type of Change Revision

BRIEF SUMMARY

Residential and commercial. Two clearances from pools and pool structures to overhead conductors have been increased.

Code Language

680-8. Overhead Conductor Clearances.
See table.

Table 680-8. Clearances

	Insulated Supply or Service Drop Cables, 0–750 volts to Ground, Supported on and Cabled Together with an Effectively Grounded Bare Messenger or Effectively Grounded Neutral Conductor	*All Other Supply or Service-Drop Conductors Voltage to Ground*	
		0–15kV	*Greater Than 15–50kV*
A Clearance in any direction to the water level, edge of water surface, base of diving platform, or permanently anchored raft	**22 ft (6.7 m)**	25 ft (7.62 m)	27 ft (8.23 m)
B Clearance in any direction to the diving platform or tower	14 ft (4.27 m)	**17 ft (5.2 m)**	18 ft (5.49 m)
C Horizontal limit of clearance measured from inside wall of the pool	This limit shall extend to the outer edge of the structures listed in (1) and (2) but not less than 10 ft (3.05 m).		

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Application

In the table, which corresponds to Figure 680-8 in the NEC, the dimension labeled "A" under the 0–750-volt column was changed to 22 feet from 18 feet. The dimension labeled "B" under the 0–15kV column was changed to 17 feet from 16 feet.

Background and Explanation

The clearances revised by this change were formerly under Section 680-8 Exception No. 1. In the 1999 code, Exception No. 1 along with Exception No. 2 were reworded into positive code language and the table became Table 680-8. The change in the required clearances was made primarily to harmonize the NEC with the National Electrical Safety Code (NESC).

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680-12 Disconnecting Means for Pool, Spa, and Hot Tub Equipment

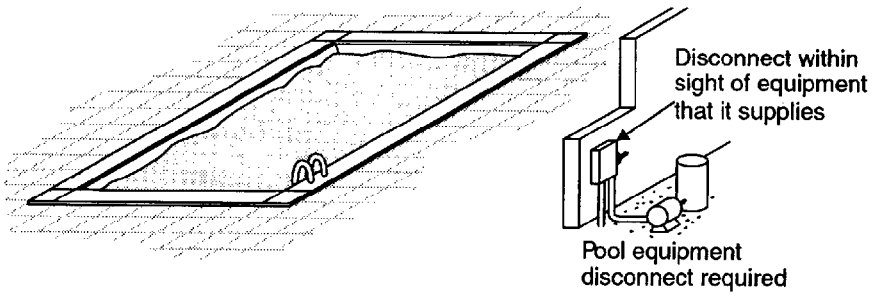
Type of Change Revision

BRIEF SUMMARY

Residential and commercial. Requirements for disconnects at pools, spas, and hot tubs have been clarified.

Code Language

680-12. Disconnecting Means. **A** disconnecting means shall **be provided** and be accessible, located within sight from all pools, spas, and hot tub equipment, and shall be located at least 5 ft (1.52 m) from the inside walls of the pool, spa, or hot tub. (ROP 20-107)



Disconnecting Means for Associated Equipment

Application

An accessible disconnect must be installed within sight of pool, spa, or hot tub equipment. This requirement ensures that a disconnect is available to workers servicing pool, spa, and hot tub equipment such as motors, heaters, and lighting fixtures. The term "accessible," as defined in Article 100, requires that the disconnecting means provide "close approach" and not be guarded by locked doors, which preclude access by service personnel.

Background and Explanation

This section has been clarified to ensure that a disconnect is installed for the servicing of equipment. The 1996 NEC required a disconnect to be accessible, but it was not clear that one was required.

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680-20(c) Liquidtight Flexible Nonmetallic Conduit for Dry-Niche Fixtures

Type of Change Revision

BRIEF SUMMARY

Residential and commercial. Liquidtight flexible nonmetallic conduit was added to the wiring methods permitted for dry-niche fixtures.

Code Language

680-20. Underwater Lighting Fixtures.

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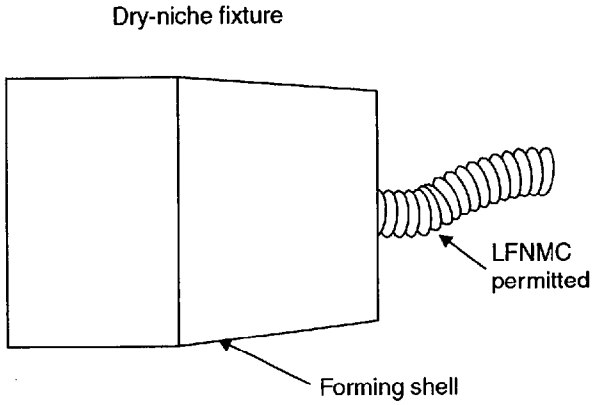
(c) Dry-Niche Fixtures. A dry-niche lighting fixture shall be provided with a provision for drainage of water and a means for accommodating one equipment grounding conductor for each conduit entry.

Approved rigid metal conduit, intermediate metal conduit, **liquidtight flexible nonmetallic conduit,** or rigid nonmetallic conduit shall be installed from the fixture to the service equipment or panelboard. Where installed on buildings, electrical metallic tubing shall be permitted to be used to protect conductors. Where installed within buildings, electrical nonmetallic tubing or electrical metallic tubing shall be permitted to be used to protect conductors. A junction box shall not be required but, if used, shall not be required to be elevated or located as specified in Section 680-21(a)(4), if the fixture is specifically identified for the purpose.



Dry-Niche Fixture Wiring

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Application

As shown in the illustration, liquidtight flexible nonmetallic conduit (LFNMC) may now be used to wire dry-niche fixtures.

Background and Explanation

LFNMC was already listed in Section 680-20(b)(1) as an acceptable method of wiring wet-niche fixtures, and it is available listed for direct burial. It is now an acceptable method of wiring dry-niche fixtures.

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680-21(a)(1) Listing of Junction Boxes for Pool Fixtures

Type of Change New

BRIEF SUMMARY

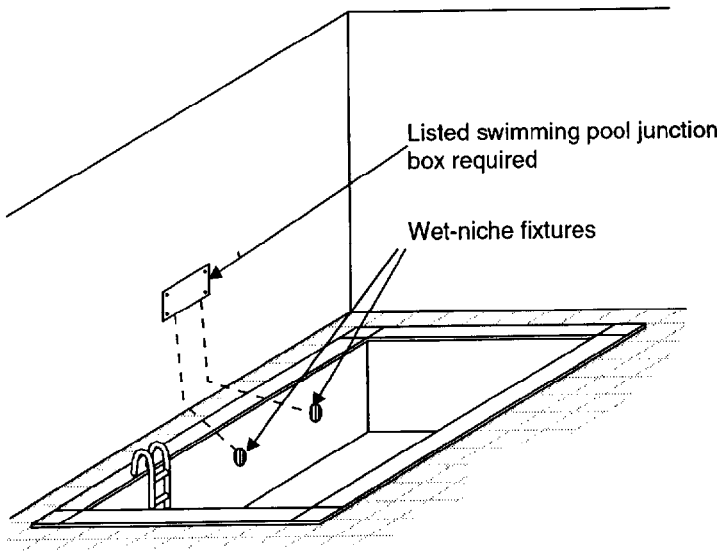
Residential and commercial. Listing of junction boxes connected to conduits that connect directly to the forming shell or mounting bracket of underwater lighting fixtures is required.

Code Language

680-21. Junction Boxes and Enclosures for Transformers or Ground-Fault Circuit Interrupters.

(a) Junction Boxes. A junction box connected to a conduit that extends directly to a forming shell or mounting bracket of a no-niche fixture shall be as follows.

1. Listed and labeled for the purpose. (ROP 20-122)



Junction Box for Pool Lighting Fixtures

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Application

Boxes used for the supply wiring to wet-niche and no-niche underwater lighting fixtures must be listed for the purpose by a recognized testing laboratory.

Background and Explanation

The requirement for a box that is listed for the purpose ensures that the integral grounding terminals needed for proper grounding and bonding of underwater lighting fixtures will be available. A box that is listed, but not specifically listed for use with swimming pools, may not provide the proper number of integral grounding and bonding terminals required by this section.

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680-22 Purpose of Bonding at Swimming Pools

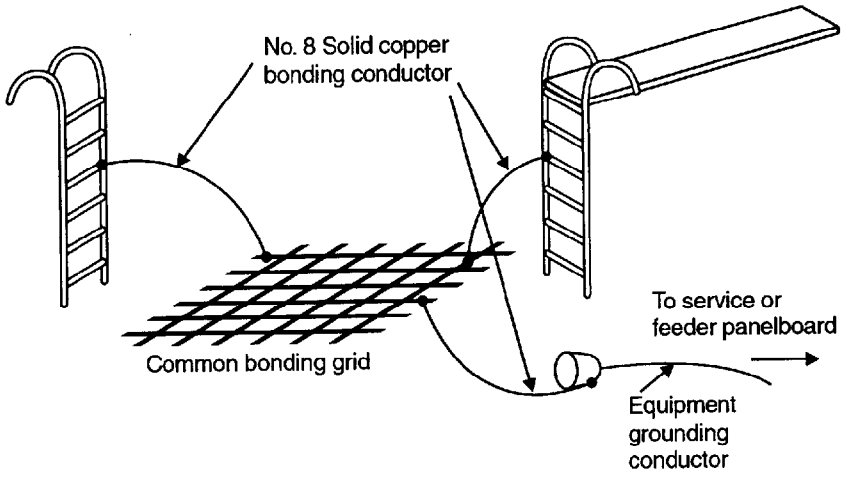
Type of Change Revision

BRIEF SUMMARY

Residential and commercial. The bonding conductors of Section 680-22 are not required to be extended to panelboards, electrodes, or service equipment.

Code Language

680-22. Bonding. It shall not be the intent of this section to require that the No. 8 or larger solid copper bonding conductor be extended or attached to any remote panelboard, service equipment, or any electrode, but only that it shall be employed to eliminate voltage gradients in the pool area as prescribed. (ROP 20-126)



Bonding at Swimming Pools

Application

As shown in the illustration, the No. 8 AWG bonding conductor is only intended to be used to bond metal parts of the pool together. A part like a metal forming shell of a fixture is required to be bonded by a No. 8 conductor as a metal part of the pool. It is also required to be grounded with respect to the electrical system supplying the light fixture. But the size of the equipment grounding conductor to the fixture may be smaller than No. 8 and is only required to be sized on the basis of the overcurrent device of the branch circuit. Section 680-25 does require

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most equipment grounding conductors to be a minimum No.12 AWG, but smaller conductors are permitted in some cases.

Background and Explanation

The 1996 code had a FPN that explained the intent of Section 680-22. The FPN was often interpreted as a code requirement because it explained the intent of the rule. Since FPNs are supposed to be advisory only, the intent statement was changed to code text, to make it more clearly a part of the rule.

As the revised rule now states, the No. 8 bonding conductor is intended only to eliminate voltage gradients in the pool area. It is not intended as a conductor of fault currents that might occur because of a problem in associated electrical equipment; nor does this section intend to require equipment grounding conductors to be No.8 or larger. Equipment grounding conductors to associated electrical pool equipment must be sized in accordance with Section 250-122 and 680-25. If the fixture in the illustration were a wet-niche fixture supplied by a flexible cord, Section 680-25(b)(5) would allow an equipment grounding conductor as small as No.16 in the cord. The bonding conductor size (No. 8 AWG minimum), material (copper), and construction (solid) provide for the mechanical integrity of the bonding conductor(s).

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NEC p. 481

680-22(a)(1) Bonding Not Required for Epoxy-Covered Reinforcing Steel

Type of Change Revision

BRIEF SUMMARY

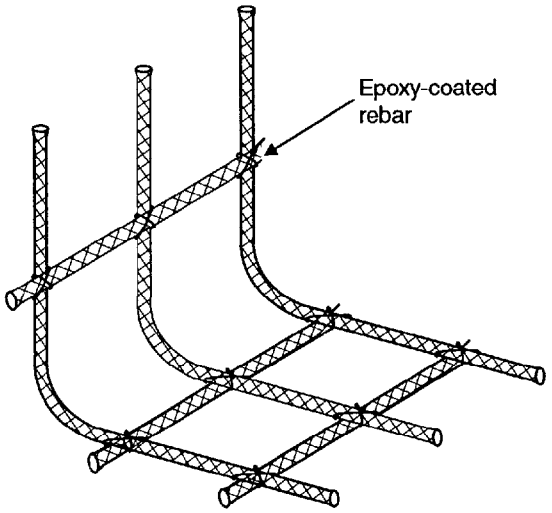
Residential and commercial. Bonding requirements for coated reinforcing steel have been clarified.

Code Language

680-22. Bonding.

(a) Bonded Parts. The following parts shall be bonded together.

(1) All metallic parts of the pool structure, including the reinforcing metal of the pool shell, coping stones, and deck. The usual steel tie wires shall be considered suitable for bonding the reinforcing steel together, and welding or special clamping shall not be required. These tie wires shall be made tight. **Where reinforcing steel is effectively insulated by a listed encapsulating nonconductive compound, at the time of manufacture and installation, it shall not be required to be bonded.** (ROC 20-115)



Reinforcing Steel Encapsulated by Listed Nonconductive Compound

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Application

Coated reinforcing steel may not provide the conductivity from piece to piece that is necessary to establish the required common bonding grid. Where the steel is effectively insulated by a listed compound during manufacture or installation, it will not form an effective bonding grid; therefore a bonding connection is not required.

Background and Explanation

This change recognizes the increased use of reinforcing steel that is epoxy coated for swimming pool structure and deck construction. The nonconductive coating is required to be listed, and the coating is to be installed at the time of manufacture or at the time of installation. The time of installation provision allows for repair of damage to the encapsulating compound that may have occurred between the point of manufacture and the point of installation.

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680-22(b) Exothermic Welding for Bonding Connection

Type of Change Revision

BRIEF SUMMARY

Residential and commercial. Exothermic welding has been added as an acceptable method of making bonding connections at pools. Other connection methods must be labeled for the purpose.

Code Language

680-22. Bonding.

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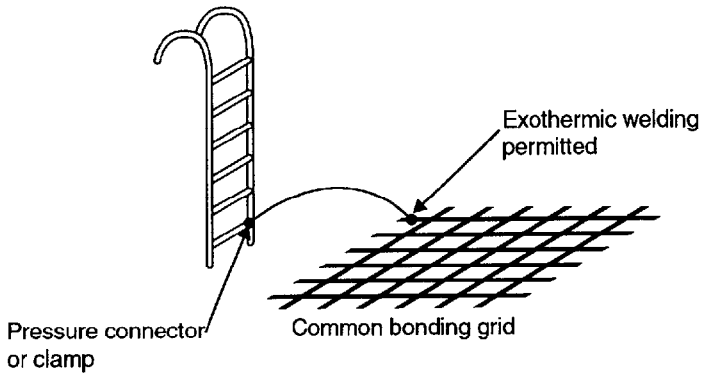
(b) Common Bonding Grid. The parts specified in (a) shall be connected to a common bonding grid with a solid copper conductor, insulated, covered, or bare, not smaller than No. 8. Connection shall be made by **exothermic welding** or by pressure connectors or clamps that are labeled as being suitable for the purpose and are of the following material: stainless steel, brass, copper, or copper alloy. The common bonding grid shall be permitted to be any of the following: . . . (ROP 20-136)



Bonding Connections at Swimming Pools

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Application

The illustration shows a bonding jumper between a metal ladder and the rebar grid of a pool structure. The connections between the bonding jumper and the grid or ladder may be made by the exothermic welding process, or by pressure connectors or clamps. Pressure connectors or clamps must be labeled as suitable for the purpose.

Background and Explanation

Exothermic welding was explicitly recognized by this change. The change also clarifies the requirement for pressure connectors or clamps to be specifically labeled for the purpose. Connections in a pool area must be suitable for the wet conditions and the high levels of chlorine.

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680-22(b)(4) Brass Conduit as Bonding Grid Component

Type of Change New

BRIEF SUMMARY

Residential and commercial. The use of metal conduits as part of the common bonding grid is permitted.

Code Language

680-22. Bonding.

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(b) Common Bonding Grid. The parts specified in (a) shall be connected to a common bonding grid with a solid copper conductor, insulated, covered, or bare, not smaller than No. 8. Connection shall be made by exothermic welding or by pressure connectors or clamps that are labeled as being suitable for the purpose and are of the following material: stainless steel, brass, copper, or copper alloy. The common bonding grid shall be permitted to be any of the following: (ROP 20-136)

(1) The structural reinforcing steel of a concrete pool where the reinforcing rods are bonded together by the usual steel tie wires or the equivalent

(2) The wall of a bolted or welded metal pool

(3) A solid copper conductor, insulated, covered, or bare, not smaller than No. 8

(4) **Rigid metal conduit or intermediate metal conduit of brass or other identified corrosion-resistant metal conduit** (ROP 20-140)

Structural reinforcing steel or the walls of bolted or welded metal pool structures shall be permitted as a common bonding grid for nonelectrical parts where connections can be made in accordance with Section 250-8. (ROC 20-123)

Application

Brass or other corrosion-resistant conduit may be used to establish common bonding between reinforcing steel and items such as deck boxes or outlet boxes for pump motors. This provision eliminates the need to install separate bonding jumpers in some cases.

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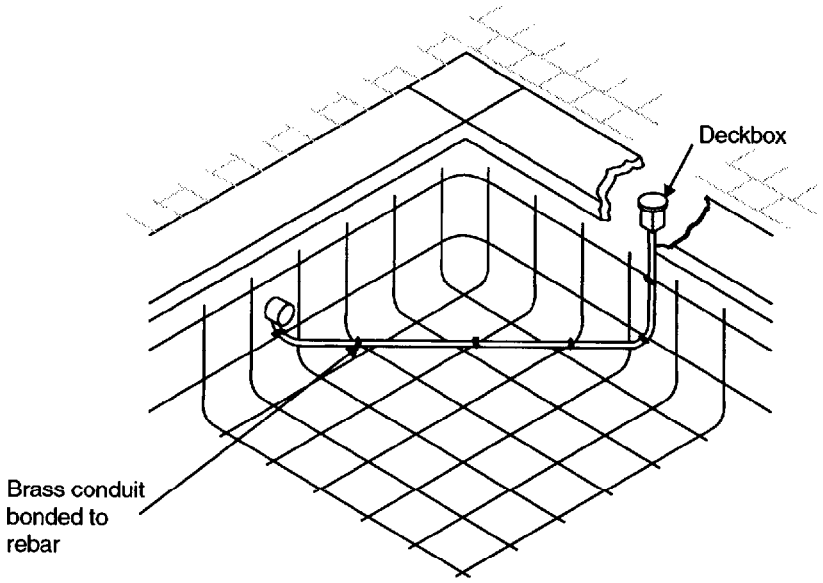

Brass Conduit as Bonding Grid

Background and Explanation

This change provides adequate bonding and recognizes that metal conduits provide an effective bonding path and can be used as part of the common bonding grid, particularly where installed aboveground and accessible. This method of bonding has been permitted by some authorities having jurisdiction.

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680-25(d) Sizing Bonding Jumper

Type of Change Revision

BRIEF SUMMARY

Residential and commercial: Grounding requirements for panelboards and disconnects that are not part of the service have been clarified.

Code Language

680-25. Methods of Grounding.

(d) Panelboards. A panelboard **and, where installed, a disconnecting means,** that are not part of the service equipment or source of a separately derived system, shall have an equipment grounding conductor installed between its grounding terminal and the grounding terminal of the applicable service equipment or source of a separately derived system. This conductor shall be sized in accordance with Table 250-122 but not smaller than No. 12. **On separately derived systems, this conductor shall be sized in accordance with Table 250-66 but not smaller than No. 8.** It shall be an insulated conductor and shall be installed with the feeder conductors in rigid metal conduit, intermediate metal conduit, liquidtight flexible nonmetallic conduit, or rigid nonmetallic conduit. Electrical metallic tubing shall be permitted to be used to protect conductors where installed on or within the building in accordance with Article 348. Electrical nonmetallic tubing shall be permitted to be used to enclose the conductors where installed within the building in accordance with Article 331. The equipment grounding conductor shall be connected to an equipment grounding terminal of the panelboard and, where installed, to the enclosure for a disconnecting means. (ROC 20-157, 20-158)

Application

Equipment grounding conductors for service supplied panelboards and disconnects are selected from Section 250-122 and Table 250-122 based on the rating of the overcurrent device. The minimum size is No. 12 AWG for panelboards that supply pool equipment.

Where the panelboard or disconnect is supplied from a separately derived system, this conductor is no longer referred to as an equipment grounding conductor. Between the source of the separately derived system and the first system disconnecting means the grounding and bonding conductor is defined as a bonding jumper and the size is selected from Section 250-66 and Table 250-66. In this

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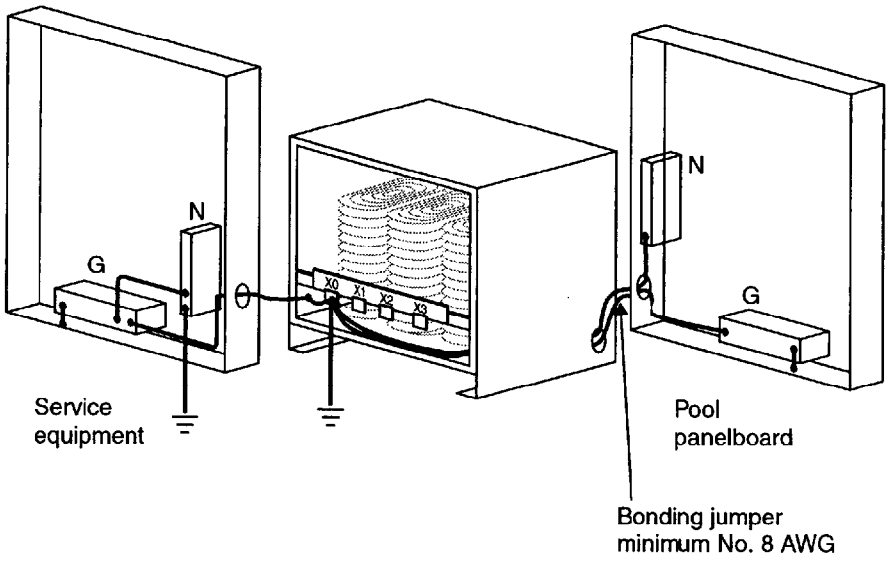
case, the selection is based on the size of the ungrounded circuit conductors installed from the source of the separately derived system to the first system disconnecting means and the minimum size specified by Table 250-66 is No. 8 AWG. This bonding jumper is required to be an insulated conductor. The illustration shows only the grounding and bonding conductor connections and does not show the required raceway or wiring method between the enclosures.



Sizing of Bonding Jumper

Background and Explanation

Section 250-30(a)(1) specifies the use of Section 250-28(d) to size bonding jumpers for separately derived systems. Section 250-28(d) requires the use of Table 250-66 resulting in a minimum size of No. 8. In prior editions of the code, the sizing of the separately derived system bonding jumper was not covered by this section.

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STD·NFPA NEC CHANGES-ENGL 1999 ■ 6474446 0577278 687 ■

680-25(d) Liquidtight Flexible Nonmetallic Conduit for Pool Feeders

Type of Change Revision

BRIEF SUMMARY

Residential and commercial. Liquidtight flexible nonmetallic conduit is permitted as a wiring method for feeders to panelboards serving swimming pool equipment.

Code Language

680-25. Methods of Grounding.

(d) Panelboards. A panelboard and, where installed, a disconnecting means, that are not part of the service equipment or source of a separately derived system, shall have an equipment grounding conductor installed between its grounding terminal and the grounding terminal of the applicable service equipment or source of a separately derived system. This conductor shall be sized in accordance with Table 250-122 but not smaller than No. 12. On separately derived systems, this conductor shall be sized in accordance with Table 250-66 but not smaller than No. 8. It shall be an insulated conductor and shall be installed with the feeder conductors in rigid metal conduit, intermediate metal conduit, **liquidtight flexible nonmetallic conduit,** or rigid nonmetallic conduit. Electrical metallic tubing shall be permitted to be used to protect conductors where installed on or within the building in accordance with Article 348. Electrical nonmetallic tubing shall be permitted to be used to enclose the conductors where installed within the building in accordance with Article 331. The equipment grounding conductor shall be connected to an equipment grounding terminal of the panelboard and, where installed, to the enclosure for a disconnecting means.

(ROP 20-157)

Application

As shown in the illustration, liquidtight flexible nonmetallic conduit (LFNMC) may be used for enclosing feeders to a swimming pool panelboard.

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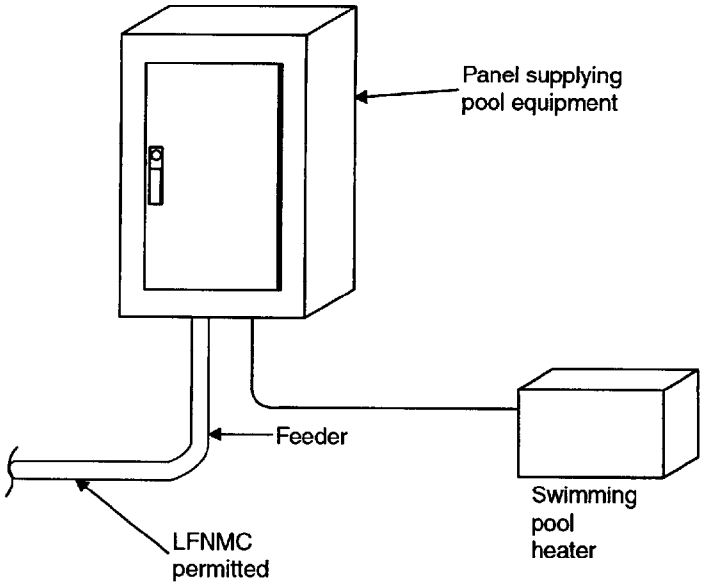

Wiring of Swimming Pool Panelboards

Background and Explanation

LFNMC was already permitted for wiring of wet-niche fixtures and pool motors and is available listed for direct burial. This change was one of many that expanded the permitted uses of LFNMC. Equipment grounding conductors must be provided with the feeder unless the panelboard is in a separate building and grounding is in accordance with Section 250-32.

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680-25(d)(2) Panelboard Grounding at Separate Building or Structure

Type of Change Revision

BRIEF SUMMARY

Residential and commercial. Swimming pool equipment may be fed from panelboards at separate buildings without equipment grounding conductors extending back to the service.

Code Language

680-25. Methods of Grounding.

•
•
•

(d) Panelboards.

•
•
•

(2) A panelboard at a separate building shall be permitted to supply swimming pool equipment if the feeder meets the requirements for grounding in Section 250-32. Where installed, an equipment grounding conductor shall be an insulated conductor. (ROC 20-130)

(ROP 20-157)

Application

The illustration depicts pool equipment fed from a panelboard at a separate building. A separate building is often supplied by a feeder and wiring method that does not include an equipment grounding conductor and does not provide a continuous metallic pathway back to the service. The grounded conductor is connected to a grounding electrode at the separate building in accordance with Section 250-32(b)(2). Equipment grounding conductors to the pool equipment need only extend to the panelboard in the separate building, and the panelboard in the separate building is not required to have an equipment grounding conductor extending back to the service.

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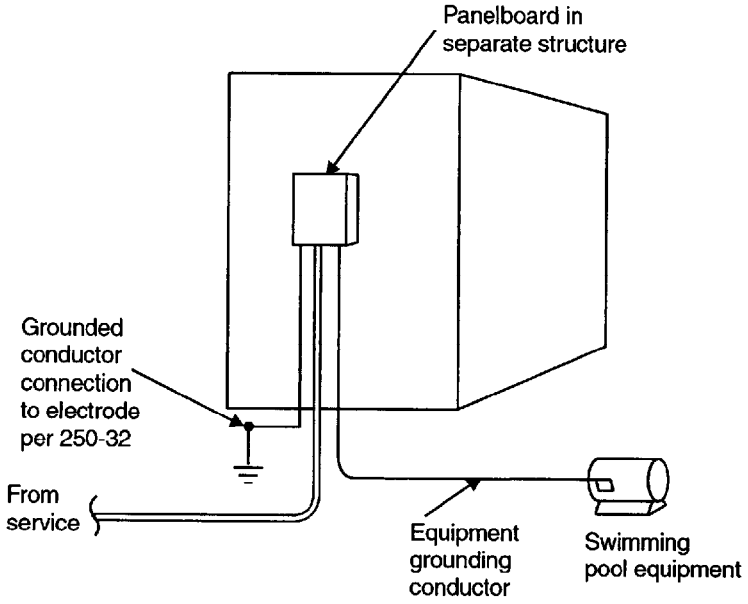

Pool Wiring from Separate Buildings

Background and Explanation

The general rule in Section 680-25(d) requires an equipment grounding conductor to be installed between a panelboard serving swimming pool equipment and the service or the source of a separately derived system. This change allows pool equipment to be supplied from a panelboard in a separate building where no equipment grounding conductor is extended from the service (or derived system) to the panelboard. Grounding at the separate building must meet the requirements of Section 250-32.

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680-38 Emergency Switch for Spas and Hot Tubs

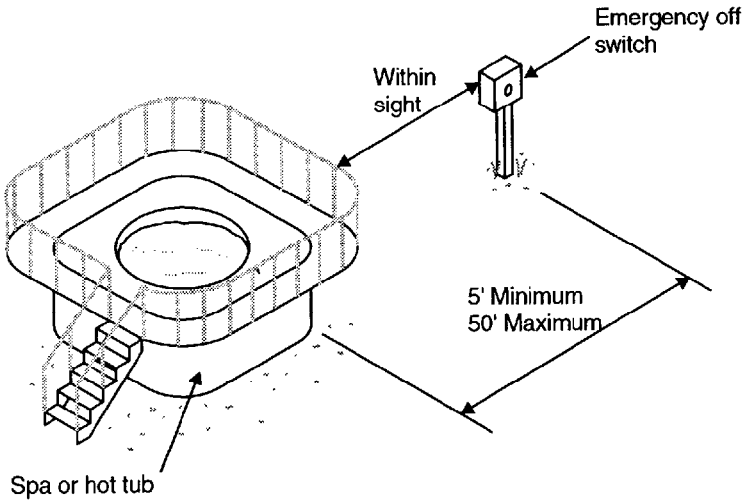
Type of Change New

BRIEF SUMMARY

Residential and commercial. An emergency shutoff switch is required for spas and hot tubs. The change does not apply to spas and hot tubs installed at a one-family dwelling.

Code Language

680-38. Emergency Switch for Spas and Hot Tubs. A clearly labeled emergency shutoff or control switch for the purpose of stopping the motor(s) that provide power to the recirculation system and jet system shall be installed readily accessible to the users and at least 5 ft (1.52 m) away, adjacent to, and within sight of the spa or hot tub. This requirement shall not apply to single-family dwellings.



Emergency Control Required

Application

An emergency shutoff switch or control switch must be installed within sight of and at least 5 feet from the spa or hot tub. This shutoff switch must be clearly labeled as an emergency shutoff. This shutoff switch can be either a line-operated device or a

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remote-control circuit that causes the pump circuit to open. This requirement does not apply to one-family dwellings. The 50-foot distance shown in the illustration is based on the definition of "within sight" (in sight from) from Article 100.

Background and Explanation

Cases of injury and drowning have been reported where hair has been pulled into water intakes causing bathers to be trapped underwater. In many installations the disconnecting means is available but not clearly identified as an emergency shutoff switch.

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680-57 Signs in Fountains

Type of Change New

BRIEF SUMMARY

Commercial. Requirements for signs located in fountains have been provided.

Code Language

680-57. Signs. (ROP 20-201)

(a) General. Includes only fixed, stationary electrically illuminated utilization equipment with words or symbols designed to convey information or attract attention.

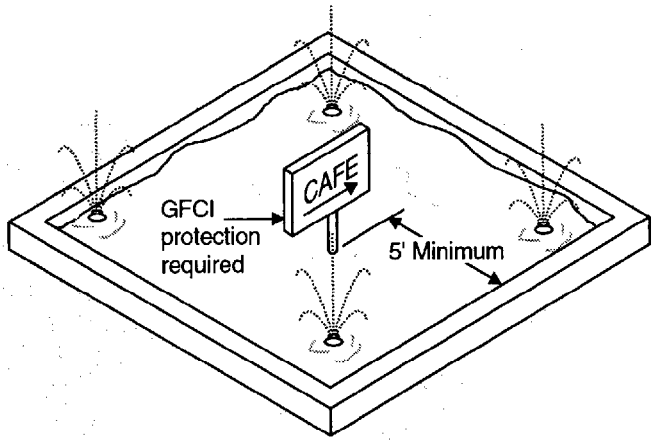
(b) Ground-Fault Circuit-Interrupter Protection for Personnel. All circuits supplying the sign shall have ground-fault circuit-interruter protection for personnel.

(c) Location. Any sign installed inside a fountain shall be at least 5 ft (1.52 m) inside the fountain measured from the outside edges of the fountain.

(d) Disconnect. Shall comply with Section 600-6.

(e) Bonding. Shall comply with Section 600-7.

(f) Grounding. Any equipment associated with the sign shall be grounded as per Article 250. (ROP 20-201)



Electric Signs in Fountains

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Application

Signs located in fountains are required to have GFCI protection for personnel. This protection may be provided in the feeder or branch circuit. To prevent contact by persons around the fountain, the sign must be at least 5 feet from the edge of the fountain. Disconnecting and bonding requirements in Article 600 apply, and grounding is to be provided in accordance with the applicable provisions of Article 250.

Background and Explanation

The use of signs within fountains is becoming an increasingly popular type of installation. Prior to the 1999 NEC, there were rules for signs in Article 600 and rules for fountains in Article 680, but there were no specific rules for signs installed in fountains. This new section provides requirements for this type of installation. In many cases, these signs may be in a location where the public has direct access to the sign and fountain.

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680-62(a) GFCI Protection for Therapeutic Pools and Tubs

Type of Change Revision

BRIEF SUMMARY

Commercial. Protection requirements for large, self-contained tubs and pools were clarified. Some therapeutic equipment is exempt from GFCI requirements.

Code Language

680-62. Therapeutic Tubs (Hydrotherapeutic Tanks). Therapeutic tubs, used for the submersion and treatment of patients, that are not easily moved from one place to another in normal use or that are fastened or otherwise secured at a specific location, including associated piping systems, shall conform to this part.

(a) Protection. The outlet(s) that supplies the following shall be protected by a ground-fault circuit interrupter:

(1) A self-contained therapeutic tub or hydrotherapeutic tank, or

(2) A packaged therapeutic tub or hydrotherapeutic tank, or

(3) A field-assembled therapeutic tub or hydrotherapeutic tank with a heater load of 50 amperes or less

A listed self-contained unit or listed packaged equipment assembly marked to indicate that integral ground-fault circuit-interrupter protection is provided for all electrical parts within the unit or assembly (pumps, air blowers, heaters, lights, controls, sanitizer generators, wiring, etc.) shall not require that the outlet supply be protected by a ground-fault circuit interrupter.

A field-assembled therapeutic tub or hydrotherapeutic tank rated greater than 250 volts or rated 3 phase shall not require the supply to be protected by a ground-fault circuit interrupter. (ROP 20-203)

Application

The illustration shows a large field-assembled therapeutic tub that is not required to have GFCI protection in its electrical supply because the heater load is over 50 amperes. The following table summarizes the rules for equipment required and not required to be GFCI protected.

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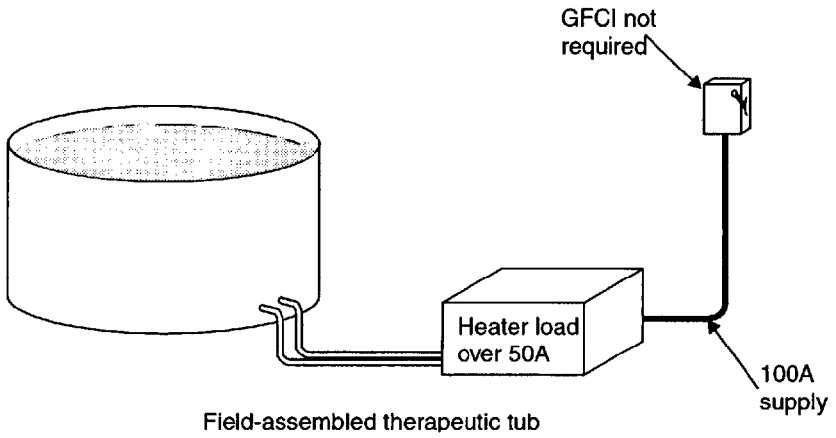
GFCI-Protected Outlet Required	*GFCI-Protected Outlet Not Required*
1. Self-contained therapeutic tub or hydrotherapeutic tank without integral GFCI protection for all components	1. Listed self-contained unit or listed packaged equipment assembly with integral GFCI protection for all components
2. Packaged therapeutic tub or hydrotherapeutic tank without GFCI protection for all components	2. Field-assembled therapeutic tub or hydrotherapeutic tank rated over 250 volts or rated 3 phase or with a heater load over 50 amperes
3. Field-assembled therapeutic tub or hydrotherapeutic tank with heater load not over 50 amperes	



GFCI Requirements for Therapeutic Tubs and Tanks

Background and Explanation

This change was intended to clarify the rules for GFCI protection of large hydrotherapeutic tanks and large therapeutic tubs. The previous rule required GFCI protection for all therapeutic equipment, which made construction of large tubs and tanks virtually impossible because GFCI protective devices are not available in all voltage and amperage ratings.

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680-72 Access Requirements for Hydromassage Tub Equipment

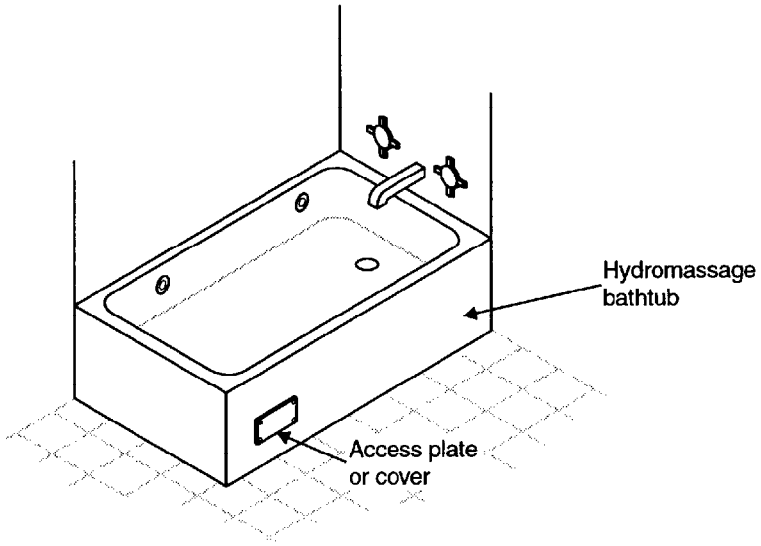
Type of Change New

BRIEF SUMMARY

Residential and commercial. Access for hydromassage bathtub equipment is required.

Code Language

680-72. Accessibility. Hydromassage bathtub electrical equipment shall be accessible without damaging the building structure or building finish. (ROP 20-209) (ROC 20-149)



Access for Associated Electrical Equipment

Application

Pump motors and other electrical components are often located below the tub unit and may require an access panel to allow maintenance. Where necessary, access panels must be provided to allow servicing of hydromassage bathtub systems without damaging the building structure or finish.

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Background and Explanation

Building codes or plumbing codes may not require access to electrical equipment. This section is intended to ensure that the electrical equipment associated with hydromassage bathtubs can be accessed for maintenance or repair without damaging the finish or structure of a building. The access panel may either be an integral part of the tub unit or one that is provided in the finish that encloses the tub.

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NEC pp. 497–500

Article 695 Fire Pump Requirements

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Article 695 has been extensively rewritten.

Code Language

Reorganization of Article 695

1996 NEC Section	*Heading or Description*	*1999 NEC Section*
695-1	Scope	695-1
695-2	Application of Other Articles	695-2
695-3	Power Source(s) for Electric Motor-Driven Fire Pumps	695-3
	Individual Sources (New heading, Rewritten)	695-3(a)
695-3(a)(1)	Electric Utility Service Connection (Rewritten)	695-3(a)(1)
695-3(a)(2)	On-Site Power Production Facility (Rewritten)	695-3(a)(2)
	Feeder Source (New)	695-3(b)(2)
695-4(a)(part)	Multiple Sources	695-3(b)
695-4(b) Exc.	Generator Capacity (Rewritten)	695-3(b)(1)
695-4(a)(part)	Arrangement	695-3(b)(3)
	Continuity of Power (New)	695-4
695-3(c)	Direct Connection	695-4(a)
695-3(c) Exc. No. 1	Supervised Connection (Rewritten)	695-4(b)
695-3(c) Exc. No. 1b	Disconnecting Means (Rewritten)	695-4(b)(2)
695-3(c) Exc. No. 2	Transformers (Rewritten)	695-5
695-5(a)	Size (Rewritten)	695-5(a)
695-5(b)	Overcurrent Protection (Rewritten)	695-5(b)
	Feeder Source (New)	695-5(c)
695-8	Power Wiring	695-6
695-8(a)	Service Conductors (Rewritten)	695-6(a)
695-8(a) Exc. No. 1	Circuit Conductors (Rewritten)	695-6(b)
695-8(a) Exc. No. 2	Supply conductors located in electrical room	695-6(b) Exc.
	Conductor Size (New)	695-6(c)
695-8(c)	Overload Protection (New and Rewritten)	695-6(d)
695-8(b)	Pump Wiring (Retitled)	695-6(e)
695-8(d)	Junction Points (Retitled and Rewritten)	695-6(f)
695-8(f)	Mechanical Protection (Retitled and Rewritten)	695-6(g)
695-8(e)	Voltage Drop (Retitled)	695-7
695-7	Equipment Location (Subsections Retitled)	695-12
695-9	Control Wiring (Subsections Retitled)	695-14

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Application

The table illustrates the reorganization of Article 695. Important specific changes are covered separately.

Background and Explanation

The rewrite of Article 695 involves some important changes such as a provision to allow power sources that do not originate from a utility. These changes will be covered separately. The table illustrating the reorganization indicates the sections that were moved, those that were rewritten or retitled, and those that are new.

The reorganization and revisions to Article 695 represent the efforts on the part of the National Electrical Code Committee and the NFPA Technical Committe on Fire Pumps to harmonize the areas of common requirements in the NEC and NFPA-20-1996. Of particular concern to both committees was resolving the problem of providing reliable power for electric fire pumps installed throughout multibuilding campus-style complexes.

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NEC pp. 497–498

695-3 Alternatives for Providing Reliable Power Source

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Power production sources other than generators are recognized as reliable power sources for fire pumps. Dual feeders to separate buildings on multibuilding, campus-style complexes are also recognized.

Code Language

695-3. Power Source(s) for Electric Motor-Driven Fire Pumps. **Electric motor-driven fire pumps shall have a reliable source of power.** (ROC 15-77) (TCC 15-77)

[x](a) Individual Sources. Where reliable, and where capable of carrying indefinitely the sum of the locked-rotor current of the fire pump motor(s) and the pressure maintenance pump motor(s) and the full-load current of the associated fire pump accessory equipment when connected to this power supply, the power source for an electric motor-driven fire pump shall be one or more of the following. (ROC 15-80)

(ROC 15-75)

(1) Electric Utility Service Connection. A fire pump shall be permitted to be supplied by a separate service, or by a tap located ahead of and not within the same cabinet, enclosure, or vertical switchboard section as the service disconnecting means. The connection shall be located and arranged so as to minimize the possibility of damage by fire from within the premises and from exposing hazards. A tap ahead of the service disconnecting means shall comply with Section 230-82(4). The service equipment shall comply with the labeling requirements in Section 230-2 and the location requirements in Section 230-72(b).

(2) On-Site Power Production Facility. A fire pump shall be permitted to be supplied by an on-site power production facility. The source facility shall be located and protected to minimize the possibility of damage by fire.

[x](b) Multiple Sources. Where reliable power cannot be obtained from a source described in Section 695-3(a), power shall be supplied from an **approved combination of** two or more of either of such sources **or from an approved combination of one or more of such sources in combination with an on-site standby generator complying with (1) and (3) or two or more feeders complying with (2) or (3) or from two or more sets of feeders complying with (2) and (3).** (ROC 15-80, 15-77)

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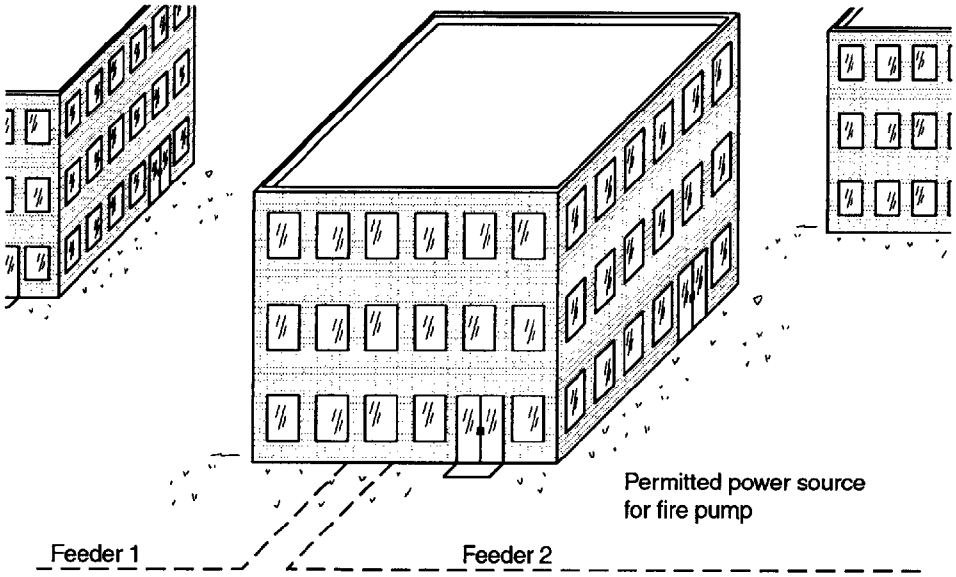
(1) Generator Capacity. An on-site generator(s) used to comply with this section shall be of sufficient capacity to allow normal starting and running of the motor(s) driving the fire pump(s) while supplying all other simultaneously operated load. Automatic shedding of one or more optional standby loads in order to comply with this capacity requirement shall be permitted. A tap ahead of the on-site generator shall not be required. (ROC 15-85, 15-86) (TCC 15-77)

(2) Feeder Sources. This section applies to multi-building campus-style complexes with fire pumps at one or more buildings. Where sources in Section 695-3(a) are not practicable, and with the approval of the authority having jurisdiction, two or more feeder sources shall be permitted as one power source or as more than one power source where such feeders are connected to or derived from separate utility services. The connection(s), overcurrent protective device(s), and disconnecting means for such feeders shall meet the requirements of Section 695-4(b). (ROC 15-77, 15-82, 15-83) (TCC 15-77)

(3) Arrangement. The power sources shall be arranged so that a fire at one source will not cause an interruption at the other source. (ROC 15-77)



Feeders Serving Fire Pumps

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Application

Power sources for electric fire pumps must be reliable and have adequate capacity to carry the locked-rotor currents of fire pump motors plus the full load currents of accessory equipment. One or more of three basic types of sources are permitted. Power may be supplied by a separate utility service, by on-site power production, or with the approval of the authority having jurisdiction, by two or more feeders on multibuilding campuses where direct utility connection or power produced on site are not reasonably available. If none of these options is individually capable of providing reliable power with adequate capacity, multiple sources may be used.

The illustration depicts a building in a campus-style complex. Utility power is not available in this case. Two feeders are used to provide the reliability required. Each feeder and its power source and overcurrent devices must be capable of allowing locked-rotor current to continue indefinitely.

The portions of Section 695-3 marked with a superscript "x" are extracted from NFPA 20-1996, *Standard for the Installation of Centifugal Fire Pumps.*

Background and Explanation

One of the most significant changes in this section is in the permission to use power sources other than separate services or on-site generation facilities as the sole reliable power source to supply electrically driven fire pumps. Since "on-site power production facilities" are now permitted, sources other than rotating generators are permitted as long as they have adequate capacity. Another significant change addresses the power source for multibuilding complexes. Since many multibuilding complexes are supplied by a single utility service, providing separate services for fire pumps at individual buildings is not feasable. To address this type of installation the 1999 NEC permits two or more feeder sources to be treated as a single reliable power source or as multiple sources where the feeders are supplied by separate utility services. The absence of this last option in the 1996 code rendered Article 695 difficult to apply to a multi-building campus-type of facility.

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695-6(a), (b), (c) & 700-9 Protection of Fire Pump and Emergency System Conductors

NEC pp. 499 & 502

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Requirements for fire protection of fire pump and emergency system wiring have been clarified.

Code Language

695-6. Power Wiring. **Power circuits and wiring methods shall comply with the requirements in (a) through (g), and as permitted in Section 230-90(a), Exception No. 4; Section 230-94, Exception No. 4; Section 230-95, Exception No. 2; Section 240-13(3); Section 230-208, Section 240-3(a), and Section 430-31.** (ROC 15-75)

(a) Service Conductors. Supply conductors shall be physically routed outside a building(s) and shall be installed as service entrance conductors in accordance with Article 230. Where supply conductors cannot be physically routed outside buildings, they shall be permitted to be routed through buildings where installed **in accordance with Condition No. 1 or Condition No. 2 of Section 230-6. Where a fire pump is wired under the provisions of Section 695-3(b)(2), this requirement shall apply to all supply conductors on the load side of the service disconnecting means that constitute the normal source of supply to that fire pump.** (ROP 15-99) (TCC 15-75)

Exception: Where there are multiple sources of supply with means for automatic connection from one source to the other, the requirement shall only apply to those conductors on the load side of that point of automatic connection between sources.

(b) Circuit Conductors. Fire pump supply conductors on the load side of the final disconnecting means and overcurrent device(s) permitted by Section 695-4(b) shall be kept entirely independent of all other wiring. They shall only supply loads that are directly associated with the fire pump system, and they shall be protected to resist potential damage by fire, structural failure, or operational accident. They shall be permitted to be routed through a building(s) encased in 2 in. (50.8 mm) of concrete or within enclosed construction dedicated to the fire pump circuit(s) and having a minimum of a 1-hour fire resistance rating, or they shall be permitted to be within listed electrical circuit protective systems with a minimum of 1-hour fire resistance. The installation shall comply with any restrictions provided in the listing of the electrical circuit protective system used. (ROP 15-99)

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Exception: The supply conductors located in the electrical equipment room where they originate and in the fire pump room ***shall not be required to have the minimum 1-hour fire separation or fire resistance rating, unless otherwise required by Section 700-9(d) of this Code.*** (ROP 15-99)

(c) Conductor Size.

(1) Conductors supplying a fire pump motor(s), pressure maintenance pumps, and associated fire pump accessory equipment shall have a minimum rating of 125 percent of the sum of the fire pump motor(s) and pressure maintenance motor(s) full-load current(s), and 100 percent of the associated fire pump accessory equipment. (ROP 15-99)

(2) Conductors supplying only a fire pump motor(s) shall have a minimum rating of 125 percent of the fire pump motor(s) full-load current(s). (ROP 15-99) (ROC 15-75)

700-9. Wiring, Emergency System.

(d) Fire Protection. Emergency systems shall meet the following additional requirements in assembly occupancies greater than 1000 persons or in buildings above 75 ft (23 m) in height with any of the following occupancy classes: assembly, educational, residential, detention and correctional, business, and mercantile. (ROP 15-126a)

(1) Feeder-circuit wiring shall meet one of the following conditions:
(ROP 15-130a)

(a) Be installed within ~~spaces~~ buildings that are fully protected by an approved automatic fire suppression system

(b) Be a listed electrical circuit protective system with a minimum 1-hour fire rating

(c) Be protected by a listed thermal barrier system for electrical system components

(d) Be protected by a fire-rated assembly having a minimum fire rating of 1 hour (ROC 15-117) (TCC 15-117)

(e) Be embedded in a minimum of 2 in. (50.8 mm) of concrete (ROP 15-130a)

(f) Be a cable listed to maintain circuit integrity for a minimum of 1 hour when installed in accordance with the listing requirements (ROC 15-114)

(2) Equipment for feeder circuits (including transfer switches, transformers, panelboards, etc.) shall be located either in spaces fully protected by approved automatic fire suppression systems (sprinklers, carbon dioxide systems, etc.) or in spaces with a 1-hour fire resistance rating.

FPN: For the definition of *occupancy class*, see Section 4-1 of *Life Safety Code*, NFPA 101-1997.

(ROC 15-113)

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Protection Methods for Fire Pump Conductors, Emergency Feeders, and Emergency Distribution Equipment Where Routed or Located Inside Building

Method of Protection	*Fire Pump Conductors per Article 695*	*Emergency Feeders for Assembly Occupancies Greater Than 1000 People or Above 75 Feet in Height per Section 700-9(d)*	*Emergency Distribution Equipment for Assembly Occupancies Greater Than 1000 People or Above 75 Feet in Height per Section 700-9(d)*
1. Raceways embedded in 2" concrete	Permitted	Permitted	Not Applicable
2. Located in buildings fully protected by automatic fire suppression system	Not Permitted	Permitted	Permitted (Sprinkler protection in equipment space)
3. Listed electrical circuit protective system with minimum 1-hour fire rating	Not Permitted (Load side of service only)	Permitted	Not Applicable
4. Listed thermal barrier system for electrical system components	Not Permitted	Permitted	Not Applicable
5. Fire-rated assembly with minimum 1-hour fire rating	Permitted (Load side of service only)	Permitted	Permitted (Building space)
6. Cable listed to maintain circuit integrity for minimum of 1-hour	Not Permitted	Permitted	Not Applicable

Application

Section 695-6(a) covers fire pump service conductors. These conductors must be installed outside the building, or beneath the building under 2 inches of concrete, or inside the building encased in at least 2 inches of concrete or brick. Section 695-6(b) requires other fire pump supply conductors on the load side of any permitted disconnecting means and overcurrent device that are inside the building to be encased in at least 2 inches of concrete or protected by a listed electrical circuit protective system with at least a 1-hour fire resistance rating. Fire pump supply conductors within enclosed spaces that have a 1-hour fire resistance rating and are dedicated to the pump circuits are also recognized.

For some emergency systems, fire protection for supply conductors is also required. The requirements in Section 700-9(d) only apply in places of assembly for over 1000 persons or in buildings over 75 feet in height for any of the following occupancies:

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1. Assembly
2. Educational
3. Residential
4. Detention and correctional
5. Business
6. Mercantile

As with fire pumps, protection may be by encasement in 2 inches of concrete or listed electrical protective systems. Other recognized methods include fire suppression systems, thermal barriers, and 1-hour fire rated assemblies.

The table illustrates the acceptable protection methods for conductors and equipment associated with fire pumps and emergency systems.

Background and Explanation

These requirements ensure reliable operation of these critical life safety systems. The routing of the conductors within a building exposes them to physical damage and possibly direct damage from a fire. The protection provisions of these two sections address those physical damage concerns. Both articles were revised to eliminate exceptions and clarify the requirements.

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695-10 Listed Fire Pump Equipment

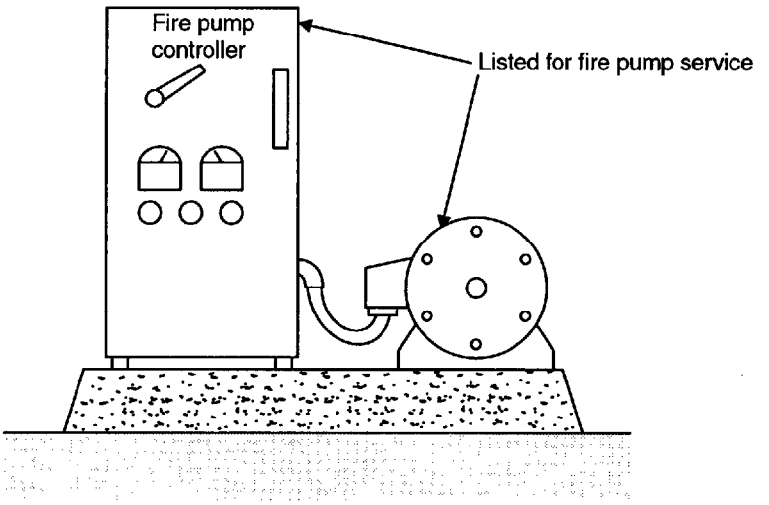
Type of Change New

BRIEF SUMMARY

Commercial and industrial. Listing for fire pump equipment is required.

Code Language

695-10. Listed Equipment. Diesel engine fire pump controllers, electric fire pump controllers, electric motors, fire pump power transfer switches, foam pump controllers, and limited service controllers shall be listed for fire pump service. (ROC 15-76) (TCC 15-76)



Equipment Listed for Fire Pump Service

Application

Controllers, transfer switches, and electric fire pump motors are required to be listed for fire pump service. This has been a requirement of NFPA 20 and has now been included in Article 695.

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Background and Explanation

Listing of components is required by NFPA 20 *Standard for the Installation of Centrifugal Fire Pumps.* An effort has been made in the last two code cycles to make the requirements of NFPA 20 and Article 695 of the NEC similar. The inclusion of the listing requirement in Article 695 reflects that harmonization effort. Quite often the inspection of the electrical components is performed by an electrical inspector using only the NEC as the basis for approval.

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NEC pp. 502 & 506

700-6(c) & 701-7 Mechanically Held Transfer Switches

Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. Automatic transfer switches for emergency or legally required standby systems are required to be mechanically held. Transfer equipment for emergency systems may not supply nonemergency loads.

Code Language

700-6. Transfer Equipment.

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(c) Automatic transfer switches shall be electrically operated and mechanically held. (ROP 15-123a)

(d) Transfer equipment shall supply only emergency loads. (ROP 15-127)

701-7. Transfer Equipment.

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(c) **Automatic transfer switches shall be electrically operated and mechanically held.** (ROP 15-151b)

Application

As shown in the illustration, automatic transfer switches for emergency systems or legally required standby systems are required to be electrically operated and mechanically held. Electrically held switches are no longer permitted.

Transfer switches used for emergency systems cannot supply nonemergency loads other than as permitted by Sections 517-30(b)(4) for hospitals and 517-41(b) for nursing homes and limited care facilities. Transfer switches for legally required standby systems may supply other loads.

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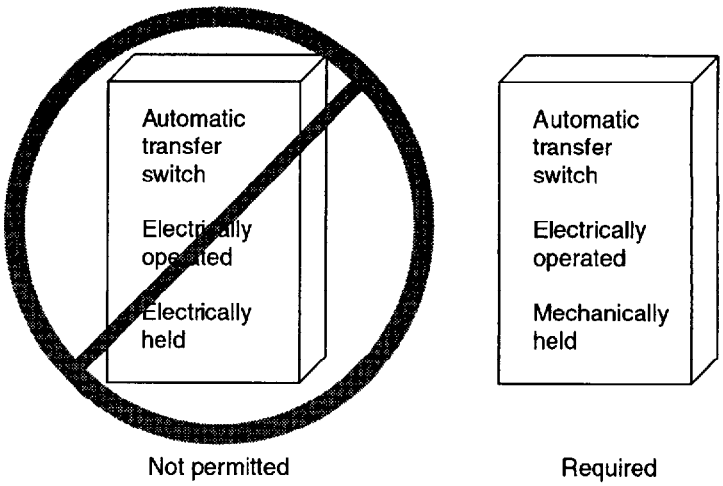

Tranfer Equipment Requirements

Background and Explanation

The new requirement for mechanically held switches was adopted because of a reported failure of an electrically held switch.

The restriction on the use of transfer switches for only emergency loads was based on the need to maximize the reliability of emergency systems. A failure of nonemergency equipment supplied by emergency transfer equipment might compromise the reliability of the emergency system.

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725-24 Exc. No. 3 Overcurrent Protection for Electronic Class 1 Power Supplies

Type of Change New

BRIEF SUMMARY

All installations. Output conductors of a listed Class 1 electronic power supply may be protected by the input overcurrent device.

Code Language

725-24. Class 1 Circuit Overcurrent Device Location. Overcurrent devices shall be located at the point where the conductor to be protected receives its supply.

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Exception No. 3: Electronic power source output conductors. Class 1 circuit conductors supplied by the output of a single-phase, listed electronic power source, other than a transformer, having only a 2-wire (single-voltage) output for connection to Class 1 circuits shall be permitted to be protected by overcurrent protection provided on the input side of the electronic power source, provided this protection does not exceed the value determined by multiplying the Class 1 circuit conductor ampacity by the output-to-input voltage ratio. Electronic power source outputs, other than 2 wire (single voltage), connected to Class 1 circuits shall not be considered to be protected by overcurrent protection on the input of the electronic power source. (ROP 16-19, 16-20)

FPN: A single-phase, listed electronic power supply whose output supplies a 2-wire (single-voltage) circuit is an example of a Class 1 power source meeting the requirements of Section 725-23. (ROP 16-20)

Application

The illustration depicts a listed Class 1 electronic power supply with output conductors that are not protected where they receive their supply as required by the main rule of Section 725-24. A new exception allows the conductors on the output side of a listed Class 1 power supply to be protected by the input overcurrent device. The maximum size input overcurrent device that will protect the output conductors is determined as follows:

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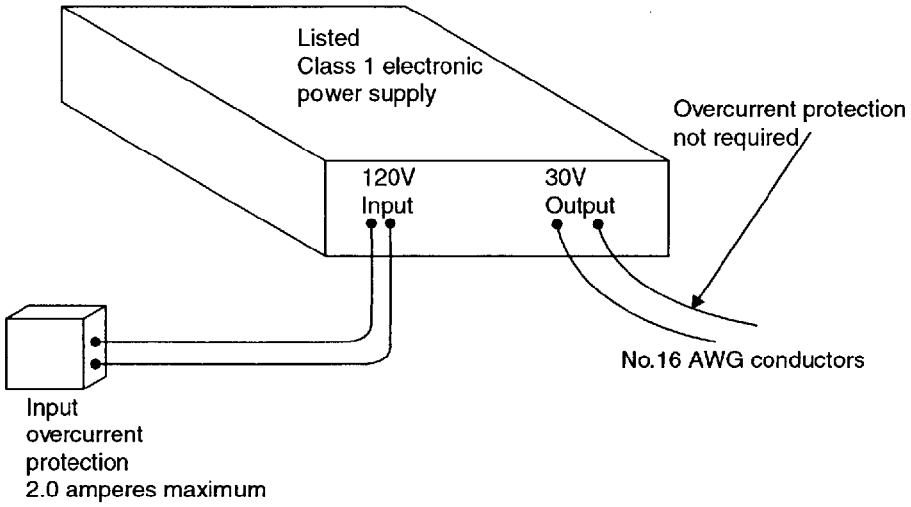
The ampacity of a No. 16 conductor is found in Sections 725-27(a) and 402-5 (8 amperes).

Max. Input OCD = output ampacity × output voltage/input voltage

Max. Input OCD = 8 amperes × 30 volts/120 volts = 8 amperes × 0.25

Max. Input OCD = 2.0 amperes

Therefore, the No. 16 Class 1 conductors can be protected by a 2.0 ampere or smaller rated input overcurrent device.



Class 1 Circuit Protection

Background and Explanation

A number of editorial changes were made in this section. Exceptions Nos. 2 and 3 to Section 725-23 in the 1996 code were moved to Section 725-24 because they addressed the location of overcurrent protection rather than the value of overcurrent protection.

The previous Exception No. 1 under Section 725-24 remains. The previous Exception No. 2 under Section 725-24 was deleted and replaced with the previous Exception No. 2 from Section 725-23. The new exception for Class 1 electronic power supplies became Exception No. 3 to Section 725-24. The previous Exception No. 3 under Section 725-23 became Section 725-24 Exception No. 4.

The exceptions to Section 725-24 are all similar to the tap rules of Section 240-21, that is, they all address protection of Class 1 conductors that are not protected where they receive their supply. Exceptions Nos. 2 and 3 both apply only to power supplies and transformers with 2-wire outputs or secondaries. Also, Section 725-24 Exception No. 3 applies only to listed power supplies.

In general, Class 1 power supplies are not required to be listed, and Class 1 circuits can be supplied in a number of ways in accordance with Section 725-21. Class 2 and Class 3 power supplies, except for those supplied by a dry cell battery or a thermocouple, are required to be listed.

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725-54(a)(1) Exc. No. 6 Separation Requirements for Class 2 and 3 Circuits in Cable Tray

Type of Change New

BRIEF SUMMARY

Commercial and industrial. Limited permission to install signaling conductors and other circuits in the same cable tray is provided.

Code Language

725-54. Installation of Conductors and Equipment.

(a) Separation from Electric Light, Power, Class 1, Nonpower-Limited Fire Alarm Circuit Conductors, and Medium Power Network-Powered Broadband Communications Cables.

(1) In Cables, Compartments, Cable Trays, Enclosures, Manholes, Outlet Boxes, Device Boxes, and Raceways. Cables and conductors of Class 2 and Class 3 circuits shall not be placed in any cable, cable tray, compartment, enclosure, manhole, outlet box, device box, raceway, or similar fitting with conductors of electric light, power, Class 1, nonpower-limited fire alarm circuits, and medium power network-powered broadband communications cables. (ROP 16-34)

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Exception No. 6: In cable trays, where the conductors of the electric light, power, Class 1, and nonpower-limited fire alarm circuits are separated by a solid fixed barrier of a material compatible with the cable tray, or where the Class 2 and Class 3 circuits are installed in Type MC cable. (ROP 16-37)

Application

When a fixed barrier is installed, Class 2 or Class 3 control circuits may be installed in the same cable tray. Where Type MC cable is used as the wiring method for the Class 2 and Class 3 circuits, the barrier is not required in the cable tray. This new exception allows a common cable tray to be used for power and signaling circuits.

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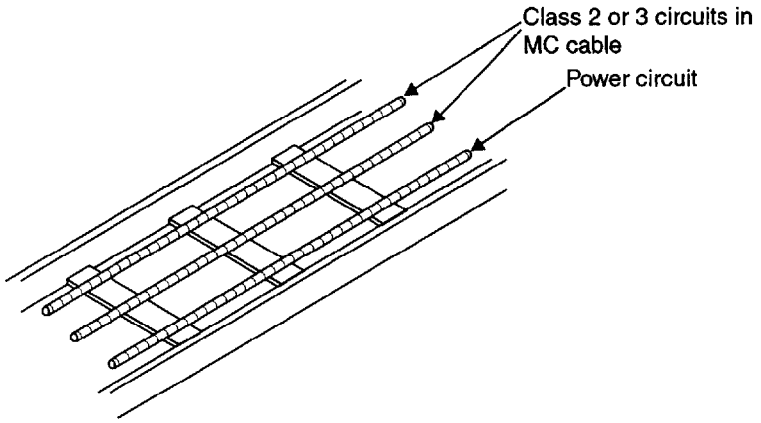

Power and Control Circuits in Common Cable Tray

Background and Explanation

A fixed barrier is the equivalent of providing two separate cable trays. There is no reason to prohibit the installation of Class 2 or Class 3 circuits in one section and power circuits in a separate section.

The cable armor of Type MC cable is also recognized as adequate separation between the Class 2 and Class 3 conductors and the conductors of power, Class 1, and nonpower-limited circuits.

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725-61,760-61, 800-53 & 820-53 Cable Substitution Table Revisions

NEC pp. 516, 525, 540 & 549

Type of Change Revisions

BRIEF SUMMARY

All installations. The cable substitution tables were revised and clarified for remote control and signaling, fire alarms, communications, and CATV. Numerous permitted substitutions were eliminated, including the permission to substitute fire alarm cables for CL2 and CL3 cables.

Code Language

(ROP 16-45a)

Table 725-61. Cable Uses and Permitted Substitutions

Cable Type	*Use*	*References*	*Permitted Substitutions*
CL3P	Class 3 plenum cable	725-61(a)	CMP
CL2P	Class 2 plenum cable	725-61(a)	CMP, CL3P
CL3R	Class 3 riser cable	725-61(b)	CMP, CL3P, CMR
CL2R	Class 2 riser cable	725-61(b)	CMP, CL3P, CL2P, CMR, CL3R
PLTC	Power-limited tray cable	725-61(c) and (d)	
CL3	Class 3 cable	725-61(b), (e), and (f)	CMP, CL3P, CMR, CL3R, CMG, CM, PLTC
CL2	Class 2 cable	725-61(b), (e), and (f)	CMP, CL3P, CL2P, CMR, CL3R, CL2R, CMG, CM, PLTC,
CL3			
CL3X	Class 3 cable, limited use	725-61(b) and (e)	CMP, CL3P, CMR, CL3R, CMG, CM, PLTC, CL3, CMX
CL2X	Class 2 cable, limited use	725-61(b) and (e)	CMP, CL3P, CL2P, CMR, CL3R, CL2R, CMG, CM, PLTC,

Application

The permitted substitutions for Class 2 and Class 3 cables are given in the revised Table 725-61. For example, cable types MPP, MPR, MPG, MP, FPLP, FPLR, and FPL are no longer permitted as substitutions for Type CL2 cable. Similar changes were made in Article 760 for power-limited fire alarm cables, in Article 800 for communications cables, and in Article 820 for community antenna television (CATV) cables.

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Background and Explanation

This change was originated by CMP 16, the code-making panel responsible for Articles 725, 760, 800, and 820. The panel substantiation was as follows: "The extensive revisions to the cable substitution tables and associated text have been made to clarify the more realistic usage of field applications for the various cable types. These changes make these tables more user-friendly and more clearly express their application."

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Article 727 Use of Instrumentation Tray Cable

Type of Change Revision

BRIEF SUMMARY

Industrial. Extensive revisions were made to correlate articles and clarify cable usage.

Code Language

This article has been extensively revised. Refer to outline. (ROP 16-61)

Article 727 — Instrumentation Tray Cable: Type ITC

727-1. Scope
727-2. Definition.
727-3. Other Articles.
727-4. Uses Permitted.
727-5. Uses Not Permitted
727-6. Construction.
727-7. Marking.
727-8. Allowable Ampacity.
727-9. Overcurrent Protection.
727-10. Bends.

Background and Explanation

This article was new in the 1996 NEC. The revision was done by a Panel 16 task group with the goal of improved usability. Efforts were made to improve correlation with other articles. The scope statement of the article was revised to clearly identify the types of circuits (instrumentation and control) that Type ITC cable can be used for and the maximum voltage and current levels (150 volts and 5 amperes) of these circuits. A new rule for overcurrent protection of the conductors in type ITC cable has also been added.

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NEC pp. 519 & 523

760-2 & 760-31(f) Circuit Integrity Cables for Fire Alarm Systems

Type of Change New

BRIEF SUMMARY

Fire alarm systems. The use of a new cable type has been recognized.

Code Language

760-2. Definitions. For purposes of this article, the following definitions apply.

Fire Alarm Circuit Integrity (CI) Cable. Cable used in fire alarm systems to ensure continued operation of critical circuits during a specified time under fire conditions. (ROP 16-74)

760-31. Listing and Marking of NPLFA Cables.

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(f) Fire Alarm Circuit Integrity (CI) Cable. Cables suitable for use in fire alarm systems to ensure survivability of critical circuits during a specified time under fire conditions shall be listed as circuit integrity (CI) cable. Cables identified in Sections 760-31(c), (d), and (e) meeting the requirements for circuit integrity shall have the additional classification using the suffix "CI" (for example, NPLFP-CI, NPLFR-CI and NPLF-CI). (ROP 16-95)

FPN No. 1: This cable may be used for fire alarm circuits to comply with the survivability requirements of *National Fire Alarm Code*,® NFPA 72-1996, subsections 3-2.4, 3-4.4, 3-12.4, and 3-12.4.3, that the cable maintain its electrical function during fire conditions for a defined period of time.

FPN No. 2: One method of defining circuit integrity (CI) cable is by establishing a minimum 2-hour fire resistance rating for the cable when tested in accordance with the *Standard for Tests of Fire Resistive Cables,* UL 2196 - 1995. (ROP 16-95)

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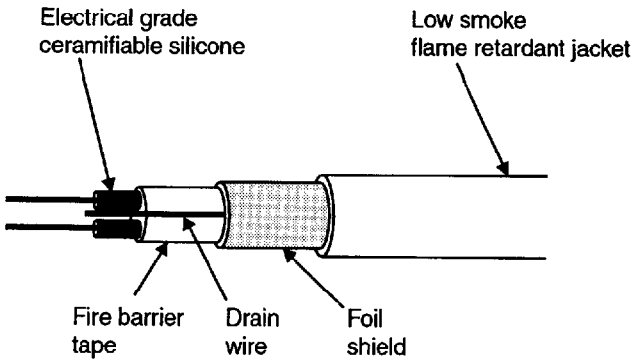

Circuit Integrity Cable

Application

There are provisions in the *National Fire Alarm Code*, NFPA 72-1996, that require continued operation of the fire alarm system including circuit wiring, under severe conditions such as attack by fire. To provide this integrity, NFPA 72 recognizes the use of 2-hour fire-rated cable assemblies. FPN No.2 refers to cables tested in accordance with UL 2196 as an example of the type of wiring method that would qualify as circuit integrity (CI) cable.

Background and Explanation

New cable types are available for use where survivability of critical fire alarm circuits is required. This new cable is identified with the cable marking suffix CI. An example of this marking would be NPLFP-CI for nonpower-limited fire alarm plenum-rated cable that not only meets the performance requirements for a cable installed in a plenum but that also has been evaluated for its ability to maintain circuit integrity for a specified time period. Although these requirements are relatively new to the NEC and NFAC, survivability requirements for critical systems has been a requirement of the U.S. Nuclear Regulatory Commission (NRC) for the construction of nuclear power plants.

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760-7 Fire Alarm Circuits Installed Outdoors

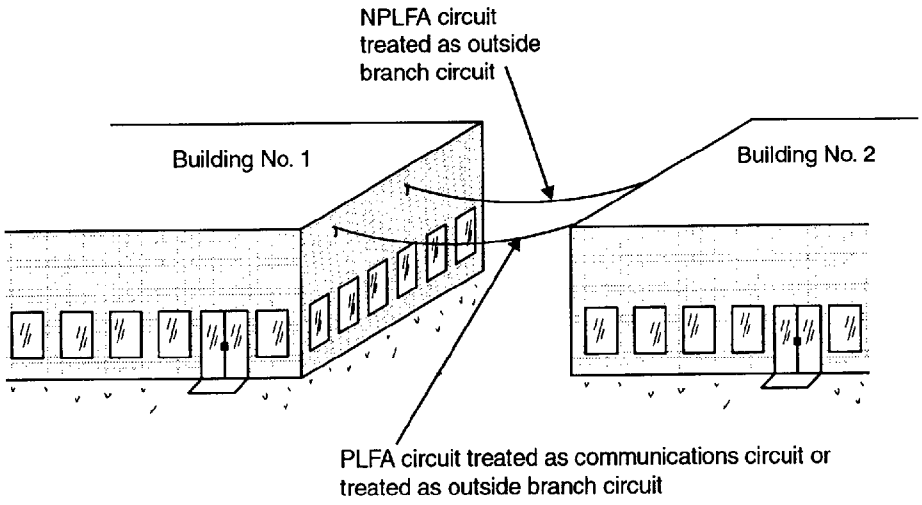
Type of Change Revision

BRIEF SUMMARY

Commercial and industrial. The installation requirements and classification of fire alarm circuits run outside has been clarified.

Code Language

760-7. Fire Alarm Circuits Extending Beyond One Building. **Power-limited** fire alarm circuits that extend beyond one building **and run outdoors** shall either meet the **installation** requirements of **Parts B, C, and D** of Article 800, ~~and be classified as communication circuits~~ or shall meet the **installation** requirements of Article 225. **Nonpower-limited fire alarm circuits that extend beyond one building and run outdoors shall meet the requirements of Article 225.** (ROP 16-78)



Outside Fire Alarm Circuits

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Application

The illustration shows two fire alarm circuits run outside between two buildings. The nonpower-limited fire alarm (NPLFA) circuit must be treated as an outside branch circuit and must be installed in accordance with Article 225. The power-limited fire alarm (PLFA) circuit may be installed either as an outside branch circuit in accordance with Article 225 or as a communications circuit in accordance with Parts B, C, and D of Article 800. If the fire alarm circuits are alternating current and the circuits are run outside and overhead as shown in the illustration, the circuits must also be grounded in accordance with Sections 250-20(a)(3) and 250-112(i).

Background and Explanation

This change was made primarily to clarify that fire alarm circuits that extend beyond a building and run outdoors are still classified as fire alarm circuits but must meet the applicable installation requirements of communications circuits or outside branch circuits. Fire alarm circuits treated as communications circuits must comply with clearance, spacing, attachment, grounding, and protection requirements of Article 800 for communications circuits, but can use communications-grade wiring methods. Fire alarm circuits treated as outside branch circuits must meet the clearance, spacing, attachment, and protection requirements of Article 225 and must use wiring methods suitable for outside branch circuits.

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760-52(a) Exc. No. 3 FPN Reclassification of Fire Alarm Circuits

NEC p. 524

Type of Change New

BRIEF SUMMARY

All installations. A FPN clarifies the reclassification of power-limited fire alarm circuits.

Code Language

760-52(a). NPLFA Wiring Methods and Materials.

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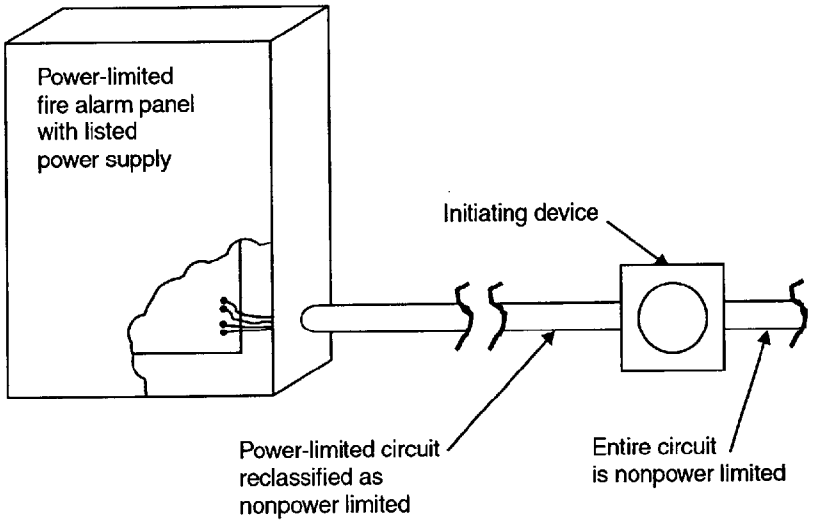
Exception No. 3: Power-limited circuits shall be permitted to be reclassified and installed as nonpower-limited circuits if the power-limited fire alarm circuit markings required by Section 760-42 are eliminated and the entire circuit is installed using the wiring methods and materials in accordance with Part B, Nonpower-Limited Fire Alarm Circuits.

FPN: Power-limited circuits reclassified and installed as nonpower-limited circuits are no longer power-limited circuits, regardless of the continued connection to a power-limited source. (ROP 16-103)



Reclassification of Fire Alarm Circuits

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Application

The illustration depicts a fire alarm circuit connected to a power-limited source. The circuit has been reclassified as nonpower-limited so that nonpower-limited wiring methods may be used and power-limited markings are not required. Reclassification would also allow mixing of the fire alarm circuits with some other systems as permitted by Section 760-26. The entire circuit becomes a nonpower-limited circuit even though it continues to be connected to a power-limited source. The entire circuit must also use nonpower-limited wiring methods as specified in Sections 760-25 and 760-27.

Background and Explanation

The new FPN is intended to clarify the fact that once a fire alarm circuit has been reclassified as nonpower-limited, the entire circuit is nonpower-limited and must be treated as such, regardless of whether or not it is supplied by a power-limited source.

The rule allowing reclassification of fire alarm circuits is quite different from the rules for Class 2 and Class 3 remote control and signaling circuits. Class 2 and Class 3 circuits are classified by their connection to power-limited sources and are not permitted to be reclassified as nonpower-limited Class 1 circuits, unless required by Section 725-8 for safety control equipment. As noted above, a power-limited fire alarm circuit may be classified as nonpower-limited even though it remains connected to a power-limited source. Unlike Class 1 power-limited, Class 2, and Class 3 circuits, fire alarm circuits may be reclassified to permit alternative wiring methods.

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NEC p. 524

760-52(b) Fire Alarm Device Installation

Type of Change Revision

BRIEF SUMMARY

Fire alarm systems. The requirements for the proper installation of devices has been clarified.

Code Language

760-52. Wiring Methods and Materials on Load Side of the PLFA Power Source.

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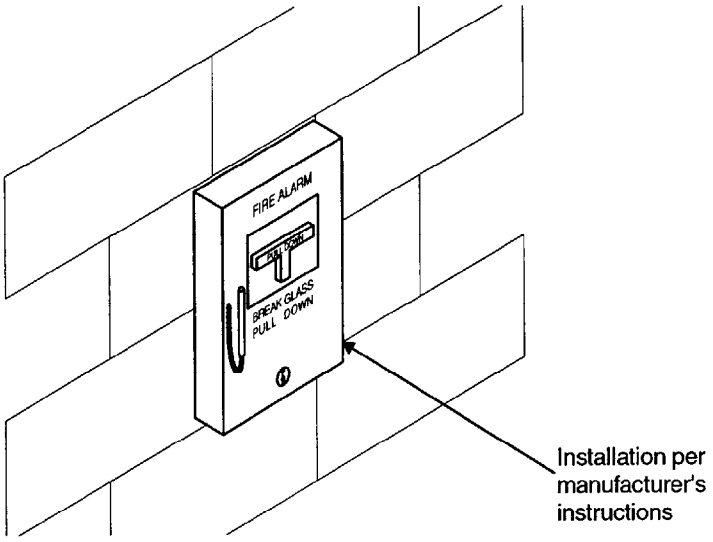
(b) PLFA Wiring Methods and Materials. Power-limited fire alarm conductors and cables described in Section 760-71 shall be installed as detailed in (1), (2), or (3) of this section. **Devices shall be installed in accordance with Sections 110-3(b), 300-11(a), and 300-15.** (ROP 16-98)



Installation Requirements for Fire Alarm System Devices

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Application

Three references have been added to this section to ensure that installers are aware of the need for compliance with instruction included in the listing and labeling. Section 110-3(b) requires listed devices to be installed in accordance with the listing and labeling instructions. Section 300-11(a) is a general requirement for proper support and securing of boxes and other equipment. This section also covers the use of ceiling support wires to secure electrical equipment above suspended ceilings. Section 300-15 requires boxes or other enclosures at all conductor splice points and the reference here applies to fire alarm devices.

Background and Explanation

Fire alarm installers may not be aware of the three sections referenced in this revised section. They typically focus on the requirements of Article 760 and the National Fire Alarm Code. This revision is intended to call attention to these sections, which require compliance with listing requirements, support of devices, and the use of boxes for the support of fire alarm devices where indicated in the device manufacturer's installation instructions.

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770-6 Exc. Conduit Fill Requirements for Optical Fiber Raceways

Type of Change New

BRIEF SUMMARY

Optical fiber systems. The exception clarifies where conduit fill rules apply.

Code Language

770-6. Raceways for Optical Fiber Cables. The raceway shall be of a type permitted in Chapter 3 and installed in accordance with Chapter 3. (ROC 16-62)

Exception: Listed nonmetallic optical fiber raceway identified as general purpose, riser, or plenum optical fiber raceway in accordance with Section 770-51 and installed in accordance with Sections 331-7 through 331-14, where the requirements applicable to electrical nonmetallic tubing shall apply. Unlisted underground or outside plant construction plastic innerduct shall be terminated at the point of entrance. (ROC 16-63, 16-64)

FPN: For information on listing requirements for optical fiber raceways, see UL 2024, *Standard for Optical Fiber Raceways.* (ROP 16-127) (ROP 16-125, 16-129)

Where optical fiber cables are installed within the raceway without current-carrying conductors, the raceway fill tables of Chapter 3 and Chapter 9 shall not apply.

Where nonconductive optical fiber cables are installed with electric conductors in a raceway, the raceway fill tables of Chapter 3 and Chapter 9 shall apply. (ROP 16-127, 16-128)

Application

Where only fiber optic cables are installed in a raceway, the raceway fill rules from Chapter 3 and Chapter 9 do not apply to the installation.Where a combination of optical fiber cables and electrical conductors are in the same raceway as permitted by Section 770-52, the Chapter 3 and Chapter 9 conduit fill limitations must be followed.

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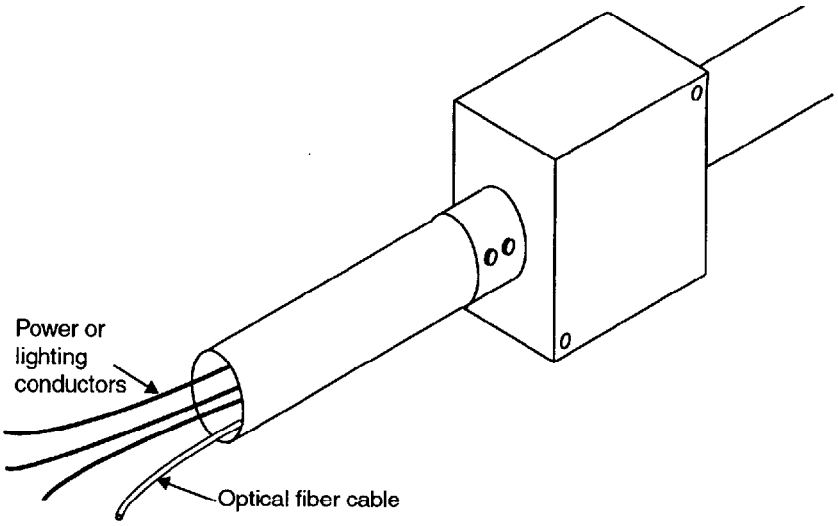

Common Raceway for Power and Fiber Optic Systems

Background and Explanation

Section 90-1 makes clear that the purpose of the code is electrical safety. Where only optical fiber cables are installed, a damaged cable will not present a safety hazard. Where electrical conductors are mixed with optical fiber, a damaged electrical conductor can present a fire or shock hazard. Section 770-6 has been changed from "Cable Trays" to "Raceways for Optical Fiber Cables."

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800-4 Installation and Use of Listed and Labeled Equipment

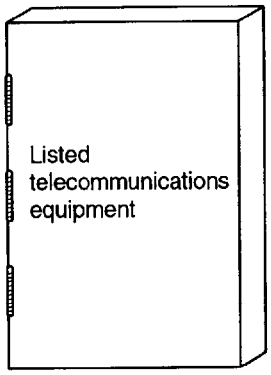
Type of Change Revision

BRIEF SUMMARY

All installations. Installation of telecommunications equipment must comply with instructions included in the listing and labeling.

Code Language

800-4. Equipment. Equipment intended to be electrically connected to a telecommunications network shall be listed for the purpose. **Installation of equipment shall also comply with Section 110-3(b).** (ROP 16-153)



110-3(b) Instructions included in listing and labeling must be followed.

Installation of Communications Equipment

Application

Electrically connected telecommunications equipment is required by Section 800-4 to be listed. The installation of such equipment must comply with the instructions included with the equipment or otherwise included in the listing and labeling instructions.

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Background and Explanation

This change was made to clarify the application of listing and labeling requirements to communications equipment. According to Section 90-3, the articles of Chapter 8 are independent from the rest of the code, unless a specific reference is made within these articles to a requirement in Chapters 1 through 7. The requirements of Chapters 1 through 7 do not apply to Chapter 8 except where they are specifically referenced in Chapter 8. Although the previous rule required equipment to be listed, there was no specific requirement that the listing and labeling instructions be followed. The addition of a reference to Section 110-3(b) makes compliance with the instructions relating to communications equipment mandatory.

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800-11(c) Point of Entry for Underground Communications

Type of Change New

BRIEF SUMMARY

All occupancies. A limited distance between communications point of entry and service entry is specified.

Code Language

800-11. Underground Circuits Entering Buildings. . . .

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•
•

(c) Point of Entry. The point of entry for communications wiring and cables shall be within 20 ft (7.0 m) of the electrical service entry point.

Exception: Where it is impracticable to install the communications service in this manner, a separate grounding electrode, installed in compliance with Section 800-4(b)(3) and bonded in accordance with Section 800-40(c) and (d).

FPN: Under certain conditions, the length of the bonding conductor has a direct relationship to the difference in potential between the communications and the power circuits.

Application

A new rule requires a communications circuit entry to a building from underground to be within 20 feet of the electrical service entry point. Where this cannot reasonably be accomplished, a separate grounding electrode shall be installed in the vicinity of the communications point of entry and bonded to the service grounding electrode system.

Background and Explanation

The intent of this section is to limit the length of bonding conductors between communications and electrical service grounding points. As the FPN points out, the difference of potential between the systems may be directly related to the length of the bonding conductors. Although the Exception does not actually

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state a requirement, the intent of the Exception is to require an additional grounding electrode where the entry points cannot be within 20 feet of each other. Note that bonding to the electrical service is still required.

Similar requirements for overhead communications entries and all CATV entries were proposed for Sections 800-10(c) and 820-11(c). These proposals were accepted by the code panels but overturned by the NFPA membership. The new rule in Section 800-11(c) was rejected at the proposal stage and accepted after public comment, but was not changed by the NFPA membership.

In practice, underground communications entries can more easily be routed to various locations in a building than can overhead communications drops, because the point of entry for an underground raceway is where the raceway emerges from the underground. In the case of a grounded rigid metal conduit or intermediate metal conduit, the point of entry may be extended to the end of the conduit in accordance with the definition of "point of entrance" in Section 800-2. Similar descriptions of the point of entrance are found in Sections 800-30(b) and 800-33.

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NEC p. 537

800-48 & 800-53 Installation and Use of Listed Communications Raceways

Type of Change New and Revised

BRIEF SUMMARY

All occupancies. These changes clarify the type of raceways allowed and recognize a new type of raceway for communications cables.

Code Language

800-48. Raceways for Communications Wires and Cables. Where communications wire and cables are installed in a raceway, the raceway shall be of a type permitted in Chapter 3 and installed in accordance with Chapter 3. (ROP 16-174) (ROC 16-97)

Exception: Listed nonmetallic communications raceway identified as general purpose, riser, or plenum in accordance with Section 800-51 and installed in accordance with Sections 331-7 through 331-14, where the requirements applicable to electrical nonmetallic tubing shall apply. (ROP 16-174) (ROC 16-63, 16-96)

800-53. Applications of Listed Communications Wires and Cables, and Communications Raceways. Communications wires and cables shall comply with (a) through (f).

(a) Plenum. Cables installed in ducts, plenums, and other spaces used for environmental air shall be Type CMP. **Also, listed plenum communications raceways shall be permitted to be installed in ducts and plenums as described in Section 300-22(b) and in other spaces used for environmental air as described in Section 300-22(c). Only Type CMP cable shall be permitted to be installed in these raceways.** (ROP 16-197)

Exception: Types CMP, CMR, CMG, CM, and CMX and communications wire installed in compliance with Section 300-22.

(b) Riser. Cables installed in vertical runs and penetrating more than one floor, or cables installed in vertical runs in a shaft, shall be Type CMR. Floor penetrations requiring Type CMR shall contain only cables suitable for riser or plenum use. **Also, listed riser communications raceways shall be permitted to be installed in vertical riser runs in a shaft from floor to floor. Only Type CMR and CMP cables shall be permitted to be installed in these raceways.** (ROP 16-197) (ROC 16-115a)

FPN: See Section 800-52(b) for firestop requirements for floor penetrations.

Exception No. 1: Where the listed cables are encased in metal raceway or are located in a fireproof shaft having firestops at each floor.

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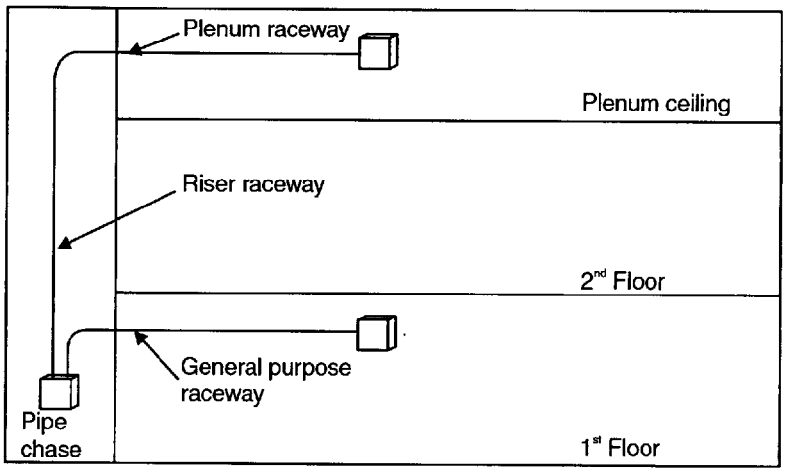
Exception No. 2: Types CM and CMX cable in one- and two-family dwellings.

(d) Other Wiring Within Buildings. Cables installed in building locations other than the locations covered in (a), (b), and (c) shall be Type CMG or Type CM. **Only Type CMG, CM, CMR, or CMP cables shall be permitted to be installed in general purpose communications raceways.** (ROP 16-197) (ROC 16-115a)



Use of communications raceways

Communication Raceways

Background and Explanation

Communication cables may be installed in any of the raceways recognized in Chapter 3 of the NEC. This change recognizes new types of communication raceways and also clarifies that raceways used for communications conductors and cables must be installed in accordance with the specific article covering that type of raceway and that only Chapter 3 raceways or listed communications raceways can be used for communication conductors and cables. The code also recognizes the use of listed nonmetallic communications raceways installed in accordance with specified provisions from Article 331, "Electrical Nonmetallic Tubing."

Section 800-53 has been revised to include three new types of listed communications raceways. Plenum communications raceways are required in ducts and plenums where smoke production and fire resistance are concerns. Riser communications raceways are used in vertical risers where vertical flame spread must be considered. General purpose communications raceways may be used in other locations.

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NEC pp. 550–559

Article 830 Network-Powered Broadband Communications Systems

Type of Change New

BRIEF SUMMARY

Residential and commercial. A new article has been added to cover network-powered broadband communications systems.

Code Language

830-1. Scope. This article covers network-powered broadband communications systems that provide any combination of voice, audio, video, data, and interactive services through a network interface unit.

FPN No. 1: A typical basic system configuration includes a cable supplying power and broadband signal to a network interface unit that converts the broadband signal to the component signals. Typical cables are coaxial cable with both broadband signal and power on the center conductor, composite metallic cable with a coaxial member for the broadband signal and a twisted pair for power, and composite optical fiber cable with a pair of conductors for power. Larger systems may also include network components such as amplifiers that require network power.

FPN No. 2: See Section 90-2(b)(4) for installations of broadband communications systems that are not covered.

Article 830 — Network-Powered Broadband Communications Systems
Part A. General
830-1 Scope
830-2 Definitions
830-3 Locations and Other Articles
830-4 Power Limitations
830-5 Network-Powered Broadband Communications Equipment and Cables
830-6 Access to Electrical Equipment . . .
830-7 Mechanical Execution of Work
830-8 Hazardous (Classified) Locations

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Part B. Cables Outside and Entering Buildings

830-9	Entrance Cables
830-10	Aerial Cables
830-11	Underground Circuits Entering Buildings

Part C. Protection

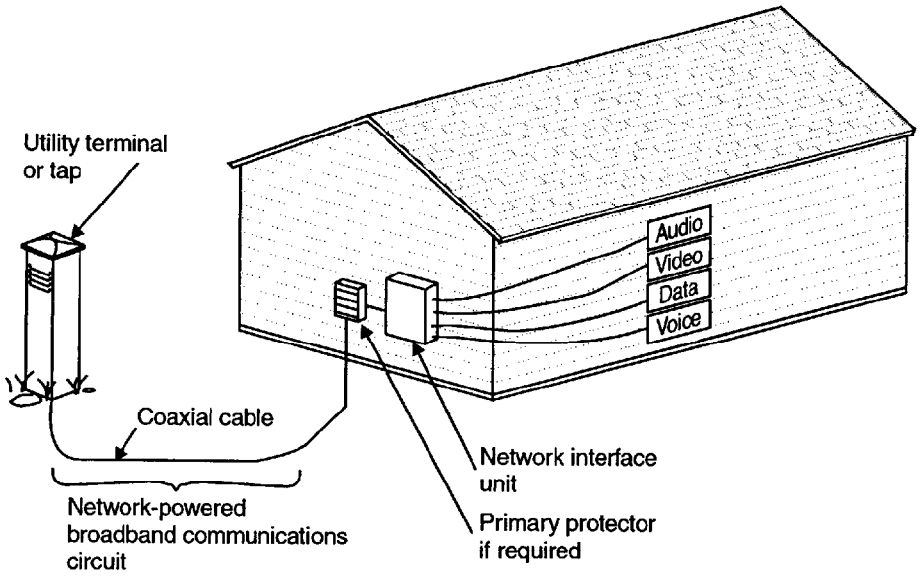
830-30	Primary Electrical Protection
830-33	Grounding or Interruption of Metallic Members . . . of Cables

Part D. Grounding Methods

830-40	Cable, Network Interface Unit, and Primary Protector Grounding
830-42	Bonding and Grounding at Mobile Homes

Part E. Network-Powered . . . Wiring Methods Within Buildings

830-54	Medium Power Network-Powered . . . Wiring Methods
830-55	Low Power Network-Powered . . . Wiring Methods
830-56	Protection Against Physical Damage
830-57	Bends
830-58	Installation of Network-Powered . . . Cables and Equipment



Network-Powered Broadband Communications System

Application

The illustration shows the typical components of a network-powered broadband communications system. Coaxial cable is shown in the diagram, but other cable types may be used. The cable carries a broadband signal for voice, audio, video, data, and interactive services. The same cable also supplies power from the network for conversion equipment. A primary protector may be required by Section 830-30. The network interface unit (NIU) separates the broadband signal into component signals as shown.

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The outline above illustrates the organization of Article 830. Equipment and cables must be listed as suitable for the purpose. In most respects, the installation requirements for these systems are similar to other communications systems. However, Sections 830-10 and 830-11 contain specific provisions for overhead clearances, spacings from other conductors, mechanical protection, and burial depths that differ from the requirements of other articles in Chapter 8.

Background and Explanation

This change recognizes a type of communications system that is capable of delivering multiple services through a single network and a single line.

Cables may be coaxial, with the single central conductor carrying both power and the broadband signal. The cables may be a composite metallic cable, with a coaxial conductor for the broadband signal and a twisted pair for power, or the cables may be hybrid fiber optic with a pair of wires for power.

The power sources are required to be significantly limited. Network power sources are classified as low and medium. Low power networks are limited to 100 volts and 250VA. Medium power networks are limited to 150 volts and 250VA. A high power classification was proposed that was limited to 150 volts but had no power limitation. The high power classification was deleted from the new article after public comments.

This type of system provides its own power from the network rather than deriving its power from a normal premises wiring system. This fact is the basis of probably the most interesting and controversial aspect of this type of system: A separate, albeit very limited, power source is introduced without the requirements typical for a service. For example, this type of system requires no main disconnecting means. A main disconnect may not be desired on communications systems that may be relied on to summon emergency help. Grounding similar to the grounding required for communications or CATV systems is required in many cases, but some systems may operate ungrounded. A task group will continue to study these and other issues raised by public comments.

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App. D Exs. D2(a) & (b) Revision to Optional Calculation Example

NEC pp. 609 & 610

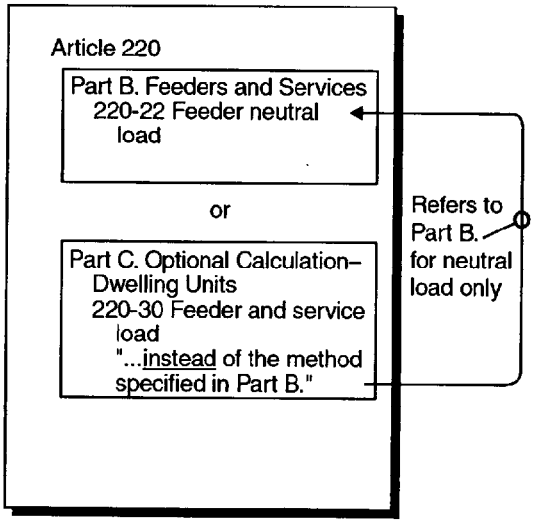
Type of Change Revision; Relocation

BRIEF SUMMARY

Residential. Optional calculation examples have been corrected.

Code Language

See illustration.



Optional Calculation Examples

Application

The examples are now located in Appendix D, which makes them advisory only. However, Examples D2(a) and D2(b) have been corrected to remove the references to Section 220-21, which is applicable only to calculations performed in accordance with Part B of Article 220.

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Background and Explanation

As shown in the illustration, Article 220, Part C specifies an optional calculation method that may be used "instead of the method specified in Article 220, Part B." Section 220-30, which outlines the optional method, refers to Section 220-22 in Part B only for the calculation of feeder neutral loads.

In the 1996 code, Examples 2(a) and 2(b) eliminated the larger of the heating and air-conditioning loads by making a reference to Section 220-21. Examples D2(a) and D2(b) have been revised in the 1999 code by removing the references to Section 220-21. The air-conditioning load in D2(a) is still eliminated from the feeder load, but for a different reason. The air-conditioning is disregarded because it falls under Item 1 in Table 220-30 and it is smaller than Item 5. Item 5 in this case is 40 percent of the 9kVA heating load that consists of four or more separately controlled units. In D2(b), the heating load is disregarded because it falls under Item 4, and 65 percent of the space heater is less than 100 percent of the air-conditioning load (Item 1).

The final results in these two examples were not changed, but following the old examples with different heating and air-conditioning loads could result in improperly sized feeders. Section 220-15 of Part B requires that fixed electric space heating loads be calculated at 100 percent unless the authority having jurisdiction permits the use of a demand factor.

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